German Public Utilities: Organisation and Productivity

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Abstract

Since 1998, public firms have had to adapt to a market environment that is very different from the post-war era in Europe. The liberalisation of services of general economic interest across Europe led to competition between public and private providers, while new technologies require infrastructure investment and innovative solutions. In addition, urbanisation and population ageing pose new challenges for local public service provision. Focusing on German energy and water utilities, the dissertation empirically analyses total factor productivity and the cost structure of contemporary public firms for the period 2003 to 2014 based on a structural production framework. First, we evaluate the performance of public firms under competition, estimating firm-level productivity in the electricity retail sector. Second, we study public utilities' internal organisation, analysing the productivity effect of three new public management strategies: corporatisation, partial privatisation, and outsourcing of business activities. Finally, we examine regional disparities in the productivity and costs of public water supply resulting from demographic changes. The empirical analysis uses official microdata on German utilities.

Keywords: structural production function, total factor productivity, multi-product firms, firm organisation, state ownership, public firms, public service provision, liberalisation, demographic change, urbanisation, electricity retail, water supply, heat supply, gas supply

Zusammenfassung

Das Marktumfeld, in dem öffentliche Unternehmen in Europa agieren, hat sich seit der Nachkriegszeit stark verändert. Die europaweite Liberalisierung von Dienstleistungen allgemeinen wirtschaftlichen Interesses im Jahr 1998 hat zu Wettbewerb zwischen öffentlichen und privaten Anbietern geführt, und neue Technologien erfordern Infrastrukturinvestitionen und innovative Lösungen. Darüber hinaus ergeben sich für die lokale Daseinsvorsorge neue Herausforderungen aus der Landflucht und der Alterung der Bevölkerung. Die Arbeit konzentriert sich auf deutsche Energie- und Wasserversorgungsunternehmen und analysiert empirisch die Gesamtfaktorproduktivität und die Kostenstruktur für den Zeitraum 2003 bis 2014 auf der Grundlage eines strukturökonometrischen Modells. Zunächst wird die Leistung öffentlicher Versorgungsunternehmen im Wettbewerbsumfeld untersucht, wofür die Unternehmensproduktivität im Stromeinzelhandel geschätzt wird. Zweitens wird die Organisationsstruktur öffentlicher Versorgungsunternehmen analysiert und die Auswirkungen von drei Strategien des New Public Managements auf die Unternehmensproduktivität untersucht: formale Privatisierung, Teilprivatisierung und die Auslagerung von Geschäftsaktivitäten. Abschließend werden regionale Disparitäten in der Produktivität und den Kosten der öffentlichen Wasserversorgung untersucht, die sich aus demografischen Veränderungen ergeben. Die empirische Analyse verwendet amtliche Mikrodaten zu deutschen Versorgungsunternehmen für den Zeitraum 2003 bis 2014.

Schlüsselwörter: Strukturelle Produktionsfunktionsschätzung, Gesamtfaktorproduktivität, Multiproduktunternehmen, Unternehmensstruktur, Staatseigentum, öffentliche Unternehmen, öffentliche Daseinsvorsorge, Liberalisierung, demografischer Wandel, Landflucht, Stromvertrieb, Wasserversorgung, Wärmeversorgung, Gasversorgung

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Rechtliche Erklärung

Hiermit versichere ich, dass ich die vorliegende Dissertation selbstständig und ohne unzulässige Hilfsmittel verfasst habe. Die verwendeten Quellen sind vollständig im Literaturverzeichnis angegeben. Die Arbeit wurde noch keiner Prüfungsbehörde in gleicher oder ähnlicher Form vorgelegt.

Berlin, den 9. Mai 2018

Caroline Stiel

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List of Abbreviations

ACF	Ackerberg-Caves-Frazer
add.	additional
AG bzw. KgA	Aktiengesellschaft beziehungsweise Kommanditgesellschaft auf Aktien
AGFW	Energieeffizienzverband für Wärme, Kälte und KWK e. V. (ehemals Arbeitsgemeinschaft für Wärme und Heizkraftwirtschaft bzw. Arbeitsgemeinschaft für FernWärme)
AGS	Allgemeiner Gemeindeschlüssel
AN	Arbeitnehmer
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle
BBR	Bundesamt für Bauwesen und Raumordnung
BBSR	Bundesinstitut für Bau, Stadt-, und Raumforschung
BDEW	Bundesverband der Energie- und Wasserwirtschaft
BET	Berliner Energietisch
BMWi	Bundeswirtschaftsministerium
BNetzA	Bundesnetzagentur
CHP	combined heat and power
Destatis	German Federal Statistical Office
DIW Berlin	Deutsches Institut für Wirtschaftsforschung e.V.
DRS	decreasing returns to scale
DSO	distribution system operator
E-Versorger	Energieversorger
EC	European Commission
EEG	Erneuerbare-Energien-Gesetz
EEX	European Energy Exchange
einschl.	einschließlich
elec.	electricity
EnWG	Energiewirtschaftsgesetz
EU	European Union
EVAS	Einheitliches Verzeichnis aller Statistiken des Bundes und

	der Länder
GDR	German Democratic Republic
GJ	Gigajoule
GmbH	Gesellschaft mit beschränkter Haftung
GmbH & Co KG	Gesellschaft mit beschränkter Haftung & Compagnie Kommanditgesellschaft
GMM	Generalised Method of Moments
GW	Gigawatt
GWB	Gesetz gegen Wettbewerbsbeschränkungen
GWel	Gigawatt electricity
GWh	Gigawatt hours
ID	identifier
ISO	independent system operator
IT	information technology
IVE	Investitionserhebung
KG	Kommanditgesellschaft
KIBS	knowledge-intensive business services
KOMIED	Kommunale Infrastrukturunternehmen zwischen Energiewende und demographischem Wandel
KWK	Kraft-Wärme-Kopplung
LLC	Limited Liability Company
Ltd.	Limited
med	median
misc.	miscellaneous
MW	Megawatt
MWel	Megawatt electricity
MWh	Megawatt hours
NA	not available
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
No.	number
NPM	New Public Management
OHG	Offene Handelsgesellschaft
OLS	Ordinary Least Squares
OTC	over the counter
pop. dens.	population density
PPI	producer price index
Q1, Q5, Q25, Q50	Quantiles - 1%, 5%, 25%, 50%

Q75, Q95, Q99	Quantiles - 75%, 95%, 99%
R&D	research and development
RDC	research data centres
RegTP	Regulierungsbehörde für Telekommunikation und Post
RES	renewable energy sources
rev.	revision
sd	standard deviation
Sondernabn.	Sonderabnehmer
std.error	standard error
Tech. rep.	Technical report
TSO	transmission system operator
TWh	Terrawatt hours
UK	United Kingdom
URS	Unternehmensregister
US	United States of America
VAT	value added tax
verfügb.	verfügbare
VG	Verarbeitendes Gewerbe
VKU	Verband kommunaler Unternehmen
WZ	Wirtschaftszweig

Chapter 1

Introduction

1.1 The issue

During the first half of the 20th century, the economic rationale for keeping firms under public ownership was fairly broad, and many economists considered nationalisations as a natural solution to organise markets that were characterised by imperfect competition, including those with natural monopolies in distribution (e.g., Franks, 1947, Simons, 1934, see also discussion of this period in Shleifer, 1998, and in Millward and Singleton, 2002). There was also widespread support for the the strategic nationalisation of key industries, such as mining, chemicals and vehicle manufacturing (Allais, 1947; Meade, 1948; Lewis, 1949). Following World War II, countries across Europe, e.g., the United Kingdom, France, or Italy, nationalised services of general interest[1] under the post-war consensus. In Germany, the East German government nationalised the provision of public services as part of its strategy to implement socialism. Although the West German government did not touch the traditional co-existence of private and public utilities in energy and water supply,[2] it explicitly allowed for (local) monopolies by exempting services of general interest from general cartel and competition law (*Gesetz gegen Wettbewerbsbeschränkungen (GWB)* in 1958).

The growing influence of liberal economists in the 1970s and 1980s (see, for instance, the Chicago School with Milton Friedman, George Stigler and Frank Knight) and the radical privatisation programme launched in 1984 by the UK prime minister Margaret Thatcher[3], initiated a change in the academic and political percep-

[1] The term *services of general interest* was defined by the European Commission and describes "services that public authorities of the EU member countries classify as being of general interest and, therefore, subject to specific public service obligations." (EC, 2011, p.1f.).

[2] Other services of general interest, such as postal services and telecommunications, were organised as state monopoly since 1872.

[3] Dissatisfied with the trade unions' power in the public sector, the state-onwed firms' perfor-

tion of the state's role in the economy by the late 1980s. Theoretical research on state-owned monopolists highlighted the efficiency losses resulting from inadequate incentives for public managers, excessive governmental influence, and weak innovation (Laffont and Tirole, 1991; Vining and Boardman, 1992; Shleifer and Vishny, 1994; Boycko et al., 1996). The assumption that natural monopolies, universal service obligations, and strategic national interests required the exemption of services of general interest from competition and private ownership was increasingly challenged. The European Commission started to consider the EU-wide liberalisation of the members' electricity and gas sectors, which was finally launched in 1998 (EC, 1988). Meanwhile, national and regional governments were privatising major public firms (e.g., Deutsche Post 1995, France Télécom in 1998, Enel in 1999) and local utilities in the search for cost reductions and efficiency gains.

Since then, the academic debate about public firms in general and the State's role in infrastructure services in particular, has subsided. This is opposed to the continued prevalence of public firms in many sectors of general interest across Europe, especially, in energy and water supply (Florio, 2013). Moreover, some countries like France and Germany experience a revival of public involvement in infrastructure services, suggesting a turning point in privatisation policies and the beginning of a second nationalisation wave in the history of infrastructure services since 1900 (Hall et al., 2013; Cullmann et al., 2016). Unlike the nationalisation wave of the postwar era, contemporary nationalisations are carried out at the municipal level, and in pursuit of different goals. They are motivated by dissatisfaction with privatised service provision in terms of consumer prices and transparency (Bauer, 2012) and are based upon an expanded definition of *public services*, which emphasises environmental and social concerns. Specifically, public utilities are perceived as a tool for implementing local environmental policies towards a low-carbon economy; for maintaining local identity within a global economy; for guaranteeing civic participation in spatial planning; and for achieving social cohesion through democratic control over prices (Berlo and Wagner, 2013; Böhnke et al., 2015; BET, 2012).

An economic evaluation of the second nationalisation wave presupposes knowledge about the performance, organisation, and strategies of contemporary public firms. However, contemporary theoretical considerations are still based on the state-monopolist theories developed during the 1990s (see Monopolkommission, 2011, 2014; Lichter, 2015), and they do not account for the changed environment in which contemporary public firms operate. Liberalisation of key sectors of general

mance and inspired by liberal economic views, Thatcher launched a comprehensive privatisation programme of the UK nationalised industries in 1984, including gas (1986), water (1989) and electricity supply (1990).

interests have introduced competition between private and public providers; and rapidly changing technologies and changed consumption patterns require product and customer service innovations. Many public firms reacted to this by internal reorganisation, applying corporatisation[4] and partial privatisation, or by implementing private-sector business routines inspired by the New Public Management movement (Hood, 1995; Kettl, 1997). The absence of new theoretical models for contemporary public firms results in a lack of sound empirical analyses. How do public firms manage to survive in competitive markets like electricity and gas supply? Do public and private firms differ in managerial productivity? To what extent do public service obligations influence production within public firms?

Focusing on German energy and water utilities, this dissertation empirically analyses managerial productivity and the cost structure of public firms for the period 2003 to 2014 based on a structural production framework. *First,* we evaluate public firms' performance under competition, estimating firm-level productivity in the retail electricity industry, and comparing municipally and privately-owned firms (chapter 3). *Second,* we address public firms' internal organisation, studying the productivity effect of three strategies for organisational innovation: corporatisation, partial privatisation, and outsourcing (chapter 4). The analysis is carried out for different sectors, including electricity, gas, heat, and water supply. *Third,* we investigate regional disparities in the productivity and costs of public water supply resulting from demographic changes (chapter 5). The empirical analysis uses a novel comprehensive panel dataset on German utilities for the period 2003 to 2014, which is described in chapter 2.

The remainder of this introduction is as follows. Section 1.2 briefly reviews the regulatory framework in Germany's energy and water supply sectors since 1998 and the implications for firms' organisation and strategy. Section 1.3 revisits the debate on public ownership and discusses the main hypotheses of the theoretical frameworks. Section 1.4 introduces the empirical methodology of this dissertation. Section 1.5 summarises its contributions, and Section 1.6 concludes.

[4] Corporatisation refers to the legal transformation of government bodies and parts of the public administration in private-law companies, owned by the State.

1.2 Germany's energy and water supply sectors

1.2.1 New challenges in electricity and gas supply

1.2.1.1 Legal framework

The EU-wide liberalisation of the electricity and gas markets in 1998 under directives 96/92/EC and 98/30/EC and the subsequent directives 2003/54/EC and 2003/55/EC in 2003 profoundly changed the market structure for all stages of the sector's respective supply chains. In Germany, the EU directives were transposed into federal law by a new version of the Energy Act (*Energiewirtschaftsgesetz (EnWG)*) in 1998 (electricity), a first amendment in 2003 (gas), and a second amendment in 2005 (electricity and gas). Table 1.1 summarises the legal framework. Unlike other EU nations, which opened the two markets in stages, Germany liberalised electricity and gas supply for all end-consumers in 1998. However, competition developed only slowly since network access had to be negotiated with the local distribution network operator and, therefore, was non-transparent. Contracts suffered from information asymmetries and the owing company - usually the local vertically integrated energy supply firm - retained full bargaining power. Network charges were high and network access could be denied relatively easily on the basis of capacity shortage (Monopolkommission, 2007). Things changed when Germany's federal regulatory authority *Regulierungsbehörde für Telekommunikation und Post (RegTP)* was put in charge of supervising the electricity and gas sector by the second amendment of the Energy Act in 2005. From then on, network access was centrally regulated by the federal regulatory authority, which was renamed *Bundesnetzagentur (BNetzA)*. Furthermore, the second amendment imposed the legal separation of network operation from generation and retail activities for all suppliers with more than 100,000 customers starting in July 2007. The EU's third package of measures, directives 2009/72/EC and 2009/73/EC, transposed into German law by the new version of the Energy Act from 2011, extended the unbundling requirements for transmission networks to full ownership unbundling.

Table 1.1: Legal framework for the liberalisation of electricity and gas supply

EU			transposition into federal law (Germany)	
	directives	content	Energy Act	measures
first energy package	96/92/EC *(electricity)*	**gradual market opening** 1999: at least customers with >20GWh, 2002: >9GWh **network access** choice between negotiated access, regulated access, single-buyer-model **unbundling** separate accounting for generation, transmission, distribution	EnWG-Novelle *(first new version)* 29/04/1998	full and immediate market opening *(electricity and gas)*, negotiated network access *(electricity)*, separate accounting *(electricity)*
	98/30/EC *(gas)*	**gradual market opening** 1999: minimum 20% of total gas supply incl. large customers with >25 mio. m3 and gas-fired plants, 2003: 28%, 2008: 33% **network access** choice between negotiated and regulated access **unbundling** separate accounting for generation, transmission, distribution, storage	1. Novellierung EnWG *(first amendment)* 20/05/2003	negotiated network access *(gas)*, separate accounting *(gas)*
second energy package	2003/54/EC *(electricity)* and 2003/55/EC *(gas)*	**gradual market opening** 2004: manufacturing 2007: residential customers **network access** independent regulatory authority, ex-ante regulation of network charges, monitoring **unbundling** legal and organisational separation for distribution and transmission, exceptions for firms with <100,000 customers	2. Novellierung EnWG *(second amendment)* 13/07/2005	regulatory authority *BNetzA* monitoring both sectors, unbundling for transmission system operators and distribution system operators with $\geq$ 100,000 customers from 07/2007
third energy package	2009/73/EC *(electricity)* and 2009/74/EC *(gas)*	**unbundling** separate ownership for transmission system operators or delegation to independent system operator (ISO), combined operation of transmission and distribution networks possible	EnWG-Novelle *(second new version)* 26/07/2011	choice between separate ownership for transmission system operators (TSOs) or delegation to independent system operator (ISO)

1.2.1.2 Implications for firms' organisation and strategies

Prior to liberalisation, local electricity and gas suppliers had signed long-term procurement contracts with regional suppliers or wholesale transmission companies, and had distributed the energy to end-consumers under local monopolies. The transformation of the market structure affected their internal processes and organisation.[5] In the following, we describe the key organisational changes and strategies after 1998.

Procurement. In the electricity sector, long-term contracts started to change soon after 1998, as their price indexes were increasingly linked to the wholesale price indexes at the European Energy Exchange (EEX). Facing wholesale price volatility, many electricity utilities abandoned their inflexible long-term contracts and pooled procurement in joint subsidiaries (known as *Beschaffungsverbände*), which functioned as intermediates for the access to the wholesale markets, bundling the volumes of the participating utilities and spreading the risk through the purchase of different tranches and from different sources. Today, *Beschaffungsverbände* typically comprise 5 to 10 public utilities of the same region (e.g., *Hexa.Kon GmbH* in Bavaria, *ehw Energiehandelsgesellschaft mbH* in Westphalia), and also offer their services to non-members.[6] Furthermore, many utilities increased investment in own generation capacities, with a focus on renewable energies (wind farms, solar parks) and combined heat and power (CHP) plants. In addition to smoother purchasing plans and stable income generation via feed-in tariffs, investments into renewable energy plants allowed the utilities to distinguish themselves from competitors as flexible, environmentally-focused suppliers, and to gain market shares in the green electricity retail market. Similar to procurement, the investments were often bundled in joint generation capacities.[7]

In the natural gas sector, bilateral contracts continued to be used after 1998, with gas prices being linked to oil prices. Larger utilities directly contracted with national or regional transmission companies and acted as re-distributors for smaller utilities. Germany's major national transmission companies are the importers *Wingas AG*, *E.On Ruhrgas AG*, *VNG AG*, *RWE AG* and *Shell/Exxon Mobil*, as well as *Erdgas Münster GmbH*, which focuses on the abstraction of domestic gas deposits. Its re-

[5] The following paragraph draws on our analysis of 50 randomly chosen annual reports from public and private energy utilities of different sizes, operating between 2003 and 2012. See the appendix at the end of the introduction for the list of reports considered.

[6] The three largest cross-regional *Beschaffungsverbände* are *Trianel GmbH* and *syneco GmbH*, each of them owned by more than 65 public utilities, and *SüdwestStrom AG* with 55 shareholders and more than 150 public utilities as customers. Larger utilities, such as *Stadtwerke Düsseldorf AG*, *Stadtwerke Leipzig GmbH* or *Vattenfall Europe AG* have established inhouse/subsidiary expertise.

[7] See, for instance, *Trianel Windpark Borkum GmbH & Co.KG* as a joint project of 33 public utilities, or *Südweststrom Kraftwerks GmbH & Co.KG* with 65 shareholders.

gional transmission companies include, for instance, *Gasversorgung Süddeutschland GmbH* or *Bayerngas GmbH*. While the public sector holds shares in two national transmission companies (*VNG AG* and *RWE AG*), it majority-owns about half of the regional companies. Only after 2009 did many utilities seek diversification by signing short-term contracts (2-3 years) with several suppliers. Utilities organised in *Beschaffungsverbände*, began to establish joint ventures for gas purchases.

Distribution. The unbundling reforms and the introduction of the incentive regulation of the electricity and gas distribution networks in 2007 by the *Incentive Regulation Act (Anreizregulierungsverordnung)* fundamentally affected distribution network operators in both sectors. Anticipating the new federal Energy Act in 2005, utilities with more than 100,000 customers started to reorganise network operation in legally independent subsidiaries in 2005, often bundling the operation of water, district heat, gas and electricity networks in the new subsidiaries. Fixed assets usually stayed with the parent utilities, while the newly formed subsidiaries, leasing the networks from the parent utility, would manage operations. The introduction of the incentive regulation affected internal organisation through efficiency measures in the search for cost reductions,[8] leading to the reorganisation of units for synergies, as well as the outsourcing of maintenance, data processing, or IT.

Retail. Competition on end-consumer markets required utilities to develop (new) marketing strategies. Instead of competing for the lowest retail price, most public utilities pursued a strategy of product differentiation and undertook branding campaigns, marketing themselves as 'local, environmentally-focused supplier close to the citizen' (see also Rottmann, 2010). Following the experience of established, independent green electricity providers, public utilities started to offer green electricity tariffs subsidising local renewable plants, and provided citizens with opportunities to invest in local wind and solar plants. Recognising the need to evolve, they also built new customer centres to publicise diverse product portfolios as well as consulting services on energy efficiency, retrofits, and heating. Other strategies promoted include energy contracting, i.e., the installation, operation, and maintenance of solar panels, heat pumps, or small-scale CHP plants in the customer-owned buildings.

[8] The incentive regulation, which replaced the general cost-based regulation (2005-2009), is organised in 5-year terms. Three years before the next regulatory period, the regulatory authority, *BNetzA*, mandates cost audits and calculates firm-level efficiency scores. Based on the results, each network operator receives an individual revenue cap at the beginning of the regulatory period. Since the revenue cap is fixed over the regulatory period, profit-maximising firms have an incentive to reduce costs.

1.2.2 Current challenges in district heat and water supply

1.2.2.1 Legal framework

The liberalisation policies of the European Union did not extend to the district heat and water supply sector. Instead, German cartel law, *Gesetz gegen Wettbewerbsbeschränkungen (GWB)* §31.1.2, fully exempts the water sector from general competition law and explicitly allows regional authorities to grant monopoly rights to a single water supplier for all steps of the value chain, from extraction to retailing to end-consumers. Since there is no obligation to unbundle generation and retail from networks operation, the majority of monopolists are vertically integrated. Some firms specialise in bulk water supply, with purified water being traded locally between neighbouring municipalities. Following the EU water directive (2000/60/EC), federal and regional laws specify quality and quantity standards for ground and surface water, thereby regulating raw water usage. The Drinking Water Act (*Trinkwasserverordnung*) from 2001 stipulates health standards for the provision of drinking water and regulates the maximum permissible values for harmful constituents.

Water tariffs are not centrally regulated. Instead, two mechanisms for ex-post control exist, whose applications depend on the legal form of the water utility. Fully publicly-owned utilities can choose to organise under public law, which implies specific rules tailored to the public sector (see section 4.2) and the possibility to charge fees instead of prices for water consumption. While ex-ante control of fees and prices is low,[9] the German cartel law includes a section on water supply, stating that regional and the Federal cartel offices can open an investigation if they suspect a water utility of charging unreasonably high tariffs (§31-31b GWB). Revised in 2011, the cartel law, however, now specifies that investigations can only be opened into prices, and not into fees (§185.1 GWB). Regarding fees, the *Kommunalaufsicht*, i.e., the county authority surveilling the activities of subordinate municipalities, can investigate whether the level of fees is in line with existing (municipal) law, and in particular, whether the principles of equivalence, cost recovery, and proportionality are respected. It does not perform cost efficiency analyses or comparisons across firms, though.

[9] The level of water fees must be approved by the municipal council and is published as an official degree (*Gebührenverordnung*). The degree needs to comply with general rules such as cost recovery, due proportionality to the services provided, and equality (BDEW, 2015). The calculation of water prices is not regulated ex-ante and firms can set prices without the formal approval of a public authority. However, in 2015, a judgement issued by the Federal Court of Justice clarifies that public firms need to follow similar guidelines for calculating water prices as for fees since the principles of equality, proportionality and cost recovery apply to any financial conduct of the State (decision no. VIII ZR 106/14, cited in Bundeskartellamt, 2016).

In the district heat sector, local monopolists have also integrated all steps of the value chain, from generation to retail. When residential housing is constructed, district heat supply competes *a priori* with other heating technologies, but once the technology has been chosen, Germany's Federal Cartel Office considers district heat as a separate market (Bundeskartellamt, 2012). Furthermore, municipalities can choose to enact compulsory connection to the main services. End-consumer tariffs are not regulated ex-ante. A sector-wide investigation by the Federal Cartel Office in 2012, which did not find systematic evidence for abuse of market power in end-user markets, concluded that ex-ante regulation would be disproportionate (Bundeskartellamt, 2012). In single cases, the Federal Cartel Office can investigate against firms following general cartel law (GWB §19.1 and §20.4).

Germany's heat generation plants and distribution networks have been affected by recent EU and federal regulations concerning the transition to a low-carbon economy. Subsidies for cogenerated power were introduced for existing plants in 2002 (*Kraft-Wärme-Kopplungsgesetz*), and extended to newly built plants in 2009, thereby incentivising the construction of CHP plants. After 2009, extensions of heat distribution networks have been subsidised if at least 60 per cent (75 per cent in 2018) of the heat is generated in CHP plants. In the same year, the Renewable Energies Heat Act (*Erneuerbare-Energien-Wärmegesetz*), stipulated that 15 per cent of the heat supplied in new buildings has to be generated from renewable energies, but can be replaced with district heat if 50 per cent is generated in CHP plants. Since 2012, subsidies also apply to heat storage facilities under the same conditions.

1.2.2.2 Implications for firms' organisation and strategies

The favourable regulatory environment for cogeneration induced substantial investments in CHP plants. Between 2009 and 2016, the annual amount of newly installed cogeneration plants increased from 542 MWel to 1,726 MWel, thereby adding 8.6 GWel of new capacity (BAFA, 2018), of which 50 per cent stem from investments undertaken by public utilities (VKU, 2011, 2017a). For comparison, Germany's total cogeneration capacity in 2014 had been estimated at 33 GWel (Gores et al., 2015). In the subsequent years, however, Germany's large-scale gas-fired CHP plants faced low annual utilisation rates (full load hours) and decreasing wholesale electricity prices. As a result, many public utilities incurred large write-downs, which put them under financial pressure (see, e.g., the case of Stadtwerke Gera in Zippel, 2014). In addition, Germany's historical focus on large-scale district heat networks has been challenged by the emergence of small-scale, decentralised solutions. A growing number of energy firms has specialised in heat contracting, providing heat to single homes and housing associations in the form of small-scale CHP plants and plants based on renewable energies (e.g., geothermal energy, solar heat) that are connected in locally self-contained heat networks. While decentralised heating systems have existed previously, the holistic approach to link them and provide integrated energy solutions in self-contained local networks is new. To keep up with their competitors, many public utilities thus have shifted their focus from pure district heat supply to offer a wider range of flexible heating solutions (see section 1.2.1.2).

In the water sector, the exemption of water fees from cartel law provides incentives for choosing legal forms under public law and lets critics suspect that some municipally-owned utilities deliberately (re-)organise under public law to avoid tariff investigations and the order of price-cuts (Monopolkommission, 2010, 2014; Bundeskartellamt, 2016). The Federal Cartel Office gives examples of utilities that reorganised following mandates of price-cuts; however, there is no systematic empirical evidence yet. Water utilities, particularly those serving rural areas, have also been challenged by demographic changes, i.e., ageing population and rural exodus to the cities. Faced with universal service obligations, they have to maintain infrastructure in sparsely populated regions despite declining populations. While universal obligations also exist in the electricity sector, problems arise in the water sector from the direct link between consumption volumes and technical infrastructure (Londong et al., 2010; Koziol, 2004): oversized mains can cause hygienic problems, whose solution create additional operational costs (Karthe et al., 2017). Given the lengthy life-cycle of technical infrastructure, immediate adjustments are often infeasible. Furthermore, more than 70 per cent of the costs in water supply are fixed costs (see section 5.2), such that per-capita costs increase in shrinking regions, fuelling a broader debate on the costs and quality of public service provision in peripheral areas (Wolf and Amirkhanyan, 2010; Herbst et al., 2016).

1.3 Revisiting the theoretical debate on public ownership

The majority of influential theoretical papers on public firms were published in the second half of the 20th century. They question the post-war consensus that had prevailed in many European countries, and which consisted of a strong welfare state and the nationalisation of key industries. They were written in an era when state-owned monopolists prevailed in sectors of general interest, and when their organisational structures were much closer to that of a public authority than to a firm (see, for instance, the *Deutsche Bundespost* from 1950 to 1995). While the models were constructed in a specific economic and historical context, their application to a completely changed environment deserves scrutiny.

The following section reviews established theories on public firms' performance and critically examines their pertinence and explanatory power with respect to today's situation. It complements in-depth summaries of traditional theories (e.g., Florio, 2004, Willner and Parker, 2007, Cavaliere and Scabrosetti, 2008) by focusing on the discussion of underlying assumptions and the angle from which the theories approach public firms.

1.3.1 Traditional views

1.3.1.1 Defining social welfare

A controversial issue in the ownership literature is the definition of the social welfare function. Shleifer and Vishny (1994), for instance, assume that excess labour enters the welfare function in a negative way. They argue that hiring extra workers helps politicians to get elected ('catering to labour unions') but there is no social gain from 'excess' labour. Likewise, the net effect from subsidising private firms to increase employment is negative. More generally, profit maximisation is assumed to be the only legitimate goal of an economic undertaking and public missions such as employment policies or regional development do not raise social welfare (see also Vining and Boardman, 1992; Boycko et al., 1996). Any objective beyond profit maximisation is 'private rent-seeking behaviour of politicians'. It is implicit that profit maximisation, on the other hand, does not produce any (negative) externalities and leads straight to the social optimum. By construction, private firms are then always superior to public firms as soon as public firms try to implement goals other than profit maximisation.

This perception is questioned by several scholars. Laffont and Tirole (1991) acknowledge that, although the government might use the public firms' profits to produce some social good and thus reduce the management's incentives to exert effort, the production of the social good may be socially optimal ex-post. Likewise, Florio (2004) argues that the 'private' agenda of politicians may not be exclusively private but include their idea of a common good. He stresses that the definition of social welfare is not objectively given but determined in a complex process between individuals of a society. Elections in democratic societies are key to this process, as Willner (2001) notes that *„to blame the need to please voters would identify democracy (the occurrence of elections), not public ownership as such, as responsible for distortions“(p.735).* According to this view, the relevant question is not: 'Is the support for regional employment a legitimate goal for a public firm?' but: 'Given that public missions must be implemented (voters demand it), how can they best be achieved?' The solution can be the provision by a public firm, the regulation of a private firm, subsidies to private firms, and so forth. Approaching the question from this point of view, Sappington and Stiglitz (1987) and Schmidt (1996) analyse when, depending on the public good's and economic agents' characteristics, nationalisation or privatisation is optimal in the presence of incomplete contracts. Since each solution has a cost, e.g., public managers could be difficult to incentivise, regulation could suffer from asymmetric information, subsidies cause costs of raising public funds etc., any given situation in reality has to be carefully examined. Wintrobe summarises the fundamental problem of traditional efficiency comparisons from this point of view: *"Since political objectives cannot be realized at zero cost, and since these non-zero costs are included in the measured costs of public firms, these studies reveal nothing about the relative efficiency of public firms"* (Wintrobe, 1987, p.445).

1.3.1.2 Managers' incentive schemes

Assume for a moment that the sole objective for firm owners – be they private or public – is profit maximisation. A common argument states that, while it is possible to develop incentive schemes for managers in private firms so that the owners' and manager's goals coincide, incentives for public managers suffer from a moral hazard problem. The reason is that public owners cannot credibly punish managers for low performance, i.e., public management can always expect a bailout by government funds if profits become negative, thereby distorting efforts towards leisure. This is the concept of the *soft budget constraint* introduced by Kornai (1986). The ownership literature insufficiently discusses the feasibility of managers' incentive schemes. Although the goal of profit maximisation seems clearly defined, there is no agreement or a golden rule on how it can be achieved. Business processes are inherently complex. Monitoring managers' performance can be difficult if ownership is diffuse, if a monopolistic market structure prevents comparison with other firms, or if takeovers in the stock market are motivated by strategic expansion strategies rather than efficiency considerations (Estrin and Pérotin, 1991; Vickers and Yarrow, 1991). Moreover, incentives and attitudes towards risk can be distorted if managers' payment schemes include rewards for high performance but no credible punishments for low performance. Take-the-money-and-run strategies become feasible since managers' performance can only be evaluated ex-post after output and profits have realised. The manager labour market is only an imperfect tool of discipline when top managers have high personal discount rates at the end of their careers or have built reputation to survive in the labour market despite single episodes of mismanagement. A recent example the case of *Deutsche Bank*'s shareholders' struggle to punish top managers ex-post for low performance during 2008 to 2015 (Rexer, 2016). Publicly-controlled firms can suffer from similar problems, as illustrated by the case of *Volkswagen*'s top managers' refusal to forgo bonuses after the emissions scandal became public in 2015 (Hawranek, 2016). In reality, it can be very difficult to punish managers after low performance, independent of ownership. Finally, an excessively short-term orientation by investors and financial analysts can have adverse effects on a firm's outcome, if the market for corporate control discounts the manager's future utility and makes him or her adopt a short-term orientation too (Estrin and Pérotin, 1991; Vickers and Yarrow, 1988). This can be problematic for energy and water sectors, which have long-term investments, and where stable supply and high quality of the output good are fundamental.

1.3.1.3 Regulating public and private firms

Shleifer (1998) argues that many services to the public provided by public firms can also be carried out by the private sector through adequate regulation. Regulation would only fail under very exceptional circumstances, e.g., if quality is not contractible and if cost reductions lead to lower quality (Hart et al., 1997).

A decade before, Sappington and Stiglitz (1987) offered a more comprehensive analysis of the circumstances under which delegation to the private sector and subsequent regulation is superior or inferior to government provision. The authors disentangle the consequences of (i) risk aversion, (ii) limited liability and commitment, (iii) limited competition, (iv) asymmetric information, (v) unknown benefits and imperfect output measurement, as well as (vi) questions related to hierarchy and conflicting interests of multiple principals on the outcome of regulated service provision. This analysis is formalised in Martimort (2006) applying a model from incentive theory. Martimort also further discusses the influence of reputation-building in repeated settings and the problem of fragmented governments. While a detailed discussion of each argument is beyond the scope of this section, the fundamental conclusion from both contributions is that the successful regulation of firms – be they private or public – depends upon a multitude of aspects and is far from self-evident in the presence of incomplete contracts.

In addition to the various challenges stemming from a theoretical point of view, a number of practical implications can complicate effective regulation. *First*, the transaction costs of regulating and monitoring firms can be substantial.[10] *Second*,

[10] This mainly motivates the German Federal Cartel Office's advice against regulating end-consumer tariffs in the district heat and water sector (Bundeskartellamt, 2012, 2016). From its perspective, transaction costs would exceed potential gains.

effective regulation must ensure that all participants understand the routine and that the transaction costs do not prevent firms from engaging in the market (Naegele, 2017). This puts a limit to the complexity of regulatory schemes and explains why first-best options sometimes cannot be reached. *Third*, asymmetries in expertise and bargaining skills between firms and the regulating authority can create distortions that may affect both the contractual output and the probability of enforcement. The majority of regulatory frameworks are not applied by national regulatory bodies but fall within the responsibility of local administrations. Local civil servants, however, are often assigned a variety of tasks and lack the juridical training they need to keep up with the legal departments of larger companies.[11] *Fourth*, complex general interests can be difficult to contract on, particularly if the goals cannot be measured metrically, if quality is not easily observed, or if the time horizon is too long. This is typically the case for regional development, social cohesion, education, or climate protection.

1.3.2 The process of privatisation and nationalisation

Another controversy concerns the *process* of privatisation and nationalisation. Examining the process of privatisation, Kay and Thompson (1986), Dunleavy (1986) and Florio (2004) point out that the act of privatisation is hard to justify by means of traditional frameworks such as public choice theory. If politicians and managers derived rents from public firms (union support, quiet life) but not from private firms, why would they ever consent to privatisation?

Apparently, the transition from public to private ownership itself creates opportunities for politicians to implement their agendas. When the selling price reflects the true value of the firm, the aggregate wealth effect is neutral. However, privatisation has distributional implications and allows income transfers to targeted interest group, e.g., to investors, suppliers of privatisation services (lawyers, consultants, financial agencies), or more generally, from labour to capital (Pint, 1991; Biais and Perotti, 2002). It can also serve to strategically alter the bargaining power of groups in the economy; for instance, by reducing the influence of trade unions (Haskel and Szymanski, 1992; Shleifer, 1998). Likewise, nationalisations might be used to implement employment goals, to weaken the influence of private investors, or to control access to natural and strategic resources. Hence, the pursuit of privatisation

[11] An example is Germany's real estate market, where civil servants face strong difficulties in enforcing local regulation (see, for instance, the issues of rent freezing, share deals, and misappropriation of housing spaces in larger cities). Examples in the energy and water sector suggest that asymmetry in legal knowledge could be the reason behind public-private-partnership contracts with rather unfavourable outcomes for the public (see *Berliner Wasserbetriebe* in Bauer, 2012 and *Stadtwerke Gera* in Zippel, 2014).

policies ('catering to capital') can be as partisan as the support for nationalisation policies ('catering to labour'). Modelling politicians' rents in public firms often neglects the rents obtained from privatising these firms. Favouring a certain economic environment has always implicit distributional implications and deregulation or privatisation constitutes a transfer in wealth as much as regulation or nationalisation. Governments cannot avoid shaping the economy. It is impossible 'not to act'.

Börner (2004), who models government objectives in more detail, shows that depending on the weights governments attach to different goals (employment, redistribution through shares, maximising public funds), incentives to privatise largely differ and can even be inefficiently high, i.e., restructuring the public firm would have led to higher social wealth.[12] Discussing the motives behind privatisation, Biais and Perotti (2002) develop a theoretical model to show that privatisation can be strategically used by right-wing political parties to gain, or remain in, power by selling shares at prices lower than a firm's true value *(underpricing)*, and that left-wing governments might privatise to gain liquidity and create revenue when other funding sources (e.g., issuing bonds) are restricted. Yarrow (1986) and Vickers and Yarrow (1991) compiled an exhaustive list of other reasons, and discuss their relevance to the UK privatisation programme between 1979 and 1991. The efficiency argument put forward by Shleifer and Vishny (1994) – that conservative governments privatise to get rid of unprofitable publicly-owned firms – seems to have played a minor role in the UK. One of the few examples is the case of National Freight in 1982 (Vickers and Yarrow (1991), p. 124).

In conclusion, a drawback of partial equilibrium analyses of privatisations and nationalisations is the narrow focus on processes *within* firms, preventing broader assessments of the firms' role in the economy. Evaluating the benefits and limitations of a privatisation or nationalisation requires extending the focus to the multitude of channels through which the transition affects economic agents.

1.3.3 Towards a new theory of the public firm?

1.3.3.1 Changes in the market structure

While large state-owned monopolists were common in Europe in the 20th century, liberalisation of energy supply, postal services and telecommunications have permanently altered the market structures in which many contemporary public firms operate. In Germany, a large number of public utilities and private energy providers

[12] In Börner's model, the inefficiency stems from the short-sightedness of governments that do not fully internalise the benefits of employment, or that try to buy votes through underpricing even if it reduces public wealth.

compete in the wholesale and retail markets, and distribution and transmission networks operation are centrally regulated. Under these circumstances, the pressure for public undertakings to mimic private companies has grown and increased the costs for managerial slack. Failure to keep up with efficient business processes in the private sector has direct consequences (loss of market shares, negative profits) visible to firms' owners. Competition introduced benchmarks which state owners and the public can use to evaluate firms, and fostered innovation, rationalisations and the development of new strategies (see section 1.2.1.2). The role of market structure on public firms' performance has been highlighted by Yarrow (1986), Vickers and Yarrow (1991), Kay and Thompson (1986) and, more recently, Florio (2014). In that context, theoretical models have addressed the question whether public firms behave more aggressively and apply anti-competitive practises more frequently than private firms. Sappington and Sidak (2003) model a theoretical situation in which a regulated firm aggressively competes for market shares by accepting negative profits, manipulating accounting data, erecting barriers to entry and reducing marginal costs through over-capitalisation. The motivation for this behaviour is the management's desire for output expansion and prestige. The authors argue that their model applies to public firms, since output expansion and the availability of some of these measures were common characteristic of public firms. The 'prestige' hypothesis, i.e., the pursuit of output maximisation instead of profit maximisation can be traced to the early bureau literature and is often assumed for public firms (see discussion in Alchian, 1965; Niskanen, 1968; Migué and Bélanger, 1974; Niskanen, 1975). However, its relevance for contemporary public firms is questionable. Within a public authority, output expansion in the form of added responsibilities increases bureaucratic power and relative importance vis-a-vis other departments and, thus, might be rational for bureaucrats. In the context of firms, however, managers' prestige is not one-dimensionally built on sales, but on a complex set of assets, including profits, innovation, and the capacity to identify consumer needs and niches in the market. More generally, Sappington and Sidak's model follows the resource-based view in industrial theory, which states that a firm's internal organisation and resources (e.g., a soft budget constraint) motivate management's competitive strategy (Penrose, 1959; Thomas and Pollock, 1999). On the other hand, the structure-conduct-performance paradigm emphasises the role of market structure in firms' behaviour, arguing that firms develop their competitive strategies in reaction to given market settings (Bain, 1968).[13] Many public firms are former incumbents

[13] For instance, Arthur and Ruszczynski (1994) show that temporarily accepting negative profits to gain market shares is a rational strategy for new entrants in platform industries, independent of ownership. Further, a report from the German Monopolies Commission showed that both public and private electricity distribution network operators exhibited anti-competitive practises before

in sectors characterised by market imperfections such as the natural monopoly in energy and water distribution. While the influence of firms' internal organisation should not be neglected, the current positioning in the market (incumbent, quasi-monopolist, new entrant etc.) could, thus, be more relevant for explaining public firm conduct than the distinction between public and private ownership.

1.3.3.2 Do public managers still have a quiet life?

The property rights literature suggests that public firms were less efficient because shares are dispersed among the public, which implies absence of effective control (Alchian and Demsetz, 1972, also Bös and Peters, 1991 and Vining and Boardman, 1992). The exertion of control rights is typically delegated to a government. Acting as the owners of public utilities, municipal governments in Germany are nowadays subject to tight budget constraints and have to file reports at the treasury and the municipal council. Revenues from public undertakings may constitute a considerable portion of the local budget and losses, in particular, are thoroughly scrutinised. The government has an interest in avoiding excessive losses to minimise subsidies and be free to direct funds towards other sources (Vickers and Yarrow, 1991).

In general, a paradigm shift in advanced economies towards performance evaluation and the application of economical principles to social spheres has not stopped short of the public administration, and has been summarised under the *New Public Management* (NPM) movement (Kettl, 1997; Gruening, 2001). The NPM approach advocates frequent evaluations of public organisations by business consultancies, and suggests rationalisation measures to improve organisational efficiency. Its popularity and wide application in many advanced economies since the 1990s has increased the pressure on public firms to justify potential slacks. In that context, Aharoni (1981) stressed the importance of studying the internal organisation of public firms, in particular the process of decision-making. He highlights that the outcome of public firms might be affected from whether directors are civil servants or elected business men. Indeed, many public companies have reformed their legal status and reorganised under private law, referred to as 'corporatisation' (Clò et al., 2014; Gottschalk, 2012). Their internal organisation, work routines and the operating environment (taxation, regulation, audits) are now much closer to those of private firms. Common labour markets for public and private managers as well as incentive schemes similar to the private sector give reason to believe that the circumstances, under which managers operate in public firms, are increasingly similar to those in the private sector.

network access was regulated in 2005 (Monopolkommission, 2007).

1.3.3.3 The quality of political institutions

Regarding the quality and structure of political institutions, some models assume that public firms use their ties with the government to influence regulation (Sappington and Sidak, 2003). This assumption presupposes that the government agrees among its members to influence the regulator and can be treated as a single agent. In reality, multiple departments at different hierarchical levels (e.g., municipality, county, federal) are often in conflict, e.g., while the treasury sees public firms as a source of income generation, the labour ministry seeks employment opportunities, and the ministry for environment wants to foster climate protection. As such, the question is rather whether government members succeed at all on agreeing on a goal. The methodological individualism with a uniform 'government' objective function does not seem to capture the main features of democracies (Aharoni, 1981; Florio, 2004). Accordingly, there is little evidence for developed countries that public firms were more successful in lobbying than private firms.[14]

Furthermore, Rentsch and Finger (2015) show that a close relationship between the government and firms is not necessarily of interest to public firms. While strong ties with the government could ease subsidisation or reduce financial risks, the public firm's management experiences lower entrepreneurial autonomy. Martimort (2006) adds to this from the perspective of the government. Government intervention in support of public firms works as a signal regarding the probability of future 'bailouts' and affects the public management's long-term effort. Likewise, interventions could discourage private firms from entering the market if they suspect unfair treatment and unfavourable production conditions. As a consequence, affirming the regulator's independence can add to the reputation of the government and provide a more reliable productive environment, in support of economic growth.

Hence, while the 'quiet life'-hypothesis might be justified with respect to specific state monopolists in the 20th century or in countries with weak political institutions, it does not sufficiently capture the changes in market structure after liberalisation and the shift in business routines among contemporary public firms in advanced economies since the 1980s. Instead, an open track for future research is to evaluate the changes in market structure structure, the effect of reorganisation and the paradigm shift towards economic principals on the recent performance of public

[14] To some extent, lobbying is institutionalised through the consultation of interest groups during the legislative process. Analysing the political process suggests that inter-trade organisations, which represent the interests of *all* firms operating in a certain sector, usually take the lead. Sometimes, very large firms lobby on their own. However, there is no reason why private firms should be less successful, since the crucial argument in lobbying – job protection – applies to all firms independent of ownership.

firms.

1.4 Methodological aspects of productivity estimation in utility industries

In this dissertation, we estimate firm-level performance of public firms as total factor productivity in a structural production framework, and formulate the production process of firm i at time t as

$$Q_{it} = F(Z_{it}, K_{it}) \exp(\omega_{it} + u_{it}), \tag{1.1}$$

where the production function is composed of output Q_{it}, freely adjustable input factors Z_{it}, dynamic input factors facing adjustment costs K_{it}, unobservable firm productivity ω_{it}, as well as a measurement error u_{it}. We apply the control function approach of Ackerberg et al. (2015), which was initially proposed by Olley and Pakes (1996). The identification strategy exploits the fact that current shocks to productivity will immediately affect firms' demand of a fully flexible, static input, but not those of dynamic inputs, which react more slowly to productivity shocks, given the adjustment costs. The inverted input demand function of a flexible, static input can then be used to express productivity in terms of observables. Therefore, we consider the possibility that firm-level productivity correlates with input choice, a well-known simultaneity problem which otherwise leads to biased estimates of the output elasticities (Mundlak and Hoch, 1965; Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Wooldridge, 2009). Furthermore, the approach assumes that productivity follows a first-order Markov process, where current productivity ω_{it} depends on past productivity ω_{it-1} and a shock. This shock can be split into a random iid component ξ_{it} and shocks related to the firm's production conditions X_{it-j}, $j \in 0, 1, 2, \ldots$:

$$\omega_{it} = g(\omega_{it-1}) + \gamma X_{it-j} + \xi_{it}. \tag{1.2}$$

This framework allows us to identify sources of productivity growth. In this dissertation, we test the impact of internal reorganisation (e.g., corporatisation, outsourcing of business activities) as well as consequences of firm-related exogenous shocks (e.g., demographic changes in the supply area) on firm-level productivity. The structural model is estimated in a two-step GMM procedure, whose details are provided in chapters 3-5.

The control function approach has been widely applied to determine total factor productivity in manufacturing industries (e.g., De Loecker, 2011a; Aw et al., 2011; Doraszelski and Jaumandreu, 2013; Parrotta et al., 2014; Collard-Wexler and De Loecker, 2015; De Loecker et al., 2016; Peters et al., 2017), but its application to sectors of general interest is new (Borghi et al., 2016). Previous analyses of utility industries measured performance as technical or cost efficiency, which can be estimated using frontier models (Byrnes et al., 1986; Hjalmarsson and Veiderpass, 1992; Kumbhakar and Hjalmarsson, 1998; Farsi and Filippini, 2009; Zschille, 2014b; Seifert et al., 2016). However, the models do not correct for the simultaneity bias, but assume (in-)efficiency to be exogenous, i.e., uncorrelated with input choice.

The specification of the production function raises three issues, which are briefly discussed below. *First*, the empirical literature commonly assumes a Cobb-Douglas production function (De Loecker, 2011a; Parrotta et al., 2014; Collard-Wexler and De Loecker, 2015), which provides a closed-form solution in the derivation of the static input's demand function (Doraszelski and Jaumandreu, 2013), and thereby reduces the complexity of the structural model. The major limitation is the imposition of constant returns to scale on the production process, while utilities are commonly found to operate under increasing returns to scale (Filippini, 1998; von Hirschhausen et al., 2006; Farsi et al., 2008). We follow the empirical literature on utilities by using a translog production function to represent the production process, and thus do not impose any restrictions on returns to scale (Kumbhakar, 1996; Saal et al., 2007; Farsi and Filippini, 2009). Furthermore, the translog function allows output elasticities to vary between firms, which is particularly usefully given the substantial differences in firm size among German utilities. A drawback of the translog production function is the large number of regressors, leading to a high-dimensional problem to be solved by numerical GMM estimation. Thus, there is a natural trade-off between the number of inputs considered and the computational efficiency of the estimation.

Second, firm-level input and output data are usually reported in monetary terms, i.e., as expenditures and revenues. However, problems arise from measuring inputs and outputs in monetary terms because the measures contain information both on quantities and prices. Neglecting price heterogeneity across firms can imply systematically biased productivity estimates, in the sense that unobserved price heterogeneity is mistaken for differences in managerial productivity. The problem has been recognised by a wide range of authors (e.g., Marschak and Andrews, 1944; Klette and Griliches, 1996; Mairesse and Jaumandreu, 2005; Ornaghi, 2006, 2008; Smeets and Warzynski, 2013). In this dissertation, we address the output-price bias by using gross-output production functions, and control for firm-specific input prices, where available (see chapter 3 and 5). In chapter 4, the firms' multi-product structure prevents the usage of a gross-output function, since outputs of different units have to be aggregated. Instead, we use a revenue-based production function, measuring total output by firm-level revenue. Consequently, productivity estimates are to be interpreted as sales-productivity.

Third, many of Germany's energy and water utilities are horizontally or vertically integrated multi-product firms. Estimating product-level production functions requires knowledge of a firm's input allocation across products.[15] Typically, firms do not report product-specific input usage, which makes it difficult to correctly estimate their input allocations (Brown et al., 1979; Just et al., 1983; Lence and Miller, 1998). Given the econometric complexity of the problem posed by notoriously under-identified sets of equations, the empirical literature has made strong simplifying assumptions, such as allocating inputs between products in proportion to product revenue shares, or according to the number of outputs produced (Foster et al., 2008; De Loecker, 2011a). A newer approach by De Loecker et al. (2016) endogenously determines the allocation across products in a system of equations. However, their approach still relies on the assumption that expenditure cost shares do not vary across inputs for a given product. For simplicity, we do not consider product-specific production functions in multi-product firms, but instead estimate production at the firm-level (see Chapter 4). Chapter 3 does not encounter the allocation problem because it considers single-product firms producing retail electricity. In Chapter 5, which focuses on water-only firms, we account for the vertical structure of the firm through a set of controls.

1.5 Contributions of this dissertation

The dissertation is one of the first comprehensive empirical analyses of German public utilities. Extending the work of Seifert (2016), Cullmann (2009) and Zschille (2014a) on electricity generation, distribution and water supply, this dissertation provides the first empirical analysis on productivity in the retail electricity market, (Chapter 3), and the consequences of demographic changes on local public service provision in the water sector (chapter 5). Furthermore, it conducts the first empirical study of German multi-utilities operating in different segments of energy and water supply (see Chapter 4). Focusing on publicly owned utilities, this dissertation contributes to limited firm-level evidence on the organisation and productivity of contemporary public firms in advanced economies undergoing liberalisation and rapid technological change. Adapting the control function approach to the utility

[15] In the utility sector, *horizontal integration* characterises the joint provision with different types of energy (district heat, electricity, gas) or water. *Vertical integration* refers to an integrated production process across different steps of the supply chain.

sector, this dissertation proposes an original framework for evaluating the link between firm's organisation and total factor productivity by means of a structural production function model. The unique panel dataset of German energy and water firms is based on novel firm-level data by the Federal Statistical Office, which are described in Chapter 2. The following briefly outlines chapters 3 to 5. Table 1.2 provides an overview of the publications that chapters 3 to 5 are based on and on the author's contribution to the individual chapters.

Table 1.2: Summary of chapters

Ch.	Publication and author's own contribution	sectors	method	main results
2	Based on (Stiel, 2015) in *DIW Data Documentation Series*, author's independent work	electricity, gas, heat, water	descriptive statistics	
3	Based on final version of (Stiel et al., 2018) published in *German Economic Review*, updated version of *DIW Discussion Paper No. 1531* (Stiel et al., 2015). Author initiated the research, was responsible for data preparation, model development, estimation, interpretation of results and paper writing.	retail electricity	ACF	no productivity differences based on ownership, retailers' mean productivity increases until 2008 but not afterwards
4	published as *DIW Discussion Paper No. 1713* (Stiel, 2017) and submitted to *The Economic Journal* (under review). Author's independent research	electricity, gas, heat, water	ACF	outsourcing of services and production positively impacts productivity growth, partial privatisation does not raise productivity, magnitude of effects is sensitive to sector
5	based on a collaborative research project with Astrid Cullmann, author was responsible for data collection and preparation, model development, estimation, interpretation of results and paper writing, idea and model set-up was collaborative.	water	ACF, system GMM, marginal costs estimation based on De Loecker (2011b)	population decline causes short-term productivity losses in shrinking regions, changes in private households' age composition affect marginal costs of production, average fixed costs increase in shrinking regions, no cost savings in growing regions

ACF: control function approach developed by Olley and Pakes (1996) and Ackerberg et al. (2015)

1.5.1 Chapter 3: Do Private Utilities Outperform Local Government-owned Utilities? Evidence from German Retail Electricity

Chapter 3, which analyses productivity growth in Germany's retail electricity market between 2003 and 2012, compares the firm-level productivity of privately owned and municipally-owned retailers. As the first empirical investigation of performance differences between public and private German utilities, it provides empirical insights into the controversial debate on nationalisation ambitions of German municipalities. Unlike existing studies of consumers' demand elasticity in liberalised retail electricity markets, this dissertation addresses the supply side, and is among the first to analyse changes in the production process of retailers and the evolution of productivity growth.

We derive the service production function of an electricity retailer, who allocates inputs to procurement and marketing. Then, we estimate firm-level productivity in a structural framework, accounting for the endogeneity between input usage and productivity through the control function approach developed by Olley and Pakes (1996) and Ackerberg et al. (2015). We test for differences in mean productivity and in the evolution of productivity growth between public and private retailers. The model is applied to a sample of 76 vertically unbundled, independent German electricity retailers observed between 2003 and 2012.

We find that mean productivity increased only until 2008 and that productivity growth did not parallel the increased competition for residential customers after 2007. It suggests that productivity gains were driven by firms' internal reorganisation between 2003 and 2008 following legal and organisational unbundling rather than actively competing for customers. Furthermore, we find no evidence for productivity differences between private and municipally-owned retailers.

1.5.2 Chapter 4: Modern Public Enterprises: Organisational Innovation and Productivity

Chapter 4 investigates the link between organisational innovation and firm productivity in contemporary public firms. It evaluates the productivity effect of three strategies in new public management: corporatisation, partial privatisation, and outsourcing. The chapter complements recent cross-country studies on contemporary public firms' performance in Europe with evidence at the micro-level. In addition, it is the first empirical analysis of Germany's integrated multi-utilities operating in different segments of energy and water supply. Addressing organisational innovation, we evaluate propositions of the New Public Management movement, for which sound empirical evidence is missing.

We estimate firm-level productivity in a structural production function framework, again following Ackerberg et al. (2015), and aggregate the outputs in multi-product firms using the firms' total revenue. We use product-level price indices for deflation and endogenously determine the differences in the price levels between products during the estimation. We model productivity as a function of past productivity and organisation, so that we can assess the influence of changes in organisation on productivity growth. We also test whether distinct organisational patterns are associated with higher mean productivity. The model is applied to a panel of 2,325 German municipally-owned multi-utilities operating in the field of electricity, gas, heat, or water supply between 2003 and 2014. We find that corporatisation and outsourcing positively impact productivity, and that partial privatisation does not increase it. Rather, fully municipally-owned utilities outperform mixed ownership utilities.

1.5.3 Chapter 5: Productivity, Marginal Costs, and Fixed Costs: Public Service Provision under Demographic Changes

Chapter 5 analyses the effects of urbanisation and population ageing on the cost structure and productivity of local infrastructure suppliers. Particular emphasis is given to the study of diverging trends between growing and shrinking regions. Taking the example of German water supply, the chapter is among the first to quantify the effetc of demographic changes on infrastructure services in advanced economies.

In a first step, we estimate annual firm-level productivity for a panel of 751 German municipally-owned water utilities operating between 2003 and 2014 by using the control function approach developed by Olley and Pakes (1996) and Ackerberg et al. (2015). We add the restriction that productivity depends on past year productivity and is potentially affected by changes in the local population structure. Demographic changes are measured through population density growth and changes in the age structure of the local population. In a second step, we derive estimates for firm-level marginal costs of production from each firm's short-term cost optimisation problem following De Loecker (2011b) and De Loecker and Warzynski (2012). After obtaining each firm's fixed costs from the dataset, we evaluate the effect of demographic changes on firms' costs structure in a dynamic panel model estimated with system GMM.

We find that population decline causes significant short-term productivity losses in fast-shrinking regions, whereas changes in the age composition of private households affect the marginal costs of production. Growing regions benefit from productivity gains, but do not incur any cost savings in the short run. Instead, average fixed costs increase together with population growth because firms invest in more infrastructure.

1.6 Concluding remarks and outlook

The dissertation provides empirical evidence on the performance of Germany's public utilities and contributes to a larger debate on public sector performance in advanced economies. Faced with transformations in the market structure following EU-wide liberalisation of electricity and gas supply, as well as changing demand patterns and technological innovations, many contemporary public firms reorganised business activities and implemented new firm strategies. Starting from traditional theories on public ownership, the dissertation focuses on the analysis of contemporary public firms, to see to what extent they differ – or not – from private-sector firms. It finds increasing similarities between public and private firms, both in term of organisation and performance. Furthermore, it addresses upcoming challenges in public service provision, showing that demographic changes pose significant problems for public service provision in peripheral areas, adding a new aspect to the mandate of universal service obligation.

To ease private-sector comparison, the dissertation measures performance of public firms by total factor productivity in relation to physical output or revenues, adopting the framework of private-sector analysis. It does not take into account broader social goals and, thus, is silent about the productivity of public firms in achieving overall objectives, that is, technical performance *and* the achievement of social goals. Situating public firms in their societal context and evaluating them with respect to their particular role, however, is necessary to inform the debate on public firms' role in today's economies; and merits future research.

1.7 Appendix

Table 1.3: List with annual reports

Year	firms' annual reports considered
2003	Stadtwerke Ettlingen GmbH, Stadtwerke Flensburg GmbH, Stadtwerke Greifswald GmbH, Stadtwerke Göttingen AG, infra fürth GmbH
2004	Stadtwerke Brühl GmbH, HEAG Südhessische Energie AG, mainova AG (Frankfurt am Main), Energieversorgung Gera GmbH, Städtische Werke AG (Kassel)
2005	badenova AG &Co.KG (Stadtwerke-Verbund Südwestdeutschland), Stadtwerke Hanau GmbH, Stadtwerke Iserlohn GmbH, Stadtwerke Karlsruhe GmbH, Stadtwerke Kiel AG
2006	Gemeinschaftsstadtwerke GmbH Kamen Bönen Bergkamen, Städtische Werke Magdeburg GmbH & Co.KG, Stadtwerke Leipzig GmbH, N-Ergie AG (Nürnberg), Stadtwerke Pforzheim GmbH & Co.KG
2007	Erlanger Stadtwerke AG, Stadtwerke Rostock AG, Neubrandenburger Stadtwerke GmbH, Stadtwerke Osnabrück AG, EnBW AG
2008	Stadtwerke Bühl GmbH, Stadtwerke Bochum Holding GmbH, swb AG (Bremen), Städtische Werke Überlandwerke Coburg GmbH, Dortmunder Energie- und Wasserversorgung GmbH, Vattenfall Europe AG
2009	Stadtwerke Bad Salzuflen GmbH, Bergische Licht-,Kraft-, und Wasserwerke GmbH, Stadtwerke Detmold GmbH, Stadtwerke Düsseldorf AG, Stadtwerke Hannover AG
2010	Stadtwerke Baden-Baden, Stadtwerke Bamberg GmbH, Stadtwerke Dachau, Stadtwerke Heidelberg GmbH, Stadtwerke Lemgo GmbH
2011	Stadtwerke Aachen AG, Stadtwerke Schwerin GmbH, RheinEnergie AG (Köln), EWE AG
2012	Stadtwerke Augsburg Holding GmbH, Stadtwerke Bielefeld GmbH, Energie- und Wasserversorgung Bonn/Rhein-Sieg GmbH, Energie- und Wasserversorgung Bünde GmbH, Stadtwerke Dresden GmbH

Chapter 2

Official Data on German Utilities

2.1 Data collection

The datasets *Energiestatistiken der amtlichen Statistik* contain information on German utilities. Belonging to a larger database of official firm data (Malchin and Voshage, 2009; Malchin and Höninger, 2011), data are collected annually by the statistical offices of German *Länder* and the German Federal Statistical Office.

The dataset used in the KOMIED research project *(Kommunale Infarstrukturunternehmen zwischen Energiewende und demografischem Wandel)* merges different data sources from *Energiestatistiken der amtlichen Statistik*. It is an unbalanced panel covering the years 2003 to 2014.[1] For each year, it contains up to 3,000 firms in the German energy sector, performing at least one of the following tasks[2]

- energy trade (retail or wholesale)
- running a distribution/transmission network
- owning parts of a distribution/transmission network
- producing energy or having subsidiaries which produce energy.

Decentralised power plants are exempt from the last definition (*EEG-Anlagen-Einspeiser*) and firms with less than 10 employees are not part of the dataset. In addition, the

[0] This chapter is an updated version of Stiel (2015).

[1] At the time of writing in 2015, only the waves 2003 to 2012 were available, hence all summary statistics are based on the period 2003 to 2012.

[2] Destatis (2011): *„Einbezogen werden [...] Unternehmen im Sinne des §2 des 2. Gesetzes zur Neuregelung des Energiewirtschaftsgesetzes sowie Energieversorgungsunternehmen, die in ihrem Unternehmen oder in ihrer Unternehmensgruppe auch über eigene Erzeugungsanlagen verfügen. Betreiber von Anlagen zur Erzeugung von Strom aus erneuerbaren Energien, die ihre Strommengen gemäß EEG in das Netz der allgemeinen Versorgung einspeisen und nicht unter die vorgenannte Definition fallen, werden [...] nicht einbezogen.“* and 2. Gesetz zur Neuregelung des Energiewirtschaftsrechts: *„Energieversorgungsunternehmen [sind] natürliche oder juristische Personen, die Energie an andere liefern, ein Energieversorgungsnetz betreiben oder an einem Energieversorgungsnetz als Eigentümer Verfügungsbefugnis besitzen.“*

dataset contains up to 7,000 firms in the field of water supply, sewerage, and waste management, who either treat more than $200,000m^3$ water/sewage or whose revenue from waste treatment exceeds 1 million EUR (Destatis, 2011).

2.1.1 Firm-level data

The data are collected by the statistical offices in different surveys, firms are legally obligated to respond. The KOMIED dataset merges the following firm-level surveys:

- *Investitionserhebung EVAS No. 43211-077* (investments)
- *Kostentrukturerhebung EVAS No. 43221-081* (costs)
- *Stromabsatz und -erlöse EVAS No. 43331-083* (electricity sales)
- *Stromeinspeisung EVAS No. 43371-070* (electricity feed-in)
- *Elektrizitätsversorgung der Netzbetreiber EVAS No. 43312-066N* (electricity distribution)

The surveys on costs and investments build the core of the panel dataset, they are sent out to all firms in the sample.[3] Table 2.1 gives an overview on their main contents, the full variable list is given in the Appendix.

Table 2.1: Data on costs and investments

costs	
labour	number of workers, gender, hours worked, labour costs, costs for external services
intermediates	material, procurement costs for energy and water
other costs	depreciation, interest on borrowed capital, insurance, R&D, rents
taxes/subsidies	concession fees, electricity and gas taxes, VAT, subsidies
revenues	from energy/water sales, merchandise, services
investments	
	gross investments into fixed assets by category (generation, storage, networks, metering, buildings, equipment, software, patents, ...)

More detailed information is available for the electricity sector, where three firm-level surveys address electricity feed-in, distribution and retail. Table 2.2 lists their main contents.

[3]Note that costs are reported at the firm-level. For multi-product utilities it is usually not possible to allocate costs across sectors nor to distinct steps of the supply chain.

Table 2.2: Data on electricity supply

installed capacity and load per distribution area	
by technology	conventional, renewables (wind, solar, ...)
by producer	manufacturing sector, others
electricity distribution	
by source	power plants, abroad, others
by destination	other utilities, abroad, end-consumers
network losses	
electricity supply/sales	
by customer group	households, business, manufacturing, other utilities
by voltage level	high, low

2.1.2 Plant-level data

Firm-level data (*Unternehmen*) is matched with plant-level data (*Betriebe*). Plants are subordinate units of firms. Each plant has two IDs: a plant ID `bnr` (*Betriebsnummer*) and a firm ID `unr` (*Unternehmensnummer*), identifying the corresponding parental firm. Surveys at the plant-level include:

- *Investitionserhebung EVAS No. 43211-076* (investments)
- *Erhebung Strom- und Wärmeerzeugung EVAS No. 43311-66K* (power plants)
- *Erhebung Wärmeversorgung EVAS No. 43411-064* (heat plants)
- *Monatsbericht Energie- und Wasserversorgung EVAS No. 43111-065* (labour)

Table 2.3 provides details on their contents (see again the Appendix for a complete list of variables). The distinction between plants should be treated with caution. *Firms* are defined as the smallest legally independent unit and can be part of a larger company, for instance, a holding company. Analysing data at the holding level, however, is not straightforward and requires additional data from the company register (*Unternehmensregister*). Although a formal definition of *plant* is given in the questionnaires[4] , it is unclear to what a plant corresponds to in reality. Distinct steps

[4] Destatis (2015c): *„Als Betriebe gelten in der Elektrizitätsversorgung: Wärmekraftwerke, Kernkraftwerke, Wasserkraftwerke, Wind-, Solar-, Geothermie- und Brennstoffzellen-Kraftwerke. Kleinere Kraftwerke in einem regional begrenzten Gebiet (z.B. Kraftwerksketten) können zu einem Betrieb zusammengefasst werden; in der Gasversorgung: Anlagen zur Erzeugung, Gewinnung, Umwandlung und Speicherung von Gasen; in der Wärmeversorgung: Heizwerke, Heizkraftwerke; in der Wasserversorgung: Anlagen zur Gewinnung, Aufbereitung und Speicherung von Wasser. Soweit*

in the supply chain (generation, distribution, retail) do not generally correspond to separate plants. Rather, plants should be interpreted geographically. If a firm has two buildings with different addresses, the two buildings are likely to be counted as different plants, even if their employees carry out the same activity. For example, the operation of the distribution network is usually organised in the headquarters, hence it is no distinct plant.

Table 2.3: Data on electricity generation and heat supply

electricity and heat generation	
general	available capacity, maximum capacity, duration time
by process technology	fuel use, electricity generated (gross/ net), heat generated (net), bottleneck capacity, ...
heat supply	
by source	manufacturing sector, other utilities, abroad
by customer groups	end-consumers, manufacturing, households, other utilities, abroad, ...
network losses	

The final structure of the dataset looks as follows:

`Jahr`	`unr`	`bnr`	`Var1[firm-level]`	`Var2[plant-level]`	`...`
2003	1	1	20	yes	...
2003	1	2	20	no	...
2004	2	3	30	NA	...

2.2 Data access

The data are subject to strict privacy conditions. Researchers may access the data at the research data centres of the Federal Statistical Office and the statistical

das zugehörige Verteilnetz örtlich begrenzt ist, können die Angaben hierüber in die Betriebsmeldung einbezogen werden. Wird das Verteilnetz durch andere Organisationseinheiten (z.B. Betriebsverwaltungen, Bezirksverwaltungen, Werksgruppen) betreut, so haben diese als Betrieb zu melden. Unternehmen, die in einem örtlich begrenzten Gebiet eine 'nur verteilende' Tätigkeit ausüben (reine Netzbetriebe) brauchen nur eine Betriebsmeldung abzugeben. Dagegen ist von Netzbetreibern, die ein größeres Gebiet mittels verschiedener Organisationseinheiten [...] versorgen, für diese betreuenden Organisationseinheiten getrennt zu melden. [...]"

offices of the *Länder*.[5] The data are anonymised and handled via remote access. Researchers are not allowed to report results for single firms; the minimum group size is 3 firms. In the following, results that cannot be reported due to confidentiality are marked with an *x*.[6]

2.3 Sample size

The dataset contains 76,466 observations in 382 variables. Roughly 3,500 firms and 5,000 plants are annually observed during 2003 to 2007 and as twice as much for the period 2008 to 2012. Each year, a small number of plants is duplicated, i.e., two or more entries have the same plant ID `bnr`. About 60 per cent of them are power and heat plants. Most of the duplicated plants are probably plants that have been resold during the year as they have pairwise the same plant ID but differ in their firm ID. Consequently, they are introduced as a new observation, although it still the same plant. Only 48 plants are real duplicates in the sense that firm ID and plant ID are identical for the year observed. Table 2.4 gives the exact number of observations.

Table 2.4: Sample size

Year	*firms*	*plants*	*duplicated plants*
2003	3,498	5,136	48
2004	3,526	5,255	54
2005	3,547	5,254	39
2006	3,532	5,283	56
2007	3,567	5,330	36
2008	6,405	9,116	54
2009	6,485	9,472	61
2010	6,560	9,855	55
2011	6,922	10,301	127
2012	7,249	10,757	174
sum	**51,291**	**75,759**	**704**
total			**76,463**

Notes: Full sample. Rows with missing values in `unr` were eliminated.

Table 2.5 lists number of firms and plants entering the panel in each year. The massive entry in 2008 can be explained by a change in the setup of the surveys.

[5] For more information see `http://www.forschungsdatenzentrum.de/bestand/afid-panel_energieunternehmen/index.asp` (in German).

[6] This does not necessarily mean that hidden results apply to less than 3 firms. To avoid that hidden results can be traced back by means of the remaining categories, at least two categories are cleared (*Sperrpartner, Restkategorien*).

From 2008 on, the sample population has been extended to firms that do waste treatment and sewerage. Observing 7,249 firms in 2012, while the total number of firms is 9,038, we may conclude that 20 per cent of the firms drop out before the end. The exit rate for plants is within the same range.

Table 2.5: Year of entry

Year of entry	*firms*	*plants*
2003	3,498	5,136
2004	178	314
2005	114	220
2006	89	200
2007	167	268
2008	3,244	4,399
2009	356	804
2010	260	683
2011	579	880
2012	553	843
sum	**9,038**	**13,747**

Notes: Full sample. Rows with missing values in `unr` were eliminated.

Table 2.6 lists summary statistics on the duration of observations. The majority of firms is observed over 5 and 10 years. The unexpected mode at '5 years' is explained by the exceptional entry of new firms in 2008. 83 per cent of them stay until the end, i.e., 2012. Leaving the new entrants from 2008 aside, remain 395 firms and 522 plants that quit after 5 years. Hence, controlling for the effect in 2008, there is no particular exit rate after 5 years.

Table 2.6: Duration

No. of years	*firms*	*plants*
1	1,003	1,613
2	809	1,392
3	497	1,048
4	515	1,066
5	3,086	3,949
6	199	303
7	119	209
8	160	259
9	118	224
10	2,532	3,684
Sum	**9,038**	**13,747**

Notes: Full sample. Rows with missing values in `unr` were eliminated.

2.4 Firm structure

2.4.1 Subunits

Firms can be composed of different plants. 85 per cent of the firms have no subsidiary, i.e., they are a single-plant firms (see Table 2.7). Consequently, the fraction of firms with more than one subunit is rather low (11 per cent). A very small group of 3 per cent have plants in different *Länder* in Germany.

Table 2.7: Internal structure of the firms

single-plant firm (*Einbetriebsunternehmen*)	44,272
> 1 plant (*Mehrbetriebsunternehmen*)	5,799
≥ 1 plant in different region (*Mehrländerunternehmen*)	1,366
<NA>	902
Sum	**52,339**

Notes: Pooled sample. Rows with missing values in `unr` were eliminated. Analysis based on `art_u`. 969 plants between 2011 and 2012 are wrongly classified as single-plant firms according to `art_u` although they belong to multi-plant firms.

Table 2.8 shows the number of subunits with multi-plant firms. The distribution is quite dispersed. It is positively skewed with the majority of firms having 1 to 5 subunits. There is a small fraction of firms with up to 48 subunits and some outliers at 76, 77, 143 and 146 subunits.

Table 2.8: Number of subunits within multi-plant firms

	Number of subunits within multi-plant firms											
Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11-146*	**sum**
2003	34	181	71	56	30	9	5	13	4	5	12	**420**
2004	31	184	78	63	28	12	5	9	6	3	12	**431**
2005	38	181	72	61	31	9	8	8	4	4	11	**427**
2006	37	164	73	60	30	6	10	10	4	4	14	**412**
2007	42	151	85	58	26	10	8	10	3	4	17	**414**
2008	235	277	127	76	35	13	13	15	4	3	26	**824**
2009	195	290	132	67	47	11	11	13	10	6	28	**810**
2010	190	301	131	71	47	11	13	11	7	9	27	**818**
2011	197	181	95	63	31	10	9	8	5	5	21	**625**
2012	179	193	97	59	33	11	9	7	6	3	24	**618**
sum	**1,178**	**2,103**	**961**	**634**	**338**	**102**	**91**	**104**	**53**	**46**	**192**	**5,799**

Notes: Subsample of firms with `art_u==Mehrbetriebsunternehmen`. Rows with missing values in `unr` and `art_u` were eliminated.

The fact that 20 per cent of the multi-plant firms have only one subunit might be surprising, and suggests that these firms were in fact single-plant firms. However, they might have further subunits outside of energy and water supply, which are not part of the panel. For instance, the majority of multi-plant firms with one subunit enters in 2008 and are sewerage firms (64 per cent). The internal structure of multi-region firms with subunits in different *Länder* of Germany is considered in Table 2.9.

Table 2.9: Number of subunits within multi-region firms

	Number of subunits within multi-region firms											
Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11-116*	**sum**
2003	x	6	6	5	3	4	x	4	5	0	x	**53**
2004	x	x	9	4	x	4	x	4	x	x	x	**54**
2005	3	6	8	3	3	6	3	4	4	3	x	**60**
2006	x	x	7	5	x	6	4	x	5	3	x	**58**
2007	4	9	4	7	3	3	6	x	x	x	x	**60**
2008	22	49	27	17	9	15	13	6	5	3	25	**191**
2009	17	54	26	18	10	18	7	8	8	x	x	**197**
2010	23	59	29	18	10	18	6	x	8	5	x	**215**
2011	20	69	36	16	10	16	x	x	x	x	x	**230**
2012	21	69	38	21	10	15	x	x	x	x	x	**248**
sum	**115**	**329**	**190**	**114**	**67**	**105**	**x**	**x**	**x**	**x**	**x**	**1,366**

Notes: subsample of firms with `art_u==Mehrländerunternehmen`. Rows with missing values in `unr` and `art_u` were eliminated. x cannot be reported due to privacy reasons.

Note that there is a second variable `art_b` which describes the type of the *plant* (being part of a single-plant firm, part of a multi-plant firm, ...). By construction, it is identical to `art_u` and only differs in the number of missing values.

2.4.2 Legal status

The dataset contains information on the legal status of the firm (`Rechtsform`). Table 2.10 lists summary statistics. The prevalent form of legal organisation is *GmbH*, *GmbH & Co KG* (43 per cent), *Eigenbetrieb* (27 per cent) and *Verband* (20 per cent). About half of the firms are corporatised, i.e., they are organised under private law (48 per cent).[7] The jump in 2008 across all types can be explained by the extension of the sample population discussed in Section 2.3.

[7]Private law includes the legal forms *AG bzw. KgA, Einzelfirma, GmbH, GmbH & Co KG, KG* and *OHG*.

Table 2.10: Legal status

Year	*AG bzw. KgA*	*Eigen-betrieb*	*Einzel-firma*	*Genossen-schaft*	*GmbH*	*GmbH & Co KG*	*KG*	*OHG*	*Verband/ misc.*	*<NA>*
2003	121	1,218	23	44	1,056	94	8	14	674	246
2004	124	1,217	23	55	1,081	118	7	16	666	219
2005	122	1,206	22	46	1,097	135	7	18	662	232
2006	117	1,182	18	44	1,106	144	8	17	662	234
2007	117	1,153	19	44	1,194	148	8	13	658	213
2008	134	1,527	119	46	2,481	463	16	22	1,362	235
2009	130	1,563	128	44	2,566	483	19	21	1,312	219
2010	135	1,547	114	41	2,607	521	18	22	1,318	237
2011	140	1,558	150	41	2,810	582	17	27	1,350	247
2012	139	1,545	163	51	2,965	637	19	27	1,379	324
sum	**1,279**	**13,716**	**779**	**456**	**18,963**	**3,325**	**127**	**197**	**10,043**	**2,406**

2.5 Sectors

2.5.1 Horizontal integration

Firms are asked to report the sectors in which they operate (`UI_Code11_x`); they can tick more than one. Sectors are *electricity supply*, *heat supply*, *gas supply*, *water supply*, *sewerage*, *waste management* and *miscellaneous*. Note that, to be considered for the panel, firms must be involved in at least one of them. Nevertheless, 3 per cent of the firms did not tick anything.[8] The total number of firms per sector is given in Table 2.11.

[8] The variables asking for the sector are coded as binary variables (yes/no) and reported at the firm-level. In addition to the 3 per cent of the firms that did not tick anything (i.e. 'no' everywhere), 1,430 firms in the current version of the dataset report <NA>. Also, between 100 and 600 firms (depending on the sector) gave inconsistent answers for the years 2011 and 2012, meaning that answers are not the same among subunit rows. They are not considered here.

Table 2.11: Number of firms in each sector

	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	**sum**
electricity	1,089	1,132	1,146	1,160	1,232	1,372	1,458	1,510	1,494	1,605	**13,198**
heat	783	816	828	836	851	848	923	936	895	908	**8,624**
gas	776	795	808	812	876	880	936	948	866	908	**8,605**
water	2,497	2,503	2,498	2,474	2,461	2,388	2,359	2,348	2,155	2,151	**23,834**
sewerage	474	502	511	521	522	1,792	1,826	1,803	1,781	1,752	**11,484**
waste	0	0	0	0	0	1,680	1,711	1,723	1,863	1,996	**8,973**
miscellaneous	589	614	620	621	611	862	936	920	1,040	1,025	**7,838**

Full sample. Rows with missing values in `unr` and `UI_Code11_1`, `UI_Code11_2`, `UI_Code11_3`, `UI_Code11_4`, `UI_Code11_5`, `UI_Code11_6`, `UI_Code11_7` were eliminated.

Table 2.12 informs about the degree of horizontal integration, i.e. the bundling of activities across different sectors. More than half of the firms focus on one sector, 17 per cent on two sectors, 13 per cent operate in three to four sectors and less than 5 per cent produce in more than 5 sectors. The second row in Table 2.12 reports the figures for single-plant firms and illustrates that a single unit can carry out more than one activity. There is no rule such as 'one plant = one activity' (see Section 2.1.2).

Table 2.12: Degree of horizontal integration

Number of sectors	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	**sum**
firms	1,625	31,184	8,357	3,649	2,863	1,896	281	6	**49,861**
single-plant firms	1,033	27,883	7,328	3,038	2,138	1,335	166	5	**42,926**

Notes: Pooled sample. Rows with missing values in `unr` and `UI_Code11_1`, `UI_Code11_2`, `UI_Code11_3`, `UI_Code11_4`, `UI_Code11_5`, `UI_Code11_6`, `UI_Code11_7` were eliminated.

Since 34 per cent of the firms are horizontally integrated, i.e., operate in more than one sector, it is worthwhile to look into the type of combinations they do. Table 2.13 gives examples for the field of *gas supply (g)*, *heat supply (h)*, *electricity supply (e)*, and *water supply (w)*. While it is very common to combine electricity with heat activities (e.g., in CHP plants) or to cover all 4 fields at once (e.g., in retail), firms perceive less synergies from joint heat and water supply. For comparison, 1,189 firms are single gas firms, 1,187 confine to heat supply, 12,301 to water supply and 3,107 purely provide electricity (not listed).

Table 2.13: Horizontal integration in gas, heat, electricity and water supply

	g/h	*g/e*	*g/w*	*h/e*	*h/w*	e/w	*g/h/e*	*g/e/w*	*h/e/w*	g/h/w	*g/h/e/w*
firms	138	833	247	1,032	97	589	629	476	214	113	1,059

Notes: Pooled subsample with firms that do electricity, gas, heat or water supply but no sewerage nor waste treatment. Rows with missing values in `unr` and `UI_Code11_1`, `UI_Code11_2`, `UI_Code11_3`, `UI_Code11_4`, `UI_Code11_5`, `UI_Code11_6`, `UI_Code11_7` were eliminated.

2.5.2 NACE classification

In addition, firms are sorted according to the classification system of economic activities NACE (*Wirtschaftszweige*). The classification is more detailed with respect to the stage of the supply chain at which the activity is carried out. On the other hand, it only reports the main activity, i.e., if a firm carries out more than one activity, information gets lost. The NACE system was revised in 2008. The ID for most categories changed and some of them were redefined. For example, in response to the unbundling reforms in the electricity and gas sectors, an own category for 'distribution' and 'trade' was formed. From 2003 to 2007 firms are sorted according to NACE rev.1 (ID starts with '4') and from 2008 to 2012 according to NACE rev. 2 (ID starts with '3'). The first column of Table 2.14 lists the total number of firms (pooled over all years) in the different categories `wz_u`. The second column addresses the plant-level. Table 2.15 lists annual numbers for selected NACE IDs.

Table 2.14: Classification according to NACE rev. 1 and 2

NACE ID	*activity*	*firms*	*plants*
4010	*electricity*	x	88
4011, 3511	*electricity generation*	5,117	11,623
4012, 3512	*electricity transmission*	59	259
3513	*electricity distribution*	2,334	4,043
3514	*electricity trade*	1,598	2,443
4013	*electricity distribution + trade*	2,373	3,653
4020	*gas*	x	x
4021,3521	*gas generation*	96	187
3522	*gas distribution*	614	1,154
3523	*gas trade*	690	1,084
4022	*gas distribution + trade*	x	2,233
4030, 3530	*heat*	2,754	8,302
4100, 3600	*water*	17,725	19,939

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NACE ID	*activity*	*firms*	*plants*
9001, 3700	*sewerage*	6,713	9,184
3811	*collection of non-hazardous waste*	3,153	4,160
3812	*collection of hazardous waste*	198	232
3821	*treatment of non-hazardous waste*	2,316	3,683
3822	*treatment of hazardous waste*	315	493
3831	*dismantling of wrecks*	275	307
3832	*recovery of sorted material*	2,207	2,930
3900	*remediation*	283	405
6323	*airport*	x	0
6399	*miscellaneous IT*	x	x
8110	*facilities support*	x	0
8411	*public administration*	x	0
9000	*waste &sewerage*	x	0
9002	*waste*	x	x
9300	*sports & culture*	x	0
9311	*sports facilities*	x	0
9999	-	x	x
NA		1,097	0
sum		**51,291**	**76,463**

Notes: Pooled sample. Rows with missing values in `unr` were eliminated. x cannot be reported due to privacy reasons.

Table 2.15: Changes in NACE classification over time[firm-level]

NACE ID Rev.1	Rev.2	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	2011	2012	**sum**
electricity												
4011	*3511*	510	512	518	521	511	435	424	416	438	475	**4,760**
4012	*3512*	5	4	4	4	6	5	6	6	5	5	**50**
4013	3513	416	444	457	x	x	446	459	442	437	480	**6,176**
	3514						236	284	341	343	384	
gas												
4021	*3521*	7	5	5	x	x	3	6	6	15	17	**68**
4022	*3522*	252	261	262	254	268	126	116	115	114	117	**2,570**
	3523						118	138	141	138	150	
heat												
4030	*3530*	194	219	215	217	218	220	239	254	264	271	**2,311**
water												
4100	*3600*	1,874	1,870	1,861	1,837	1,817	1,710	1,670	1,659	1,671	1,631	**17,600**
sewerage												
	3700	0	0	0	0	0	1,260	1,311	1,318	1,370	1,404	**6,663**

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Notes: Reduced sample with firms that did respond to the cost and investment structure survey. Rows with missing values in unr and wz_u were eliminated. x cannot be reported due to privacy reasons.

Finally, we did some cross-checks between the NACE classification and other variables. For example, we would expect from a firm participating in survey No. 066N on electricity networks to have at least one plant in the main field of electricity distribution or transmission. This corresponds to a NACE code (wz_b) of 3512, 4012, 3513 or 4013. The results are given in Table 2.16. Roughly half of the network operators participating in survey No. 066N could not be identified via the NACE code classification. All of their plants including themselves have NACE code classifications other than 3512, 4012, 3513 or 4013. Judging from the NACE code, we would not identify them as network operators. We investigated that issue somewhat further and found that the majority of these firms (61 per cent) focus on electricity generation instead (wz_u 3511 or 4011). This is not surprising since the survey setup allows firms with small distribution networks to make a joint declaration for the power plant and the related distribution network (see footnote 4). Another 20 per cent report electricity trade as main activity (wz_u 3514).

Table 2.16: Reliability of the NACE classification I

	Participants in survey No. 066N (electricity networks survey)										
	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	**sum**
NACE match failed	359	356	355	334	334	369	358	355	361	358	**3,547**
total participants	723	721	733	711	728	710	701	694	708	711	**7,150**

Notes: Full sample. 'NACE match failed' means that no plant of the firm has a NACE code classification (wz_b) of 3512, 4012, 3513 or 4013 nor the firm itself (wz_u).

A similar result is obtained for electricity traders (retail and wholesale, see Table 2.17). More than half of them cannot be identified via the NACE code classification. The firms themselves and all of their plants have main activities other than electricity trade (wz_b/wz_u 3514 or 4013). 52 per cent of them do electricity generation and 26 per cent focus on electricity distribution instead.

Table 2.17: Reliability of the NACE classification II

	Participants in survey No. 083 (electricity trade)										
	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	**sum**
NACE match failed	514	517	517	521	527	827	821	794	802	863	**6,712**
total participants	942	958	968	978	1,009	1,036	1,081	1,080	1,085	1,178	**10,326**

Notes: Full sample. 'NACE match failed' means that no plant of the firm has a NACE code classification (`wz_b`) of 3514 or 4013 nor the firm itself (`wz_u`).

2.5.3 Further variables on sector activities

There are two more variables in the dataset addressing the fields of activity. `BI_Code1100` reports the main activity at the plant-level. It is more detailed than the variables `UI_Code11_x`; however, data is only available until 2007. `BI_Code1100_neu` covers the whole period, but reports the main activity of each plant in the same general manner as `UI_Code11_x`. It merely says whether a plant operates in the electricity or heat supply sector etc., without further specifying the stage of the supply chain. In contrast to `UI_Code11_x`, it only reports the *main* activity, hence no conclusion with respect to horizontal integration can be drawn. As such, it contains even less information than the classification of economic activities `wz_b`.

2.6 Survey quality

2.6.1 Response rates

The panel dataset combines different surveys. If a firm or plant did not respond to a certain survey, it has a missing value `NA` in all variables stemming from that survey. Further missing values can result from firms not responding to a particular item (item non-response). To distinguish between both and to get an idea about the relevance of particular surveys in the dataset, we report survey participation rates below.

2.6.1.1 Firm-level surveys

The two most important surveys are those on the costs and investment structure (*Kostenstrukturerhebung* and *Investitionserhebung der Unternehmen*). They build the core of the panel since all firms have to complete them. The binary variable `TMEVU_u` reports participation at the firm-level and `TMEVB_b` informs about participation at the plant-level (*Investitionserhebung der Betriebe*).

Table 2.18: Participation in Survey No. 081, 077 and 076

	TMEVU_u		*TMEVB_b*	
Year	*yes*	*no*	*yes*	*no*
2003	3,252	240	3,942	1,242
2004	3,307	211	4,001	1,308
2005	3,315	225	4,022	1,271
2006	3,298	227	4,032	1,307
2007	3,254	208	4,109	1,257
2008	6,170	229	8,036	1,134
2009	6,266	212	8,227	1,306
2010	6,223	229	8,506	1,404
2011	6,651	271	9,002	1,426
2012	6,924	325	9,429	1,502
sum	**48,860**	**2,377**	**63,306**	**13,157**

Notes: Full sample. Rows with missing values in `unr` were eliminated. 54 firms report inconsistent participation behaviour at the plant-level for `TMEVU_u` (were eliminated).

Almost all firms took part in the costs and investments survey (see Table 2.18). A very small number of firms (54) report inconsistent participation behaviour, i.e., values for `TMEVU_u` are not the same among subunits, although the survey is carried out at the firm-level. The interpretation of `TMEVB_b` (participation in *Investitionserhebung der Betriebe*) is not straightforward. Single-plant firms are eligible for both surveys. They may answer *Investitionserhebung der Unternehmen* at the firm-level and *Investitionserhebung der Betriebe* at the plant-level. Survey design is roughly the same except for the plant-level survey being less detailed. The advantage of the plant-level survey is that it provides separate information on investment per subunit within multi-plant firms. However, two out of three positive responses to the plant-level survey stem from single-plant firms that responded to both, providing no additional information. Regarding multi-plant firms, only 64 per cent have subunits participating in the plant-level survey.

The three other surveys at the firm-level address electricity supply: electricity sales (No. 083), electricity feed-in (No. 070), and electricity distribution (No. 066N). Comparing participation across these surveys, Table 2.19 shows a steady increase in participation in the sales survey, while the number of network operators rises rather slowly over the years. Since the NACE classification only reports the main activity and since most firms are single-plant-firms, participation in one of these surveys is a good indicator to decide whether a firm does electricity trade or electricity distribution.[9]

[9] The strategy to identify network operators and retailers by the classification of economic activities NACE is problematic, see the discussion in Section 2.5.2.

Table 2.19: Participation in survey No. 083, 070 and 066N

	TM083_u		*TM070_u*		*TM066N_u*	
Year	*yes*	*no*	*yes*	*no*	*yes*	*no*
2003	946	2,548	631	2,866	727	2,767
2004	963	2,558	653	2,870	726	2,795
2005	968	2,576	656	2,890	733	2,812
2006	979	2,551	661	2,871	712	2,819
2007	1,009	2,555	648	2,919	728	2,838
2008	1,037	5,364	644	5,759	710	5,692
2009	1,081	5,401	671	5,812	701	5,782
2010	1,080	5,477	676	5,883	694	5,865
2011	1,085	5,837	688	6,234	708	6,214
2012	1,178	6,071	705	6,544	711	6,538
sum	**10,326**	**40,938**	**6,633**	**44,648**	**7,150**	**44,122**

Notes: Full sample. Rows with missing values in `unr` were eliminated. 27 firms report inconsistent participation behaviour at the plant-level for `TM083_u`, 10 for `TM070_u` and 19 for `TM066N_u` (all eliminated).

2.6.1.2 Plant-level surveys

Finally, three more surveys are conducted at the plant-level: a general survey on labour input (No. 065) and two specific surveys for power plants (No. 066K) and heat plants (No. 064). Table 2.20 lists their participation rates. The labour survey *Monatsberichte bei Betrieben in der Energie- und Wasserversorgung* is sent out to 1,600 plants with more than 20 employees whose main activity is in the field of energy and water supply (Destatis, 2015b). In addition, it includes plants of energy and water supply whose parental companies pursue main activities outside of energy and water supply (e.g., sewerage, waste treatment). Participation in the labour survey is, however, low. 3 out of 4 plants in the *KOMIED* dataset did not take part in the labour survey (see Table 2.20, first column). Half of them belong to firms which have less than 20 employees, the remaining half is difficult to explain. They might have more than 20 employees at the firm-level but less than that at the plant-level. Also, the threshold of 1,600 plants considered is much below the sample population of 3,000 firms for the other surveys.

Table 2.20: Participation in survey No. 065, 066K and 064

Year	*TM065_b*		*TM064_b*		*TM066K_b*	
	yes	*no*	*yes*	*no*	*yes*	*no*
2003	1,600	3,584	1,217	3,967	847	4,337
2004	1,760	3,549	1,260	4,049	866	4,443
2005	1,637	3,656	1,273	4,020	855	4,438
2006	1,765	3,574	1,281	4,058	884	4,455
2007	1,800	3,566	1,237	4,129	897	4,469
2008	1,808	7,362	1,231	7,939	912	8,258
2009	1,935	7,598	1,311	8,222	951	8,582
2010	2,055	7,855	1,361	8,549	982	8,928
2011	2,059	8,369	1,393	9,035	935	9,493
2012	2,096	8,835	1,410	9,521	968	9,963
sum	**18,515**	**57,948**	**12,974**	**63,489**	**9,097**	**67,366**

Notes: Full sample. Rows with missing values in `unr` were eliminated.

2.6.1.3 Item non-response

As is the case for most survey-based data, item non-response is a major problem. Answers in the data get less frequent the more detailed the questions are and it is not always plausible to conclude that firms were not concerned. A major difficulty is to distinguish between non-response and zero values since `NA` and `0` are sometimes used synonymously. Own plausibility checks across surveys are strongly encouraged.

2.6.2 Representativity

The following section compares aggregate supply in the dataset with published data on German energy and water supply from other sources.

2.6.2.1 Generation

Electricity generation. Table 2.21 summarises coverage rates and time trends in electricity production. Aggregate gross electricity production in the sample (`B_kraftw_EF2201U2`) does not reflect the published trend for Germany. While the Federal Ministry for Economic Affairs observes a steady increase in Geman production until the economic crisis in 2009, gross production in the sample remains stable or even decreases. At the beginning, 87 per cent of German gross electricity production is represented in the sample, against 74 per cent in 2012. The reason is the survey's focus on generation from conventional energy sources, such such as black coal, lignite, fuel oil, gas or nuclear. However, an increasing share of German electricity is generated from renewable energy sources (RES), which are not adequately represented in the survey.

Table 2.21: Coverage electricity production

	electricity production [TWh]					
	gross		*net*		*cogenerated (net)*	
Year	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*
2003	533.7	608.8	489.8	568.6	50.3	76.5
2004	533.2	617.5	498.8	576.8	52.4	78.4
2005	532.8	622.6	497.9	581.6	52.5	79.5
2006	540.6	639.6	505.2	597.4	54.0	85.4
2007	522.8	640.6	488.4	598.5	51.9	85.5
2008	522.7	640.7	488.6	599.0	53.8	90.4
2009	478.6	595.6	446.5	557.6	50.5	91.4
2010	501.4	633.0	468.7	591.4	53.4	99.2
2011	462.1	613.1	413.2	574.1	51.1	97.6
2012	467.5	629.8	435.7	590.5	51.2	102.0

Notes: Full sample. Rows with missing values in `unr`, `B_kraftw_EF2201U2`, `B_kraftw_EF2201U3` and `B_kraftw_EF2101U2` were eliminated. Data for Germany taken from BMWi (2014).

Aggregate data on net production (`B_kraftw_EF2201U3`) and cogenerated net power production (`B_kraftw_EF2101U2`) suffer from similar problems. At the beginning of the observation period, the sample represents 86 per cent (65 per cent) of total German production, while in the end numbers decrease to 74 per cent (50 per cent). In particular, the increasing share of cogenerated power in German electricity production is not reflected in the sample.

Table 2.22 and 2.23 compare aggregate electricity generation capacities in the sample to those actually installed in Germany, distinguishing the type of generation technology. Conventional technologies are well-represented (Table 2.22), sometimes leading to over-representation. Renewable energy sources are less well represented (Table 2.23). The data for solar power and geothermal energy cannot even be aggregated for lack of data points. The extraordinary decline in generation capacity for black coal, fuel oil, gas, nuclear and water in 2011 is probably an error and should be checked with the research data centres.

Table 2.22: Coverage electricity generation capacities

	electricity generation capacities [GW]									
	black coal		*lignite*		*fuel oil*		*gas*		*nuclear*	
Year	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*
2003	26.5	30.5	21.6	22.2	4.5	5.1	17.3	19.5	22.0	22.1
2004	29.6	32.3	21.5	22.1	5.0	5.6	16.7	19.4	23.6	21.5
2005	26.5	29.4	21.3	22.0	4.9	5.5	17.2	20.6	21.7	21.4
2006	25.9	28.7	21.2	21.8	4.9	5.5	17.8	21.2	21.3	21.2
2007	26.7	29.3	21.7	22.5	4.8	5.4	17.9	21.3	21.3	21.3
2008	26.7	29.6	22.2	22.4	4.8	5.4	19.2	22.8	21.6	21.6
2009	27.0	29.0	21.8	22.4	4.8	5.2	19.3	23.1	21.6	21.5
2010	27.2	30.2	21.8	22.7	5.2	5.9	19.8	23.8	21.5	21.5
2011	22.0	30.2	21.9	24.9	2.8	6.4	15.0	23.9	6.8	12.7
2012	29.5	29.8	23.3	24.2	3.7	4.2	22.7	26.4	12.7	12.7
	water		*wind*		*biomass*		*solar*		*geothermical*	
Year	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*
2003	9.2	9.0	0.1	14.6	0.04	1.0	-	0.4	-	-
2004	9.7	9.8	0.1	16.6	0.1	1.5	-	1.1	-	0.0002
2005	10.1	10.2	0.2	18.4	0.2	2.4	-	2.1	-	0.0002
2006	10.1	10.1	0.2	20.6	0.2	3.1	-	2.9	-	0.0002
2007	10.1	10.1	0.2	22.2	0.3	3.6	-	4.2	-	0.003
2008	10.1	10.1	0.2	23.9	0.4	4.1	-	6.1	-	0.003
2009	10.3	10.3	0.2	25.8	0.4	4.7	-	9.9	-	0.008
2010	10.4	10.4	0.3	27.2	0.5	5.0	-	17.6	-	0.008
2011	4.8	10.6	-	29.1	0.4	5.7	-	25.0	-	0.008
2012	10.3	10.4	-	31.3	0.6	6.2	-	32.6	-	0.012

Notes: Full sample. Rows with missing values in `Jahr` and `B_kraftw_EF1101U2_mean` were eliminated. Data for Germany taken from BMWi (2014).

Data on generation capacities from RES are also available from the network operators' survey No. 070. The distribution system operators report installed capacities and the amount of electricity fed into their networks (`U_Stromein_EF10x`) for each type of renewable energy source. However, data are aggregated at the distribution area, i.e., no plant-level data is available. Data quality is good for solar power, whereas the amount of installed hydropower stations can probably be better inferred from survey No. 066K. Data collection on wind capacities seems to have started only in 2010.

Table 2.23: Coverage electricity generation capacities from RES

	electricity generation capacities from renewable energy sources					
	water		*wind onshore*		*solar*	
Year	*sample*	*Germany*	*sample*	*Germany*	*sample*	*Germany*
2003	0.6	9.0	-	14.6	0.4	0.4
2004	0.7	9.8	-	16.6	0.7	1.1
2005	0.8	10.2	-	18.4	1.9	2.1
2006	0.8	10.1	-	20.6	4.0	2.9
2007	0.8	10.1	-	22.2	3.7	4.2
2008	0.8	10.1	-	23.9	7.9	6.1
2009	0.8	10.3	-	25.8	9.8	9.9
2010	0.7	10.4	24.2	27.2	12.7	17.6
2011	0.7	10.6	22.9	29.1	16.5	25.0
2012	5.5	10.4	25.5	31.3	23.2	32.6

Notes: Full sample. Rows with missing values in `unr`, `U_Stromein_EF1032`, `U_Stromein_EF1042a`, and `U_Stromein_1052` were eliminated. Data for Germany taken from BMWi (2014).

Heat generation. Table 2.24 addresses heat production based on data from surveys No. 064 and No. 066K. Survey No. 064, section A, asks heat retailers for detailed information on the customer structure, whereas section B addresses heat generation in *single* heat plants (*Fernheizwerke*). Information on *cogenerated* heat production must be taken from survey No. 066K. Among all types of energy production, coverage for cogenerated net heat production (*Netto-KWK-Wärme*) is worst, less than 50 per cent of German production is represented in the sample. This is problematic given the important role of cogeneration in German heat production: 85 per cent of total German heat supply is produced in combined heat power plants (see Table 2.24, columns (2) and (4), and AGFW, 2011). The German production of cogenerated heat is steadily increasing, which is not reflected in the data. Coverage rates for single heat production fluctuate around 60 per cent, with exceptionally good representation in the first and in the last year of the dataset.

Table 2.24: Coverage heat production

	(district) heat production [TWh]			
	cogenerated (net)		*single (net)*	
Year	*sample*	*Germany*	*sample*	*Germany*
2003	91.3	181.1	24.4	29.0
2004	98.8	185.4	24.1	37.4
2005	99.1	188.0	23.9	37.0
2006	100.3	191.3	23.4	35.5
2007	94.4	188.7	22.0	34.4
2008	97.0	194.7	22.2	35.2
2009	93.5	196.8	21.6	36.2
2010	99.1	212.1	25.6	43.6
2011	91.6	203.3	21.7	38.1
2012	94.4	212.5	34.5	39.7

Notes: Full sample. Rows with missing values in `unr`, `B_kraftw_EF701_sum` and `B_waerme_EF2301U4` were eliminated. Data for Germany taken from BMWi (2014) and AG Energiebilanzen (2003-2012)

2.6.2.2 Distribution and retail

The following section examines aggregate data on the amount of energy supplied to end-consumers and compares it to data from the Federal Ministry for Economic Affairs. Table 2.25 starts with electricity retail, for which data are available both in surveys No. 83 and No. 066N. The first column lists the amount of electricity distributed to end-consumers reported by the network operators (`netzb_EF203_sum`), the second one compares to the electricity supplied by retailers (`U_ABS_EF1601`). Coverage in both cases is fairly good. At the beginning of the period, 89 per cent of the electricity supplied to German end-consumers is reflected in the network operators' data and 83 per cent in the figures provided by the retailers. For the latter, accuracy increases with time and during 2007 and 2008, coverage exceeds 90 per cent. The data for network operators is less consistent. There is a drop after 2007 which did not take place in reality. Consequently, coverage rates drop for network operators and decrease to 73 per cent by the end of 2012.

Table 2.25: Coverage electricity distribution and retail

	electricity supply to end-consumers [TWh]		
	distributors	*retailers*	*domestic consumption*
Year	*sample*	*sample*	*Germany*
2003	468.7	436.1	525.0
2004	476.8	453.9	531.9
2005	495.8	469.0	534.2
2006	472.3	471.0	539.6
2007	477.5	505.4	541.2
2008	439.3	515.4	538.4
2009	371.0	458.2	509.3
2010	379.5	471.2	540.6
2011	387.2	459.8	535.2
2012	390.3	446.8	534.0

Notes: Full sample. Rows with missing values in `unr`, `U_netzb_EF203_sum` and `U_ABS_EF1601` were eliminated. Data for Germany taken from BMWi (2014).

Table 2.26 addresses heat retail (`B_waerme_EF1011`) based on data from survey No. 064. The aggregate sample data is in line with the official data published by the Federal Ministry for Economic Affairs. Over-representation for the years 2011 and 2012 is probably due to duplications (see Section 2.3).

Table 2.26: Coverage heat retail

	heat supply to end-consumers [TWh]	
	retailers	*domestic consumption*
Year	*sample*	*Germany*
2003	97.1	119.0
2004	119.2	124.6
2005	123.6	125.1
2006	126.8	124.9
2007	118.9	118.7
2008	120.8	121.1
2009	124.6	118.8
2010	135.8	131.1
2011	122.9	116.7
2012	126.2	119.6

Notes: Subsample with `B_waerme_EF1011 > 0`. Rows with missing values in `unr`, `B_waerme_EF1011` were eliminated. Data for Germany taken from BMWi (2014).

Table 2.27 lists water supply to end-consumers (`UK_Code8601`), data is taken from survey No. 081 (*Kostenstrukturerhebung*). The aggregate amounts reported in the sample exceed those from official statistics for Germany.

Table 2.27: Coverage water retail

	water supply to end-consumers [million m3]	
	retailers	*domestic consumption*
Year	*sample*	*Germany*
2003	4,926	4,864
2004	5,460	4,730
2005	5,327	4,651
2006	5,264	4,660
2007	5,160	4,544
2008	5,726	4,488
2009	5,005	4,437
2010	5,101	4,473
2011	5,146	4,495
2012	5,900	4,491

Notes: Subsample with `UK_Code8601 > 0`. Rows with missing values in `Jahr`, `UK_Code8601` were eliminated. Data for Germany taken from BDEW (2014) and confirmed by Destatis (2014) for the years 2004, 2007 and 2010.

2.7 Example: summary statistics for retail activities

As the dataset contains more than 380 variables, it is impossible to give a complete overview on each topic covered in the dataset. The following analysis addresses energy and water retail and is an example of how variables can be used to describe German utilities based on summary statistics from the dataset.

2.7.1 Electricity

Electricity retailers are firms selling electricity to end-consumers and can be identified via variable `U_ABS_EF1061 > 0`.[10] The number of firms in the dataset grows from 854 in 2003 to 962 in 2012 (Table 2.28). There is an exceptionally high wave of entry into the sample in 2012.[11]

[10] The definition is not exclusive. In the following section, electricity retailers may be horizontally or vertically integrated and pursue further activities other than electricity retail.

[11] A similar increase can be observed for district heat retailers in 2012 (see Section 2.7.2). It suggests that the sampling method changed in 2011.

Table 2.28: Number of electricity retailers

Year	*firms*	*plants*
2003	854	1,701
2004	870	1,759
2005	879	1,777
2006	881	1,800
2007	875	1,769
2008	882	1,657
2009	901	1,797
2010	899	1,848
2011	908	1,857
2012	962	2,033

Notes: Subsample with `U_ABS_EF1061 > 0`. Rows with missing values in `unr` were eliminated.

Table 2.29 gives an overview on their legal status. The prevalent form of organisation is *GmbH* and *GmbH & Co KG* (66 per cent), followed by *Eigenbetrieb* (14 per cent) and *AG bzw. KGaA* (9 per cent). 79 per cent of the firms are corporatised under private law, which is well above the average in the German utility sector (see Section 2.4.2).

Table 2.29: Legal status of electricity retailers

Year	*AG bzw. KgA*	*Eigen-betrieb*	*Einzel-firma*	*Genossen-schaft*	*GmbH*	*GmbH & Co KG*	*KG*	*OHG*	*Verband/ misc.*	*<NA>*
2003	85	144	20	36	486	40	5	8	3	15
2004	90	146	19	36	490	48	x	x	4	12
2005	89	143	17	36	502	56	x	x	4	9
2006	88	139	15	36	507	57	x	x	5	10
2007	85	134	15	36	508	61	x	x	4	11
2008	75	110	15	36	528	56	7	6	21	16
2009	74	108	14	36	550	63	6	4	28	12
2010	75	108	8	36	545	71	8	4	18	14
2011	76	102	11	35	531	71	8	4	22	26
2012	74	102	8	39	598	78	8	4	23	28
sum	**811**	**1,236**	**142**	**362**	**5,245**	**601**	**65**	**62**	**128**	**153**

Notes: x cannot be reported due to privacy reasons.

Most of the variables on electricity retail address the customer structure. The dataset offers two ways for classifying end-consumers. The first approach distinguishes small customers (`U_ABS_EF105x`) from large customers (`U_ABS_EF104x`). Large customers are further subdivided into high voltage customers and low voltage customers (U_ABS_EF102x and U_ABS_EF103x). The second approach differentiates between private households (U_ABS_EF108x), the manufacturing and quarrying sector (U_ABS_EF107x), other end-consumers (U_ABS_EF109x) and transportation (U_ABS_EF114x). In addition, information is given on electricity sold to other utilities (U_ABS_EF101x). The remainder of this section uses the second approach.

Figure 2.1 shows the number of firms per customer segment. Regarding the supply to end-consumers, most of the firms are 'all-rounders' since each type (households, manufacturing, others) is supplied by more than 90 per cent of the firms. An increasing number of firms sells to other utilities (about 50 per cent), combining retail and wholesale. Only few firms supply the transportation sector.

Figure 2.1: Number of firms in each customer segment (electricity)

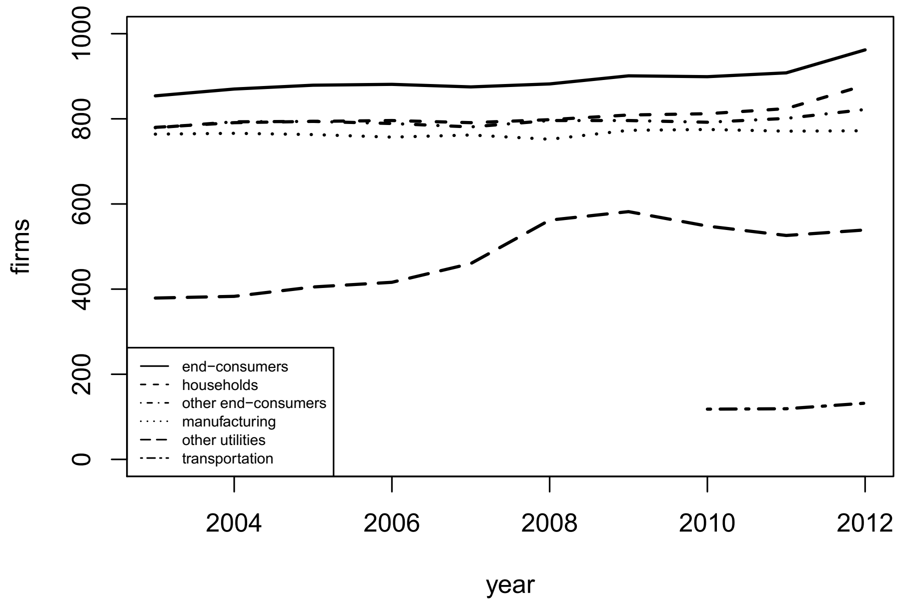


Figure 2.2 compares the total amount of electricity sold per customer segment. Not surprisingly, the largest amounts are supplied to other utilities, while the transportation sector is rather unimportant. The remaining 400 TWh are equally distributed between households, other end-consumers and manufacturing.

Total sales in Figure 2.3 follow a different time trend compared to quantities. Sales in all segments keep steadily increasing. Meaningful interpretation is not straight forward and requires at least adjustment for changes in consumer tax rates.

Figure 2.2: Total electricity [TWh] sold to each customer segment per year

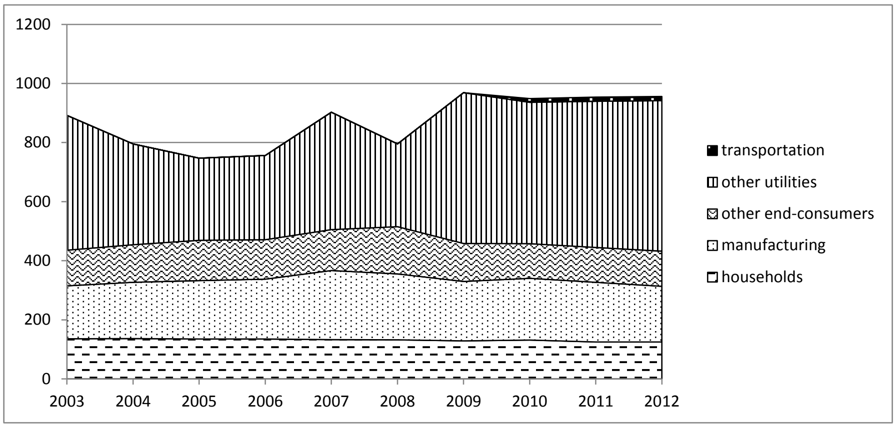
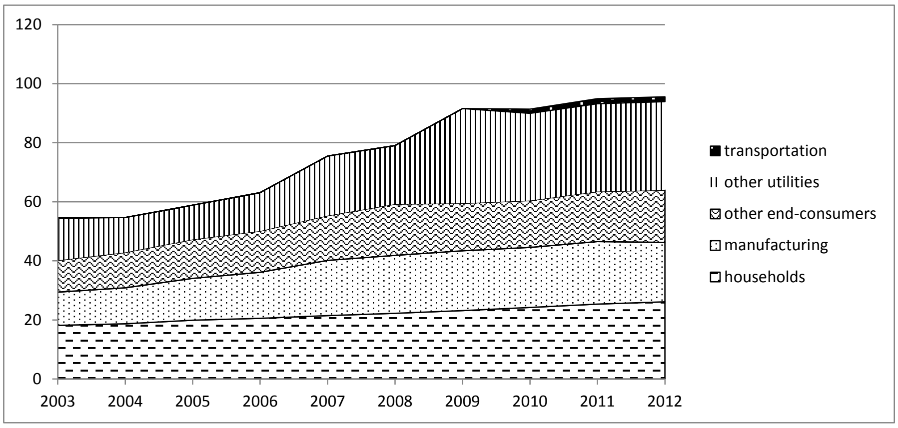


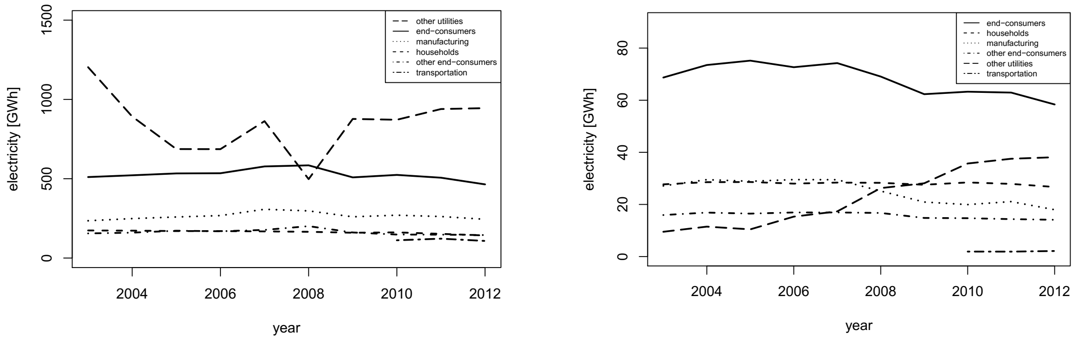
Figure 2.3: Total sales [billion EUR] per customer segment and year



The next figures address the importance of each segment in a standard firm's portfolio, analysing mean and median supply.[12] Figure 2.4a focuses on the mean amount of electricity supplied per customer group. On average, firms supply 160GWh to private households and to other end-consumers and 260GWh to the manufacturing sector. Numbers are different for median supply (see Figure 2.4b). The median firm sells ten times less, around 25GWh, to private households and the manufacturing sector. Hence, the distribution is heavily skewed to the right and few large firms dominate electricity supply to end-consumers. The median amount of electricity sold to other utilities grows over the years. Interesting enough, the opposite downward trend in mean supply stems from large retailers reducing their trading volume, while all other firms increased their supply (see Figure 2.5).

[12]For each segment, only active firms are considered, i.e., summary statistics are calculated for firms with positive output quantities.

Figure 2.4: Average electricity [GWh] sold per customer segment and year



(a) mean **(b) median**

Figure 2.5: Quantiles of electricity [GWh] supplied to other utilities

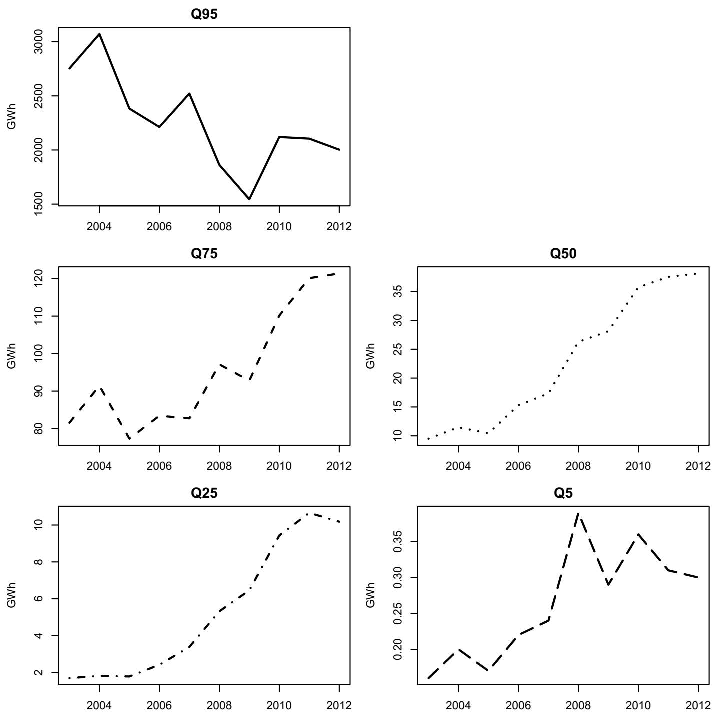
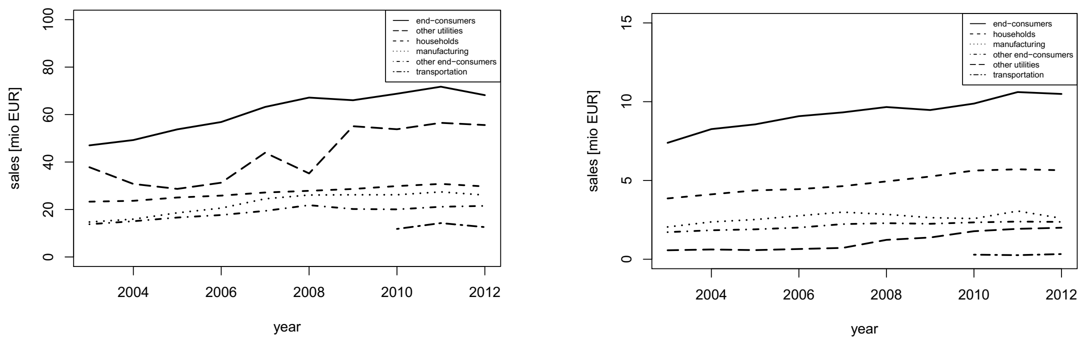


Figure 2.6 compares sales. Among end-consumers, most of the sales are generated from households. Their consumption leads to 27 million EUR revenue for the mean firm per year and 5 million EUR for the median firm. While the mean firm generates up to 55 million EUR from selling to other utilities, it is only 2 million for the median firm in 2012. For the median firm, other utilities are the least important category after transportation. Nevertheless, numbers keep increasing and the median sales volume to other utilities tripled between 2003 and 2012.

Figure 2.6: Average electricity sales [million EUR] per customer segment and year



(a) mean **(b) median**

2.7.2 District heat

District heat retailers can be identified via `B_waerme_EF1011 > 0`. Their number is slightly lower than the number of electricity retailers (see Table 2.30). It steadily increases until 2006 and then suddenly drops by more than 50 firms in 2007. It is unclear, whether this is an artefact of sample selection, or whether there was true consolidation in Germany after 2006. Numbers increase again after 2010 and get back to the values before 2007.

Table 2.30: Number of district heat retailers

Year	*firms*	*plants*
2003	776	1,073
2004	795	1,162
2005	802	1,160
2006	804	1,174
2007	750	1,124
2008	745	1,121
2009	768	1,200
2010	764	1,237
2011	769	1,271
2012	818	1,276

Notes: Subsample with `B_waerme_EF1011 > 0`. Rows with missing values in `Jahr` were eliminated.

The following figures provide details on end-consumer supply per customer segment. They are composed of private households and residential buildings (`B_waerme_EF1011b`), the manufacturing and quarrying sector (`B_waerme_EF1011a`), the transportation sector (`B_waerme_EF1011d`) and other end-consumers (`B_waerme_EF1011c`). Moreover, some firms sell to other utilities (`B_waerme_EF1010`).

Figure 2.7 gives the number of firms per customer group, where the solid line represents the total number of heat retailers. 69 per cent of the firms supply private households, 28 per cent supply the manufacturing industry and 75 per cent supply other end-consumers. Only 50 firms a year, i.e. 7 per cent, sell to other utilities. Hence, intra-retailer trade is rather unimportant in the heat sector. The number of firms supplying the transportation segment is particularly low and not listed for confidentiality restrictions.

Figure 2.7: Number of firms in each customer segment (district heat)

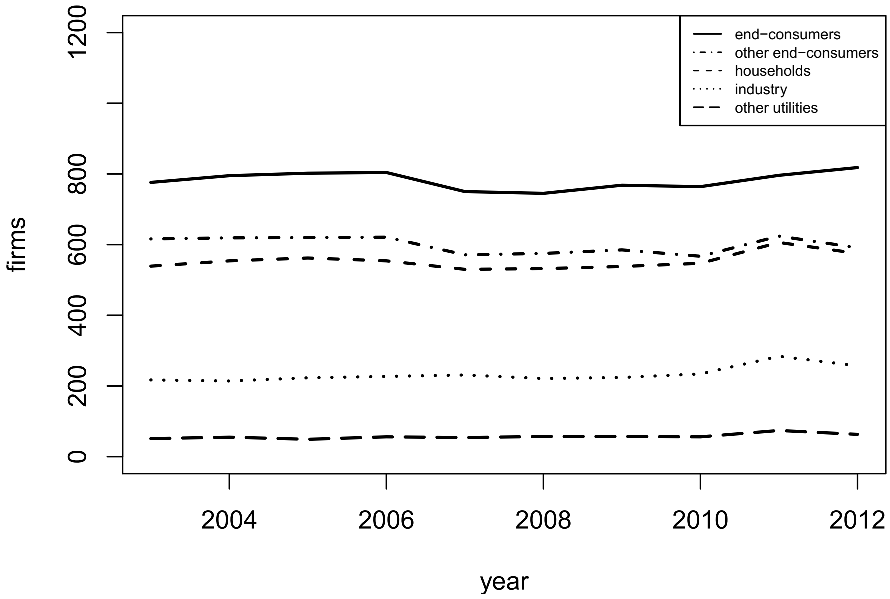


Figure 2.8 illustrates the amount of heat sold to each customer group. The most important part, 35 per cent, is sold to households and residential buildings. A slightly lower, albeit increasing part is sold to the manufacturing and quarrying sector; save for the economic crisis in 2009/2010, the latter exceeds the share to private households after 2006. A decreasing share goes to other end-consumers.

Figure 2.8: Total district heat [TWh] sold to each customer segment per year

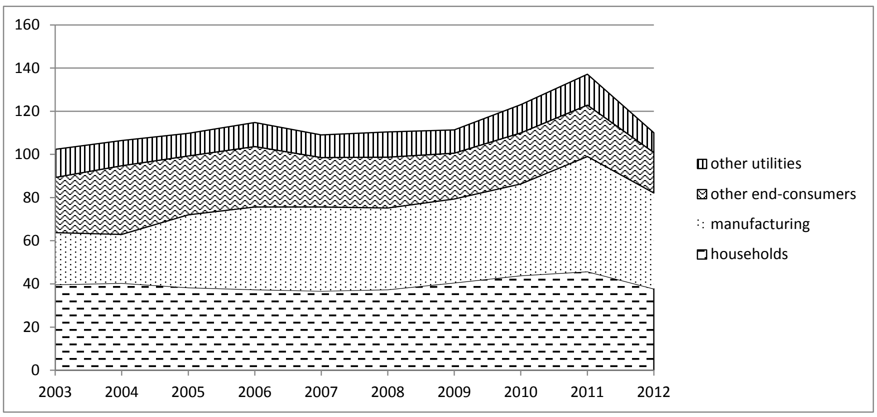
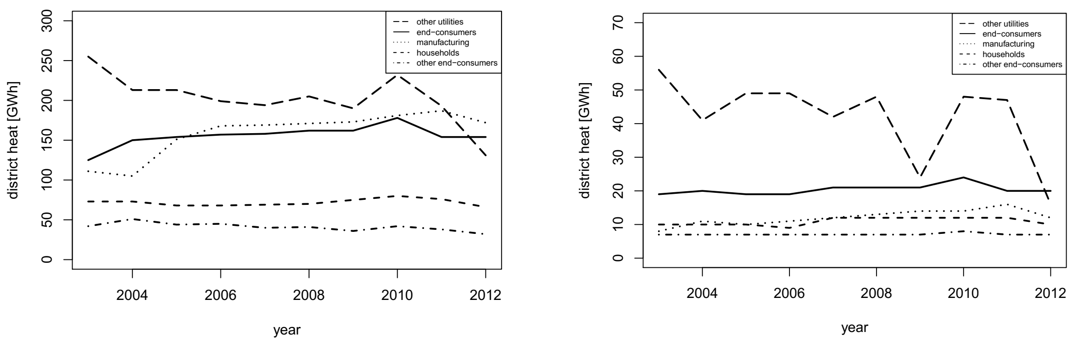


Figure 2.9 shows mean and median supply.[13] As one would expect, those firms which sell to other utilities actually sell large amounts: on average, a volume of

[13]For each segment, only active firms are considered, i.e., summary statistics are calculated for firms with positive output quantities.

200GWh is sold between retailers (see Figure 2.9a), exceeding the amount of heat sold to end-consumers (160GWh). Likewise, the manufacturing sector is clearly more important in terms of volume (170GWh) than households and residential buildings (70GWh), when broken down to supply-per-firm. The amounts supplied to other end-consumers (40GWh) are in line with supply to households. As for electricits supply, output quantities in each segment are positively skewed, i.e. few large firms dominate. This is representative of district heat supply in Germany, where many retailers are local monopolists and output correlates with the size of the municipality. Figure 2.9b provides median values. Overall numbers are much smaller, and the gap between supply to other utilities (50GWh) and those to end-consumers (20GWh) increased. Median supply to the manufacturing sector (12GWh) is now more in line with supply to households and residential buildings (10GWh).

Figure 2.9: Average heat supply [GWh] per customer segment and year



(a) mean **(b) median**

2.7.3 Water

Water retailers can be identified via (`UK_Code8601>0 > 0`). Table 2.31 lists the number of firms selling water to end-consumers. With an annual average of 2,200 firms, the number of retailers in the water sector is three to four times higher than those in electricity and heat supply, indicating a highly fragmented market.

Table 2.31: Number of water retailers

Year	*firms*	*plants*
2003	2,285	3,095
2004	2,291	3,161
2005	2,282	3,051
2006	2,259	3,005
2007	2,237	2,959
2008	2,203	3,000
2009	2,168	2,959
2010	2,143	2,979
2011	2,139	2,993
2012	2,131	3,022

Notes: Subsample with `UK_Code8601>0 > 0`. Rows with missing values in `unr` were eliminated.

The variables on the customer structure are less detailed compared to the electricity and heat sector, distinguishing only between the amount of water supplied to end-consumers (`UK_Code8601`) and water sold to other utilities (`UK_Code8501`). In addition, the dataset includes sales data on imports (`UK_Code8801`) and exports (`UK_Code8901`). The following figures compare the amounts sold to end-consumers with those sold to other utilities. As for district heat, intra-retailer trade does not seem to be important in the water sector since more than 85 per cent of the water is directly distributed to the end-consumer (see Figure 2.10).

Figure 2.10: Yearly total water supply [millions m3] sold to each customer segment

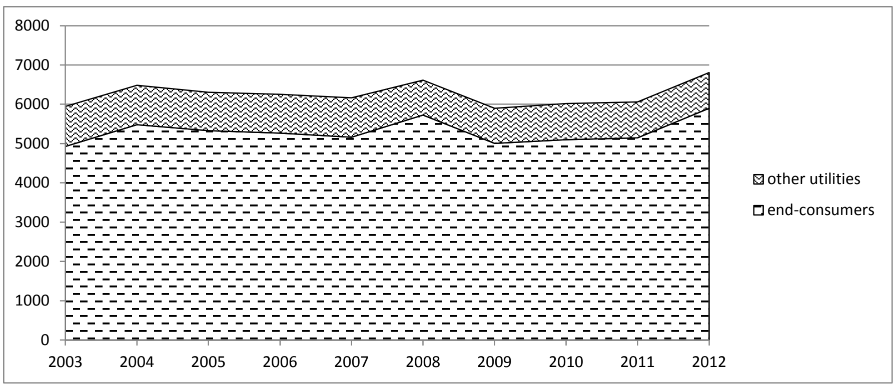
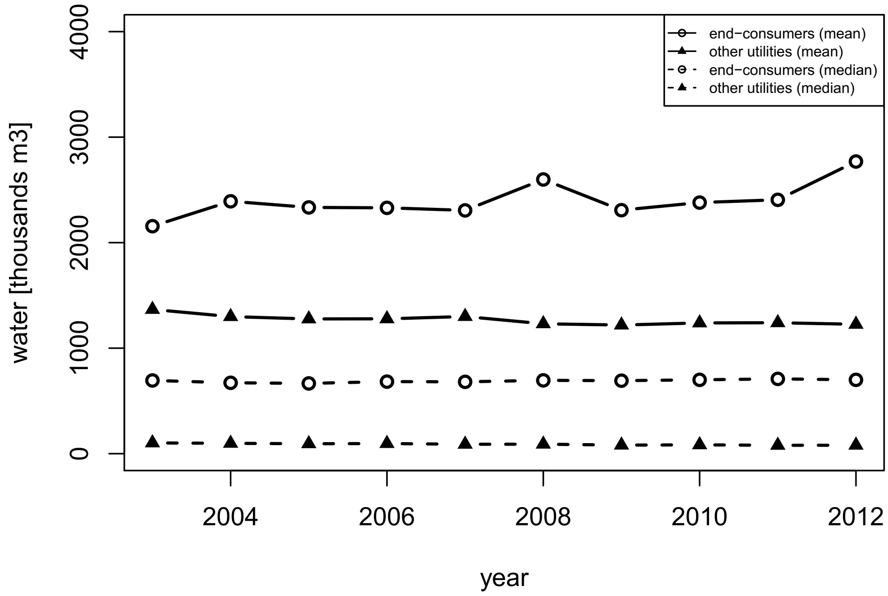


Figure 2.11 addresses mean and median supply. The distribution is positively skewed. While the mean retailer sells 2.3 millions m3 of water to end-consumers per year and 1.2 millions m3 to other utilities, the median firm sells 0.7 millions m3 of water to end-consumers and only 0.08 millions m3 of water to other utilities.

Figure 2.11: Yearly average water supply [thousands m3] sold to each customer segment



2.7.4 Horizontal integration

The last section addresses product bundling among retailers, i.e. the degree of horizontal integration. Available data is limited to electricity, heat and water supply (*Abgabe an Letztverbraucher*). We cannot exclude that firms are also present in gas supply, sewerage or waste treatment. Table 2.32 compares the number of retailers and their product bundles. Altogether, roughly 3,000 firms energy and water retailers are in the sample, with the majority of them being water retailers (1,700). When offering joint products, it is most common to combine electricity and water retail and least common to combine water with heat provision. About 170 firms offer the standard multi-utility portfolio, i.e., all three products.

Table 2.32: Retail combinations

	Combination of retail sectors (electricity, heat, water)										
	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	2011	2012	**sum**
none of them	578	613	635	640	723	3,584	3,666	3,758	4091	4327	**22,615**
water	1,765	1,750	1,740	1,714	1,697	1,680	1,642	1,625	1,627	1,598	**16,838**
electricity & water	310	309	318	316	313	306	302	310	307	327	**3,118**
electricity	293	297	289	293	299	305	330	333	335	384	**3,158**
heat	256	240	243	245	221	224	240	247	278	325	**2,519**
all of them	153	167	165	167	167	170	178	165	165	169	**1,666**
heat & electricity	86	86	98	96	87	89	81	79	79	82	**863**
heat & water	57	64	59	61	60	47	46	43	40	37	**514**
sum	**3,498**	**3,526**	**3,547**	**3,532**	**3,567**	**6,405**	**6,485**	**6,560**	**6,922**	**7,249**	**51,291**

Notes: Full sample. Rows with missing values in `unr` were eliminated. Analysis based on `B_waerme_EF1011>0`, `U_ABS_EF1061>0`, `UK_Code8601`. We cannot control for other sectors, i.e. all firms might be additionally present in gas retail, waste treatment or sewerage.

Chapter 3

Do Private Utilities Outperform Local Government-owned Utilities? Evidence from German Retail Electricity

3.1 Introduction

In many EU countries including Germany, energy policy is influenced by an ongoing political debate which links utility ownership to productivity. The privatisation waves of the 1990s in the utilities industries, including the energy sector, do not seem to have fulfilled the hopes German municipalities placed into privatisation. Thus, many municipalities are dissatisfied with the quality of private service production and the local population further criticises the absence of substantial tariff reductions after privatisation. As a consequence, many municipal governments have begun to reinforce economic activities by re-purchasing privatised firms (also referred to as deprivatisation or remunicipalisation). They are often strongly supported from the local population (see, e.g., the referendum in the city of Hamburg 2013). Against this background, critics explicitly warn about an increased municipal economic activity arguing that public firms were less productive than their private counterparts (see, for instance, Germany's Monopolkommission, 2014). They base their arguments on privatisation theories in the tradition of the property rights and principal-agent

[0]This chapter is a postprint version of the following article: Stiel, C., Cullmann, A., Nieswand, M., 2018, Do Private Utilities Outperform Local Government-Owned Utilities? Evidence from German Retail Electricity, German Economic Review 19, 401-425, which has been published at `https://doi.org/10.1111/geer.12134`. It is joint research with Astrid Cullmann and Maria Nieswand. The author initiated the research, was responsible for data preparation, model development, estimation, interpretation of results and paper writing.

literature (see, e.g., Laffont and Tirole, 1991; Shleifer and Vishny, 1994; Boycko et al., 1996). On the other hand, Clò et al. (2014) point to changes in public firms' internal governance structure as well as to changes in their operating environments. They doubt if the earlier literature on privatisation is still relevant with respect to contemporary public enterprises.[1] The policy debate lacks sound empirical evidence and existing empirical studies from other sectors or countries in time are not easily transferable (see Mühlenkamp, 2013). This chapter aims to fill the gap and provide first empirical insights into the link between performance and ownership for German utilities.

To avoid any bias from differing product portfolios between utilities, this chapter focusses on retail electricity. It attempts to identify possible productivity differences between public and private utilities in the retail electricity market, while analysing in a more broader sense productivity changes for a European country after liberalisation. The EU started in 1998 to liberalise the electricity markets in the belief that the introduction of competition would lower retail prices and encourage productivity gains (EC, 2007).[2] Only few studies address productivity explicitly in the retail segment and those which do cast some doubt on expected productivity gains (e.g. Defeuilley, 2009).[3] However, the retail electricity sector plays an important role for the local population. Consumers may now choose among various private and municipally-owned retailers. Detecting productivity changes over time as well as differences between private and municipally-owned retailers is therefore a direct matter of concern for local policymakers.

To estimate firm-level productivity, we derive the service production technology of an electricity retailer involving a procurement and a marketing decision. Labour and external services are the main inputs. We address the endogeneity of input choice using a structural model with the control function approach developed by Olley and Pakes (1996) and extended by Ackerberg et al. (2015).[4]

[1] In Germany's energy sector, the share of corporatised public utilities rose from 38 per cent in 1990 to 55 per cent in 2010 (Gottschalk, 2012). The move to abolish local monopolies and promote competition has resulted in more than 1,000 electricity retailers. The average consumer has a choice of more than fifty retailers in a region.

[2] This chapter defines productivity as the amount of inputs a retailer uses to reach a certain number of customers and sell a subsequent level of energy. The chapter considers technical productivity without taking into account any allocative inefficiencies.

[3] The reason is that the production process within the retailing units changed fundamentally after liberalisation. Additional inputs are needed to develop marketing strategies and engage in complex procurement activities on the wholesale markets. In contrast to that, total output, i.e. the number of customers, did not change. As a consequence, the net effect of liberalisation on productivity in the retail segment remains ambiguous and largely unstudied.

[4] The structural production function framework is well-known and has been applied to other sectors, mainly manufacturing (De Loecker, 2011a; De Loecker and Warzynski, 2012; Doraszelski and Jaumandreu, 2013).

To the best of our knowledge, this chapter is the first empirical investigation into performance differences between government-owned and private utilities for Germany and the first estimation of retail productivity after liberalisation altered Europe's traditional energy market structures. Constructing a unique dataset of German utilities based on newly-available data by the German Federal Statistical Office for the years 2003 to 2012, we show that firm-level productivity for private and publicly-owned firms increased until 2008 but not afterwards. Further, our results clearly indicate that firm ownership does not have an impact on productivity. To verify our results we conduct several robustness checks with respect to demand shocks, the specification of the production function and the general governance structure of the firms. Our results offer initial insights into the link between ownership and productivity in modern public utilities against the background of remunicipalisation debates in European public service sectors.

The remainder of the chapter is organised as follows. Section 3.2 provides some background information on the German retail electricity sector and remunicipalisation trends. Section 3.3 surveys relevant literature. Section 3.4 derives the retail production function while Section 3.5 introduces the dataset, before Section 3.6 presents the empirical strategy. Section 3.7 discusses the results along with the robustness checks. Section 3.8 concludes.

3.2 Electricity supply in Germany

3.2.1 The German retail electricity sector

Prior to 1998, electricity in Germany was supplied by more than 800 local monopolists governed by private, public, or mixed ownership. Most were vertically and horizontally integrated and offered other products too, such as natural gas and district heating. EU Directives 96/92/EC and 2003/54/EC initiated the reorganisation of the European electricity sector and envisioned a gradual opening of end-consumer markets until 2007.[5] During the first years, competition among suppliers was mostly limited to large customers, such as commercial clients and the manufacturing sector. 93 per cent of residential households stayed with local incumbents, of which 59 per cent would still subscribe to the most expensive baseline tariffs (Table 3.1, year 2007).

In 2005, Germany's regulatory authority was put in charge of supervising the elec-

[5] Contrary to other countries, such as France or Italy, the German government decided to liberalise supply to all consumers classes (large industrials, businesses, residential consumers) directly in 1998. Full competition, however, in particular for residential customers, took some time to develop.

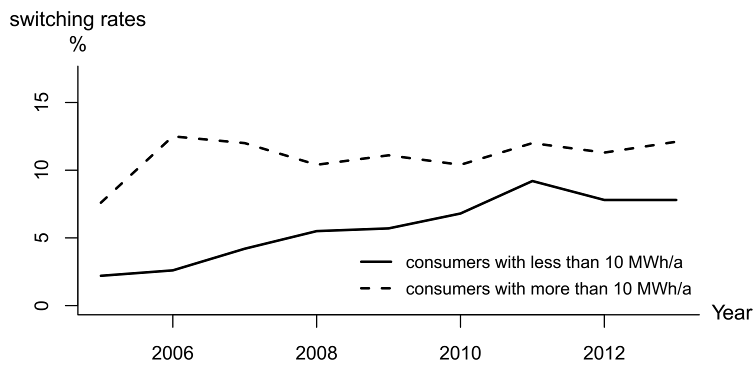
Table 3.1: Cumulated switching rates (%)

	2007	2008	2009	2010	2011	2012	2013
households							
switch to competitor	6.4	11.2	13.9	15.5	16.8	20.1	20.9
incumbent low tariff	35	37.8	41.2	41	43.4	43.2	45
incumbent base tariff	58.6	51	44.9	43.5	39.8	36.7	34.1
business and manufacturing							
switch to competitor	46.7	47.6	48.6	51.8	54	58.6	66
incumbent low tariff	50.2	50.3	49.3	45.8	42.8	39.3	34
incumbent base tariff	3.1	2.1	2.1	2.4	3.1	2.1	<1

Source: Bundesnetzagentur (BNetzA): Monitoringberichte 2006-2014 (BNetzA, 2006-2014).

tricity sector. Centralised regulation and the unbundling reforms[6] in 2007 significantly reduced discrimination in network access for third parties. As a consequence, switching rates for residential customers slowly increased, more than doubling by 2011 (Figure 3.1). Likewise, the share of supply areas with more than 50 competitors increased from 23 per cent in 2007 to more than 80 per cent in 2013 (Figure 3.2).

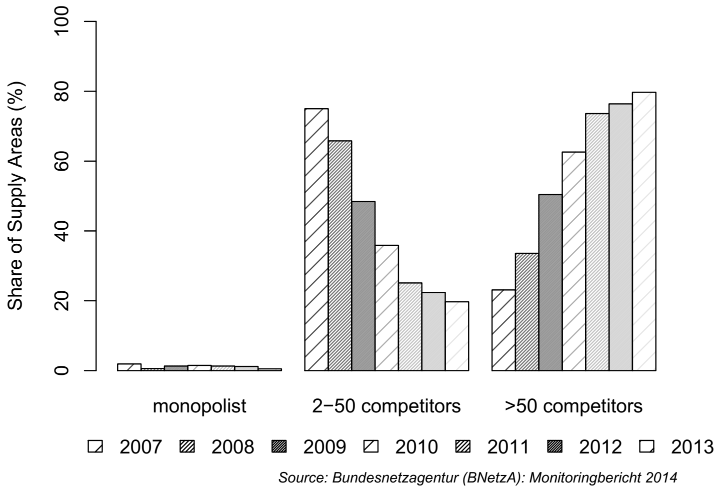
Figure 3.1: Consumer switching rates (%), 2006-2014



Source: Bundesnetzagentur (BNetzA): Monitoringberichte 2006−2014

[6] These reforms imposed the legal separation of the distribution networks from the generation and retail segments of vertically integrated companies with more than 100,000 customers.

Figure 3.2: Competition intensity across supply areas, 2007-2013



Today, depending on the region, residential customers can choose among more than 50 retailers offering a wide range of supply contracts. Most competitors are former local incumbents of other regions along with some new entrants specialising in green energy (*Ökostrom*) or low-cost tariffs. In 2015, Germany had over 1,000 suppliers, two-thirds of which were majority-owned by public government entities.

3.2.2 Remunicipalisation trend

Since recently, the number of government-owned electric utilities is increasing. Many municipalities realise the chance to pursue an independent energy policy at a local level. Local policymakers argue that remunicipalisation is critical in creating a transformation towards a sustainable energy system based on energy efficiency and renewable energies. They are often strongly supported by the public, as shown by campaigns and referenda initiatives in favour of remunicipalisation in major large German cities such as Berlin (2013), Hamburg (2013) and Stuttgart (2014). But also smaller cities re-purchase privatised firms in the energy sector: over 60 new local public utilities (so called "Stadtwerke") have been established between 2007 and 2012. It is expected that this process will continue and even accelerate in the future (Hall et al., 2013). The new and remunicipalised local public utilities operate as supply companies, either buying or generating the mix of electricity they want.

3.3 Literature survey

3.3.1 Theoretical approaches

Three distinct streams of thought address the public-private firm comparison: Agency/Property Rights Theory; Public Choice Theory; and Organisation Theory (Villalonga, 2000). These streams postulate two reasons why public firms are less efficient than private firms: managerial discretion and social goals.

Managerial discretion. This hypothesis is based on some moral hazard problem. Managers of public firms are assumed to put less effort into profit-maximisation and instead to maximise a private agenda (e.g., output expansion, leisurely workload) (Williamson, 1963; Alchian, 1965; Migué and Bélanger, 1974; Niskanen, 1968, 1975). Managers are free to do so because of the belief that public firms' disciplining mechanisms or incentive schemes tend to be weak. Reasons involve soft budget constraints (Kornai, 1986), the absence of the market for corporate control (signalling the firm's value and thus the manager's performance, Millward and Parker (1983)), incomplete contracts if the government cannot credibly commit to punish the manager for low effort (Schmidt, 1996) and ex-post expropriation of efficiency gains by the government to serve other (social) goals (Laffont and Tirole, 1991).

Social goals. The pursuit of social goals (e.g., employment) by the owner is central to the second argument. Interest groups are assumed to exert pressure on governments to implement policies through public firms and thus divert a firm's objective away from profit maximisation. While some authors stress that social goals may still be ex-post efficient from a welfare point of view (cf. ‚common good' hypothesis Wintrobe, 1987; Florio, 2004), more radical contributions assume malevolent governments with private agendas offering few or no social benefit (Shleifer and Vishny, 1994; Boycko et al., 1996). As a consequence, production in public firms would inevitably lead to a deadweight loss in efficiency and welfare.

Other studies emphasise the importance of market structure in determining performance. Studies analysing UK privatisations from 1979 to 1991 (Kay and Thompson, 1986; Yarrow, 1986; Vickers and Yarrow, 1991), find that regulation and market structure are much more relevant for performance than pure transfer of ownership, and that many empirical studies fail to compare ‚likes with likes' and to disentangle ownership effects from the influences of regulation and market environment.[7] While private firms can be more effective at reaching technical efficiency in the absence of market power, allocative efficiency is higher with public firms in the presence of market failure. In other words, government policies should promote competition

[7] This is particularly true for cross-sector and cross-country studies (see Mühlenkamp, 2013).

and effective regulation.

3.3.2 Empirical evidence for the electricity sector

Although traditional economic theory offers manifold suggestions why public firms should perform less efficiently than private companies, empirical evidence is ambiguous and does not easily confirm theory.[8] The majority of empirical studies on performance differences in the electricity sector examine US utilities in the 1960s to the 1990s. In general, the conclusions drawn about the performance differences between public and private utilities during this period are rather weak. In an overview of the literature, Peters (1993) and Pollitt (1995) point out that many early studies suffer from small sample sizes, overly restrictive assumptions, and failure to account for the impact of market structure, regulation, or vertical integration (see also critique in Atkinson and Halvorsen, 1986). Estimation methods differ and questions addressed range from the study of managers' turnover rates (De Alessi, 1974) to price discrimination (Peltzman, 1971), investment behaviour (Rose and Joskow, 1990), and cost efficiency (Neuberg, 1977). A newer study by Kwoka (2005) using cross-sectional data from 1989, finds cost advantages for public firms in electricity distribution, whereas private firms outperform in generation. Still, evidence for the time after 1990 is limited and comparisons of performance after partial electricity market restructuring in the US, the development of individual states' renewable portfolio standards, and other recent changes in federal and state regulatory schemes are scarce.

Studies of the EU's power markets are even scarcer, partly due to the absence of relevant datasets. Power markets in Europe tend to be highly concentrated (see, for instance, Enel in Italy and EDF in France) which restricts the available sample sizes. In Sweden, Kumbhakar and Hjalmarsson (1998) challenge earlier findings by Hjalmarsson and Veiderpass (1992) and conclude that private distributors are relatively more cost efficient. Fumagalli et al. (2007) do not find any differences between public and private distributors in Italy when service quality is considered. Arocena and Waddams-Price (2002) investigate the cost efficiency of public and private generators in Spain under different regulatory regimes and show that there is no difference under price-cap regulation, whereas public firms are more cost-efficient under cost-plus regulation.[9] In summary, despite the attention that economic the-

[8] There exist some general surveys which aim at summarising empirical evidence on performance difference between public and private firms across countries and sectors (see e.g. Megginson and Netter, 2001; Vining and Boardman, 1992). However, these meta surveys neglect any differences in regulation, market structure and firms across industries, countries and time.

[9] Some studies for the UK investigate performance changes after the privatisations (see Florio, 2004, for a summary), but do not allow for a direct comparison of private and public utilities, thus

ory attributes to alleged performance differences between public and private firms, empirical evidence for an important sector of public involvement in Europe, the electricity sector, is rare.

All of the studies above focus on the capital-intense segments, generation and distribution, or analyse vertically integrated utilities. However, production processes fundamentally differ between the capital-intense parts of the value chain and the retailing unit, which is a service business. Furthermore, market structure and regulation are dissimilar, i.e. in the EU, distribution companies are regulated natural monopolies, whereas retail electricity firms must compete in open markets. Results from other sectors are not easily transferable. Our chapter contributes to the literature in two ways. It is the first empirical study on performance differences between public and private utilities in Germany. Second, on a global level, it is the first empirical study to explicitly address productivity in energy retail markets, considering the new market structures after European liberalisation.

3.4 Model

A novel contribution of this chapter is the derivation of a service production function for retail electricity, which may include both independent electricity retailers as well as the retailing units of legally unbundled firms. For simplicity, this chapter subsumes both under the term ‚retailer'. We exclude horizontally and vertically integrated firms that did not unbundle as the dataset lacks information on input allocation across activities.[10] Comparing independent electricity retailers with integrated firms would introduce a negative productivity bias for integrated firms as parts of their inputs are used to produce other products than retail electricity. The multitude of vertical (generation, distribution) and horizontal (gas, water, district heat, waste, ...) products creates a high-dimensional space of business models. This is one the main challenges in the utilities literature and one of the reasons why up to date no studies existed for the German market. To be sure that potential productivity differences do not root in different business activities, we decided to focus on a clearly defined subsample of pure electricity retailers.

When specifying the production function in detail, we note that retailers do not produce a physical good but rather provide a service. They are the link between consumers, network operators, and generators. Retailers contract for electricity, in

failing to disentangle the effect of ownership from the changes in regulation and market structure.

[10]Vertically integrated firms serve further steps of the value chain such as electricity generation or distribution. Horizontal integration refers to product bundling across sectors, e.g., the joint provision with gas, water, district heat or waste.

return for which consumers accept a price above the wholesale price, which compensates the retailers. The retailer performs two main activities which determine the success (i.e. profit) of the enterprise: procuring electricity and marketing it. The two activities are explained below.

3.4.1 Procurement

Retailers either purchase electricity from external sources or from generators in their holding company. In the case of external sources, retailers can choose among a variety of contracts, such as long-term contracts, indexed contracts, or procurement in the spot market. The marginal cost of the electricity provided to consumers depends on the portfolio of contracts chosen. Moreover, in Germany, retail prices for residential customers are adjusted only a few times annually, whereas wholesale electricity prices fluctuate daily. Assuming the risk of price volatility can be interpreted as another part of the services provided by a retailer to its customers. Procuring adequate supply by managing price volatility can involve hiring procurement experts or outsourcing. Evidence for Germany shows that in particular small retailers tend to use outsourcing. We model the labour choice related to procurement as a decision between own labour force L and external services S.

3.4.2 Marketing

The retailer's objective is to maximise the number of customers and thereby sales. The amount of electricity consumed by a single customer is exogenous to the retailer, i.e. it cannot convince a single consumer to consume more electricity.[11] To increase sales, a retailer must acquire new customers or at least prevent current customers from switching to its competitors. In Germany, many established electricity retailers develop print advertising and social media campaigns to attract new customers (and remind existing customers about the benefits of staying with them), whereas new entrants will employ a variety of approaches to build a reputation and to overcome the

[11] One might argue that the level of electricity consumption is influenced by electricity prices and thus affected by the retailer's pricing policy, yet the empirical evidence shows that the short-run price elasticity of electricity demand for residential customers is highly inelastic and that even long-run elasticities are rather low. Long-run estimates range from -0.2 to -0.7 and short-run estimates from -0.2 to 0 (Silk and Joutz, 1997; Narayan et al., 2007; Alberini and Filippini, 2011; Blazquez et al., 2013). This is intuitive, since a large percentage of electricity consumption is fixed in the short-run by the types of appliances owned by consumers. Nakajima and Hamori (2010) offer interesting findings in that regional deregulation of US electricity retail markets does not seem to have increased price responsiveness. A retailer's objective is then to raise market share by maximising the number of customers. Apart from that, there is a strong movement in Germany towards energy efficiency which is accompanied by various government policies that encourage less electricity consumption. Thus, it is infeasible to run marketing campaigns inciting customers to raise their individual consumption.

tendency of consumers to stay with their local incumbent. Unlike many consumer products, electricity does not differ in its physical appearance, and thus retailers often engage in ‚branding', in order to differentiate their products and services from the competitors.[12] Retailers may turn to in-house marketing staff or outsourcing to devise campaigns. Again, we translate the labour choice related to customer relations as a simple decision between using own labour force L and external services S.

3.4.3 Capital inputs

A typical production function contains capital input, so it is useful to think about the relevant capital for service providers. Production functions were originally designed for the manufacturing sector, where machines are considered the capital and the employees operating the machines are the labour. A straightforward extension to the service sector would be to consider computers, office buildings etc. as relevant capital and include them in the production function. The problem is that while a manufacturing firm potentially can increase output by purchasing a new machine, it is not clear why upgrading to faster computers or adding more floorspace should lead to more customers. Unlike brick-and-mortar retail, retail electricity providers mostly rely on an online presence to sell their products and services. They also do not need to build and operate distribution centres to stock commodities. Fox and Smeets (2011) estimate a production function for the Danish advertisement industry 1992-2001 and show that the capital coefficient is not significantly different from zero while labour is a clearly dominant input ($\beta_l = 0.94$). Concluding that physical capital does not appear to be a major driver behind productivity, we abstract from capital in our service production function.[13]

[12] See Florio (2013), p.88: "Competition for water or phone calls cannot be of the same type as for furniture or restaurants. Given the relative homogeneity of the good provided by utilities, one would argue that for the consumer it is mostly a matter of searching for the lowest price. [...] Profit-maximising firms, however, know this and [...] then try to win brand loyalty by obfuscating the essential homogeneity of their supply. This translates into advertising and other marketing expenditure including the offer of multi-product packages. These expenditures are likely increased with the number of entrants, without actually offering the consumer substantial price/quality difference. In a precise sense they are wasteful expenditures, which should be seen as a social cost of market opening, when consumers are not well informed."

[13] We could argue that intangible capital matters in this context. It is the motivation and the abilities of the labour force (creativity, innovation, identifying customer needs), which are often subsumed under the term of *human capital*. Accounting for human capital in general is very difficult due to data availability and is beyond the scope of this chapter.

3.4.4 A more general production function applied to retail electricity

Based on the previous ideas we adapt the production function framework from the manufacturing sector to the retail sector. Consider the Walras-Leontief function

$$Q = \min(Q_1, Q_2) \tag{3.1}$$

where Q_1 is the amount of the retail product in stock (in our case, procured electricity) and Q_2 is output created by the combination of marketing and a competitive procurement strategy. Q_2 is a function of labour and external services $Q_2 = F_2(L, S)$ and is measured as the number of customers multiplied by their consumption. Output Q is the actual output sold, i.e. the amount of electricity ordered from the customers adjusted for physical limitations in procurement. A retailer can substitute within F_2, but not between Q_1 and Q_2. The Leontief condition thus expresses the fact that retailers are not trained in producing the commodity, i.e. they cannot produce electricity to meet a spike in consumer demand. The assumption is intuitive in the case of independent electricity retailers that do not own generation. We argue that this holds also true for vertically integrated firms. In a vertically integrated firm, managers are responsible for different units and the production decision of the generation unit is exogenous to the manager of the retail department. The retail manager can only decide over staff in his own division who are white-collar workers and do not have access to the power plant. Hence, L cannot be used to produce Q_1.[14] The final output is determined by the limiting factor of Q_1 and Q_2. In some retail sectors Q_1 might be pivotal, e.g. in high-tech appliance industries.[15] In retail electricity, by contrast, Q_1 is not the limiting factor, because electricity demand is always met by production and the retailer is forced to continually adjust its procurement via the spot market. In this situation, total output Q is then given by the outcome of F_2 and the Leontief function reduces to

$$Q = Q_2 = F_2(L, S). \tag{3.2}$$

[14] Exogeneity holds at least from a short-term perspective. The retailer could influence generation decisions in the long-run, i.e. by procuring more electricity from renewable energy sources, but doing so would not affect the non-substitutability of inputs expressed in the Leontief condition.

[15] Imagine a retail market for notebook computers, where a customer walks into the retailer's brick-and-mortar store and wants to purchase ten notebooks. Unfortunately, the retailer has only three in stock. When the retailer explains that it will take three months to procure the remaining seven, the customer is unwilling to wait. The retailer's marketing campaign was successful, i.e. it created a potential output Q_2 of ten notebooks, but the limiting factor is now physical procurement Q_1, i.e. only three notebooks are actually in stock.

3.5 Data

The main limitation for empirical studies of retail electricity in Europe is the lack of firm-level data on input use, customer structure, and ownership status. To overcome these limitations, we construct a unique panel dataset based on newly-available firm data provided by the German Federal Statistical Office. The rich data include various cost components, output and revenue structures, and other variables related to the production process (see chapter 2). The panel dataset comprises all German utilities with more than ten employees which provide electricity, natural gas, district heating, water supply, sewerage, and waste treatment. The utilities have different degrees of vertical and horizontal integration. Depending on the year of observation, the data represent 80-90 per cent of true electricity consumption in Germany. We use a subsample of independent electricity retailers and the retailing units of legally unbundled firms to ensure comparability of firms with respect to homogeneous inputs and output. (see Section 3.4). We allow for horizontal integration with gas retail, but compute separate inputs between electricity and gas retail. Firms with zero input values are discarded from the analysis. After cleaning the data and checking for implausible entries, we obtain a final subsample of 76 retailers operating up to ten years between 2003 and 2012 ($N = 212$). Table 3.2 gives an overview of the number of observations per year.[16] Intensified competition for residential customers can explain the strong increase of private firms after 2011 (see Section 3.2).

Table 3.2: Number of observations

	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
private	11	15	13	16	17	8	14	15	15	23
public	5	3	7	5	8	4	7	8	9	9
all	**16**	**18**	**20**	**21**	**25**	**12**	**21**	**23**	**24**	**32**

3.5.1 Inputs and outputs

The retail production function has two inputs, labour L, measured in number of workers and expenditure for external services S. External services include various kinds of outsourced labour services but no commodities. The expenditure is deflated using the German yearly price index for NACE class M (Professional, scientific and

[16] Poor data quality causes the kink in 2008 and is a general problem as about half of the observations were lost due to missing data points. The result is an unbalanced panel which lowers the efficiency of the estimation. However, it should not affect the main result as long as private and public firms do not systematically differ in their non-response rates.

technical activities).[17] Table 3.3 lists the summary statistics. We include labour costs in the table to give a better idea of the relative importance of external services in input use. The amounts spent on external services clearly exceed those spent on internal staff. Outsourcing is therefore an important factor in retail electricity.

Table 3.3: Summary statistics

		Q5	*median*	*mean*	*Q95*	*sd*	*sum*	N
employees L								
public		1	7	47	194	73	3,063	65
private		2	16	75	437	136	10,982	147
external services S								
public	[mio €]	0.02	0.66	24.5	157.4	53.3	1,595	65
private	[mio €]	0.00	1.05	52.9	397.1	157.7	7,780	147
labour costs								
public	[mio €]	0.06	0.34	3.08	16.6	5.4	200.0	65
private	[mio €]	0.04	0.51	5.58	29.3	13.7	819.7	147
wages p_L								
public	[€/h]	21	33	34	55	12	-	65
private	[€/h]	16	32	36	73	18	-	147

Notes: Labour costs are divided between electricity supply and gas supply following the staff ratio. Wages are averaged across employees and computed as total payroll over total hours worked.

Output Q, the total amount of electricity supplied by the retailer, is measured in TWh and consists of deliveries to both end-consumers Q^e and to other retailers Q^{or}

$$Q = Q^e + Q^{or}. \tag{3.3}$$

We observe that 39 per cent of the retailers sell to other retailers ($Q^{or} > 0$). Table 3.4 provides summary statistics for Q. Note that the distribution is heavily skewed to the right, i.e. few large firms dominate. This is representative of electricity supply in Germany, where many retailers are in fact former municipal incumbents and a few large cities dominate a number of small municipalities. In general, there is much dispersion between very small firms (serving an equivalent of less than 100 inhabitants) and large firms with an output Q^e equivalent to the electricity consumption of a large city. Altogether, private firms sell 95 per cent of the electricity in the sample.

[17] The number of workers is reported separately for electricity and gas retail in the data. External services are divided between electricity and gas retail in proportion to the staff ratio.

Table 3.4: Summary statistics for total electricity sold

		Q5	*median*	*mean*	*Q95*	*sd*	*sum*	N
total supply Q								
public	[TWh]	0.003	0.3	1.1	5.0	1.7	69.0	65
private	[TWh]	0.002	0.09	9.3	43.4	33.6	1,374	147
all	[TWh]	0.002	0.1	6.8	26.1	28.2	1,443	212

3.5.2 Control variables

Retailers produce multiple outputs as they serve different customer groups with distinct consumption patterns. Ideally, this would be modelled through a multi-output production function.[18] Due to the limited sample size, we refrain from a multi-output approach. However, we control for the importance of each customer group and include the share of residential customer deliveries in supply to end-consumers in the estimation equation

$$\tau = \frac{\text{supply to residential customers } Q^r}{\text{supply to end-consumers } Q^e}. \tag{3.4}$$

Residential customers *(Tarifkunden)* are private households and small businesses that are served based on two-part tariffs which are typically adjusted once annually. Large customers *(Sondervertragskunden)* are manufacturing firms but also government entities, housing associations, and (non-energy) retailers. They are served by variable tariffs which link to the fluctuations in wholesale electricity prices. Since residential customers usually have lower per-capita consumption levels, controlling for their percentage avoids the risk of productivity scores reflecting the customer structure instead of providing an isolated measure of productivity. Likewise, deliveries to other retailers imply higher volumes than those sold to end-consumers. Firms with a large percentage of electricity supplied to other retailers thus would appear to be relatively more productive. We account for it by the share of deliveries to other retailers in total supply

$$\pi = \frac{\text{supply to other retailers } Q^{or}}{\text{total supply } Q}. \tag{3.5}$$

Table 3.5 lists the summary statistics for both control variables. 91 per cent of public retailers serve residential customers. The rate for private firms is somewhat lower but still high (73 per cent). The proportion of firms selling to other retailers is balanced and lies around 39 per cent.

[18] Shephard (1971), for instance, introduced the distance function approach for modelling multiple outputs in a production framework, which today is widely used in the frontier literature (see e.g., Saal et al., 2007).

Table 3.5: Summary statistics for customer structure

	Q25	*median*	*mean*	*Q75*	*sd*	*nonzeros (%)*
share of residential customers τ						
public	0.25	0.51	0.51	0.73	0.32	90.8
private	0.57	0.77	0.71	0.94	0.27	72.8
share of other retailers π						
public	0.22	0.85	0.67	0.99	0.36	38.5
private	0.17	0.42	0.44	0.56	0.29	39.5

3.5.3 Ownership

We define public undertakings as firms where public authorities have a dominant influence by either majority of vote or majority of capital (directive 2000/52/EC). Ownership is then measured as a dummy variable $d \in \{0, 1\}$ which becomes 1 if public entities own more than 50 per cent of either shares.[19]

$$d_i = \begin{cases} 1 & \text{if company has more than 50 per cent public shares} \\ 0 & \text{if company has more than 50 per cent private shares} \end{cases} \tag{3.6}$$

Annual ownership data are taken from the survey on public firms *Jahresabschlussstatistik öffentlicher Fonds, Einrichtungen und Unternehmen* collected by the German Federal Statistical Office. In total, we observe 65 public firms and 147 private firms.[20]

3.6 Empirical strategy

We approximate the retail production function in (3.2) by a second order Taylor series with the median as the focal point. This translates to a translog production function with median-corrected inputs and outputs (Boisvert, 1982). The translog function provides more flexibility regarding the elasticities of substitution between input factors. It is standard in the utility sector (Kumbhakar, 1996; Saal et al., 2007; Farsi and Filippini, 2009) and is also applied to productivity estimation (e.g., De Loecker and Warzynski, 2012). We additionally control for level effects in the production function which result from different customer structures (see Section 3.5.2). The estimation equation of the retail production function is then given by

[19] It would be interesting to consider other thresholds as well. We were restricted in our choice by the dataset made available from the Statistical Office.

[20] The dominance of private firms among independent retailers seems plausible since most public utilities tend to be vertically or horizontally integrated for historical reasons. Since input use is only reported at the firm-level, we cannot perform separate estimations of the retailing unit for these firms unless they are legally unbundled.

$$\begin{aligned} q_{it} = &\beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} \\ &+ \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + \omega_{it} + \epsilon_{it}, \end{aligned} \tag{3.7}$$

where i is the firm in the year t, q_{it} is total supply (logs), β_0 is a constant, l_{it} is the number of employees (in logs), s_{it} is deflated expenditure for external services (in logs), τ_{it} controls for the share of electricity delivered to residential customers, π_{it} is the share of electricity supplied to other retailers, ω_{it} denotes unobserved technical productivity, and ϵ_{it} captures iid errors.

When estimating a production function with unobserved productivity ω_{it}, productivity is likely to affect input choice, which leads to an endogeneity problem, the so-called simultaneity bias.[21] Olley and Pakes (1996) were the first to introduce a control function approach meant to overcome the simultaneity bias. They divide the estimation process into two stages. In the first stage, productivity is expressed in terms of observables by inverting the firm's investment decision. The production function is estimated by OLS. In a second stage, unbiased coefficients are estimated using moment conditions on the innovation in productivity and past input choice. Our estimation strategy builds on the extension of Ackerberg et al. (2015) (ACF). The ACF approach explicitly allows for modelling labour as a dynamic, non-flexible input, which reflects the legal situation in the German utility sector and it does not rely on investment as a proxy function for productivity.

3.6.1 First-stage estimation

Assume external services s_{it} to be a static, flexible input without any dynamic implications and with no adjustment costs. Assume that most contracts for external services are adjusted at least once annually and that retailers' marketing campaigns are designed for the short term. The input demand function is then determined in a static optimisation problem and given by

$$s_{it} = s_t(l_{it}, \tau_{it}, \pi_{it}, \omega_{it}, p_{Lit}), \tag{3.8}$$

where l_{it} is pre-determined, p_{Lit} are firm-specific input prices of the substitute (staff wages), and $s_t(\cdot)$ is strictly monotone in ω_{it}. The index t conveys that $s_t(\cdot)$ depends on further firm-invariant variables, such as the price-level of external services, which

[21] In the utility sector, performance indicators, such as technical or cost efficiency, are traditionally estimated in the context of frontier models (see Charnes et al., 1978; Aigner et al., 1977, for an introduction). However, these models assume (in-)efficiency to be exogenous, i.e. uncorrelated with input choice.

are not explicitly modelled. Except for ω_{it}, all variables are observed. $s_t(\cdot)$ is then inverted for ω_{it}, giving

$$\omega_{it} = h_t(l_{it}, \tau_{it}, \pi_{it}, p_{Lit}, s_{it}), \tag{3.9}$$

where $h_t(\cdot)$ is modelled as a polynomial series of degree 2. The proxy function for productivity (3.9) is inserted into the retail production function (3.7) to estimate the prediction $\Phi_{it}(\cdot)$ by OLS. $\Phi_{it}(\cdot)$ represents the predicted output net of the iid error ϵ_{it}.

$$q_{it} = \underbrace{\beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} + \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + h_t(\cdot)}_{\Phi_{it}(l_{it}, s_{it}, \tau_{it}, \pi_{it}, p_{Lit})} + \epsilon_{it} \tag{3.10}$$

The (unbiased) prediction $\hat{\Phi}_{it}$ can be used to express productivity as

$$\omega_{it}(\boldsymbol{\beta}) = \hat{\Phi}_{it} - \beta_0 - \beta_l l_{it} - \beta_s s_{it} - 0.5\beta_{ll} l_{it}^2 - 0.5\beta_{ss} s_{it}^2 - \beta_{ls} s_{it} l_{it} - \beta_\tau \tau_{it} - \beta_\pi \pi_{it}. \tag{3.11}$$

3.6.2 Second-stage estimation

In the second stage, assume a first-order Markov process for productivity

$$\omega_{it} = c + g(\omega_{it-1}) + \varphi d_{it-1} + \xi_{it} \tag{3.12}$$

where ξ_{it} refers to an iid shock to productivity and d_{it-1} controls for public ownership. We imply that a change in the managerial strategy in response to a new owner takes at least one year to be implemented. Controlling for additional effects in the law of motion for productivity has been studied previously (De Loecker and Warzynski, 2012; Doraszelski and Jaumandreu, 2013; Maican and Orth, 2015). By including ownership status in the Markov process for productivity, we test for the pertinence of two theories on public firms (see Section 3.3.1). According to the managerial discretion hypothesis, a change in the ownership structure, e.g., the privatisation of a formerly public firm, should modify managers' incentives for efficient input use and thus affect productivity. Likewise, the pursuit of social goals in a public firm should distract managers from profit maximisation and predict a negative effect on productivity. The Markov process is modelled as a polynomial series of degree 3.

We then regress ω_{it} on ω_{it-1}, ownership and a constant term to obtain an estimate for the innovation in productivity $\hat{\xi}_{it}$

$$\hat{\xi}_{it}(\boldsymbol{\beta}) = \omega_{it}(\boldsymbol{\beta}) - \hat{c} - \hat{\psi}_1\omega_{it-1}(\boldsymbol{\beta}) - \hat{\psi}_2\omega^2_{it-1}(\boldsymbol{\beta}) - \hat{\psi}_3\omega^3_{it-1}(\boldsymbol{\beta}) - \hat{\varphi}d_{it-1} \tag{3.13}$$

where $\boldsymbol{\beta}$ is the vector of coefficients from the retail production function. The coefficients are identified by the respective moment conditions

$$E[\xi_{it} \begin{pmatrix} 1 \\ l_{it} \\ l^2_{it} \\ s_{it-1} \\ s^2_{it-1} \\ l_{it}s_{it-1} \\ \tau_{it} \\ \pi_{it} \end{pmatrix}] = 0.$$

exploiting the fact that current productivity shocks are uncorrelated to past input choice and predetermined variables. The iterative procedure requires first guesses on the vector $\boldsymbol{\beta}$ which we take from an OLS estimation of the production function without the productivity term.

3.7 Results

3.7.1 Production function estimates

Table 3.6 lists the estimates for the coefficients of the retail production function and the Markov process. All coefficients have the expected sign. The negative coefficient for the interaction term between labour and external services indicates, as expected, that the two inputs behave as substitutes at the median. Furthermore, after correcting for the upward bias we find constant returns to scale at the median level of inputs as the sum of the coefficients of l_{it} and s_{it} sum up to one. The OLS estimation confirms that a translog specification seems appropriate despite the small sample size. It also reaffirms the importance of controlling for customer classes. A higher share of electricity delivered to residential customers leads to smaller output at the median, whereas a higher share of electricity supplied to other retailers leads to higher output at the median. An obvious drawback of the ACF method is the loss of precision due to numerical optimisation and the block-bootstrap of standard errors.

The estimate for φ is not significantly different from zero and suggests that private firms do not seem to have a better strategy for dealing with market opening than the public firms. They do not systematically achieve higher productivity gains, or incur fewer losses between 2003 and 2012. Section 3.7.3 analyses the influence of ownership structure in more detail.

Table 3.6: Production function coefficients

	variable	*OLS* total supply q_{it}	*ACF* total supply q_{it}
β_0	*constant*	0.315*	0.315
		(0.159)	(0.260)
β_l	*labour*	0.730***	0.788***
		(0.062)	(0.250)
β_{ll}	*labour*^{2}	0.296***	0.188
		(0.072)	(0.138)
β_s	*external services*	0.421***	0.216
		(0.034)	(0.192)
β_{ss}	*external services*^{2}	0.091***	0.179**
		(0.019)	(0.082)
β_{ls}	*labour* × *external services*	−0.143***	−0.180
		(0.031)	(0.136)
β_τ	*share residential customers*	−1.584***	−1.256**
		(0.199)	(0.591)
β_π	*share other retailers*	1.119***	2.058***
		(0.226)	(0.676)
φ	*public ownership*		0.061
			(0.109)
		N=212	N=212

Notes: p-values: *** p<0.01, ** p<0.05, * p<0.1. ACF: standard errors block-bootstrapped at firm-level.

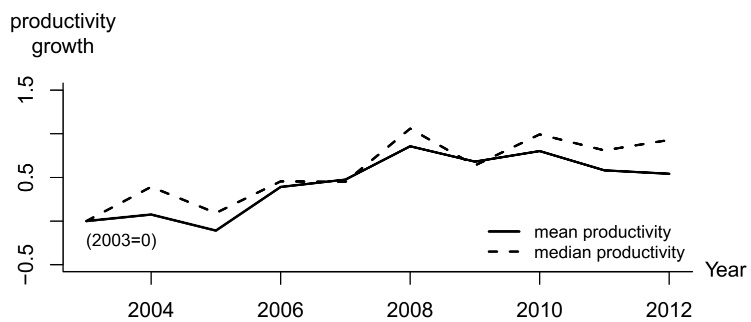
3.7.2 Productivity time trend

Firm-level productivity estimates are computed according to

$$\hat{\omega}_{it} = \hat{\Phi}_{it} - \hat{\beta}_0 - \hat{\beta}_l l_{it} - \hat{\beta}_s s_{it} - 0.5\hat{\beta}_{ll} l_{it}^2 - 0.5\hat{\beta_{ss}} s_{it}^2 - \hat{\beta}_{ls} s_{it} l_{it} - \hat{\beta}_\tau \tau_{it} - \hat{\beta}_\pi \pi_{it} \quad (3.14)$$

Figure 3.3 illustrates the evolution of productivity over time and shows the mean and median productivity growth using 2003 as the reference year.

Figure 3.3: Productivity growth, 2003-2012



We observe an initial upward trend in mean productivity between 2003 and 2008. After 2008, both mean and median productivity stabilise. At first glance, the observed evolution in productivity growth is slightly at odds with the developments in the residential customer segment after liberalisation (see Section 3.2). The evolution of productivity growth does not parallel the increased competition for residential customers after 2007. Although competition gradually intensifies during that time, we observe that annual productivity growth is close to zero after 2008 and even becomes negative. The results indicate that productivity gains are probably more drive by reorganisation within firms rather than active competition for consumers. During 2003 and 2007, many firms reorganised units, partly in reaction to unbundling requirements, which possibly led to better input use and explains productivity growth.[22] With the start of active competition for residential customers, however, input intensity in the retailing unit of the firms steadily increases without a considerable increase in output, industry-wide. The overall number of residential electricity customers remains constant since coverage is already at 100 per cent. Also, the amount of electricity consumed remains fairly stable. In contrast, the production process at the retailing stage changes fundamentally (see Section 3.4). Competition, in particular for residential customers, introduces the need for more marketing and enhancing customer relations. At the same time, procurement, which becomes more complex, requires in-house or outsourced expertise. Since all firms have to engage in these additional activities, the higher input requirements likely outweigh the potential productivity gains from competitive pressure.

3.7.3 Ownership and productivity

The first-order Markov process does not control for the base year effect, i.e. the initial productivity level. If public firms start at lower initial productivity levels but the productivity levels evolve at the same rate as private firms, then past productivity captures much of the ownership variation. Therefore, we use an equality of means test to check for an overall effect of ownership on productivity. We use a bootstrap algorithm, since our group sample sizes are small and we are unwilling to make any distributional assumptions. The following test is standard and based on Efron and Tibshirani (1993).

We divide the sample into private firms ($n_1 = 147$) and public firms ($n_2 = 65$). The null hypothesis is

[22] Reorganisation could also be motivated by *anticipation* of increased competition. On the other hand, one might wonder why it did not already take place in 1998 when markets were liberalised.

$$H_0 : \mathbb{E}[\mu_1] = \mathbb{E}[\mu_2]$$

against $H_1 : \mathbb{E}[\mu_1] > \mathbb{E}[\mu_2]$. Productivity values in each group are adjusted according to $\tilde{\omega}_{ijt} = \omega_{ijt} - \bar{\omega}_{nj} + \bar{\omega}_n$ with $j = 1, 2$, such that both groups have equal means under H_0. We sample from $\{\boldsymbol{\tilde{\omega}_1}\}$ and $\{\boldsymbol{\tilde{\omega}_2}\}$ with replacement. The test statistic is given by

$$\tau(\chi_b) = \frac{\bar{\omega}_{n1}^b - \bar{\omega}_{n2}^b}{\sqrt{\bar{\sigma}_{n1}^{2,b}/n_1 + \bar{\sigma}_{n2}^{2,b}/n_2}},$$

where $\bar{\sigma}_{n1}^{2,b}$, $\bar{\sigma}_{n2}^{2,b}$ are the respective group variances. The asymptotic sample distribution is computed using the bootstrap algorithm. The p-value is then given by

$$\hat{p} = \frac{\sum_{b=1}^{B} \mathbb{1}(\tau_b > \tau_{obs})}{B},$$

where τ_b is the test statistic from the bootstrapped sample, t_{obs} is the observed test statistic for the full sample, and $B = 2,000$ is the number of replications. Having estimated a p-value of $\hat{p} = 0.663$, we conclude that the null hypothesis cannot be rejected.

3.7.4 Robustness checks

We conduct further robustness checks to verify our model with respect to the influence of demand, the specification of technology and the overall governance structure of the firms.

3.7.4.1 Demand

Problems can arise from output being measured as electricity supplied instead of by number of customers. Fluctuations in electricity supply can be caused by demand-side shocks beyond a firm's control. The residual ω_{it} would then capture demand shocks rather than productivity (see critique in De Loecker, 2011a). Therefore, we test for the impact of aggregate demand-side shocks, in particular the 2009 global economic crisis, by including annual German electricity consumption as a control variable in the service production function. The results for the first stage (OLS) suggest that demand-side shocks do not drive the average productivity trend over time (see Table 3.8, column 1, in the section Appendix 3.9).[23]

[23] The limited sample size restricts the study of additional variables to the OLS regression.

3.7.4.2 Technology

Public firms can also differ in technology and customer structure. As a consequence, the pooled estimation in Section 3.6 might be too general and the model would be misspecified. We interact the first-order input terms L_{it}, S_{it} as well as the indicators of the customer structure τ_{it} and π_{it} with the ownership dummy to verify this hypothesis. Based on the results listed in column 2 of Table 3.8, we find no systematic difference in technology and customer structure for both groups.

3.7.4.3 Scale

Output includes supply to other retailers. Perhaps not surprisingly, the estimated impact of serving this particular customer segment on the level of output is strongly positive (see Table 3.6). Although the technology coefficients in Section 3.7.1 suggest constant returns to scale at the median level of inputs, very large firms could benefit from increasing returns to scale and have higher productivity values. We observe 13 extraordinary large observations in the sample having outputs 200 times that of the median firm. To avoid systematic bias in the productivity values, we ran a sensitivity analysis and excluded all firms with outputs exceeding 20TWh (see Table 3.8, column 3). We find that the coefficient β_π decreased by one half compared to its original value and was more in line with β_τ. The group mean tests were unaffected.

3.7.4.4 Governance structure and productivity

It might not only be the shareholders themselves who matter but also the degree to which they can influence decisions taken within the firm (see, e.g., Estrin and Pérotin, 1991). In Germany, governance differs depending on a firm's legal form. The differences are particularly pronounced between public firms organised under public law and private law. Public law grants less independence to public undertakings. They are subordinate to the local public administration and public officials usually head the firms. Over the last decade, many utilities have changed their legal status by reorganising under private law (e.g., AG, GmbH, GmbH& Co. KG, and KG). The share of public utilities organised under private law increased from 38 per cent in 1990 to 55 per cent in 2010 (Gottschalk, 2012). The governance structure within reorganised public firms is now much closer to that of a private firm and stricter accounting rules apply. Thus, we hypothesise that the difference in productivity between public and private firms of the same legal form is small. To verify this, we regress productivity on the legal form interacted with ownership status (see Table 3.7). We control for time effects.

Table 3.7: Governance structure and productivity

	pooled OLS		*std.error*
dependent variable	*productivity*		
(Intercept)	−0.512	***	(0.116)
public GmbH	0.107		(0.187)
time effects	yes		

Notes: $N = 212$. p-values: *** p<0.01. Reference group: private GmbH. Regression controlled for all other governance structures (AG, GmbH & Co. KG, Eigenbetrieb, Genossenschaft, private KG, other private firms).

In the sample, 71 per cent of the public firms and 50 per cent of the private firms are organised as *GmbH*.[24] Since we only observe 65 public firms in total, we focus on *public GmbH* in relation to our reference group *private GmbH*. We find no difference between public and private firms organised as *GmbH*. *GmbH* is by far the most common legal form in the retail electricity sector and these firms do not seem to behave differently under competition, whether they are publicly or privately owned.[25]

3.8 Conclusions

Based on a robust structural model, this chapter investigated the evolution of productivity from 2003 to 2012 for independent electricity retailers in Germany following the imposition of liberalisation. Furthermore, we tested whether government ownership has an impact on productivity. It is the first empirical work which explicitly addresses public versus private productivity differences in the retail electricity market for a European country, taking into account the new market structure after the beginning of liberalisation in 1998.

We adapted the manufacturing production framework to the retail sector and developed a service production technology based on a procurement and a marketing decision. Labour and external services were the main inputs. Using a newly-available and unique dataset of German electricity retailers, the control function approach was applied to the structural model for the estimation of firm-level productivity.

The results focus on the subgroup of independent electricity retailers and provide first empirical evidence to a controversial theoretical debate on municipal ownership

[24] *Gesellschaft mit beschränkter Haftung* is a company with limited liability comparable to *Ltd.* in the UK or *LLC* in the US.

[25] The interpretation of results for other legal forms deserves caution. Restrained by data, we do not observe enough firms in the remaining subgroups to clearly identify their legal forms as driving the results. Coefficients could be driven by unobserved individual characteristics.

in the European utilities industries. We found no evidence of ownership having an impact on productivity, possibly due to increasing corporatisation among public utilities and the new competitive environment. The alleged dichotomy between public and private firms in the remunicipalisation debate, therefore, could be exaggerated. Productivity differences between firms could be the result of more complex sources, which suggests that future research should examine precise firm strategies (e.g., green electricity products, branding campaigns, etc.) and input quality. Also, the majority of German utilities is vertically and horizontally integrated, but could not be analysed due to absent information on input allocation. Extending the analysis to integrated utilities is desirable and left for future research.

3.9 Appendix

Table 3.8: Robustness checks

		I	*II*	*III*
		OLS	*OLS*	ACF
β_0	*constant*	-1.968	-0.088	0.294
		(3.539)	(0.200)	(0.256)
l_{it}	*labour*	1.055***	1.000***	0.427
		(0.083)	(0.112)	(0.277)
l_{it}^2	*labour*^{2}	0.607***	0.612***	0.187
		(0.111)	(0.113)	(0.126)
s_{it}	*external services*	0.443***	0.463***	0.432*
		(0.056)	(0.060)	(0.229)
s_{it}^2	*external services*^{2}	0.129***	0.133***	0.090
		(0.031)	(0.031)	(0.076)
$l_{it}s_{it}$	*labour × external services*	-0.345***	-0.338***	-0.126
		(0.055)	(0.057)	(0.109)
τ_{it}	*share residential customers*	-1.164***	-1.327***	-0.949**
		(0.190)	(0.267)	(0.439)
π_{it}	*share other retailers*	1.217***	1.176***	0.795
		(0.219)	(0.329)	(0.594)
	German electricity demand	0.004		
		(0.007)		
d_{it}	*public*		0.115	
			(0.276)	
$d_{it}l_{it}$	*labour × public*		0.124	
			(0.141)	
$d_{it}s_{it}$	*external services × public*		-0.027	
			(0.069)	
$d_{it}\tau_{it}$	*share residential customers × public*		0.300	
			(0.419)	
$d_{it}\pi_{it}$	*share other retailers × public*		0.018	
			(0.422)	
		N=212	N=212	N=199
	Group mean test			
	$\hat{p}$			0.474
	$\hat{p}$ GMM sample			0.288

Notes: p-values: *** p<0.01, ** p<0.05, * p<0.1. Model I: controls for German electricity demand in the service production function. Model II: controls for ownership in technology and customer structure. Model III: excludes firms with more than 20TWh/a supply.

Chapter 4

Modern Public Enterprises: Organisational Innovation and Productivity

4.1 Introduction

Throughout the 20th century, the performance of public enterprises gained a lot of attention in economic literature, with various theoretical contributions discussing incentives, control, and government influence within public firms (Laffont and Tirole, 1991; Vining and Boardman, 1992; Shleifer and Vishny, 1994; Boycko et al., 1996). Using the private sector as a reference point, the major conclusions from this strand of literature were that public firms suffer inherent efficiency problems due to managerial slack, excessive government influence, and weak incentives for innovation.

In line with this rationale, the New Public Management (NPM) movement suggested the introduction of market-oriented practises in the spheres of public administration, which also extends to public service provision (see Hood, 1995; Kettl, 1997, for an overview). To improve efficiency, public enterprises are encouraged to (i) reform their organisational structure towards more autonomy and less direct government influence; (ii) focus on core activities through the use of subcontracting; and (iii) enjoy knowledge spill-overs from joint ventures with the private sector.

The empirical evaluation of public enterprises' new organisational practise, however, is scarce. More fundamentally, Florio (2014) remarks, that „economists and policy-makers no longer seem to have a firm understanding of why PE [public enterprises] exist, what explains their performance, and the role of the State as

[0]This chapter is based on Stiel (2017).

owner"(p.201). The study of public enterprises seems to have disappeared from economic manuals, signalling definitive obsolescence of the former, which is curiously at odds with the vital role that public enterprises still occupy in advanced economies. Rather, we observe a renaissance of public involvement in economic activities, particularly at the local level (Hall et al., 2013; Cullmann et al., 2016). Thus, understanding the drivers behind public sector performance is essential. Since 1998, public enterprises have had to adapt to market environments which are very different from those of the post-war era. Liberalisation in sectors of general interests, such as telecommunications, postal services, and energy provision, introduced competition between public and private companies. New technologies and demand patterns require new infrastructure and product lines, and call for permanent innovation. Reorganisation and more efficient input usage could be instrumental in successfully managing this transformation.

The present chapter investigates the link between organisational innovation and productivity focusing on three elements: (i) corporatisation; (ii) outsourcing; and (iii) partial privatisation[1], i.e. selling minority shares to the private sector. Performance is measured as total factor productivity derived from a translog production function and estimated in a novel multiproduct framework following the control function approach developed by Ackerberg et al. (2015). The model is applied to public service provision, analysing German state-owned firms in energy and water supply between 2003 and 2014.

Our contribution is three-fold. First, we contribute empirical evidence on contemporary public enterprises at the micro-level. For this, we construct the first comprehensive dataset of 2,325 German energy and water firms that are owned by the state using newly available official data. While several cross-country studies exist (e.g., Florio, 2013; Borghi et al., 2016; Clò et al., 2017), firm-level evidence on the performance of European public enterprises is limited. Second, we empirically assess propositions of the New Public Management approach, which has not yet been done in a systematic way. Third, given that German energy and water firms are multiproduct firms, which operate at different stages of the value chain and combine different output products, we suggest a method for accounting for different output and input price levels at the product level.

Results show that corporatisation and outsourcing are positively correlated with productivity, while private sector participation does not increase productivity. Rather, fully state-owned firms outperform those with private minority shareholders.

[1] Extending the analysis to fully-privatised firms is unfortunately beyond the scope of this chapter due to lack of adequate microdata on the private sector. For an empirical comparison of state-owned and fully privately-owned firms in German electricity supply, see Chapter 3 and Cullmann et al. (2017).

The chapter is structured as follows. Section 4.3 reviews the relevant literature and Section 4.2 provides some background on the use of NPM strategies among German energy and water firms under state-ownership. After the model and the estimation strategy are explained in Sections 4.4 and 4.5, the data are introduced in Section 4.6. Sections 4.7 and 4.8 discuss the results and Section 4.9 concludes.

4.2 Background

4.2.1 Public utilities

German energy and water supply is traditionally characterised by strong decentralisation. Most municipalities established their own multi-utilities that provide the local population with electricity, gas, heat, and water *(horizontal integration)*. Many of them integrate production steps from generation to retail *(vertical integration)*.[2] In 2012, Germany counted roughly 2,000 energy firms and 6,000 water firms (Cullmann et al., 2016; Destatis, 2015b) and public firms co-exist with private and mixed-ownership firms. About half of the energy firms and the vast majority of water firms were majority-owned by local authorities.

4.2.2 Corporatisation

State-owned energy and water firms can choose between different legal structures. Corporatisation denotes the transition of government organisations under *public law* to *private law* companies. This does not change the ownership composition of the firms, i.e., they are still fully state-owned, but affects internal organisation of the firm. The following differences exist between organisations under *public law* and *private law*.

Public law. Firms that are fully owned by state authorities may choose to organise under public law and benefit from specific rules in terms of taxation and accounting. Managers' autonomy is usually low in these firms and local politicians can exert direct influence on day-to-day decision making trough membership in advisory boards. Under public law, advisory boards have extensive discretionary power and firms are treated as branches of the local administration. The dataset distinguishes two types of organisations under public law: *Eigenbetrieb* and *Zweckverband*. The latter denotes a formal cooperation of pure water utilities from different municipalities.

[2] The only exception are conventional electricity generation, electricity transmission and gas transmission, where nationwide private firms dominate the market.

Private law. State-owned firms organised under private law (*'corporatised'*), by contrast, resemble private firms. Managers are legally autonomous in daily decision making and local politicians can only decide on general strategies. Corporatised firms can apply private labour law, thus benefiting from greater flexibility (e.g., temporary working contracts). They are subject to the same accounting and taxation rules as private firms. We analyse two forms, *Gesellschaft mit beschränkter Haftung (GmbH)*, which is close to a limited liability company in the British context, and *Aktiengesellschaft (AG)*, which is a stock corporation.

4.2.3 Outsourcing

Subcontracting is widely used among state-owned energy and water firms with a strong focus on knowledge-intensive business services (KIBS, such as IT, marketing, procurement). Since procurement with energy became increasingly complex with the liberalisation of electricity and gas markets, small firms especially tend to rely on external services. Likewise, intensified competition in the retail markets after liberalisation requires more elaborate marketing strategies and the design of a corporate identity.

It is worth noting that external services are not only provided by the private sector. Several state-owned energy and water firms have founded joint ventures that bundle expertise on KIBS and are available both to members and outsiders. Large state-owned firms sell their expertise to other market participants and there is a general network of exchange and consultancy (see, e.g., *Trianel*, *Thüga*).

4.3 Related literature

Outsourcing. The relationship between organisational structure and firm performance is gaining increasing attention. López (2014) stresses that decisions to outsource can be interpreted as a form of organisational innovation. While traditional innovation literature usually focuses on innovation in products and measures the influence of R&D expenditure on productivity (see, for instance, Aw et al., 2011; Doraszelski and Jaumandreu, 2013), reorganisation within the firm and the decision to subcontract can affect firm performance in an equally fundamental way. For services requiring specific knowledge or on-the-job-training (knowledge-intensive business services such as IT, marketing), internal provision might be inadequate and costly. External suppliers can benefit from a centralisation of expertise and economies of scale (Roodhooft and Warlop, 1999) and offer these services at lower costs and higher quality. Costs of outsourcing, on the other hand, consist in finding reliable suppliers, in monitoring and enforcing contracts and in a loss of strategic flexibility. Windrum et al. (2009) discuss the outsourcing productivity paradox in this regard. While outsourcing should ideally lead to productivity growth in the short term, long-term productivity can be negatively affected. The reason is the lack of investment in knowledge and related human capital. Firms risk becoming locked-in to subcontracting by lack of adequate staff and infrastructure, thus losing flexibility in responding to demand changes and competitors' moves. If asymmetry in knowledge prevents effective monitoring of suppliers' performance, firms could depend on outdated services and technologies, further losing efficiency.

Firm-level evidence on the link between productivity and outsourcing is mostly obtained from the manufacturing sector, with a focus on imports and the consumption of intermediates. Fariñas et al. (2014) and López (2014) investigate subcontracted production over total consumption of intermediates for Spanish manufacturers and observe a positive impact from outsourcing. Antonietti (2016) distinguishes between production outsourcing and service outsourcing. In the case of production outsourcing, there are positive effects for Italian manufacturers if subcontracting is embedded in a broader human resources strategy with simultaneous investment into skills of the established workforce. Antonietti does not find any impact from service outsourcing. Morrison Paul and Yasar (2009) study Turkish textile plants and find that input outsourcing is associated with higher productivity and high-skilled labour use, while output outsourcing is negatively correlated with productivity and skilled-labour intensity. Survey-based studies for Sweden and the US, on the other hand, find no significant impact of outsourcing on various measures of performance (Bengtsson and Dabhilkar, 2009; Gilley and Rasheed, 2000). While evidence for the manufacturing sector is growing, no systematic studies exist for the public sector and the relevance of outsourcing to public enterprise performance is largely unstudied.

Corporatisation. The general approach taken to analysing public sector performance is usually a comparison with the private sector, which establishes a dichotomy between two extreme options - privatisation and nationalisation. However, some early contributions already remarked that 'organisation matters'. Public enterprises differ by governance structure and exhibit different degrees of legal autonomy, managerial professionalism, and exposition to financial restrictions (Aharoni, 1981; Estrin and Pérotin, 1991). Bartel and Harrison (2005) conduct an empirical study of Indonesian manufacturers and show that only those public enterprises that had close ties with the government, e.g., through soft budget constraints and trade protection, performed worse than the private sector. Bertero and Rondi (2000) analyse a panel of Italian state-owned manufacturers and find that total factor productivity increased in a period of hard budget constraints. Fumagalli et al. (2007) are close to what is done in this chapter. They investigate drivers behind service quality of Italian electricity distributors and consider two aspects: managerial discretion and partial privatisation. They find that service quality is higher for firms with strong external boards but remains unaffected by partial privatisation. Corporatisation, i.e., the transition from government organisations to private-sector-law companies, is usually associated with all of these aspects. Although the number of corporatised public organisations is increasing (e.g. from 38 per cent to 55 per cent between 1990 and 2010 in the German energy sector, Gottschalk, 2012), empirical evaluation of performance changes is missing.

Partial privatisation. Partial privatisation raises the question why private shareholders should be willing to hold minority shares in state firms at all. If state firms were inherently less efficient than private firms, should investments not be directed towards more profitable undertakings? Pargendler et al. (2013) point out that investing in state-owned firms gives access to some privileges such as subsidies, lower cost of debts, implicit government guarantees, and monopolistic rents. Furthermore, governments might sell shares at discount prices or commit to guaranteed dividend schemes in order to attract private sector participation. From the viewpoint of the government, partial privatisation can be valuable in order to raise funds and benefit from knowledge spill-over, improved managerial practise, and access to new technology. This is particularly relevant if shares are not dispersed but sold to competitors from the same industry, which is the case in German energy and water supply.

The conventional reasoning of a positive link between partial privatisation and performance is put into question by the motivation crowding-out literature (see Polidori and Teobaldelli (2013) for a literature review). The main critique is that standard theory completely abstracts from intrinsic motivation, which can be an important source of commitment in the public sector where extrinsic incentives, such as performance-related pay, are low. Studies on prosocial behaviour among civil servants provide evidence for the existence of a *public service motivation* (Rainey, 1982; Crewson, 1997; Houston, 2000) and for self-selection of intrinsically motivated individuals into the public sector (Gregg et al., 2011). To illustrate the motivation crowding out dilemma, Grönblom and Willner (2014) construct a principal-agent model where privatisation leads to a reduction in managerial effort. They argue that the introduction of rigid business principles from private owners could be perceived by public managers as arbitrary top-down control that interferes with their own strategy of countervailing social and profit goals. The mixture of different goals is also discussed in Bénabou and Tirole (2003). Focus on profit maximisation and related performance-pay could distort the manager's effort from the achievement of a more tedious long-term social objective towards an easy measurable goal which produces immediate rewards.[3] Similarly, mixed enterprises could suffer from a multiple principals problem that adversely affects effort and output level (Laffont and Martimort, 1997).

4.4 Model

Total factor productivity ω is estimated in a production function framework with the three main inputs of labour L, capital K, and external services S, as well as two intermediate inputs of material M, and procured energy and water E, and, lastly, an error term ϵ. Total output is denoted by Q.

$$Q = f(L, K, S, M, E) * \exp(\omega + \epsilon) \tag{4.1}$$

4.4.1 Multiproduct structure and unobserved prices

4.4.1.1 Output

Since most state-owned energy and water firms are integrated multiproduct firms, total output is difficult to measure in physical terms. We observe total sales at the firm-level and have information on the product space of each firm. However, we observe neither input allocation per product nor the quantity and prices of each product sold. We estimate production at the firm-level, and use the following strategy to account for unobserved input and output prices at the product level. Loglinearising equation (4.1) gives

$$q_{it} = \sum_J q_{ijt} = f(l_{it}, k_{it}, s_{it}, m_{it}, e_{it}) + \omega_{it} + \epsilon_{it}, \tag{4.2}$$

where firm i is observed in year t and sells product j.[4] Exploiting the fact that total

[3] Francois (2000, 2007) offer an interesting revision of the standard residual rights claimant argument. If effort within a public agency is mostly driven by belief that the quality of service provision decreases in case of shirking (as bureaucrats are only weakly interested in profit maximisation and the government owner exerts lose control), genuinely motivated employees will increase their labour donation to offset poorly motivated colleagues. Private firms do not benefit from this voluntary increase in labour as they cannot commit not to adjust other inputs in reaction to reduced effort (e.g., through hiring extra staff). They are residual claimants of the profits that would otherwise be lost.

[4] The product space is composed of 8 products $J = \{$electricity sold to residents, electricity sold to business customers including manufacturing, wholesale electricity, electricity distribution, district heat sold to households, district heat sold to non-residents, gas supply, water supply$\}$. Information on vertical activities is only available for the electricity sector. However, we argue that this is less important in the remaining sectors for the following reasons. Since water and district heat supply are local monopolies, the majority of water and district heat firms in Germany are vertically integrated. Gas generation plays a minor role in Germany (<12 per cent of German gas consumption, BMWi, 2017). For historical reasons, most municipal gas providers also own the

revenue is calculated from total output times prices, i.e. $R_{it} = \sum_J R_{ijt} = \sum_j Q_{ijt}P_{ijt}$, we can formulate the left-hand side as

$$r_{it} - \sum_J p_{ijt} = f(l_{it}, k_{it}, s_{it}, m_{it}, e_{it}) + \omega_{it} + \epsilon_{it}. \tag{4.3}$$

Firm-specific product prices p_{ijt} are typically not available. Instead, total revenue r_{it} of multiproduct firms is usually deflated by some producer price index (PPI) that reflects a weighted sum of products within the industry.[5] This can be problematic if the firms do not produce the same product mix and if price levels differ significantly between products (see Collard-Wexler and De Loecker (2015) for quantifying the bias). This is the exact case for German energy and water supply, where selling one unit of electricity provides much more revenue than selling one unit of water. Using a global PPI would bias productivity scores downwards for firms that focus on water supply.

We overcome this by assuming that $p_{ijt} = p_{jt}$ but $p_{jt} \neq p_t$, i.e. output prices are comparable across firms but large differences exist between sectors. We relax the first assumption later for the electricity sector, i.e. firms can differ in their unit output prices for electricity sold.[6] The intuition for the assumption is that while minor prices differences may exist between firms, differences between activities are much more pronounced. We can then proxy for the aggregate firm-specific output price in the following way:

$$p_{it} = \sum_J p_{ijt} \approx \sum_J \gamma_j \bar{p}_{jt} d_{ijt}, \tag{4.4}$$

where $\bar{p}_{jt}$ is the PPI for product j, γ_j is a scaling parameter that captures the price difference relative to all other products J_{-1} and d_{ijt} is a dummy variable characterising the product mix of the firm, i.e., whether firm i sells product j or not. The parameter γ_j is estimated within the model, while $\bar{p}_{jt}$ is taken from official statistical data and d_{ijt} is observed.

4.4.1.2 Material

Similarly, as material input is usually difficult to aggregate in physical terms, material expenditure is used instead. The most important material in energy sectors is the fuel for electricity and heat generation. However, not all firms use the same

distribution networks. Independent gas retailers that entered the market after liberalisation are more commonly found in the private sector.

[5] The PPI reflects price changes over time but is uninformative about level differences between prices of the same year.

[6] For the other products, no product-level output price data is available.

fuel technology when producing electricity or heat. This may lead to very different input prices for material. Assume instead that all firms face identical fuel prices but differ in the type of fuel they use. Material expenditure $\tilde{m}_{it}$ is then given by the log sum of material use, fuel prices p_{ft} and the average price of the remaining material inputs $p_{other,t}$

$$\tilde{m}_{it} = m_{it} + \sum_{F} p_{ft} d_{ift} + p_{other,t}. \tag{4.5}$$

The dummy variable d_{ift} characterises the fuel mix of the firm. Those fuel prices for which no price level data is available (e.g. lignite) are proxied as

$$p_{ft} \approx \gamma_f \bar{p}_{ft}, \tag{4.6}$$

where $\bar{p}_{ft}$ is the PPI for fuel f and γ_f is a scaling parameter that captures the price difference of fuel f relative to the remaining material input. Parameter γ_f is estimated within the model, while $\bar{p}_{ft}$ is taken from official statistical data and d_{ift} is observed.

4.4.1.3 Procured energy and water

Many firms in the utility industry buy parts of the energy and water retailed to end-consumers from third parties (e.g., traders, importers, other utilities). The type of energy or water procured is directly linked to the output portfolio and thus varies across firms. Deflating procured energy and water expenditure $\tilde{E}$ by a global PPI, which assumes a fixed energy mix, would lead to the same problem as on the output side. We argue that this is addressed by the following set of unrestrictive assumptions.

- A1 Assume that procured energy and water is a subset of the energy and water sold as outputs, e.g., firms that sell heat and gas buy only heat or gas, but no other products.
- A2 Assume that the relative price difference of procured energy types is comparable to the relative price difference on the output side. Likewise, assume that price trends over time mirror those on the output side (same PPI).

Then differences in input structure for procured energy and water are already accounted for in equation (4.4).

4.4.2 Production environment

State-owned energy and water firms differ in the production environment. Distribution networks in urban areas tend to connect more people who live closer together, thus providing economies of density to the firm.[7] The same applies to water retail and district heat supply, which are organised as local monopolies in Germany, such that the firm's customers are identical with the local population. We argue that population density is exogenously given and there is no self-selection into locations for state-owned energy and water firms.[8] This is a standard assumption in the literature comparing performance of network operators (see, e.g., Kumbhakar and Hjalmarsson, 1998; Kwoka, 2005; Celen, 2013). We approximate population density through settlement type[9] and model it as an exogenous shock ξ_p to output $\tilde{q}_{it}$

$$q_{it} = \tilde{q}_{it} + \xi_p, \tag{4.7}$$

where $\tilde{q}_{it}$ is the equilibrium output if all firms operated in the same environment.

4.4.3 Summarising the production function

We model the true underlying production function by a translog function with median-corrected inputs and outputs. The translog function provides more flexibility regarding the elasticities of substitution between input factors and allows output elasticities to vary between firms. It is commonly used for models in the energy and water sectors (Kumbhakar, 1996; Saal et al., 2007; Farsi and Filippini, 2009) and is also applied to productivity estimation (e.g., De Loecker and Warzynski, 2012). The final equation estimates output elasticities and productivity at the firm-level, controlling for different output and input prices at the product level. It is obtained by plugging equations (4.4) to (4.7) into the translog production function based on (4.3)

[7] Economies of density mean that a firm uses the same amount of inputs as another firm but reaches more customers due to its location in a more densely populated area. Both in urban and rural areas, network operators have to build lines to connect newly built facilities (including housing and offices). In a big city, new housing tends to be apartment houses with multiple customers, whereas rural areas are typically characterised by single family homes.

[8] They traditionally operate in the geographic area of the owning municipality. Population density plays a minor role in electricity and gas *trade*, which is open to nation-wide competition, such that firms are not restricted to their own municipality.

[9] The categories are *big cities*, *suburban regions*, *densely populated rural areas* and *sparsely populated rural areas*, see Section 4.6 for details.

$$
\begin{aligned}
y_{it} =& c + \beta_l l_{it} + \beta_s s_{it} + \beta_k k_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + 0.5\beta_{kk} k_{it}^2 \\
& + \beta_{ls} l_{it} s_{it} + \beta_{lk} l_{it} k_{it} + \beta_{ks} k_{it} s_{it} \\
& - \sum_F \gamma_f \bar{p}_{ft} d_{ift} + \sum_J \gamma_j \bar{p}_{jt} d_{ijt} + \xi_p \\
& + \omega_{it} + \epsilon_{it}.
\end{aligned} \tag{4.8}
$$

The left-hand side y_{it} can be interpreted as the value added composed of $y_{it} = r_{it} - \tilde{e}_{it} - (\tilde{m}_{it} - \bar{p}_{other,t})$. We assume a stable relationship between output and intermediate goods (e_{it}, m_{it}), but model intermediate services as a flexible input on the right-hand side, thereby allowing its output elasticity to vary over time and between firms. Section 4.6.3.1 presents more details on the subcontracting of services and show that usage is subject to some important changes over time and between sectors. The dummy d characterises the product mix, i.e. whether a firm sells product j or uses fuel f.

4.5 Empirical strategy

The model is estimated using a control function approach based on Ackerberg et al. (2015). The advantage of this approach over other techniques is that it does not require productivity to be exogenous. Rather, productivity may be correlated with input choice. This is quite likely if firms take their own productivity level into account when making input decisions. While the productivity level is known to the firm, it is usually unobservable to the econometrician. Olley and Pakes (1996) are the first to suggest a method for proxying unobservable productivity with the help of a control function.

4.5.1 Controlling for unobserved productivity

The estimation procedure consists of two steps. In the first step, unobservable productivity is backed out using the input demand function of one static, flexible input without adjustment costs. We assume that demand for external services is such a flexible input, i.e. firms can re-negotiate contracts with services providers at least once a year and adjust the level of external services to their current needs. The choice of external services then depends on the level of capital k_{it} and labour l_{it} (which are pre-determined[10]), productivity, the product mix, the fuel mix, and

[10] Investment into capital is usually long-term oriented and strict union contracts in public services prevent immediate changes to labour force.

the production environment

$$s_{it} = s_t(l_{it}, k_{it}, \omega_{it}, d_{ijt}, d_{ift}, \xi_p). \tag{4.9}$$

If $s_t(\cdot)$ is strictly monotone in ω_{it}, the function can be inverted to obtain an expression for productivity ω_{it}

$$\omega_{it} = h_t(l_{it}, k_{it}, s_{it}, d_{ijt}, d_{ift}, \xi_p). \tag{4.10}$$

Inserting (4.10) into (4.8) yields an estimation equation that only depends on observables and the error term ϵ_{it}

$$\begin{aligned} y_{it} =& c + \beta_l l_{it} + \beta_s s_{it} + \beta_k k_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + 0.5\beta_{kk} k_{it}^2 \\ &+ \beta_{ls} l_{it} s_{it} + \beta_{lk} l_{it} k_{it} + \beta_{ks} k_{it} s_{it} \\ &- \sum_F \gamma_f \bar{p}_{ft} d_{ift} + \sum_J \gamma_j \bar{p}_{jt} d_{ijt} + \xi_p \\ &+ h_t(l_{it}, k_{it}, s_{it}, d_{ijt}, d_{ift}, \xi_p) + \epsilon_{it}. \end{aligned} \tag{4.11}$$

Equation (4.11) is estimated by OLS, where $h(\cdot)$ is approximated by a polynomial of order 2. We obtain an (unbiased) prediction Φ_{it} which is used to express productivity as

$$\begin{aligned} \omega_{it}(\boldsymbol{\beta}, \boldsymbol{\gamma}) =& \Phi_{it} - c - \beta_l l_{it} - \beta_s s_{it} - \beta_k k_{it} - 0.5\beta_{ll} l_{it}^2 - 0.5\beta_{ss} s_{it}^2 - 0.5\beta_{kk} k_{it}^2 - \beta_{ls} l_{it} s_{it} \\ &- \beta_{lk} l_{it} k_{it} - \beta_{ks} k_{it} s_{it} + \sum_F \gamma_f \bar{p}_{ft} d_{ift} - \sum_J \gamma_j \bar{p}_{jt} d_{ijt} - \xi_p. \end{aligned} \tag{4.12}$$

The vector $(\boldsymbol{\beta}, \boldsymbol{\gamma})$ is still biased, since the related variables appear both in the translog production function and in $h_t(\cdot)$. This is addressed in the second step of the estimation.

4.5.2 Productivity growth through reorganisation

For this, we assume that productivity follows a first-order Markov process and is potentially affected by reorganisation under private law (corporatisation) μ_{it}, outsourcing intensity with respect to services $\pi_{it} = S_{it}/L_{it} + S_{it}$, outsourcing intensity with respect to generation $\tau_{it} = E_{it}/R_{it}$, and the sale of minority shares to the private sector η_{it}

$$\omega_{it} = c + g(\omega_{it-1}) + \alpha_1\pi_{it} + \alpha_2\tau_{it} + \alpha_3\mu_{it-1} + \alpha_4\mu_{it-1}\eta_{it-1} + v_{it}. \tag{4.13}$$

Partial privatisation is conditional on corporatisation, i.e., only corporatised firms can sell minority shares to the private sector. This is accounted for by the interaction term $\mu_{it-1}\eta_{it-1}$. Corporatisation and partial privatisation are fundamental forms of reorganisation and potentially involve complex firm restructuring. Therefore, we assume that any effect on productivity takes at least one year to materialise and lag the corresponding variables by one period. Outsourcing, on the other hand, and the subcontracting of services, in particular, are more short-term oriented and could imply productivity gains within the same year.[11]

Note that the coefficients $\boldsymbol{\alpha}$ measure incremental effects and that the Markov process is particularly suited to identify organisational *innovation*. The coefficients capture *changes* in productivity related to the organisational structure, which can have two sources: (i) an initial effect from recent reorganisation if the firm changed its organisational structure between $t-1$ and t and this has an immediate effect on its productivity; or (ii) gradual productivity growth if the firm chose an organisational structure some years ago but still obtains a yearly productivity gain from this (learning from reorganisation[12]).

The function $g(\omega_{it-1})$ is approximated through a third-order polynomial and the final estimation routine exploits the fact that any current shock to productivity v_{it} is uncorrelated with past and predetermined input values, i.e. $\mathbb{E}[v_{it}|I_{it-1}] = 0$ where $I_{it-1} = \{l_{it}, k_{it}, s_{it-1}, l_{it}^2, k_{it}^2, s_{it-1}^2, ..., d_{ijt}, d_{ift}, \xi_p\}$. As a result, we obtain unbiased estimates for the vector $(\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\alpha})$ and recover productivity ω_{it} through (4.12).

4.5.3 Permanent effect from organisational practise

The vector $\boldsymbol{\alpha}$ measures *intra-firm* productivity *growth* over time from reorganisation, but not differences in productivity *levels between firms* with distinct organisational patterns. By construction, $\boldsymbol{\alpha}$ can only explain deviations of current productivity from past year productivity, hence productivity growth. For the α's

[11]We control for outsourcing intensity in addition to the levels of L and S in the production function to assess productivity gains through substitution, since reorganisation often involves replacing internal staff with external staff. Moreover, outsourcing might not just produce direct effects on output through higher quality input, but also improve managerial practise. The manager could focus on core activities and optimise input usage therein, instead of allocating time to planning and monitoring peripheral activities.

[12] The intuition is that the manager, who was hired when the firm was previously corporatised, each year produces new ideas on how to make the firm more productive. It will lead to an increase in productivity between $t-1$ and t, which is explained by the firm's status as 'corporatised firm'. See De Loecker (2013) for estimating a similar model for 'learning from exporting'.

to be identified, we require variation over time in productivity. Consequently, the Markov process does not capture permanent differences in productivity levels between firms if these differences are stable in magnitude over time and if there is no switching between groups.[13]

In this case, we are interested in knowing whether some organisational patterns are generally associated with higher productivity levels, even if we do not observe any switchers between patterns. Consequently, we complement the analysis by following Collard-Wexler and De Loecker (2015) and regress the log productivity estimates $\hat{\omega}_{it}$ *ex post* on organisation (legal status μ_{it-1}, partial private ownership η_{it-1}, outsourcing intensities τ_{it}, π_{it}), a set of covariates $\boldsymbol{X_{it}}$ (fuel usage, product space, firm size, population density)[14], and an error term u_{it}.

$$\hat{\omega}_{it} = c + \gamma_1 \pi_{it} + \gamma_2 \tau_{it} + \gamma_3 \mu_{it-1} + \gamma_4 \mu_{it-1} \eta_{it-1} + \boldsymbol{X_{it}} + u_{it} \tag{4.14}$$

4.6 Data

We analyse all state-owned firms in the German energy and water sectors (NACE ID 35 and 36) between 2003 and 2014 with more than 10 employees and more than $200,000 m^3$ water treatment. This has not yet been done for lack of comprehensive microdata in this field.[15] We fill this gap by constructing a unique panel dataset from a rich set of newly available data sources on German energy and water firms from the German Federal Statistical Office *(Destatis)*. The dataset is composed of surveys from *Energiestatistiken der amtlichen Statistik*, a collection of state-owned firms' financial statements *Jahresabschlüsse öffentlicher Fonds, Einrichtungen und*

[13] Consider the following example. Firm A is fully state-owned and has a productivity level of $\omega_{A2003} = 1.5$ in year 2003, whereas firm B is partially privatised and has $\omega_{B2003} = 1.0$. In 2004, both firms keep their composition of owners unchanged and productivity is stable, i.e. $\omega_{A2003} = \omega_{A2004} = 1.5$ and $\omega_{B2003} = \omega_{B2004} = 1.0$ such that $\Delta\omega_{At} = \Delta\omega_{Bt} = 0$. The vector $\boldsymbol{\alpha}$ in equation (4.13) would not identify any difference between fully and partially state-owned firms, since it requires variation over time in ω_{it}. The variation may either stem from variation in organisation (reorganisation, i.e., switchers) or from learning from reorganisation (see above). However, all other things being equal, in the present example the fully state-owned firm is more productive than the partially privatised one. This is what we call the *permanent effect from organisational practise.*

[14] Note that we already control for all of these measures, except firm size, in the initial production function estimation. Hence, we find that the majority of covariates do not contribute any further (significantly) to explaining productivity. Nevertheless, we included them in order to purge the organisational coefficients from any potential confounding influence.

[15] There are single sector studies for German electricity DSOs and water companies based on data from the industrial association BDEW (e.g., Cullmann (2010), Zschille 2014b, 2015). However, no dataset for multiproduct firms previously existed, even though most German energy and water firms are either vertically or horizontally integrated.

Unternehmen, the German company register *Unternehmensregister (URS)* and data on settlement patterns published by the Federal Institute for Research on Building, Urban Affairs and Spatial Development *(BBSR)*. A detailed description of each data source and the linkage strategy is provided in the section Data appendix 4.11. *Destatis* considers firms as public/state-owned if government entities hold more than 50 per cent of the shares and/or votes.

4.6.1 Sample composition

After eliminating observations with missing or clearly erroneous data, we obtain a final dataset of 2,325 firms, which are observed up to 12 years between 2003 and 2014 ($N = 18,535$). These are divided into 4 groups: mixed utilities ($n = 846$), water-only utilities ($n = 1170$), electricity and gas utilities ($n = 186$), as well as heat and power generation plants ($n = 123$). Mixed utilities form the core sample of the study. They are multiproduct firms representing various horizontal and vertical output combinations. They should give an average picture of how productivity in the German public utility sector is affected by re-organisation since 2003. Water-only companies, by contrast, are considered as an example of firms with a homogeneous product space and few dynamics in the market structure. Pure electricity and gas utilities are treated distinctly in order to explore potential effects from market restructuring following liberalisation.[16] Finally, heat and power plants are considered as an example of particularly capital-intensive industries. They are grouped together since they share important technologies.

The data is an unbalanced panel dataset, which raises the concern of an unobserved correlation between productivity and firms' entry/exit decision (Olley and Pakes, 1996). For instance, competition could drive low productivity firms out of the market or low-performing state-owned firms could be privatised and subsequently disappear from the sample. We argue that firm entry and exit is negligible in our case. First, drop-out rates are low. Less than 5 per cent of the firms leave the sample before 2014. About 10 per cent of the firms enter after 2003, with the majority entering in 2008. The observed mass entry in 2008 is the result of two occurrences that are unrelated to productivity. First, the revision in the classification of economic activities in 2008 changed the population from which firms were drawn. Notably, firms with their main activity in sewerage (NACE ID 38) became part of the surveys. The majority of new entrants are pure water companies, formerly classified as

[16]The electricity and gas sectors were exposed to EU-wide liberalisation in 1998, in contrast to the water and heat sector that remained local monopolies. Corporatisation and outsourcing in the liberalised industries might have been spurred by competitive pressure and, thus, have had more ample effects.

sewerage firms. The second group of new entrants is composed of electricity distributors. The electricity unbundling reforms in 2007 encouraged firms to reorganise network operation across all sectors in legal spin-offs, even though only large firms with more than 100,000 customers were legally obligated to do so.

Table 4.1: Sample composition

	water	gas	heat	electricity
mixed utilities	X	X	X	X
water-only utilities	X			
electricity and gas utilities		X		X
heat and power plants			X	G

Notes: G = generation only. Transmission operators are excluded from the analysis. All groups are mutually exclusive.

4.6.2 Production

The three main inputs are labour L, external services S, and capital K. Labour is measured by the wage bill to reflect differences in the composition of workforce, i.e., labour quality. This is particularly relevant when comparing multiproduct firms with different product mixes. The last row in Table 4.2 compares hourly wages at the firm-level, showing that average wages are not the same across sectors. If hourly wages are correlated with labour quality, then workforce composition in electricity and gas supply differs from that in water supply and energy generation.[17] External services are measured by expenditure and deflated using the PPI of the relevant service industries (NACE category M). Information on the capital stock and investments is taken from financial statements to construct a capital measure based on the perpetual inventory method with $K_{it} = (1 - \delta_i)K_{it-1} + I_{it}$, where both investments and the initial capital stock are deflated with the PPI of capital goods. The average depreciation rate δ_i is computed at the firm-level as the consumption of fixed capital divided by gross fixed capital. Output is measured by revenues minus

[17] The rationale behind this is that the production process in electricity and gas supply changed fundamentally after liberalisation, which induced a shift in workforce composition towards more high-qualified personnel. Procurement in electricity supply is now much more complex because electricity is traded at the EEX and since OTC contracts are increasingly varied. The introduction of incentive regulation of the distribution networks requires experts on regulatory affairs. Further, new markets in the retail segment, such as energy efficiency consulting and marketing campaigns, rely on white collar workers. Consequently, firm-level wages in these sectors are higher. Measuring labour by the number of employees comes at the risk of obtaining productivity values that capture differences in labour quality rather than differences in performance. Fox and Smeets (2011) show that productivity dispersion among firms substantially decreases when the wage bill is used to measure labour input.

expenditure on intermediate goods (material, procured energy and water). Table 4.2 provides summary statistics and shows that most firms are local small-sized suppliers, reflecting the municipality structure in Germany.

Table 4.2: Summary statistics inputs and output

	mixed utilities			water			electricity and gas			heat and power plants		
	med	mean	sd	med	mean	sd	med	mean	sd	med	mean	sd
L [mio €]	2.70	6.84	15.84	0.30	1.19	3.55	0.80	2.66	6.12	0.46	2.50	10.75
S [mio €]	1.38	7.31	25.33	0.22	0.89	2.54	0.93	8.14	26.96	0.31	3.84	11.30
K [mio €]	28.51	61.16	119.3	9.14	31.36	70.60	10.01	30.20	72.48	6.77	39.43	120.02
Y [mio €]	10.39	28.48	66.01	1.32	4.42	11.2	6.69	22.12	47.85	2.05	13.21	38.35
w [€]	33	33	7	30	30	8	34	35	11	30	30	9
N		7,495			9,188			1,163			689	

Notes: Hourly wages w are average gross wages computed from wage bill divided by number of hours worked.

Table 4.3 summarises characteristics of the production environment. We rely on information from the federal institute *BBSR* to proxy for population density in the service supply areas. The institute sorts each German county according to its population pattern into one of the four categories: big cities, suburban areas, densely populated rural areas, and sparsely populated rural areas. County data is matched to firm-level data based on the location of the firm.

Table 4.3: Summary statistics production environment

Share of firms situated in...			
big cities	suburban	dense rural	sparse rural
0.07	0.51	0.23	0.19

4.6.3 Organisation

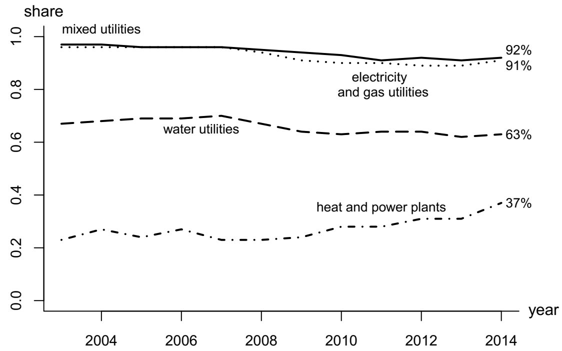
4.6.3.1 Outsourcing

We distinguish two types of outsourcing: (I) outsourced services (e.g., maintenance work, customer relations); and (II) outsourced generation of energy and water. Between 92 per cent and 98 per cent of the firms rely on external services. Usage is lowest in water supply and highest among electricity and gas utilities. Figure 4.2a illustrates a vital growth in outsourcing intensity during 2003 and 2014. While average outsourcing intensity rose by 7 percentage points among mixed utilities, the ratio for electricity and gas utilities increased by 21 percentage points to 61 per cent in 2014.[18]

Generation outsourcing is more heterogeneous across sectors. In 2014, 91 per cent of state-owned electricity and gas firms purchased energy generated from third parties, whereas only two third of the water suppliers sourced water production externally (Figure 4.1). This reflects the fact that state-owned firms own less than 30 per cent of the electricity generation capacity and Germany imports virtually all of its natural gas (Monopolkommission, 2015). Water, on the other hand, is consumed locally and transportation over long distances is not efficient. The growing share of heat and power plants that at least partially outsource generation might look puzzling at first. However, it can be rationalised by the increasing use of process heat from manufacturing and waste combustion. Among those firms that outsource generation, outsourcing *intensity* further differs across sectors (Figure 4.2b).

The most important message emerging from the graphs is that, both for services and generation, outsourcing intensity varies over the years. The variation in time is important to test our reorganisation hypothesis. Dynamics are stronger in the sectors affected by liberalisation and they are least pronounced in the water supply sector.

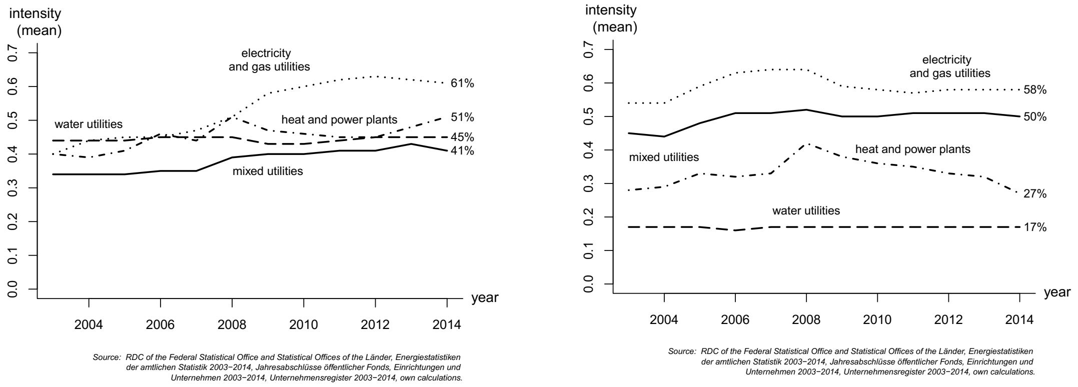
Figure 4.1: Share of firms buying energy or water from third parties



Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Energiestatistiken der amtlichen Statistik 2003−2014, Jahresabschlüsse öffentlicher Fonds, Einrichtungen und Unternehmen 2003−2014, Unternehmensregister 2003−2014, own calculations.

[18] The sharp increase after 2008 is in line with increased competition for end-consumers after the unbundling reforms in 2007, which triggered demand for marketing campaigns and strategic energy procurement, see footnote 17.

Figure 4.2: Outsourced services and generation



(a) Intensity of outsourced services **(b) Intensity of outsourced generation**

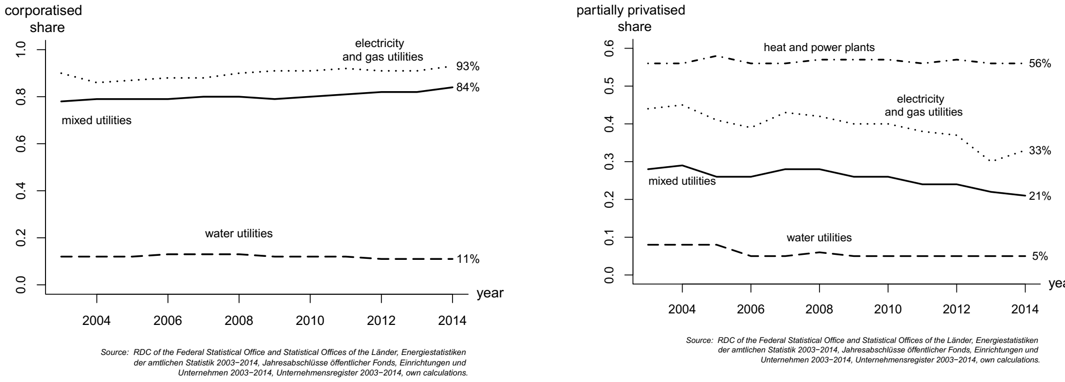
4.6.3.2 Corporatisation and partial privatisation

Figure 4.3 summarises the legal structure and ownership composition. Organisation under private law is relatively common in the energy sectors (Figure 4.3a). In 2014, roughly 93 per cent of the electricity and gas firms were organised either as *GmbH* or *AG* and virtually all electricity and heat plants were corporatised (not displayed). By contrast, only 11 per cent of the water firms chose a private legal status. The water sector, however, is peculiar in this respect as it disposes of a hybrid organisational form, an association of different municipalities called *Zweckverband*, which formally belongs to the public law but is open to private shareholders. This form of organisation is quite popular such that 40 per cent of the water firms are organised as *Zweckverbände*.

While dynamics in corporatisation are rather weak with a 5 percentage point increase among mixed utilities, we see a more obvious trend towards nationalisation in Figure 4.3b.[19] The fraction of mixed utilities with private minority shares declined by 7 percentage points between 2003 and 2014. Again, the initial distribution is quite heterogeneous. While the private sector holds minority shares in roughly half of the heat and power plants, it is negligible in the water sector (5 per cent).

[19]Note that the private sector may only participate in firms organised under private law. Thus, the share of private participations is bounded by the fraction of corporatised firms.

Figure 4.3: Legal form and partial privatisation



(a) share of firms organised under private law

(b) share of firms with private participation

4.6.3.3 Determinants for reorganisation

Before commencing the main analysis, we explore the determinants for organisational innovation and potential correlations between the different reorganisation measures. Therefore, we regress outsourcing intensity on the remaining reorganisation measures (legal status, partial private ownership) and a set of covariates. These include firm size, proximity of external suppliers, labour costs (wages), investments, customer structure, fuel usage, and product space. Local availability of specialised suppliers is approximated through the *BBSR* data on settlement structure, hypothesising that large cities offer a wider range of specialised suppliers than rural areas (Abraham and Taylor, 1996).

Table 4.4 shows the results for the main sample of mixed utilities. Private shareholders seem to foster outsourcing, while the legal status does not play a major role. Investment intensity is negatively correlated with outsourced generation, which illustrates the strategic decision between building up inhouse capacity and relying on external generation. We can confirm the proximity hypothesis for the availability of *service* suppliers, but not for generation. Rather, rural firms source more generation externally than those in larger cities. Surprisingly, firm-level wages cannot be identified as a major driver behind service outsourcing, suggesting that other motives than costs, e.g., access to external suppliers' expertise, could be more relevant in explaining service outsourcing among public utilities. This finding underlines the importance of studying alternative mechanisms, other than cost savings, through which outsourcing affects firm performance. As the focus of this model, outsourcing can also be conducted in search of productivity enhancing effects, through access to knowledge-intensive business services (KIBS) and managerial focus on core activities, for instance. With regard to generation outsourcing, the picture is different.

Table 4.4: Determinants for reorganisation among mixed utilities

	outsourced services π		outsourced generation τ	
corporatised status $_{t-1}$	-0.001	(0.007)	0.000	(0.006)
corporatised status$_{t-1}$ $\times$ *private*$_{t-1}$	0.038***	(0.006)	0.027***	(0.005)
outsourced generation $_{t-1}$	-0.198***	(0.016)		
outsourced services $_{t-1}$			-0.131***	(0.010)
investment intensity$_{t-1}$	-0.002	(0.008)	-0.022***	(0.007)
wages$_{t-1}$	0.000	(0.000)	0.001***	(0.000)
size medium	-0.008	(0.007)	0.025***	(0.006)
size large	0.012	(0.009)	0.074***	(0.007)
elec: share residential supply$_{t-1}$	-0.018	(0.010)	0.062***	(0.008)
elec: share wholesale$_{t-1}$	-0.016	(0.011)	-0.086***	(0.009)
heat: share residential supply$_{t-1}$	-0.010	(0.009)	-0.069***	(0.007)
heat: share wholesale$_{t-1}$	0.055**	(0.020)	-0.095***	(0.016)
suburban	-0.060***	(0.010)	0.055***	(0.008)
dense rural	-0.094***	(0.011)	0.064***	(0.009)
sparse rural	-0.108***	(0.011)	0.038***	(0.009)
(Intercept)	0.536***	(0.021)	0.177***	(0.018)
fuel usage	X		X	
product space	X		X	
customer structure	X		X	
time trend	X		X	
R^2	0.14		0.35	
N	6,542		6,542	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. Reference group: organisation under public law (Eigenbetrieb). Organisations under public law in mixed ownership (private shares) are ruled out by law. Investment intensity is measured as gross investments over revenues. Firm size categories defined according to EC (2003).

Wages seem to motivate outsourcing, even though the effect is very low in magnitude.

Table 4.8 in the section Appendix 4.10 provides results by sector. Smaller firms increasingly rely on external services in water, electricity and gas supply, providing further evidence for the 'lack of expertise in KIBS' hypothesis described in Section 4.2.3. Electricity and gas supply are the only segments where corporatisation entails higher outsourcing levels. The water sector differs in various dimensions. First, private shareholders are associated with less generation outsourcing, for both corporatised firms and municipal associations. In addition, higher wages are negatively correlated with generation outsourcing, suggesting that in-house generation requires more qualified personnel. Third, the proximity hypothesis extends to generation, i.e., rural water companies purchase less water from other companies.

4.7 Results

4.7.1 Production technology

Tables 4.5 below and Table 4.9 in the section Appendix 4.10 report average output elasticities and returns to scale. Although average returns to scale are close to one, 97 per cent of the mixed utilities and 96 per cent of the water firms operate under decreasing returns to scale.[20] Output elasticities vary between firms and sectors, which confirms the choice of a flexible translog production function and the separate estimation of sector-wise production technologies.

Table 4.5: Median output elasticities and returns to scale

	labour L	capital K	external services S	returns to scale	
	med	med	med	med	share DRS
mixed utilities	0.502	0.243	0.201	0.943	0.97
water	0.361	0.360	0.250	0.949	0.96
electricity/gas	0.441	0.153	0.309	0.887	0.82
heat and power	0.538	0.077	0.355	0.937	0.68

4.7.2 Productivity growth through reorganisation

The estimated evolution of productivity following the Markov process in equation (4.13) is given in Table 4.6. Water supply experiences the lowest annual changes in productivity ($\varphi = 0.871$), which is intuitive given that German water supply is characterised by local monopolies and a stable regulatory environment. Corporatisation has a small positive effect on future productivity in the main sample, but this relationship only holds for unlimited companies (*GmbH*) and not for listed companies (*AG*). Partial privatisation results in lower coefficients when compared to purely state-owned corporatised firms, although the difference is not statistically significant. Services subcontracting has a positive impact on productivity growth, while external generation does not seem to influence productivity growth. Zooming into the different sectors, we see that the relationship is reversed for electricity and gas firms, where generation outsourcing entails productivity gains, while service outsourcing does not affect productivity. Performance in water supply and among generation plants is not significantly influenced by reorganisation at all.

Overall immediate productivity gains from reorganisation are small. An increase in outsourcing intensity by 10 percentage points entails productivity growth of 0.4

[20]This is in line with the recent findings of Zschille (2016a) who identifies cost advantages for local suppliers over regional suppliers in German water supply.

percentages among mixed utilities and 0.3 percentages in electricity and gas supply.

Table 4.6: Productivity growth through reorganisation

	mixed utilities (1)	water (2)	electricity/gas (3)	heat/power (4)
productivity	0.808*** (0.032)	0.871*** (0.025)	0.835*** (0.031)	0.751*** (0.044)
productivity^2	0.290** (0.099)	−0.001 (0.146)	0.473** (0.145)	−0.428** (0.131)
productivity^3	−0.273*** (0.066)	0.605 (0.837)	−0.463*** (0.113)	−0.301* (0.135)
corp (GmbH)	0.003* (0.001)	−0.001 (0.001)	0.005 (0.008)	
corp (AG)	0.002 (0.004)			
mun. association		0.000 (0.000)		
corp (GmbH) × priv	0.000 (0.001)	0.002 (0.002)	-0.013* (0.006)	0.006 (0.006)
corp (AG) × priv	−0.005 (0.006)			
mun. association × priv		−0.001 (0.001)		
outsourced services	0.040*** (0.008)	0.002 (0.002)	0.000 (0.011)	−0.025 (0.019)
outsourced generation	−0.004 (0.003)	0.002 (0.002)	0.033* (0.016)	0.012 (0.016)
(Intercept)	−0.009** (0.003)	−0.001 (0.001)	−0.019 (0.010)	0.001 (0.011)
R^2	0.76	0.76	0.76	0.74
N	6,542	7,578	941	545

Notes: Results from estimating the specification as given in (4.13). p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. WHITE standard errors in parentheses. corp = corporatised (organised under private law). priv = minority shares held by private sector. In columns (5)-(8), GmbH and AG form a joint category 'corporatised'. Reference group for columns (1)-(6): organisation under public law (Eigenbetrieb). Reference group for columns (7)-(8): organisation under private law, fully publicly owned.

4.7.3 Permanent effect from organisational practise

While the Markov process focused on intra-firm productivity *growth* through reorganisation, equation (4.14) estimates differences in productivity *levels* between firms with distinct organisational structures. Results are given in Table 4.7. We do not find any significant effect for corporatisation, meaning that organisations under private law do not generally outperform organisations under public law. There are three possible reasons: (1) management autonomy plays a less crucial role for explaining state-enterprise performance than economic theory predicts; (2) legal autonomy does not necessarily imply actual autonomy, in the sense that political influence might also persist in state-owned firms organised under private law, e.g. through executive boards and selection of management staff; or (3) results could be interpreted the other way around. State-owned firms -whether organised under private law or public law- perform equally well, i.e. firms under public law do not suffer from any disturbing influence on (technical)[21] productivity, despite being more

[21]It is beyond the scope of this chapter to compare the productivity of state-owned firms in achieving overall objectives, i.e. including both technical performance *and* the achievement of social goals. This chapter only measures technical productivity in the tradition of the private sector.

closely connected to the political administration. However, this does not mean that individual firms never profit from corporatisation. In the previous section, we have shown that those firms reorganising under private law between 2003 and 2014, on average did experience a positive impact on productivity.

Table 4.7: Permanent effect from organisational practise

	mixed utilities		water		electricity/gas		heat/power	
corp (GmbH)	0.009	(0.006)	−0.008	(0.004)	0.061	(0.032)		
corp (AG)	−0.016	(0.016)						
mun. association			−0.001	(0.002)				
corp (GmbH) × priv	−0.001	(0.004)	0.019	(0.017)	-0.056**	(0.021)	0.072*	(0.031)
corp (AG) × priv	−0.034	(0.022)						
mun. association × priv			−0.001	(0.005)				
outsourced services	0.154***	(0.016)	0.016*	(0.006)	0.111**	(0.034)	−0.058	(0.069)
outsourced generation	0.002	(0.013)	0.003	(0.009)	0.210***	(0.056)	−0.005	(0.076)
(Intercept)	0.001	(0.020)	−0.005	(0.012)	−0.207***	(0.055)	−0.197*	(0.087)
fuel usage	X						X	
product space	X				X		X	
firm size	X		X		X		X	
population density	X		X		X		X	
R^2	0.23		0.02		0.27		0.17	
N	6,542		7,578		941		545	

Notes: Results from estimating the specification as given in equation (4.14). p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. WHITE standard errors in parentheses. corp = corporatised (organised under private law). priv = minority shares held by private sector. In columns (5)-(8), GmbH and AG form a joint category 'corporatised'. Reference group for columns (1)-(6): organisation under public law (Eigenbetrieb). Reference group for columns (7)-(8): organisation under private law, fully publicly owned.

The effect of private shareholders is ambiguous. For the main sample of mixed utilities, we do not find any significant difference, whereas in the electricity and gas sectors, firms with private shareholders are 6 per cent less productive, on average, than purely state-owned firms. The difference is statistically significant at <1 per cent and confirms the indicative result from the Markov process (see column (3) in Table 4.6). At the same time, electricity and gas supply are those sectors that experienced the largest shift in nationalisation, either through remunicipalisation or the new establishment of public utilities (see Figure 4.3b). This suggests that this new generation of purely state-owned firms does not depend on the private sector for implicit knowledge transfer or the implementation of effective business routine, but rather it sometimes outperforms the latter. Interesting enough, this pattern does not hold for electricity generation in isolation and for heat supply. Here, private-sector participation increases average productivity by 7 per cent. Given that more than two thirds of installed power generation capacity is in the hands of the private sector (Monopolkommission, 2015), technical knowledge transfer might take a more vital role here, thus explaining the positive impact of private participations.

Finally, services outsourcing has a stable positive impact on productivity, ranging from 2 per cent in water supply to 15 per cent in the main sample. Production outsourcing plays a positive role among electricity and gas firms, which is consistent with the results from the Markov process.

4.8 Discussion

4.8.1 Selection into privatisation or corporatisation

Economic theory suggests that poor performers might self-select into privatisation or corporatisation (see, e.g., Boycko et al., 1996). If private firms were inherently more productive at running certain businesses, then selling poor performing state-owned firms to the private sector could foster productivity growth and appeal to market-oriented politicians. Furthermore, privatisation could allow treasuries to save on transfer payments to loss-making firms.

Self-selection is accounted for in the model by means of the Markov process.[22] As current ω_{it} is regressed on past ω_{it-1}, the coefficients α_3, α_4 of the organisational variables μ_{it-1} and η_{it-1} measure their contribution to productivity *change* between $t-1$ and t, i.e. the growth (or decline) in productivity since reorganisation took place. This is independent of the starting level. Even if firms had particularly low performance levels prior to partial privatisation (or corporatisation), this information is contained in ω_{it-1} and does not affect the estimation of a subsequent change in productivity. Rather, α_3 and α_4 address the question of whether partial privatisation (corporatisation) have changed productivity for a *given* level of productivity: „Given hypothetical poor performance under state ownership, did private investors save the firm or did they make everything worse?“.[23]

Furthermore, empirical evidence for the selection hypothesis in advanced economies is limited. Studies of the UK privatisations under Margaret Thatcher, for instance, suggest that other motives were more frequent, and that the government welcomed proceedings from privatising highly profitable firms to overcome public borrowing constraints (Yarrow, 1986; Florio, 2004). Among German public utilities, loss-making as a result of poor performance has also been of little concern. Instead, profits from public utilities are an important source of cross-subsidisation for other

[22] See De Loecker (2013) for originally discussing this issue with respect to selection into exporting.

[23] Finding a negative effect for partial privatisation further backs a unidirectional mechanism and speaks against the hypothesis of selection. Poor initial performance levels of state-owned firms should make it easier for private investors to induce productivity growth in the following years, when compared to a state-owned firm that is already highly efficient prior to privatisation. If there was selection into privatisation and the private sector was inherently more productive, we would expect $\Delta_\eta = \hat{\alpha}_4 - \hat{\alpha}_3$ to be positive, which is not the case.

public services, such as public transport.

4.8.2 Selection into outsourcing

In Section 4.5, we argue that it is reasonable to expect effects from outsourcing on productivity to happen (if at all) within a short time horizon, which is why we measure the effect of outsourcing intensity on contemporaneous productivity rather than on future (next year) productivity. This raises the concern of another endogeneity issue, where those firms, which incurred high productivity gains from other sources, self-select into outsourcing. Productivity gains stemming from other sources would then be wrongly attributed to increased outsourcing. To explore whether self-selection into outsourcing is a concern, we run the model again and lag outsourcing intensity for services by one, respectively two, periods. Thereby, we consider the decision of the firm made before any productivity gains (or losses) took place. Results are given in column (1) and (2) of Table 4.11 in the section Appendix 4.10. The positive effect of a 10 percentage point increase in outsourcing intensity remains significant in both settings. The magnitude of the productivity gain decreases from 0.4 per cent in the same year to 0.2 after one year and 0.02 per cent after two years. Results are also confirmed when looking at permanent effects from organisation.

4.8.3 Interactions between organisational strategies

So far, the model analyses outsourcing in isolation from major restructuring (partial privatisation, corporatisation). However, the development of new business routines following corporatisation and changes in ownership might also involve modifications in outsourcing behaviour. Section 4.6.3.3 explored the determinants for outsourcing intensity and showed that in the main sample of mixed utilities, private owners favour higher outsourcing ratios and that firms organised under private law displayed higher outsourcing rates in the electricity and gas sectors. To disentangle the channels through which productivity is affected, we augment the baseline model and additionally include interactions between different organisational strategies in the productivity process. Results are given in column (4) of Table 4.11 in the section Appendix 4.10 for the main sample and column (3) of Table 4.12 in the section Appendix 4.10 for electricity and gas supply.

Despite the observation that partially privatised firms source more externally than fully state-owned firms, we do not see any distinct effects on productivity among mixed utilities. Rather, the magnitude of productivity gains from service outsourcing seems to be independent of legal status and ownership composition.

Much as in the baseline model, generation outsourcing does not have any effect at all.

In electricity and gas supply, however, the augmented model provides some important additional insights. First, we see that a positive effect from service outsourcing among fully state-owned firms organised under *public law* is nearly completely offset by the negative impact among fully state-owned firms organised under *private law*. For this reason, we do not find any effect from service outsourcing in the baseline model (see column (3) in Tables 4.6 and 4.7). The higher outsourcing intensity among the latter group actually seems to produce a negative impact on productivity growth, which suggests some over-saturation effect. This is also supported by the observation that corporatised firms in mixed ownership source less externally and do not suffer from a negative impact on performance. Concerning generation outsourcing, the pattern is reversed. Private shareholders are associated with a negative effect of generation outsourcing on productivity, which is particularly surprising given the fact that electricity generation capacity in Germany is predominantly owned by the private sector. We would rather expect positive spill-overs from preferential procurement. Thus, the positive impact of generation outsourcing on productivity in the baseline model is mediated by fully state-owned corporatised firms.

4.8.4 Generation outsourcing in electricity and gas supply

Electricity and gas supply are the only sectors where outsourced generation had a significant effect on productivity. Given very limited domestic natural gas resources in Germany, gas suppliers have no choice but to externally source gas production (apart from biogas solutions). The strongly positive result for outsourced generation could then mask inherent productivity gains in the gas sector unrelated to reorganisation. To verify this, we run the estimation again on a reduced sample, where we exclude all pure gas firms to ensure that the firms considered indeed have a true choice for subcontracting generation or not. The reduced sample is composed of pure electricity firms and mixed electricity-gas firms. Results are provided in column (1) of Table 4.11 in the section Appendix 4.10. Importantly, the positive effect from generation outsourcing is robust to excluding pure gas firms and only marginally decreases in magnitude when compared to the full sample.

4.8.5 Pass-through

The way generation outsourcing intensity is measured raises another concern. Generation outsourcing is defined in monetary terms as expenditure for procurement over revenues. In Section 4.4, we assume that retail prices proportionally reflect procurement unit costs, i.e. pass-through is constant across firms and time (assumption A2). Only then can changes in output intensity be attributed to changes in volumes and not to price effects. What if this assumption does not hold? Is there reason to believe that the positive relationship between increased outsourcing intensity merely reflects a price effect, i.e. some firms charge higher markups than others, thus appearing to be more 'sales' productive? Our findings do not support this hypothesis. To see this, assume that some firms simply raise the markup from one period to another while keeping volumes constant, i.e., despite decreasing expenditure for outsourced generation, they maintain retail prices and thus their level of revenues. Consequently, observed outsourcing intensity would decrease. Since we find a positive impact from *increasing* outsourcing intensity on productivity, this would actually mean that firms with higher markups are less (sales) productive.

4.8.6 Time-varying production technology

The rise in outsourced services between 2003 and 2014 might not only affect productivity but change the production technology as a whole. This is partially accounted for by the translog specification, which allows output elasticities to vary by input levels and over time. To increase flexibility and assess any changes over time, we re-estimate the model with an augmented production function including a time-trend $t \in \{1, 2, 3, ..\}$ in the first-order input coefficients:

$$\begin{aligned} y_{it} = & c + \beta_l l_{it} + \beta_s s_{it} + \beta_k k_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + 0.5\beta_{kk} k_{it}^2 \\ & + \beta_{ls} l_{it} s_{it} + \beta_{lk} l_{it} k_{it} + \beta_{ks} k_{it} s_{it} \\ & + \beta_{lt} l_{it} t + \beta_{st} s_{it} t + \beta_{kt} k_{it} t \\ & - \sum_F \gamma_f \bar{p}_{ft} d_{ift} + \sum_J \gamma_j \bar{p}_{jt} d_{ijt} + \xi_p \\ & + \omega_{it} + \epsilon_{it}. \end{aligned} \tag{4.15}$$

Table 4.10 in the section Appendix 4.10 summarises average output elasticities for the augmented model. The interacted time-trend coefficients turn out to be not significant in the main sample and output elasticities remain roughly unchanged when compared to the baseline model in Table 4.9.[24] For comparison, we also re-estimate the model in the electricity and gas sectors, where outsourcing dynamics are most pronounced (see Figure 4.2a). Here, we find that average output elasticities increased for labour and external services, while it decreased for capital. Indeed, the time coefficient for capital is negative and significant ($\beta_{kt} = -0.021$), which

[24]Detailed regression output is available upon request from the author.

results in decreasing average output elasticities over time (see Figure 4.4b). This probably reflects the growing importance of personnel-intensive business services such as marketing, procurement, and regulatory affairs after liberalisation to the detriment of the 'old business model' with a purely technical focus and reduced customer management. Turning to the effect of reorganisation on productivity, column (3) in Table 4.11 and column (2) in Table 4.12 in the section Appendix 4.10 globally confirm findings from the baseline model. The effect from partial privatisation is reinforced, though, such that it now exerts a significantly negative impact on productivity.

4.9 Conclusion

Public enterprises have not disappeared from European economies. They are still prevalent in many sectors of general interest such as energy provision, transportation, and postal services. Moreover, some countries like Germany are experiencing a renaissance of public sector involvement at the local level. Since 1998, however, liberalisation and the emergence of new technologies required public enterprises to adapt to new market environments and engage in organisational innovation.

The present chapter evaluates three elements of organisational innovation among 2,325 state-owned German energy and water firms between 2003 and 2014: (i) outsourcing; (ii) corporatisation; and (iii) selling minority shares to the private sector. Performance is measured as total factor productivity derived in a structural production function framework and estimated applying a control function approach. Since energy and water firms are traditionally multiproduct firms, we suggest a method to account for different input and output prices at the product level.

Results suggest that outsourcing and corporatisation are positively correlated with productivity, while partial privatisation does not increase productivity. Rather, fully state-owned firms outperform firms in mixed ownership. The reason could be conflicting owner interests (multiple-principals problem) and frustration among public managers when their intrinsic public service motivation is crowded out by inflexible business rules. The chapter contributes to scarce empirical evidence on contemporary public enterprises in advanced economies and sheds light on the link between reorganisation and firm performance.

4.10 Appendix

Table 4.8: Determinants for reorganisation across subsectors

	water				electricity and gas				heat and power			
	outsourced services π		outsourced generation τ		outsourced services π		outsourced generation τ		outsourced services π		outsourced generation τ	
$corp_{t-1}$	−0.012	(0.009)	0.010	(0.006)	0.121***	(0.036)	0.096***	(0.025)				
$corp_{t-1} \times priv_{t-1}$	0.078***	(0.019)	−0.047***	(0.011)	0.036	(0.021)	0.019	(0.015)	0.100***	(0.027)	−0.272	(0.020)
mun. association$_{t-1}$	−0.010	(0.006)	−0.014***	(0.004)								
mun. association$_{t-1} \times priv_{t-1}$	0.009	(0.015)	−0.029**	(0.009)								
outsourced generation $_{t-1}$	0.185***	(0.019)			−0.327***	(0.048)			0.040	(0.060)		
outsourced services $_{t-1}$			0.069***	(0.007)			−0.150***	(0.022)			0.017	(0.034)
investment intensity$_{t-1}$	0.004	(0.005)	−0.156***	(0.003)	0.030	(0.023)	0.000	(0.016)	−0.003	(0.002)	0.001	(0.002)
wages$_{t-1}$	−0.006	(0.000)	0.000	(0.000)	−0.002*	(0.001)	−0.002**	(0.001)	−0.005**	(0.001)	0.001	(0.001)
size medium	−0.038***	(0.008)	−0.048***	(0.005)	−0.066**	(0.024)	0.043**	(0.017)	0.054	(0.032)	0.067**	(0.025)
size large	−0.177***	(0.021)	−0.077***	(0.013)	−0.087**	(0.033)	0.108***	(0.022)	0.054	(0.054)	0.043	(0.041)
elec: share residential supply$_{t-1}$					−0.081*	(0.038)	−0.006	(0.026)				
elec: share wholesale$_{t-1}$					−0.078*	(0.035)	−0.121***	(0.023)				
heat: share residential supply$_{t-1}$									0.026	(0.042)	0.181***	(0.031)
heat: share wholesale$_{t-1}$									0.114**	(0.041)	−0.029	(0.032)
suburban	−0.131***	(0.017)	0.005	(0.011)	−0.155***	(0.038)	0.176***	(0.025)	−0.117**	(0.035)	−0.025	(0.027)
dense rural	−0.155***	(0.018)	−0.060***	(0.011)	−0.144***	(0.042)	0.171***	(0.029)	−0.330	(0.049)	−0.116**	(0.038)
sparse rural	−0.180***	(0.018)	−0.097***	(0.011)	−0.176***	(0.042)	0.117***	(0.029)	−0.323***	(0.046)	−0.081*	(0.037)
(Intercept)	0.752***	(0.025)	0.148***	(0.016)	0.073***	(0.080)	0.385***	(0.056)	0.738***	(0.093)	0.05	(0.084)
fuel usage									X		X	
product space					X		X		X		X	
customer structure					X		X		X		X	
time trend	X		X		X		X		X		X	
R^2	0.08		0.15		0.23		0.28		0.23		0.18	
N	7,578		7,578		941		941		545		545	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. corp = corporatised (organised under private law), priv = minority shares held by private sector. Investment intensity is measured as gross investments over revenues. Firm size categories defined according to EC (2003) based on number of employees and turnover.Reference group for columns (1)-(8): organisation under public law (Eigenbetrieb). Reference group for columns (9)-(12): organisation under private law, fully publicly owned.

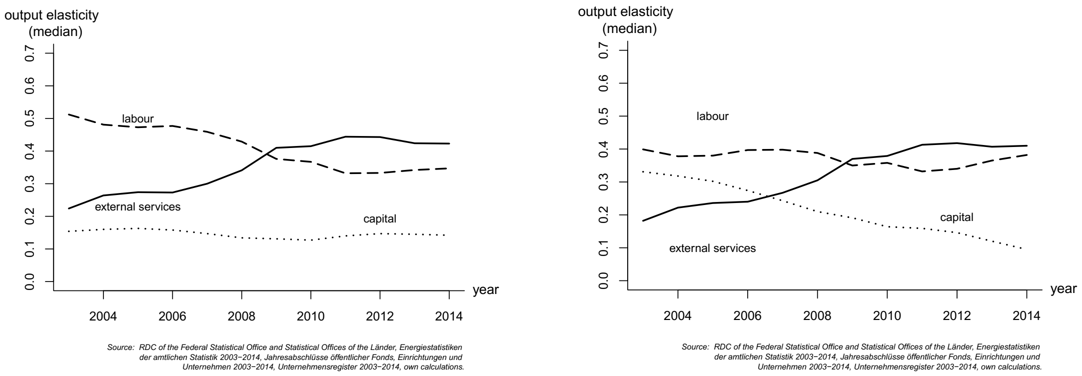
Table 4.9: Mean output elasticities and mean returns to scale

	labour L		capital K		external services S		returns to scale	
	mean	sd	mean	sd	mean	sd	mean	sd
mixed utilities	0.487	(0.129)	0.238	(0.074)	0.213	(0.116)	0.938	(0.04)
water	0.337	(0.161)	0.363	(0.110)	0.248	(0.138)	0.948	(0.03)
electricity/gas	0.401	(0.263)	0.145	(0.087)	0.364	(0.314)	0.910	(0.09)
heat and power	0.499	(0.352)	0.083	(0.106)	0.375	(0.256)	0.957	(0.10)

Table 4.10: Output elasticities and returns to scale under time trend

	labour L		capital K		external services S		returns to scale	
	mean	sd	mean	sd	mean	sd	mean	sd
mixed utilities	0.486	(0.141)	0.228	(0.062)	0.219	(0.144)	0.933	(0.03)
electricity/gas	0.370	(0.255)	0.202	(0.123)	0.333	(0.281)	0.888	(0.07)

Figure 4.4: Output elasticities in electricity and gas supply



(a) baseline model **(b) time trend model**

Table 4.11: Sensitivity analyses among mixed utilities

	service outsourcing (t-1)		service outsourcing (t-2)		time trend production		interactions organisation	
	(1)		(2)		(3)		(4)	
Productivity growth through reorganisation								
corp (GmbH)	0.001	(0.001)	0.002**	(0.001)	0.001	0.001	−0.008	(0.007)
corp (AG)	0.000	(0.003)	0.001	(0.001)	0.002	(0.002)	−0.008	(0.008)
corp (GmbH) × *priv*	0.000	(0.001)	0.000	(0.000)	0.000	(0.001)	−0.012	(0.006)
corp (AG) × *priv*	−0.004	(0.005)	−0.005*	(0.002)	−0.005	(0.003)	−0.018*	(0.008)
serv	0.018***	(0.004)	0.006*	(0.002)	0.037***	(0.004)	0.015	(0.029)
prod	−0.003	(0.003)	−0.006*	(0.002)	−0.001	(0.003)	0.002	(0.012)
*s*erv × prod							−0.016	(0.029)
serv × *corp*							0.026*	(0.011)
serv × *corp* × *priv*							0.029**	(0.009)
prod × *corp*							0.001	(0.008)
prod × *corp* × *priv*							0.001	(0.008)
(Intercept)	0.006	(0.002)	0.000	(0.002)	−0.014***	(0.002)	0.006	(0.006)
R^2	0.75		0.75		0.78		0.75	
N	6,542		5,697		6,542		6,542	
Permanent effect from organisational practise								
corp (GmbH)	0.007	(0.005)	0.010*	(0.004)	0.007	(0.004)	−0.027	(0.024)
corp (AG)	−0.011	(0.012)	−0.001	(0.007)	−0.003	(0.007)	−0.043	(0.027)
corp (GmbH) × *priv*	−0.003	(0.003)	−0.004	(0.002)	−0.005	(0.003)	−0.030	(0.021)
corp (AG) × *priv*	−0.028	(0.016)	−0.024**	(0.008)	−0.023**	(0.008)	−0.063*	(0.028)
serv	0.081***	(0.012)	0.033***	(0.008)	0.093***	(0.010)	0.082	(0.055)
prod	0.006	(0.012)	−0.004	(0.009)	−0.004	(0.009)	0.027	(0.042)
serv × *prod*							−0.074	(0.093)
serv × *corp*							0.089*	(0.041)
serv × *corp* × *priv*							0.083**	(0.031)
prod × *corp*							0.007	(0.032)
prod × *corp* × *priv*							−0.006	(0.028)
(Intercept)	0.031*	(0.016)	0.008	(0.013)	0.007	(0.013)	0.031	(0.027)
fuel usage	X		X		X		X	
product space	X		X		X		X	
firm size	X		X		X		X	
population density	X		X		X		X	
R^2	0.12		0.08		0.18		0.23	
N	6,542		5,697		6,542		6,542	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. WHITE standard errors in parentheses. corp = corporatised (organised under private law). priv = minority shares held by private sector. serv = outsourced services intensity. prod = outsourced generation intensity. Reference group: organisation under public law (Eigenbetrieb).

Table 4.12: Sensitivity analyses in electricity and gas supply

	without gas firms (1)		time trend production (2)		interactions organisation (3)	
Productivity growth through reorganisation						
corp	0.006	(0.008)	0.008	(0.006)	0.043	(0.026)
corp × *priv*	−0.011	(0.006)	−0.012*	(0.005)	−0.021	(0.023)
serv	−0.011	(0.012)	0.016	(0.010)	0.118***	(0.027)
prod	0.041**	(0.015)	0.037**	(0.013)	0.029	(0.040)
*s*erv × prod					−0.033	(0.060)
serv × *corp*					−0.109***	(0.028)
serv × *corp* × *priv*					0.017	(0.023)
prod × *corp*					0.031	(0.037)
prod × *corp* × *priv*					−0.002	(0.032)
(Intercept)	−0.028*	(0.012)	−0.028**	(0.009)	−0.068**	(0.021)
R^2	0.77		0.74		0.76	
N	724		941		941	
Permanent effect from organisational practise						
corp	0.065	(0.033)	0.050*	(0.022)	0.051	(0.067)
corp × *priv*	−0.048*	(0.020)	−0.052**	(0.018)	0.040	(0.070)
serv	0.029	(0.046)	0.095***	(0.027)	0.319***	(0.071)
prod	0.177**	(0.063)	0.040	(0.047)	0.067	(0.103)
serv × *prod*					0.011	(0.169)
serv × *corp*					−0.245***	(0.064)
serv × *corp* × *priv*					0.062	(0.063)
prod × *corp*					0.244*	(0.096)
prod × *corp* × *priv*					−0.222*	(0.106)
(Intercept)	−0.212**	(0.079)	−0.112*	(0.043)	−0.235**	(0.081)
fuel usage	X		X		X	
product space	X		X		X	
firm size	X		X		X	
population density	X		X		X	
R^2	0.22		0.19		0.29	
N	724		941		941	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05. WHITE standard errors in parentheses. corp = corporatised (organised under private law). priv = minority shares held by private sector. serv = outsourced services intensity. prod = outsourced generation intensity. Reference group: organisation under public law (Eigenbetrieb).

4.11 Data appendix

4.11.1 Energiestatistiken

The survey data on German energy and water firms *Energiestatistiken* consists of 9 separate surveys that are conducted each year by the regional statistical offices. Cumulatively, these surveys cover all German firms with NACE ID 35 and 36 above a certain threshold (more than 10 employees/1MW installed capacity/200,000m3 water treatment). Firms are legally obligated to respond. The data are used by the Federal Statistical Office to publish aggregate figures on the German energy and water sector on a regular basis. Anonymised microdata at firm-level are available for the years 2003 to 2014 and can be analysed in remote access at the research data centres of the statistical offices.

Each survey covers distinct aspects of German energy and water supply, collecting, for instance, data on physical inputs, output, customer structure, fuel use, network losses, installed capacity or investments (see Chapter 2 for details). The panel dataset used for the analysis was constructed merging the surveys listed in Table 4.13 for the period between 2003 and 2014 with firm ID and year as identifiers.

Table 4.13: List of surveys from *Energiestatistiken* used

survey code	original title	english translation
43211-077	Investitionserhebung bei Unternehmen der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen	investment structure of firms in the energy, water, sewerage and waste management sectors
43211-076	Investitionserhebung bei Betrieben der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen	investment structure of plants in the energy, water, sewerage and waste management sectors
43221-081	Kostenstrukturerhebung bei Unternehmen der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen	cost structure of firms in the energy, water, sewerage and waste management sectors
43331-083	Erhebung über Stromabsatz und Erlöse der Stromversorgungsunternehmen und Stromhändler	survey on electrity sales and quantities delivered by electricity traders
43371-070	Erhebung über die Stromeinspeisung bei Netzbetreibern	electricity feed-in of distribution network operators
43312-66N	Erhebung über die Elektrizitätsversorgung der Netzbetreiber	general survey on electricity distribution network operators
43411-064	Erhebung über die Erzeugung, Bezug, Verwendung und Abgabe von Wärme	survey on the generation, purchase, use and supply of heat
43111-065	Monatsbericht bei Betrieben der Energie- und Wasserversorgung	monthly report on energy and water plants
43311-66K	Monatsbericht über die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen für die allgemeine Versorgung	monthly report on electricity and heat generation in power plants

4.11.2 Jahresabschlüsse öffentlicher Fonds, Einrichtungen und Unternehmen

The official dataset *Jahresabschlüsse öffentlicher Fonds, Einrichtungen und Unternehmen* collects financial statements of all German firms where public authorities hold more than 50 per cent of the shares and/or votes. It covers all sectors of the German economy. Anonymised microdata is available for the years 1998 to 2014 and can be accessed at the research data centres of the regional statistical offices. Information (in German) is given on the webpage of the research data centres `http://www.forschungsdatenzentrum.de/bestand/jahresabschluss/index.asp`.

4.11.3 Unternehmensregister (URS)

The company register *Unternehmensregister (URS)* kept by the statistical offices allows for deriving unique firm IDs to merge the above datasets (`http://www.forschungsdatenzentrum.de/bestand/urs/index.asp`). It contains further information on tax group relationships, which, in theory, would allow for the identification of affiliated firms that belong to the same enterprise group. However, the quality of the tax data is limited.

4.11.4 Settlement data from BBSR

The Federal Institute for Research on Building, Urban Affairs and Spatial Development *(BBSR)* collects information on spatial development in Germany and provides a classification system for comparing the settlement structure of German counties. It may be accessed through the webpage (in German): `http://www.bbsr.bund.de/BBSR/DE/Raumbeobachtung/Raumabgrenzungen/Kreistypen4/kreistypen.html`. The settlement data is merged to the panel dataset using the official community identification number distributed to all municipalities by the regional statistical offices (*Amtlicher Gemeindeschlüssel*).

Chapter 5

Productivity, Marginal Costs, and Fixed Costs: Public Service Provision under Demographic Changes

5.1 Introduction

Across many developed countries, demographic changes profoundly alter the population structure, involving both population ageing and intra-country migration movements (Hans et al., 2016; Martinez-Fernandez et al., 2012). They do not only pose significant challenges to the pension systems (Disney, 1996; Miles, 1999) but also affect the provision of local public services (Wolf and Amirkhanyan, 2010; Geys et al., 2008). Germany's adjustment costs of municipal infrastructure to changing demographics are estimated to comprise 25 billion EUR within 5 years, for instance, amounting to 20 per cent of total investment plans (Köller, 2013). One of the critical infrastructures is municipal water supply. In Germany, households account for more than 86 per cent of the supply to end-consumers, making water supply particularly vulnerable to demographic changes.

> "While social or education infrastructure can be closed down and public transportation can be phased out, solutions such as shutting down or demolishing water supply infrastructure are not available because the remaining population must still be supplied. " (Hummel and Lux, 2007,

[0]This chapter is based on joint research with Astrid Cullmann. The author was responsible for data collection and preparation, model development, estimation, interpretation of results and paper writing. Idea and model set-up was collaborative.

p.183)

Municipalities are not all affected in the same way. Urbanisation and population ageing often result in troubling regional disparities, as rural areas face declining populations while urban agglomerations grow and attract young families. Most of urban water utilities cope with population growth by adding more services and extending their networks, thus benefiting from increased customer density. However, universal service obligations and the lengthy life-cycles of technical infrastructure make adjustments difficult for rural utilities (Einig et al., 2006; Londong et al., 2010; Koziol, 2004). This does not only affect fixed costs but also marginal costs since reduced water consumption in oversized mains requires regular flushing of the mains to avoid nucleation. For rural water utilities decreased population density translates into increased costs per capita, leading to regional disparities in water tariffs. The growing disparities in local water tariffs violate the premise of equal living conditions, laid down in many constitutions, and fuel the political debate on the quality of public service provision in rural areas.

In this chapter, we study two facets of demographic changes and their effect on municipal water supply: local population growth/decline and changes in the population age structure, as measured by the percentage of children under 18 years of age and adults over 60 years of age. The empirical literature on water supply acknowledges that customer density affects the costs of drinking water supply (Filippini et al., 2008; Egerton et al., 2011; Zschille, 2016a) but largely ignores underlying dynamics. An analysis of changes in demographics and the speed, at which the changes occur, is rare. Karthe et al. (2017) are the first to empirically analyse the link between demographic change and water supply. Analysing the effect of depopulation on water quality, the authors show that the frequency of non-compliance with microbiological standards significantly correlates with population shrinkage.[1]

Regarding changes in the age structure, studies on the link between population age and residential water demand conclude that the impact from population ageing on water supply is unclear. Nauges and Thomas (2000) and Martinez-Espiñeira (2002) find that water demand decreases with age, Lyman (1992) suggests a U-shaped demand curve over life, where children's per capita consumption is highest, while Mazzanti and Montini (2006) and Koegst et al. (2008) find no difference in water demand by age group.

We assess the influence of the demographic changes on firm productivity and cost structure for a panel of 751 municipally-owned water utilities, operating between

[1] The reason is that water flowing in under-utilised mains is slowed down, eventually leading to the creation of stagnation zones in the mains, which are susceptible to sedimentation and increased contamination.

2003 and 2014 in Germany. Germany is particularly suited for the analysis as it has been faced with fundamental changes in demographics. The median age increased from 37 years in 1990 to 45 years in 2013; by 2060, 33 per cent of the population is expected to be 65 years and older (Destatis, 2015a). Moreover, the number of inhabitants living in large cities throughout Germany increased by 1.4 million between 2005 and 2015 (BBR, 2017). In the same time period, half of the peripherally located municipalities in the former GDR lost more than 10 per cent of their population, compared to 8.1 per cent of the municipalities in western Germany. These trends are also reflected in our dataset. Considering the years 2003 to 2014 and the municipalities, which have a local water utility in our dataset, the percentage of children under 18 years of age decreased from 19 per cent on average to 17 per cent, whereas the percentage of those 60 years and older increased from 24 per cent on average to 28 per cent. Comparing the most and least populated municipalities, we observe that population density steadily increased in the most populated regions by 0.3 per cent each year and decreased by -0.4 per cent in the least populated regions.

The influence of demographic changes on local water supply is assessed by means of a structural production function framework. We derive total factor productivity and marginal costs following De Loecker and Warzynski (2012) and estimate them using the control function approach developed by Olley and Pakes (1996) and Ackerberg et al. (2015). The results show that population decline and population ageing affect firm productivity negatively, leading to an annual productivity loss of 17 per cent in fast-shrinking regions. For the evolution of marginal costs, the results indicate that the age composition within private households matters more than population density. A decreasing percentage of children under 18 among the local population causes marginal costs to rise.

To the best of our knowledge, this work is one of the first to quantify the impact of demographic changes on local infrastructure services. It contributes to empirical evidence on the provision of local public services under demographic changes, highlighting diverging trends between urban and peripheral regions.

5.2 Background: Organisation and cost structure in German water supply

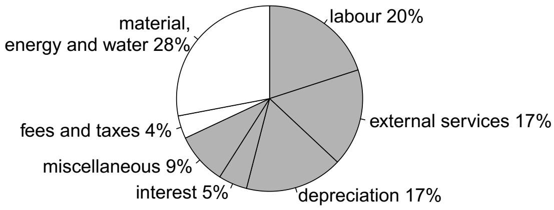
In Germany, the provision of potable water is a core duty of public service under municipal responsibility. It is locally organised in a public or privately managed water utility, which has monopoly rights. The production process includes raw water abstraction and treatment, transmission of treated water, and final distribution of potable water to end-consumers. German water utilities usually own some raw water abstraction facilities, but also purchase treated water from pure bulk water supply companies and other water utilities. Some are horizontally integrated into larger public utilities, which also supply natural gas, electricity or heat. Most of the water utilities are under public ownership. In 2013, 87 per cent of potable water in Germany was supplied by municipally-owned utilities (VKU, 2017b).

As in other countries, the supply of water in Germany is capital-intensive, with large-scale infrastructures consisting of pipelines, pumping stations, purification plants, and storage. Most of this infrastructure has a service life of up to 80 years, from which the capital costs derive in the form of depreciation and replacement investment. Other costs include labour for operations, maintenance, and customer relations, as well as material usage, e.g., energy, bulk water and chemicals for water purification. Both capital and personnel costs are considered fixed costs, resulting in a fixed cost share of 70 per cent of total costs on average (Destatis, 2017). Figure 5.1 illustrates the cost structure of German water suppliers in 2015.

The cost structure of each utility may be affected by topography, geology, local availability of water resources (groundwater, surface water), settlement structure, farming intensity, and climate.[2] Local taxation policies may incur different levels of water extraction and concession fees. Water extraction fees, which are set individually by each German state *(Bundesland)*, range from 0 to 0.31 EUR/m3 (BDEW, 2015), and concession fees are determined locally by the municipality. The maximum level, which a municipality is allowed to charge, is based on the number of inhabitants and ranges from 12 per cent (<100.000 inh.) to 18 per cent (>500.000 inh.) of the utility's revenue (KAEAnO, 1941).

[2] Depending on the altitude, the numbers of pressure reduction and pressure boosting plants required also involve different levels of energy consumption. Population density determines the pattern and calibre of the pipe network. Agricultural byproducts such as nitrate in the groundwater affect the costs of water purification. Climatic conditions, such as droughts and rainfall, affect the availability of raw water and the patterns of consumption.

Figure 5.1: Cost structure of Germany's water utilities in 2015



Source: Own representation based on Destatis (2017)

5.3 Model

5.3.1 Production function

We set up a structural production model to determine the total factor productivity and the marginal costs of production. Assume that water utility i (hereafter, the firm) at time t uses four inputs, capital K_{it}, labour L_{it}, intermediate goods (including bulk water) M_{it}, and external services S_{it} to produce output $\tilde{Q}_{it}$. The firm's production depends on (unobserved) firm-level productivity ω_{it}, and a set of environmental production conditions summarised in the vector $\boldsymbol{X_{it}}$:

$$\tilde{Q}_{it} = F(K_{it}, L_{it}, M_{it}, S_{it})exp(\omega_{it} + \boldsymbol{\gamma X_{it}}). \tag{5.1}$$

Assume that the intermediate goods are a flexible, static input, whose level can be adjusted in each period without adjustment costs.[3] Capital and labour, on the other hand, have dynamic implications such that current input levels are partially pre-determined through past input decision. Investments into water facilities are long-term oriented and Germany's strict union contracts in the public sector prevent immediate adjustment of the labour force. While contracts on external services *a priori* can be renegotiated in each period, they are less flexible than intermediate goods. It is not possible to adjust the demand for external services in proportion to actual water output, since some of the services are unrelated to water volumes, e.g., maintenance work of water pipelines.

As mentioned above, drinking water production depends on environmental factors such as geology, topography, the local availability of water sources, raw water composition, and climate. While the general process technology, i.e., raw water

[3] *Static* relates to timing, whereas *flexible* characterises the production technology. The distinction between *static* and *dynamic* describes the costs, and thus the frequency, at which the input can be adjusted. *Flexibility*, on the other hand, is the concept of divisibility, and denotes the technical possibility of adjusting the input in proportion to changes in output.

abstraction, treatment, storage, distribution through pipelines, is identical, local environmental conditions affect each firm's input usage. For example, the operation of water networks in mountainous regions requires more pumping facilities and energy input to confront shifts in altitude, and regions with intensive farming or mining require specialised water treatment to eliminate residues such as sulphate and nitrate. Under the assumption of no self-selection into locations[4], production conditions are exogenous to the firms. They are usually unknown to the researcher, but ignoring them leads to biased productivity scores, where managerial productivity ω_{it} is confused with differences in exogenous production and market characteristics. We use a set of observable characteristics to proxy for the individual production environment, controlling for raw water composition, river basin location, topography and altitude. They are summarised in the vector $\boldsymbol{X_{it}}$.

Most water utilities are vertically integrated and serve all steps of the supply chain from water extraction to distribution to end-consumers. However, some firms purchase water from third parties and sell bulk water to neighbouring utilities.[5] The degree of vertical integration and own bulk water supply activities affect the choice of inputs, particularly capital. External procurement requires less extraction and treatment facilities, whereas bulk water supply is more capital-intensive. Therefore, we add two measures for the importance of water extraction in the firm's production portfolio, controlling for the share of external procurement and the production of bulk water in total supply. For notational simplicity, we also include them in the vector $\boldsymbol{X_{it}}$.

5.3.2 Demographics and heterogeneous demand

A utility's water demand depends on the local demographics. Public water companies usually operate in the area of the municipality which owns them. Given the local monopoly, the firm's customers are identical to the local population, who each consume some amount of water. Therefore, demand is partially determined by demographic factors such as population density, settlement structure, and household composition, which affect the dimension of the pipeline networks and the quantities supplied, i.e., networks in urban areas tend to connect more people living closer together and thus provide economies of density to the urban firms. We model het-

[4] We focus on municipally-owned firms, which usually operate in the area of the owning municipality.

[5] There exist also bulk-water-only supply companies, which usually operate at the regional level and provide treated water to several utilities. Examples include *Bodenseewasserversorgung* in the state Baden-Württemberg, *Landestalsperrenverwaltung* in Saxony, *Hessenwasser* in Hesse, and *Thüringer Fernwasserversorgung* in Thuringia. Due to different scale and focus, pure bulk-water supply firms, which do not distribute water to end-consumers, are not considered in this study.

erogeneous demand patterns as an exogenous composite shock D_{it} to the current output level

$$Q_{it} = \tilde{Q}_{it} exp(\boldsymbol{\eta D_{it}}), \tag{5.2}$$

where $\tilde{Q}_{it}$ is the equilibrium output if all firms operated under the same demand conditions and Q_{it} is the output realised under individual demand conditions. The term $\boldsymbol{\eta D_{it}} = \eta_1 log(D^p_{it}) + \eta_2 D^{18}_{it} + \eta_3 D^{60}_{it} + \eta_4 D^h_i$ controls for population density D^p_{it}, the share of inhabitants below age 18 D^{18}_{it}, the share of inhabitants above age 60 D^{60}_{it}, and the share of households in supply to end-consumers D^h_i as opposed to business and manufacturing consumers.

5.3.3 Marginal costs

We model the marginal costs of production following De Loecker (2011b) and De Loecker and Warzynski (2012).[6] Let all firms determine their levels of intermediate inputs in a short-run cost minimisation problem, taking input prices and output at time t as given, and consider the Lagrangian function

$$\mathcal{L}(K_{it}, L_{it}, M_{it}, S_{it}, \lambda_{it}) = w^k_{it} K_{it} + w^l_{it} L_{it} + w^m_{it} M_{it} + w^s_{it} S_{it} + \lambda_{it}(Q_{it} - Q_{it}(\cdot)), \tag{5.3}$$

where w^X_{it} are the input prices. If $Q_{it}(\cdot)$ is continuous and twice differentiable, then the first order condition with respect to the intermediate input M_{it} is given by

$$\frac{\delta \mathcal{L}_{it}}{\delta M_{it}} = w^m_{it} - \lambda_{it} \frac{\delta Q_{it}(\cdot)}{\delta M_{it}} = 0, \tag{5.4}$$

where $mc_{it} \equiv \lambda_{it}$ is the marginal cost of production at a given level of output. Define the output elasticity for the intermediate input as

$$\theta^m_{it} \equiv \frac{\delta Q_{it}(.)}{\delta M_{it}} \frac{M_{it}}{Q_{it}}. \tag{5.5}$$

Multiplying equation (5.4) by (M_{it}/Q_{it}), we use the definition in (5.5) to obtain the following expression for marginal costs

[6] The approach has the advantage of not imposing any assumptions on the specific demand system or on the long-term production technology. Dynamic decisions related to the production technology (capital) or staff composition and wages (labour) can deviate from cost minimisation, as firms may want to implement a specific public agenda (see Pescatrice and Trapani, 1980 for the assumption on cost minimisation in public utilities).

$$mc_{it} = \frac{1}{\theta^m_{it}} \frac{w^m_{it} M_{it}}{Q_{it}}. \tag{5.6}$$

Since observed output in the data differs from true output by measurement error ϵ_{it}, we adjust equation (5.6) to obtain an estimate for firm-level marginal costs as

$$\hat{mc}_{it} = \frac{1}{\hat{\theta}^m_{it}} \frac{w^m_{it} M_{it}}{Q_{it}/e^{\widehat{\epsilon_{it}}}}. \tag{5.7}$$

In summary, marginal costs depend on the expenditure for intermediate goods divided by firm output and the corresponding output elasticity of intermediates.

5.4 Estimation strategy

5.4.1 Productivity and demographic changes

We estimate the production model in (5.1) and (5.2) following the control function approach of Ackerberg et al. (2015), which was initially proposed by Olley and Pakes (1996). The identification strategy exploits the fact that current shocks to productivity immediately affect firms' demand of a fully flexible, static input but not those of dynamic inputs, which react more slowly to productivity shocks given the adjustment costs. The inverted input demand function of a flexible, static input can then be used to express productivity in terms of observables. Thus, we take into account that firm-level productivity may correlate with input choice, a well-known simultaneity problem which otherwise leads to biased estimates of the output elasticities (Mundlak and Hoch, 1965; Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Wooldridge, 2009).

We allow for a log additive measurement error and unanticipated shocks to output ϵ_{it}, and take the logs of equation (5.1). Combining (5.1) with equation (5.2) then obtains

$$q_{it} = f(k_{it}, l_{it}, m_{it}, s_{it}; \boldsymbol{\beta}) + \omega_{it} + \boldsymbol{\gamma X_{it}} + \boldsymbol{\eta D_{it}} + \epsilon_{it}, \tag{5.8}$$

where the lower case letters denote logs and q_{it} is the log output with $q_{it} = ln(Q_{it}exp(\epsilon_{it}))$. We assume a translog production function for $f(\cdot)$ with median-corrected inputs for (5.1), which is a second-order Taylor series approximation to the true production function with the median as the focal point. The translog function has the advantage of not imposing any restrictions on the elasticities of substitution between input factors and allows output elasticities to vary between firms. As a result, q_{it} is given by

$$\begin{aligned} q_{it} =& c + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_s s_{it} \\ &+ 0.5\beta_{kk} k_{it}^2 + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{mm} m_{it}^2 + 0.5\beta_{ss} s_{it}^2 \\ &+ \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} + \beta_{ks} k_{it} s_{it} + \beta_{ls} l_{it} s_{it} + \beta_{ms} m_{it} s_{it} \\ &+ \omega_{it} + \boldsymbol{\gamma} \boldsymbol{X_{it}} + \boldsymbol{\eta} \boldsymbol{D_{it}} + \epsilon_{it}. \end{aligned} \tag{5.9}$$

Now we use the assumption that intermediate goods are a static, flexible input whose level can be adjusted at least once a year without adjustment costs in proportion to changes in output (section 5.3.1). The demand for intermediate goods $m_t(\cdot)$ then depends on the current level of the pre-determined and inflexible inputs $\{k_{it}, l_{it}, s_{it}\}$, on unobserved productivity ω_{it}, individual input prices w_{it}^L, demand patterns $\boldsymbol{D_{it}}$, and further individual production conditions $\boldsymbol{X_{it}}$. Subscript t implies that demand can depend on additional input costs, e.g., capital costs, or costs for external services, which are assumed to be uniform across firms.

$$m_{it} = m_t(k_{it}, l_{it}, s_{it}, \omega_{it}, w_{it}^L, \boldsymbol{X_{it}}, \boldsymbol{D_{it}}) \tag{5.10}$$

If m_t is strictly monotone in ω_{it}, the function can be inverted to obtain an expression for productivity

$$\omega_{it} = h_t(k_{it}, l_{it}, m_{it}, s_{it}, w_{it}^L, \boldsymbol{X_{it}}, \boldsymbol{D_{it}}). \tag{5.11}$$

Inserting (5.11) into (5.9) yields an estimation equation for the production function which only depends on observables and the error term ϵ_{it}.

$$\begin{aligned} q_{it} =& c + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_s s_{it} \\ &+ 0.5\beta_{kk} k_{it}^2 + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{mm} m_{it}^2 + 0.5\beta_{ss} s_{it}^2 \\ &+ \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} + \beta_{ks} k_{it} s_{it} + \beta_{ls} l_{it} s_{it} + \beta_{ms} m_{it} s_{it} \\ &+ h_t(k_{it}, l_{it}, m_{it}, s_{it}, w_{it}^L, \boldsymbol{X_{it}}, \boldsymbol{D_{it}}) + \boldsymbol{\gamma} \boldsymbol{X_{it}} + \boldsymbol{\eta} \boldsymbol{D_{it}} + \epsilon_{it}. \end{aligned} \tag{5.12}$$

We approximate the nonparametric function $h_t(\cdot)$ through a second-order polynomial and estimate equation (5.12) by OLS. The (unbiased) prediction Φ_{it} can be used to express productivity in terms of observables

$$\begin{aligned}\omega_{it}(\boldsymbol{\beta}) = \Phi_{it} - c - \beta_k k_{it} - \beta_l l_{it} - \beta_m m_{it} - \beta_s s_{it}\\ - 0.5\beta_{kk} k_{it}^2 - 0.5\beta_{ll} l_{it}^2 - 0.5\beta_{mm} m_{it}^2 - 0.5\beta_{ss} s_{it}^2\\ - \beta_{kl} k_{it} l_{it} - \beta_{km} k_{it} m_{it} - \beta_{lm} l_{it} m_{it} - \beta_{ks} k_{it} s_{it} - \beta_{ls} l_{it} s_{it} - \beta_{ms} m_{it} s_{it}\\ - \boldsymbol{\gamma X_{it}} - \boldsymbol{\eta D_{it}}.\end{aligned} \tag{5.13}$$

We address the fact that coefficients $(\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\eta})$ are biased because they cannot be uniquely identified from (5.12) in the second step of estimation.[7] For this, we assume that productivity follows a first-order Markov process where current productivity depends on past year productivity, a random iid shock v_{it}, and is potentially affected by demographic changes $\boldsymbol{\Delta_{Dit}}$. Here, the intuition is that water firms cannot immediately adapt dynamic input usage to changes in demand, given the long service life of their network infrastructures and treatment facilities. Moreover, universal service obligations force them to maintain pipelines and connection points even if the number of customers and therefore the amount of water consumption decreases. In a short-term view, total factor productivity as a measure of output (water) delivered in relation to input usage decreases. We test two aspects of demographic change: recent changes in population density Δ_{Dit}^p, and changes in the age composition of the local population $\Delta_{Dit}^{18}, \Delta_{Dit}^{60}$. This gives

$$\omega_{it} = g(\omega_{it-1}, \Delta_{Dit}^p, \Delta_{Dit}^{18}, \Delta_{Dit}^{60}) + v_{it}. \tag{5.14}$$

Exploiting the fact that any current iid shock v_{it} to productivity is uncorrelated with past and pre-determined input values and observable production conditions, allows us to identify the vector $(\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\eta})$ from the moment conditions $\mathbb{E}[v_{it}|I_{it-1}] = 0$ where $I_{it-1} = \{k_{it}, l_{it}, m_{it-1}, s_{it-1}, k_{it}^2, l_{it}^2, m_{it-1}^2, s_{it-1}^2, \boldsymbol{X_{it}}, \boldsymbol{D_{it}}\}$. We then calculate the output elasticity of intermediate goods, which is required for the calculation of marginal costs, from

$$\theta_{it}^m = \beta_m + \beta_{mm} m_{it} + \beta_{km} k_{it} + \beta_{lm} l_{it} \tag{5.15}$$

and recover productivity through (5.13).

[7] Note that the input vector $(k_{it}, l_{it}, m_{it}, s_{it})$ shows up both in the original translog production function and in the productivity control function $h_t(\cdot)$.

5.4.2 Costs structure and demographic changes

We assess the influence of demographic changes on marginal costs in a dynamic panel model by regressing the estimate for marginal costs $\hat{mc}_{it}$, computed according to equation (5.7), on past year marginal costs $\hat{mc}_{it-1}$, the changes in demographic variables which took place in between Δ_{Dit}, and an error term u_{it}

$$\ln \hat{mc}_{it} = \alpha_1 ln\hat{mc}_{it-1} + \alpha_2 \Delta^{p}_{Dit} + \alpha_3 \Delta^{18}_{Dit} + \alpha_4 \Delta^{60}_{Dit} + u_{it}. \qquad (5.16)$$

The OLS estimation will be biased since unobserved individual effects most likely influence the firm's marginal cost level. The within transformation of the static fixed effect estimator does not resolve the problem, since the group mean $\bar{u}_{i.}$ correlates with the explanatory variable $\hat{mc}_{it-1}$. To address this issue, we follow Arellano and Bond (1991) and Blundell and Bond (1998) to apply first differences and use the full set of instruments $(\hat{mc}_{i0}, ..., \hat{mc}_{it-2})$ for each period, augmented by the first difference in instruments (system GMM). For the remaining variables, assume $\mathbb{E}[u_{it}\Delta_{Dis}] = 0$ for $s < t$, which allows using $(\Delta_{Di0}, ...\Delta_{Dit-1})$ as additional instruments.[8]

For comparison, we also estimate the evolution of average fixed costs per m3 sold. We compute average fixed costs per m3 and not per capita since we only observe the number of customers in a three-year interval. Fixed costs of each firm are given in the data. We construct the process in analogy to equation (5.16) to obtain

$$\ln fc_{it} = \alpha_5 lnfc_{it-1} + \alpha_6 \Delta^{p}_{Dit} + \alpha_7 \Delta^{18}_{Dit} + \alpha_8 \Delta^{60}_{Dit} + u_{it}. \qquad (5.17)$$

The same estimation procedure applies.

5.5 Data

We consider a sample of 751 German municipally-owned water utilities, which operating between 2003 and 2014 (N=5,770).[9] Ensuring the comparability of the water utilities in the sample, we restrict our sample to single product firms that deliver water and have no other activities such as energy provision or sewerage. We neglect bulk water supply firms without deliveries to end-consumers.

[8] *A priori*, it is reasonable to assume strict exogeneity, which implies $\mathbb{E}[u_{it}\Delta_{Dis}] = 0$ for $(s, t = 0, 1, ...T)$. However, large sets of instruments are often difficult to manage in empirical estimations, which is why we restrict ourselves to a reduced set of past lags (see section 5.6.2).

[9] The lack of adequate data source precludes us from considering water firms that are majority-owned by the private sector. However, we do include firms in mixed ownership with private minority shares, which comprise about 5 per cent of the firms in the German water sector (Stiel, 2017). Since more than 80 per cent of the water delivered in Germany is supplied by municipally-owned firms, it should not constitute a major restriction.

We obtain firm-level data on input usage, output supplied, and costs from two official datasets collected by the German Federal Statistical Office: the newly available dataset *Energiestatistiken* on energy and water firms, and the financial statements of public firms *Jahresabschlüsse öffentlicher Fonds, Einrichtungen, und Unternehmen.* We merge them with physical data on raw water usage, river basin location, and customer structure obtained from the *Statistik über die öffentliche Wasserversorgung.* Since the latter survey is only conducted on a three-year-interval (2004, 2007, 2010, 2013), we compute the mean values for water sources, river basin location, and customer structure over the whole observation period 2003 to 2014. We obtain data on the service areas, including land use and demographics, for each year from official regional data at the municipal level in the database *Regionaldatenbank Deutschland* and *Statistik Lokal.* Further information on the different datasets is given in the section Data appendix 5.10.

5.5.1 Inputs and output

The firms use four inputs to produce water Q_{it}, measured in cubic metres. Labour L_{it} is measured by the wage bill, which is deflated by the German index of labour costs in the water and sewerage industry (NACE category E). External services S_{it} are measured by expenditure and deflated by the German PPI for technical services (NACE category M). Intermediate goods M_{it} are composed of material expenditure and bulk water purchases and deflated by the German PPI of intermediate goods. We construct a measure for capital K_{it} from information on investments and the capital stock using the perpetual inventory method with $K_{it} = (1 - \delta_i)K_{it-1} + I_{it}$. We compute the depreciation rate δ_i as the consumption of fixed capital over fixed gross capital and averaged across all years for each firm i. Yearly investments and the capital stock are deflated with the German PPI for investment goods. Table 5.1 lists the summary statistics.

Table 5.1: Summary statistics: inputs and output

	q1	med	mean	q99	sd
L [mio €]	0.00	0.21	0.63	6.74	1.43
S [mio €]	0.00	0.16	0.43	5.82	1.12
M [mio €]	0.02	0.24	0.55	6.50	1.22
K [mio €]	0.98	6.66	14.16	148.84	27.02
Y [mio m3]	0.21	0.66	1.61	16.00	4.28
N			5,770		

5.5.2 Firms' structure and production environment

Tables 5.2 and 5.3 summarise firms' vertical structure. 73 per cent source water externally, of which 30 per cent completely rely on external sources and 43 per cent complement internal water abstraction with external sources. Half of the water supplied on average comes from external sources. Considering firms which own water abstraction facilities, Table 5.2 shows that 41 per cent produce more water than they need and sell the excess to other utilities. Among them, the share of wholesale supply in total supply accounts for 24 per cent on average, but the median value is only 9 per cent, i.e., wholesale activities are negligible for the majority of these firms.[10]

Table 5.2: Summary statistics: firms' vertical structure

	med	mean	sd	N[>0]	N
firms using external water sources				4,217	5,770
share water from external sources	0.53	0.52	0.40		
firms with wholesale activities				1,915	5,770
share wholesale in total output	0.09	0.24	0.32		

Notes: Summary statistics for the subset of firms with positive shares, N[>0] is the number of firms with positive shares. 1,553 firms do not source water externally and 3,855 firms do not pursue wholesale activities. The share of water from external sources is defined as water from external sources [m3] over total water input [m3]. The share of wholesale in total output is computed from water supply to other water utilities [m3] over total water supply [m3].

The European Union's water framework directive 2000/60/EC defines the *river basin districts* that correspond to the drainage basins of the main European rivers and coastal areas. The river basin districts differ in their hydrological conditions, which determine the availability of raw water sources for the water utilities. Table 5.3 reports that 67 per cent of the water firms in our sample are in the Rhine river basin and 16 per cent are in the Danube river basin. We group the smaller number of firms in the Oder basin and at the coast with those in the adjacent Elbe basin.

The source of raw water determines the technology required for abstraction, transportation, and treatment. Data on the composition of raw water sources for own water abstraction are available, but not for external sourcing. Groundwater is the most important raw water source for own abstraction with an average share of 81 per cent in total abstraction (Table 5.3). More than 50 per cent of the firms completely rely on groundwater sources. Although spring water collection accounts for 9 per cent of raw water abstraction in Germany (Destatis, 2015b), 36 per cent of the firms collect it.

[10] While 73 per cent of the firms purchase bulk water from external sources, most of the local utilities are served by large regional bulk-water-only suppliers (see section 5.3.1). Since this chapter's focus is on the impact of local demographic factors, pure bulk-water suppliers are not part of the sample.

Table 5.3: Summary statistics: firms' water supply sources

	med	mean	sd	N[>0]	N
raw water composition					
share groundwater	1.00	0.81	0.28	3,548	5,770
share spring water	0.51	0.53	0.36	2,054	5,770
no internal sources					1,661
river basin location					share
Danube					0.16
Rhine					0.67
Ems					0.02
Weser					0.06
Elbe, Oder, coast					0.09

Notes: Summary statistics for the subset of firms with positive shares, N[>0] is the number of firms with positive shares. Raw water composition only available for firms with own pumping activities (internal sources).

Table 5.4 lists the topographic characteristics in the municipalities where the firms are located. On average, 41 per cent of the areas are farmland, which potentially influences the quality of groundwater sources, about 2 per cent are covered with surface water. The mean altitude is 284 m above sea level, ranging from below 7m to above 809m (not listed).

Table 5.4: Summary statistics: topography in supply areas

	med	mean	sd
share residential and infrastructure area	0.17	0.19	0.10
share forest	0.29	0.31	0.18
share water	0.01	0.02	0.03
share agriculture	0.41	0.41	0.20
altitude [m]	249	284	181
N		5,770	

5.5.3 Demographics

We approximate the population density D^p_{it} in the water supply area by using the population density of the municipality where the water utility is located. The water supply areas in our sample have a population density of 393 inhabitants per km2 on average, which corresponds to *suburban regions* in the classification of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (Milbert and Krischausky, 2012). The sample also includes sparsely populated rural areas with less than 43 inh./km2 and cities with more than 2,032 inh./km2. Table 5.5 lists the summary statistics.

We calculate the annual growth rate of population density Δ^p_{Dit} from

$$\Delta^p_{Dit} = \frac{D^p_{it} - D^p_{it-1}}{D^p_{it-1}}. \tag{5.18}$$

It is negative with -0.3 per cent on average. In other words, the majority of water supply areas face declining population rates and its water mains are potentially affected by underutilisation. The tails of the distribution include fast-growing and fast-shrinking municipalities with an annual rate of +/- 2.5 per cent (Table 5.5, second row). While 2.5 per cent appears to be small for a single year, these amounts lead to cumulative rates of +28/-22 per cent within ten years. This can have strong effects on the settlement structure, in particular for shrinking regions, as illustrated by the spatial development in the former districts of the GDR (Hannemann, 2003).[11]

Regarding age composition, we find that 26 per cent on average of the inhabitants in the water supply areas are more than 60 years old and 18 per cent are below the age of 18. We compute the age growth rates by substracting past year shares D^{18}_{it-1} from the current share D^{18}_{it} to obtain

$$\Delta^{18}_{Dit} = D^{18}_{it} - D^{18}_{it-1} \tag{5.19}$$

$$\Delta^{60}_{Dit} = D^{60}_{it} - D^{60}_{it-1}. \tag{5.20}$$

In line with the general trend of population ageing in Germany, the share of younger inhabitants is decreasing in the majority of the water supply areas, whereas the share of older inhabitants is increasing (Table 5.5, rows 4 and 6).

[11] However, positive large growth rates can also create substantial challenges for the respective regions. For instance, the city of Berlin, which has been growing at an annual rate of 1.3 per cent between 2010 and 2017, is struggling to accommodate a yearly surplus of 40,000 inhabitants.

Table 5.5: Summary statistics: demographics

	q1	med	mean	q99	sd	$N[\neq 0]$	N
population density							
levels [inh./km2]	43	283	393	$2,032$	388	$5,770$	$5,770$
growth [%]	-2.87	-0.06	-0.29	2.43	4.58	$5,733$	$5,770$
share under 18 years							
levels [%]	12	18	18	24	2	$5,770$	$5,770$
growth [%]	-1.12	-0.29	-0.28	0.70	0.37	$5,770$	$5,770$
share above 60 years							
levels[%]	18	25	26	36	4	$5,770$	$5,770$
growth [%]	-0.70	0.32	0.32	1.35	0.49	$5,769$	$5,770$
firms supplying private households							
share in total end-consumer supply	0.20	0.86	0.83	1.00	0.14	$5,099$	$5,770$

Pearson's r between levels and growth	$cor(D^p_{it}, \Delta^p_{Dit})$	$cor(D^{18}_{it}, \Delta^{18}_{Dit})$	$cor(D^{60}_{it}, \Delta^{60}_{Dit})$
	0.06	-0.13	0.14

Notes: Summary statistics for "share in total end-consumer supply" for the subset of firms with positive shares, $N[\neq 0]$ is the number of firms with positive shares and non-zero growth rates. 671 firms do not supply households. "Share in total end-consumer supply" is defined as supply to households [m3] in total end-consumer supply [m3].

Table 5.5 also shows that for half of the firms, households account for more than 86 per cent of the supply to end-consumers, thus highlighting the importance of household deliveries in end-consumer supply and the vulnerability of local water utilities to demographic changes. Households constitute the most important customer group for 95 percent of the firms; three out of four firms sell more than 77 per cent of their end-consumer supply to households.[12] Their other end-consumers are businesses and industry (manufacturing, energy supply). However, industry customers play a negligible role since they meet 92 per cent of their water demand through own production (Destatis, 2016).

The last row in Table 5.5 lists the correlation rates between levels $\boldsymbol{D_{it}}$ and growth rates $\boldsymbol{\Delta_{Dit}}$, showing that demographic changes are unrelated to the initial situation, i.e., towns can shrink and rural municipalities can grow, or *vice versa*. During the suburbanisation trend in the second half of the 20th century, for instance, sparsely populated areas surrounding larger cities began to grow, while densely populated cities lost inhabitants (Adam, 2002). Likewise, two equally populated districts close to each other can start to diverge following changes in local employment opportunities. Local disparities are one of the key characteristics of German intra-country migration movements, and it is common to find growing regions coexisting next to shrinking regions (BBR, 2017).

[12]Table 5.5 does not show the results for the q5 and q25-quantile.

5.6 Empirical results

5.6.1 Productivity growth under demographic changes

We start by focusing on the evolution of firms' productivity under demographic changes. Table 5.6 summarises the results for the variables of interest (see Table 5.9, column 2, in the section Appendix 5.9 for the full estimation output).

The results indicate that economies of density exist in water supply, although the coefficient for $log(D_{it}^{p})$ is only weakly significant at the 0.07 p-level.[13] Furthermore, we find that in regions with a 1 percentage point higher share of children under 18, total water supply is, *ceteris paribus*, 3 percentage points higher. A possible reason could be that households with children use more water for washing machines, cleaning etc., which is in line with the findings in Lyman (1992). We observe the negative relationship between elderly persons and water consumption suggested in Nauges and Thomas (2000) and Martinez-Espiñeira (2002); however, the coefficients are not significant.

The parameters above measure the effect of the status quo, and explain differences in output levels according to the demographic characteristics in the water supply areas. Provided the demographic conditions do not change, firms can adapt to the demand structure in the long run and use their inputs as efficiently as possible *under the given demographic situation.* Problems arise when the demand structure changes as a consequence of demographic changes. These changes can affect both urban and rural regions, and are *a priori* unrelated to the existing demographic pattern (see Section 5.5.3). Water utilities often have difficulties adapting to demographic changes within short time frames because of the long service life of their infrastructure equipment. As a result, two firms operating under the same demographic conditions can have different productivity levels because one of the firms experienced a recent demographic shock and struggles to adapt input usage to reduced output (demand), whereas the other, which has been living with that same level of population density for a long time, has adjusted its water network accordingly. The last four rows in Table 5.6 provide estimates for the impact of demographic changes on water utilities' total factor productivity. A 1 percentage point increase in population density shifts productivity by 7 per cent. Given that the average growth rate in population density is -0.3 per cent (see section 5.5.3), firms experienced an annual

[13] A limitation of the ACF algorithm is the low efficiency of the block-bootstrapping of the standard errors. For comparison, the first column in Table 5.9 estimates equation (5.9) by OLS. The point estimates of the coefficients are biased, but further support the general hypothesis that population density matters, i.e., that water suppliers located in regions with higher population density sell more water than firms located in sparsely populated regions, all other things being equal.

decrease of 2 per cent on average in total factor productivity resulting from changes in population density. The effect is more pronounced for firms in fast growing or shrinking regions at the tail of the distribution. With an absolute growth rate of 2.5 per cent in population density, they experience hypothetical productivity shifts of more than 17 per cent within one year.

Table 5.6: Productivity and demographic changes

		full sample (1)		growing regions (2)		shrinking regions (3)	
production		$\ln q_{it}$					
$log(D^p_{it})$	*population density*	0.054	(0.029)				
D^{18}_{it}	*share young*	0.029**	(0.009)				
D^{60}_{it}	*share old*	−0.003	(0.006)				
	N	5,770					
productivity		$\ln \omega_{it}$					
Δ^p_{Dit}	*growth pop. dens.*	0.069***	(0.013)	0.089***	(0.024)	0.063***	(0.013)
Δ^{18}_{Dit}	*growth share young*	0.003	(0.003)	0.000	(0.005)	0.005	(0.003)
Δ^{60}_{Dit}	*growth share old*	−0.004**	(0.002)	−0.006*	(0.003)	−0.003	(0.002)
	R^2	0.83		0.81		0.86	
	N	4,665		2,194		2,457	

Notes: The coefficients for production are derived from estimating the specification given in (5.12), with block-bootstrapped standard errors given in parentheses. The coefficients for productivity are estimated according to equation (5.14), with WHITE standard errors given in parentheses. p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05.

To explore whether dynamics differ between growing and shrinking regions, we sort the firms ex-post into two groups, based on the overall change in population density in their water supply area between 2003 and 2014, and estimate equation (5.14) again separately for each group (see column (2) and (3) in Table 5.6). The findings are robust across region type.

Regarding age composition, Table 5.6 shows that population ageing negatively impacts productivity, i.e., a 1 percentage point increase in the share of people above 60 reduces total factor productivity by 0.4 per cent. However, since the share of older people only grows at 0.3 percentage points on average, the effect on total factor productivity is small. For firms at the tail of the distribution, the annual productivity shift ranges from -0.3 per cent to 0.5 per cent.

5.6.2 Evolution of costs under demographic changes

Tables 5.7 and 5.8 list the estimated evolution of marginal costs and average fixed costs per m3 under demographic changes. While we find no evidence that short-term changes in population density affect marginal costs, a change in the age composition of the local population does seem to affect them. An increase in the share of children under 18 by 1 percentage point entails a decrease in marginal costs by 7 percent (see Table 5.7). This effect, which is particularly pronounced in shrinking regions, suggests an opposite interpretation. Hypothesising that young people in particular move away from shrinking regions, a decrease in the share of children causes marginal costs to rise, possibly because of underlying changes in the consumption patterns of households. Section 5.6.1 showed that water supply positively correlates with the share of children under 18. Therefore, less water demand in oversized networks may effectively imply higher marginal costs resulting from the firms' efforts to avoid nucleation.

Table 5.7: Marginal costs and demographic changes

	full sample (1) $\ln mc_t$		growing regions (2) $\ln mc_t$		shrinking regions (3) $\ln mc_t$	
$\ln mc_{t-1}$	0.363***	(0.100)	0.407***	(0.106)	0.543***	(0.141)
pop.dens. growth	0.076	(0.122)	0.003	(0.176)	−0.083	(0.144)
growth share young	−0.068**	(0.026)	−0.037	(0.033)	−0.079**	(0.027)
growth share old	0.003	(0.019)	−0.011	(0.019)	0.017	(0.025)
add. instruments: lags(Δ_D)	0...t-1		t-2, t-1		0...t-1	
Sargan test (p-value)	0.00		0.19		0.27	
Wald test (p-value)	0.00		0.00		0.00	
AR(1) (p-value)	0.01		0.00		0.12	
AR(2) (p-value)	0.10		0.16		0.23	
N	5,770		2,748		3,004	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05.

Regarding fixed costs, we find a direct link between population density growth and average fixed costs growth. This may be less surprising in shrinking regions given the construction of the dependent variable: Fewer inhabitants imply less consumption, and therefore, the average fixed costs per m3 sold increase. Thus, the negative coefficient for Δ^p_{Dit} confirms the hypothesis that water utilities have difficulties in reducing fixed costs proportionally to population decline, since pipe networks cannot be easily dismantled, given universal service obligations and the long service life of their infrastructure. In shrinking regions, average fixed costs are estimated to grow by 14 per cent if population density decreases by 1 percentage point (see Table 5.8, column (3)). Considering the average annual growth rate in population density in German water supply areas with -0.3 per cent (see section 5.5.3), this means that average fixed costs increase by 3 per cent annually.

The relationship is not significant for growing regions, which suggests that short-term adjustments to satisfy growing demand, e.g., in the form of additional mains and labour, raise fixed costs proportionally to population growth, at least in the short-term. Population age does not play a role in the evolution of fixed costs.

Table 5.8: Average fixed costs per m3 and demographic changes

	full sample		growing regions		shrinking regions	
	(1)		(2)		(3)	
	$\ln fc_t$		$\ln fc_t$		$\ln fc_t$	
$\ln fc_{t-1}$	0.631***	(0.075)	0.583***	(0.109)	0.771***	(0.046)
pop.dens. growth	−0.167*	(0.067)	−0.083	(0.088)	−0.136*	(0.065)
growth share young	0.023	(0.015)	0.033	(0.025)	0.002	(0.014)
growth share old	0.003	(0.008)	−0.014	(0.016)	0.005	(0.007)
add. instruments: lags(ΔD)	0...t-1		t-3...t-1		0...t-1	
Sargan test (p-value)	0.07		0.12		0.32	
Wald test (p-value)	0.00		0.00		0.00	
AR(1) (p-value)	0.00		0.00		0.00	
AR(2) (p-value)	0.52		0.97		0.04	
N	5,770		2,748		3,004	

Notes: p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05.

5.7 Discussion

Another aspect of demographic changes is the decreasing trend in household size, which is observed for nearly all advanced economies (OECD, 2011). Arbués et al. (2004, 2010) and Domene and Saurí (2006) argue that each household has a minimum demand for water (e.g., for domestic cleaning), such that the number of households influences water demand independently of the number of people living in them. Consequently, water demand might change following changes in the number of households even if the population numbers stay constant. The link between household size and population ageing is *a priori* unclear. Engstler and Menning (2004) highlight that decreasing household size is not a phenomenon exclusive to the elderly but that it is found also in the younger generation.

While the study of household size is beyond the scope of this chapter for lack of adequate data sources, our results indicate that the link between household size and water consumption is not straightforward. Assuming that regions with a higher share of children under 18 years on average have larger households, we do not find that larger households consume less water than smaller households. Rather, water supply in family regions is higher, all other things being equal. The impacts of demographic changes on water demand caused by changes in household size is unclear and merits future research.

5.8 Conclusion

This chapter analysed the provision of local public services under demographic changes and highlighted diverging trends between central and peripheral regions. We considered the example of municipal drinking water supply, where the lengthy life-cycle of technical infrastructure and universal service obligations preclude immediate adjustment to changing demand patterns. Rather, oversized pipe networks require additional flushing of the mains to avoid nucleation, thereby further rising operations costs. Analysing a panel of 751 German municipally-owned water utilities between 2003 and 2014, we examined the short-term productivity effect and the cost implications from changes in population density and changes in the age structure of the local population. Total factor productivity and firm-level marginal costs were estimated in a structural production framework, while controlling for a large set of individual production characteristics and taking into account the demographic situation in the water supply areas. We found that population decline induced significant short-term productivity losses in fast-shrinking regions, and caused average fixed costs to rise. Results are reversed in growing regions, except that fixed costs increase in the same rhythm with population growth. Regarding the age composition, the results show that population ageing negatively impacts productivity, yet to a smaller extent than changes in population density. Furthermore, the age composition within private households matters for marginal costs, as a decreasing share of children under 18 among the local population causes these costs to rise. To the best of our knowledge, this work is one of the first to quantify the impact of demographic changes on local infrastructure services.

5.9 Appendix

Table 5.9: Production function estimates

	OLS (1)		ACF (2)	
l	0.244***	(0.008)	0.149***	(0.040)
k	0.194***	(0.009)	0.162***	(0.048)
m	0.203***	(0.007)	0.248***	(0.053)
l^2	0.082***	(0.004)	0.101***	(0.018)
s^2	0.062***	(0.004)	0.046*	(0.020)
k^2	0.053***	(0.009)	0.053	(0.062)
m^2	0.106***	(0.006)	0.164***	(0.041)
kl	−0.008	(0.006)	−0.053*	(0.025)
km	−0.031***	(0.006)	−0.054	(0.041)
ks	0.017**	(0.006)	0.058	(0.039)
lm	−0.036***	(0.004)	−0.028	(0.030)
ls	−0.034***	(0.004)	−0.044	(0.026)
ms	−0.020***	(0.004)	−0.002	(0.031)
log(population density)	0.089***	(0.007)	0.054	(0.029)
share young	0.029***	(0.003)	0.029**	(0.009)
share old	−0.003	(0.002)	−0.003	(0.006)
share households	−0.053**	(0.018)	0.006	(0.105)
share spring water	−0.020	(0.015)	−0.126	(0.070)
share external sources	−0.180***	(0.016)	−0.157	(0.101)
share bulk water supply	0.842***	(0.023)	0.774***	(0.086)
share forest	−0.357***	(0.042)	−0.343**	(0.132)
share water surface	−0.153	(0.190)	−0.155	(0.425)
share farmland	−0.095**	(0.035)	−0.139	(0.117)
log(altitude)	−0.105***	(0.008)	−0.083*	(0.034)
river basin Elbe/Oder/coast	−0.214***	(0.023)	−0.250*	(0.107)
river basin Ems	0.002	(0.037)	−0.003	(0.155)
river basin Weser	−0.049	(0.026)	−0.014	(0.109)
river basin Rhine	−0.203***	(0.015)	−0.170*	(0.076)
log(wage)	0.008	(0.017)	−0.021	(0.036)
(Intercept)	−0.018	(0.132)	−0.018	(0.362)
R^2	0.87			
N	5.770		5,770	

Notes: The coefficients in column (1) are derived from estimating the specification given in (5.9) with OLS, subsuming ω_{it} with the error term ϵ_{it}. The coefficients in column (2) are derived from estimating the specification given in (5.12) within the ACF framework, with block-bootstrapped standard errors given in parentheses. p-values: 0 '***' 0.001 '**' 0.01 '*' 0.05.

5.10 Data appendix

5.10.1 Energiestatistiken

Energiestatistiken is a bundle of 9 firm-level surveys conducted annually by the German Federal and regional Statistical Offices among all firms in Germany with

NACE ID 35 and 36 above a certain threshold (more than 10 employees/1MW installed capacity/200,000m3 water treatment). Firms are legally obligated to respond. The statistical offices use the data to publish aggregate data on German energy and water supply. Anonymised microdata at firm-level are available for the years 2003 to 2014 and can be analysed in remote access at the research data centres of the statistical offices. We use the two main surveys, *Kostenstrukturerhebung* and *Investitionserhebung bei Unternehmen der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen* to obtain information on the water firms' input usage, cost structure, and output delivered. We use the participation in additional sector-specific surveys to separately identify pure water utilities from mixed utilities, which have also other activities such as electricity or gas supply. Chapter 2 provides a full description of the dataset.

5.10.2 Statistik über die öffentliche Wasserversorgung

Statistik über die öffentliche Wasserversorgung maintains physical information (raw water collection, output delivered, customer structure) on German drinking water supply at the firm-level, collected by the regional statistical offices every three years (see Zschille, 2016b, for details). Anonymised microdata are available for the years 2001, 2004, 2007, 2010, 2013, and can be accessed at the research data centres of the regional statistical offices (see `http://www.forschungsdatenzentrum.de/bestand/wasserversorgung/index.asp` (in German only)).

5.10.3 Jahresabschlüsse öffentlicher Fonds, Einrichtungen und Unternehmen

Jahresabschlüsse öffentlicher Fonds, Einrichtungen und Unternehmen collects the financial statements of all German firms where public authorities hold more than 50 per cent of the shares and/or votes (see Wägner, 2017, for details). It covers all sectors of the German economy. Anonymised microdata is available for the years 1998 to 2014 and can be accessed at the research data centres of the regional statistical offices (see `http://www.forschungsdatenzentrum.de/bestand/jahresabschluss/index.asp`. (in German only)).

5.10.4 Unternehmensregister (URS)

The company register *Unternehmensregister (URS)* maintained by the statistical offices allows for deriving unique firm IDs to merge the above datasets (see `http://www.forschungsdatenzentrum.de/bestand/urs/index.asp` (in German only)).

5.10.5 Regional data

Regional data on German municipalities for the years 2008 to 2014 are taken from the official database, *Regionaldatenbank Deutschland*, maintained by the Federal and regional statistical offices. It is freely accessible under `www.regionaldatenbank.de`. Data for the years 2002 to 2007 are taken from *Statistik Lokal*, a DVD-based collection of regional official data published by the same authorities.

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Appendix

The following table lists all variables from the *KOMIED* dataset on German utilities as of October 2015.

Table A.10: Variable list

Variable name	Variable label
General Information	
bnr	Betriebsnummer
unr	Unternehmensnummer
Jahr	Berichtsjahr
Organ	Organschaftsverhältnis
Rechtsform	Rechtsform des Unternehmens
wz_b	Wirtschaftszweig Betrieb
wz_u	Wirtschaftszweig Unternehmen
ags_b	AGS des Betriebes
ags_u	AGS des Unternehmens
art_b	Betriebsart
art_u	Unternehmensart
bl_b	Bundesland des Betriebes
bl_u	Sitz des Unternehmens - Bundesland
energie	Teilnahme Energiestatistik
taet	Tätigkeitsschwerpunkt Betrieb nach WZ
taet_abfall	Abfallbeseitigung lt. Leitdatei Unternehmen
taet_abwasser	Abwasserbeseitigung lt. Leitdatei Unternehmen
taet_gas	Gasversorgung lt. Leitdatei Unternehmen
taet_sonst	sonstige Tätigkeit lt. Leitdatei Unternehmen
taet_strom	Elektrizitätsversorgung lt. Leitdatei Unternehmen
taet_waerme	Wärmeversorgung lt. Leitdatei Unternehmen
taet_wasser	Wasserversorgung lt. Leitdatei Unternehmen
Investitionserhebung bei Unternehmen der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen EVAS No. 43211-077	
TMEVU_u	Teilnahme Investitions- und Kostenstrukturerhebung Unternehmen
UI_Code11_1	Tätigkeit Elektrizitätsversorgung lt. Fragebogen IVE
UI_Code11_2	Tätigkeit Wärmeversorgung lt. Fragebogen IVE

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UI_Code11_3	Tätigkeit Gasversorgung lt. Fragebogen IVE
UI_Code11_4	Tätigkeit Wasserversorgung lt. Fragebogen IVE
UI_Code11_5	Tätigkeit Abwasserbeseitigung lt. Fragebogen IVE
UI_Code11_6	Tätigkeit Abfallbeseitigung lt. Fragebogen IVE
UI_Code11_7	Tätigkeit sonstige lt. Fragebogen IVE
UI_Code1500	Umweltschutzanlagen enthalten?
UI_Code2001	Bruttozugänge - Bestehende. Gebäude und Bauten
UI_Code2101	Bruttozugänge - Errichtung und Umbau von Gebäuden
UI_Code2201	Bruttozugänge - Grundstücke ohne Bauten
UI_Code3001	Bruttozugänge - Anlagen zur Erzeugung und Gewinnung
UI_Code3101	Bruttozugänge - Anlagen zur Speicherung
UI_Code3201	Bruttozugänge - Leitungs- und Rohrnetze
UI_Code3301	Bruttozugänge - Zähler und Messgeräte
UI_Code3401	Bruttozugänge - sonst. Anlagen zur Verteilung und Ãœbertragung
UI_Code3501	Bruttozugänge - andere Anlagen
UI_Code3601	Bruttozugänge - Betriebsaustattung einschl. Werkzeuge, Fahrzeuge usw.
UI_Code4001	Bruttozugänge insgesamt - (Code 20-36)
UI_Code4101	Bruttozugänge insgesamt - darunter selbsterst. Anlagen zu Herstellungskosten
UI_Code4801	Wert neuer Sachanlagen - Grundstücke mit Bauten
UI_Code4901	Wert neuer Sachanlagen - neue Anlagen und Maschinen
UI_Code5001	Wert neuer Sachanlagen - insgesamt (Code 48-49)
UI_Code6001	Wert mit Leasing beschaffter Sachanlagen
UI_Code7001	Verkaufserlöse aus Sachanlagen
UI_Code7101	Verkaufserlöse aus Sachanlagen - darunter Grundstücke ohne Bauten
UI_Code8001	Investitionen in Konzessionen, Patente, Lizenzen, Warenzeichen u.ä.
UI_Code8101	Erworbene Software
Kostenstrukturerhebung bei Unternehmen der Energieversorgung, Wasserversorgung, Abwasser- und Abfallentsorgung, Beseitigung von Umweltverschmutzungen EVAS No. 43411-064	
UK_Code0501	A1 - Tätige (Mit) Inhaber (Anzahl)
UK_Code0601	A2 - Arbeitnehmer (Anzahl)
UK_Code0701	A22 - Teilzeit - Arbeitnehmer (Anzahl)
UK_Code0801	A23 - Teilzeit in Vollzeiteinheiten (Anzahl)
UK_Code0901	A11 - weibliche Tätige (Mit) Inhaber (Anzahl)
UK_Code1401	A21 - weibliche Arbeitnehmer (Anzahl)
UK_Code1501	A3 - Gesamtzahl tätige Personen A1+A2 (Anzahl)
UK_Code1601	B1 - geleistete Stunden
UK_Code2001	C11 - Umsatz aus eigenen Erzeugnissen & Weiterverkauf fremdbezogener Energie
UK_Code2101	C12 - Umsatz aus sonstiger Handelsware (Euro)
UK_Code2201	C13 - Umsatz aus Dienstleistungen & Nebengeschäften (Euro)
UK_Code2501	C14 - Gesamtumsatz C11+C12+C13 (Euro)

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UK_Code2601	C21 - Bestände von Erzeugnissen eigener Produktion Jahresanfang (Euro)
UK_Code2701	C22 - Bestände von Erzeugnissen eigener Produktion Jahresende (Euro)
UK_Code2801	C3 - selbsterstellte Anlagen (Euro)
UK_Code3301	C31 - Gesamtleistung C14+C3+C22 - C21 (Euro)
UK_Code3401	D11 - Bestände fremdbezogenes Material Jahresanfang (Euro)
UK_Code3501	D12 - Bestände fremdbezogenes Material Jahresende (Euro)
UK_Code3601	D2 - Eingänge fremdbezogenes Material (Euro)
UK_Code3701	D3 - Verbrauch fremdbezogenes Material D2+D11 - D12 (Euro)
UK_Code4201	E11 - Bestände fremdbezogene Energie & Wasser Jahresanfang (Euro)
UK_Code4301	E12 - Bestände fremdbezogene Energie & Wasser Jahresende (Euro)
UK_Code4401	E2 - Eingänge fremdbezogene Energie & Wasser (Euro)
UK_Code4501	E3 - Einsatz fremdbezogene Energie & Wasser E2+E11 - E12 (Euro)
UK_Code4601	F11 - Bestände sonstige Handelsware Jahresanfang (Euro)
UK_Code4701	F12 - Bestände sonstige Handelsware Jahresende (Euro)
UK_Code4801	F2 - Eingänge sonstige Handelsware (Euro)
UK_Code4901	F3 - Einsatz sonstige Handelsware F2+F11 - F12 (Euro)
UK_Code5001	G1 - bezahlte Entgelte (Brutto inkl. AN - Anteile Sozialkosten) (Euro)
UK_Code5201	G21 - gesetzliche Sozialkosten AG - Anteile (Euro)
UK_Code5301	G22 - sonstige Sozialkosten (Euro)
UK_Code5401	G3 - Kosten Leiharbeiter (Euro)
UK_Code5501	G41 - Kosten fremde Dienstleistungen (Euro)
UK_Code5701	G411 - darunter Zahlungen an Unterauftragnehmer (Euro)
UK_Code5901	G5 - Mieten und Pachten (Euro)
UK_Code6001	G51 - darunter Mieten und Pachten für Produktionsanlagen (Euro)
UK_Code6101	G6 - Steuern, Abgaben & öffentliche Gebühren und Beiträge (Euro)
UK_Code6201	G61 - darunter Verbrauchsteuern (Euro)
UK_Code6301	G62 - darunter Konzessionsabgaben (Euro)
UK_Code6401	G7 - sonstige Kosten (Euro)
UK_Code6501	G8 - steuerliche Abschreibungen (Euro)
UK_Code6601	G9 - Fremdkapitalzinsen (Euro)
UK_Code6801	G71 - darunter Versicherungen (Euro)
UK_Code6901	G10 - Summe Kosten G1+G21+G22+G3+G41+G5+G6+G7+G8+G9 (Euro)
UK_Code7001	H1 - Umsatzsteuer (Euro)
UK_Code7101	H2 - abzugsfähige Umsatzsteuer (Euro)
UK_Code7201	H21 - darunter abzugsfähige Vorsteuer (Euro)
UK_Code7301	I1 - Stromsteuer ohne auf Betriebsverbrauch (Euro)
UK_Code7401	J1 - Subventionen für lfd. Produktion (Euro)
UK_Code8501	L1 - Abgabe Wasser an Versorger zur Weiterverteilung (1000ccm)
UK_Code8601	L2 - Abgabe Wasser an Letztverbraucher (1000ccm)
UK_Code8701	L3 - Abgabe Wasser gesamt L1+L2 (1000ccm)
UK_Code8801	M1 - Bezüge Wasser aus Ausland (Euro)
UK_Code8901	M2 - Lieferung Wasser ans Ausland (Euro)

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UK_Code9001	K1 - Aufwendungen Forschung & Entwicklung (Euro)
UK_Code9101	K2 - Arbeitnehmer Forschung & Entwicklung (Anzahl)
UK_Code9201	I2 - Erdgassteuer ohne auf Betriebsverbrauch (Euro)
Erhebung über Stromabsatz und Erlöse der Elektrizitätsversorgungsunternehmen und Stromhändler EVAS No. 43331-083	
TM083_u	Teilnahme Stromabsatz
U_ABS_EF1011_sum	Absatz an E-Versorger (in MWh)
U_ABS_EF1012_sum	Erlös von E-Versorger (in 1.000 Euro)
U_ABS_EF1021_sum	Absatz an Hochspannung (in MWh)
U_ABS_EF1022_sum	Erlös von Hochspannung (in 1.000 Euro)
U_ABS_EF1031_sum	Absatz an Niederspannung (in MWh)
U_ABS_EF1032_sum	Erlös von Niederspannung (in 1.000 Euro)
U_ABS_EF1041_sum	Absatz an Sonderabn. gesamt (EF1021+EF1031) (in MWh)
U_ABS_EF1042_sum	Erlös von Sonderabn. gesamt (in 1.000 Euro)
U_ABS_EF1051_sum	Absatz an Tarifabnehmer (in MWh)
U_ABS_EF1052	Erlös von Tarifabnehmer (in 1.000 Euro)
U_ABS_EF1061	Absatz an Letztverbraucher gesamt (EF1041+EF1051 = EF1071+EF1081+EF1091)
U_ABS_EF1062	Erlös von Letztverbraucher gesamt (in 1.000 Euro)
U_ABS_EF1071	Absatz an VG (in MWh)
U_ABS_EF1072	Erlös von VG (in 1.000 Euro)
U_ABS_EF1081	Absatz an Privathaushalte (in MWh)
U_ABS_EF1082	Erlös von Privathaushalten (in 1.000 Euro)
U_ABS_EF1091	Absatz an Sonstige (in MWh)
U_ABS_EF1092	Erlös von Sonstige (in 1.000 Euro)
U_ABS_EF1101	Absatz an Fahrstrom (in MWh)
U_ABS_EF1111	Betriebsverbrauch (in MWh)
U_ABS_EF1121	Verfügb. Strommenge Inland (EF1061+EF1111) (in MWh)
U_ABS_EF1131	Absatz an Ausland (in MWh)
U_ABS_EF1132	Erlös von Ausland (in 1.000 Euro)
U_ABS_EF1141	Absatz an Verkehr (in MWh)
U_ABS_EF1142	Erlös von Verkehr (in 1.000 Euro)
Erhebung über die Stromeinspeisung bei Netzbetreibern EVAS No. 43371-070	
TM070_u	Teilnahme Stromeinspeisung
U_Stromein_EF1013	Stromeinspeisung Industrie (MWh) = ZL01 Konventionelle Energieträger
U_Stromein_EF1014	Stromeinspeisung Andere (MWh) = ZL01 Konventionelle Energieträger
U_Stromein_EF1021	Anzahl der einspeisenden Anlagen = ZL02 Erneuerbare Energien (Summe ZL03-
U_Stromein_EF1022	Leistung (MW) = ZL02 Erneuerbare Energien (Summe ZL03-ZL12)
U_Stromein_EF1023	Stromeinspeisung Industrie(MWh) = ZL02 Erneuerbare Energien (Summe ZL03-ZL12)
U_Stromein_EF1024	Stromeinspeisung Andere (MWh) = ZL02 Erneuerbare Energien (Summe ZL03-ZL12)

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U_Stromein_EF1025	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL02 Erneuerbare Energien
U_Stromein_EF1026	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL02 Erneuerbare Energien
U_Stromein_EF1031	Anzahl der einspeisenden Anlagen = ZL03 Wasserkraft
U_Stromein_EF1032	Leistung (MW) = ZL03 Wasserkraft
U_Stromein_EF1033	Stromeinspeisung Industrie (MWh) = ZL03 Wasserkraft
U_Stromein_EF1034	Stromeinspeisung Andere (MWh) = ZL03 Wasserkraft
U_Stromein_EF1035	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL03 Wasserkraft
U_Stromein_EF1036	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL03 Wasserkraft
U_Stromein_EF1041	Anzahl der einspeisenden Anlagen = ZL04 Windkraft
U_Stromein_EF1041a	Anzahl der einspeisenden Anlagen = ZL04 Onshore-Windkraft
U_Stromein_EF1041b	Anzahl der einspeisenden Anlagen = ZL04 Offshore-Windkraft
U_Stromein_EF1042	Leistung (MW)= ZL04 Windkraft
U_Stromein_EF1042a	Leistung (MW)= ZL04 Onshore-Windkraft
U_Stromein_EF1042b	Leistung (MW) = ZL05 Offshore-Windkraft
U_Stromein_EF1043	Stromeinspeisung Industrie (MWh) = ZL04 Windkraft
U_Stromein_EF1043a	Stromeinspeisung Industrie (MWh) = ZL04 Onshore-Windkraft
U_Stromein_EF1043b	Stromeinspeisung Industrie (MWh) =ZL04 Offshore-Windkraft
U_Stromein_EF1044	Stromeinspeisung Andere (MWh) = ZL04 Windkraft
U_Stromein_EF1044a	Stromeinspeisung Andere (MWh) = ZL04 Onshore-Windkraft
U_Stromein_EF1044b	Stromeinspeisung Andere (MWh) = ZL04 Offshore-Windkraft
U_Stromein_EF1045a	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL04 Onshore-Windkraft
U_Stromein_EF1045b	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL04 Offshore-Windkraft
U_Stromein_EF1046a	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL04 Onshore-Windkraft
U_Stromein_EF1046b	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL04 Offshore-Windkraft
U_Stromein_EF1051	Anzahl der einspeisenden Anlagen = ZL05 Photovoltaik
U_Stromein_EF1052	Leistung (MW) = ZL05 Photovoltaik
U_Stromein_EF1053	Stromeinspeisung Industrie (MWh) = ZL05 Photovoltaik
U_Stromein_EF1054	Stromeinspeisung Andere (MWh) = ZL05 Photovoltaik
U_Stromein_EF1055	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL05 Photovoltaik
U_Stromein_EF1056	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL05 Photovoltaik
U_Stromein_EF1061	Anzahl der einspeisenden Anlagen = ZL06 Geothermie
U_Stromein_EF1062	Leistung (MW) = ZL06 Geothermie
U_Stromein_EF1063	Stromeinspeisung Industrie (MWh) = ZL06 Geothermie
U_Stromein_EF1064	Stromeinspeisung Andere (MWh) = ZL06 Geothermie

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U_Stromein_EF1065	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL06 Geothermie
U_Stromein_EF1066	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL06 Geothermie
U_Stromein_EF1071	Anzahl der einspeisenden Anlagen = ZL07 Deponiegas
U_Stromein_EF1072	Leistung (MW) = ZL07 Deponiegas
U_Stromein_EF1073	Stromeinspeisung Industrie (MWh) = ZL07 Deponiegas
U_Stromein_EF1074	Stromeinspeisung Andere (MWh) = ZL07 Deponiegas
U_Stromein_EF1075	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL07 Deponiegas
U_Stromein_EF1076	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL07 Deponiegas
U_Stromein_EF1081	Anzahl der einspeisenden Anlagen = ZL08 Klärgas
U_Stromein_EF1082	Leistung (MW) = ZL08 Klärgas
U_Stromein_EF1083	Stromeinspeisung Industrie (MWh) = ZL08 Klärgas
U_Stromein_EF1084	Stromeinspeisung Andere (MWh) = ZL08 Klärgas
U_Stromein_EF1085	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL08 Klärgas
U_Stromein_EF1086	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL08 Klärgas
U_Stromein_EF1091	Anzahl der einspeisenden Anlagen = ZL09 Biogas
U_Stromein_EF1092	Leistung (MW) = ZL09 Biogas
U_Stromein_EF1093	Stromeinspeisung Industrie (MWh) = ZL09 Biogas
U_Stromein_EF1094	Stromeinspeisung Andere (MWh) = ZL09 Biogas
U_Stromein_EF1095	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL09 Biogas
U_Stromein_EF1096	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL09 Biogas
U_Stromein_EF1101	Anzahl der einspeisenden Anlagen = ZL10 Feste Biomasse
U_Stromein_EF1102	Leistung (MW) = ZL10 Feste Biomasse
U_Stromein_EF1103	Stromeinspeisung Industrie (MWh) = ZL10 Feste Biomasse
U_Stromein_EF1104	Stromeinspeisung Andere (MWh) = ZL10 Feste Biomasse
U_Stromein_EF1105	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL10 Feste Biomasse
U_Stromein_EF1106	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL10 Feste Biomasse
U_Stromein_EF1111	Anzahl der einspeisenden Anlagen = ZL11 Flüssige Biomasse
U_Stromein_EF1112	Leistung (MW) = ZL11 Flüssige Biomasse
U_Stromein_EF1113	Stromeinspeisung Industrie (MWh) = ZL11 Flüssige Biomasse
U_Stromein_EF1114	Stromeinspeisung Andere (MWh) = ZL11 Flüssige Biomasse
U_Stromein_EF1115	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL11 Flüssige Biomasse
U_Stromein_EF1116	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL11 Flüssige Biomasse

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U_Stromein_EF1121	Anzahl der einspeisenden Anlagen = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1122	Leistung (MW) = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1123	Stromeinspeisung Industrie (MWh) = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1124	Stromeinspeisung Andere (MWh) = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1125	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1126	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL12 Sonstige erneuerbare Energien
U_Stromein_EF1131	Anzahl der einspeisenden Anlagen = ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1132	Leistung (MW)= ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1133	Stromeinspeisung Industrie (MWh) = ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1134	Stromeinspeisung Andere (MWh) = ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1135	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1136	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL13 Abfälle einschl. Klärschlamm
U_Stromein_EF1141	Anzahl der einspeisenden Anlagen = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1142	Leistung (MW) = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1143	Stromeinspeisung Industrie (MWh) = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1144	Stromeinspeisung Andere (MWh) = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1145	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1146	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = ZL14 Abfälle, darunter Klärschlamm
U_Stromein_EF1151	Anzahl der einspeisenden Anlagen = Insgesamt (Summe ZL 02+13)
U_Stromein_EF1152	Leistung (MW) = Insgesamt (Summe ZL 02+13)
U_Stromein_EF1153	Stromeinspeisung Industrie (MWh) = Insgesamt (Summe ZL 01+ 02+13)
U_Stromein_EF1154	Stromeinspeisung Andere (MWh) = Insgesamt (Summe ZL 01+ 02+13)
U_Stromein_EF1155	Vom Einspeiser selbst erzeugter und verbrauchter Strom Industrie (MWh) = Insgesamt (Summe ZL 01+ 02+13)
U_Stromein_EF1156	Vom Einspeiser selbst erzeugter und verbrauchter Strom Sonstige (MWh) = Insgesamt (Summe ZL 01+ 02+13)
Erhebung über die Elektrizitätsversorgung der Netzbetreiber EVAS No. 43312-066N	
TM066N_u	Teilnahme Netzbetreiber
U_netzb_EF101_mean	Bezug von Elektrizität von Marktteilnehmern im Inland (EF102+EF103) in MW

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U_netzb_EF101_sum	Bezug von Elektrizität von Markteilnehmern im Inland (EF102+EF103) in MW
U_netzb_EF102_mean	darunter Bezug von Elektrizität von konzerneigenen Kraftwerken und anderen in MWh - Jahresdurchschnitt
U_netzb_EF101_sum	darunter Bezug von Elektrizität von konzerneigenen Kraftwerken und anderen in MWh - Jahresdurchschnitt
U_netzb_EF103_mean	darunter Bezug von Elektrizität von sonstigen Markteilnehmern in MWh - Jahrensdurchschnitt
U_netzb_EF101_sum	darunter Bezug von Elektrizität von sonstigen Markteilnehmern in MWh - Jahressumme
U_netzb_EF111_mean	Bezug von Elektrizität aus dem Ausland in MWh - Jahresdurchschnitt
U_netzb_EF111_sum	Bezug von Elektrizität aus dem Ausland in MWh - Jahressumme
U_netzb_EF190_mean	Bezug von Elektrizität insgesamt (EF101 + EF111) in MWh - Jahresdurchschnitt
U_netzb_EF190_sum	Bezug von Elektrizität insgesamt (EF101 + EF111) in MWh - Jahressumme
U_netzb_EF201_mean	Abgabe von Elektrizität an Markteilnehmern im Inland (EF202+EF203) in MWh - Jahresdurchschnitt
U_netzb_EF201_sum	Abgabe von Elektrizität an Markteilnehmern im Inland (EF202+EF203) in MWh - Jahressumme
U_netzb_EF202_mean	darunter Abgabe von Elektrizität an anderen EVU in MWh - Jahresdurchschnitt
U_netzb_EF202_sum	darunter Abgabe von Elektrizität an anderen EVU in MWh - Jahressumme
U_netzb_EF203_mean	darunter Abgabe von Elektrizität an Letztverbraucher in MWh - Jahresdurchschnitt
U_netzb_EF203_sum	darunter Abgabe von Elektrizität an Letztverbraucher in MWh - Jahressumme
U_netzb_EF211_mean	Abgabe von Elektrizität an das Ausland in MWh - Jahresdurchschnitt
U_netzb_EF211_sum	Abgabe von Elektrizität an das Ausland in MWh - Jahressumme
U_netzb_EF290_mean	Abgabe von Elektrizität insgesamt (EF201 + EF211) in MWh - Jahresdurchschnitt
U_netzb_EF290_sum	Abgabe von Elektrizität insgesamt (EF201 + EF211) in MWh - Jahressumme
U_netzb_EF301_mean	Netzverluste in MWh - Jahresdurchschnitt
U_netzb_EF301_sum	Netzverluste in MWh - Jahressumme
Investitionserhebung bei Betrieben der Energie- und Wasserversorgung EVAS No. 43211-076	
TMEVB_b	Teilnahme Investitionserhebung der Betriebe
BI_Code1100	Tätigkeitsschwerpunkt des Betriebes lt. Fragebogen
BI_Code1100_neu	Tätigkeitsschwerpunkt des Betriebs zusammengefasst
BI_Code1500	Umweltschutzanlagen enthalten?
BI_Code2001	Bruttozugänge - Bestehende. Gebäude und Bauten
BI_Code2201	Bruttozugänge - Grundstücke ohne Bauten

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BI_Code3001	Bruttozugänge: Technische Anlagen und Maschinen
BI_Code4001	Bruttozugänge insgesamt - (Code 20-30)
BI_Code4101	Bruttozugänge - darunter selbsterst. Anlagen zu Herstellungskosten
BI_Code4801	Wert neuer Sachanlagen - Grundstücke mit Bauten
BI_Code4901	Wert neuer Sachanlagen - neue Anlagen und Maschinen
BI_Code5001	Wert neuer Sachanlagen - insgesamt (Code 48-49)
BI_Code6001	Gesamtzahl tätige Personen nur Betriebe Abwasser- und Abfallentsorgung sowie Beseitigung Umweltverschmutzungen
Monatsbericht bei den Betrieben der Energie- und Wasserversorgung EVAS No. 43111-065	
TM065_b	Teilnahme Monatsbericht
B_MBE_EF11_mean	Tätige Personen (einschliesslich tätiger Inhaber) im fachl. Betriebsteil Elektrizität - Jahresdurchschnitt
B_MBE_EF13_mean	Tätige Personen (einschliesslich tätiger Inhaber) im fachl. Betriebsteil Gas - Jahresdurchschnitt
B_MBE_EF15_mean	Tätige Personen (einschliesslich tätiger Inhaber) im fachl. Betriebsteil Fernwärme - Jahresdurchschnitt
B_MBE_EF17_mean	Tätige Personen (einschliesslich tätiger Inhaber) im fachl. Betriebsteil Wasser - Jahresdurchschnitt
B_MBE_EF19_mean	Tätige Personen (einschliesslich tätiger Inhaber) im fachl. Betriebsteil Baugewerbe - Jahresdurchschnitt
B_MBE_EF21_mean	Tätige Personen (einschliesslich tätiger Inhaber) in sonst. fachl. Betriebsteilen - Jahresdurchschnitt
B_MBE_EF23_mean	Tätige Personen (einschliesslich tätiger Inhaber) insgesamt - Jahresdurchschnitt
B_MBE_EF24_mean	tatsächlich geleistete volle Arbeitstunden insgesamt - Jahresdurchschnitt
B_MBE_EF24_sum	tatsächlich geleistete volle Arbeitstunden insgesamt - Jahressumme
B_MBE_EF25_mean	Bruttolohn- und â€“gehaltsumme einschl. Vergütungen für Auszubildende - Jahresdurchschnitt
B_MBE_EF25_sum	Bruttolohn- und â€“gehaltsumme einschl. Vergütungen für Auszubildende - Jahressumme
Erhebung über die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen für die allgemeine Versorgung EVAS No. 43311-066K	
TM066K_b	Teilnahme Kraftwerkeerhebung
Hauptenergietraeger	Hauptenergietraeger
B_kraftw_EF30_mean	Benutzungsdauer Anlagen in KWK-Prozessen (Std) - Jahresdurchschnitt
B_kraftw_EF30_sum	Benutzungsdauer Anlagen in KWK-Prozessen (Std) - Jahressumme
B_kraftw_EF401U3	Brennstoffeinsatz (Jahressumme) - insgesamt (GJ)
B_kraftw_EF401U3_mean	Brennstoffeinsatz (Jahresdurchschnitt) - insgesamt (GJ)
B_kraftw_EF401U4	Brennstoffeinsatz (Jahressumme) - darunter für ungekoppelte Stromerzeugung
B_kraftw_EF401U4_mean	Brennstoffeinsatz (Jahresdurchschnitt) - darunter für ungekoppelte Stromerzeugung

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B_kraftw_EF401U5	Brennstoffeinsatz (Jahressumme) - darunter für KWK (GJ)
B_kraftw_EF401U5_mean	Brennstoffeinsatz (Jahresdurchschnitt) - darunter für KWK (GJ)
B_kraftw_EF501U3	Brennstoffbezug (Jahressumme) (GJ)
B_kraftw_EF501U3_mean	Brennstoffbezug (Jahresdurchschnitt) (GJ)
B_kraftw_EF501U4	Brennstoffbestand (Jahressumme) (GJ)
B_kraftw_EF501U4_mean	Brennstoffbestand (Jahresdurchschnitt) (GJ)
B_kraftw_EF601U1_mean	Eigenverbrauch der Anlage â€“ Strom (MWh) - Jahresdurchschnitt
B_kraftw_EF601U1_sum	Eigenverbrauch der Anlage â€“ Strom (MWh) - Jahressumme
B_kraftw_EF601U2_mean	Eigenverbrauch der Anlage â€“ Wärme (MWh) - Jahresdurchschnitt
B_kraftw_EF601U2_sum	Eigenverbrauch der Anlage â€“ Wärme (MWh) - Jahressumme
B_kraftw_EF602U1_mean	Pumparbeit (nur Pumpspeicher-Anlagen) â€“ Strom(MWh) - Jahresdurchschnitt
B_kraftw_EF602U1_sum	Pumparbeit (nur Pumpspeicher-Anlagen) â€“ Strom(MWh) - Jahressumme
B_kraftw_EF701_mean	Wärmeabgabe aus KWK-Prozessen insgesamt (ohne Wärmebetriebsverbrauch)
B_kraftw_EF701_sum	Wärmeabgabe aus KWK-Prozessen insgesamt (ohne Wärmebetriebsverbrauch)
B_kraftw_EF702_mean	Wärmeabgabe aus KWK-Prozessen â€“ darunter Ausfuhr (MWh)
B_kraftw_EF702_sum	Wärmeabgabe aus KWK-Prozessen â€“ darunter Ausfuhr (MWh) - Jahressumme
B_kraftw_EF1101U1	Anzahl der Anlagen - Jahresdurchschnitt
B_kraftw_EF1101U1a	Anzahl der Anlagen - Typ A "konventionelle Anlagen"
B_kraftw_EF1101U1b	Anzahl der Anlagen - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF1101U2	Engpassleistung der Anlagen (MW) - elektrisch brutto - Jahressumme
B_kraftw_EF1101U2_mean	Engpassleistung der Anlagen (MW) - elektrisch brutto - Jahresdurchschnitt
B_kraftw_EF1101U2a	elektrische Engpassleistung (MW) brutto - Typ A "konventionelle Anlagen"
B_kraftw_EF1101U2a_mean	elektrische Engpassleistung (MW) brutto (Jahresdurchschnitt) - Typ "konventionelle Anlagen"
B_kraftw_EF1101U2b	elektrische Engpassleistung (MW) brutto - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF1101U2b_mean	elektrische Engpassleistung (MW) brutto (Jahresdurchschnitt) - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF1101U3	Engpassleistung der Anlagen (MW) - elektrisch netto - Jahressumme
B_kraftw_EF1101U3_mean	Engpassleistung der Anlagen (MW) - elektrisch netto - Jahresdurchschnitt
B_kraftw_EF1101U3a	elektrische Engpassleistung (MW) netto - Typ A "konventionelle Anlagen"
B_kraftw_EF1101U3a_mean	elektrische Engpassleistung (MW) netto (Jahresdurchschnitt) - Typ A "konventionelle Anlagen"
B_kraftw_EF1101U3b	elektrische Engpassleistung (MW) netto - Typ B "kohlenstoffarme Anlagen"

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`B_kraftw_EF1101U3b_mean`	elektrische Engpassleistung (MW) netto (Jahresdurchschnitt) - Typ B "kohlenstoffarme Anlagen"
`B_kraftw_EF1101U4`	Engpassleistung der Anlagen (MW) - thermisch netto - Jahressumme
`B_kraftw_EF1101U4_mean`	Engpassleistung der Anlagen (MW) - thermisch netto - Jahresdurchschnitt
`B_kraftw_EF1101U4a`	thermische Engpassleistung (MW) netto - Typ A "konventionelle Anlagen"
`B_kraftw_EF1101U4a_mean`	thermische Engpassleistung (MW) netto (Jahresdurchschnitt) - Typ A "konventionelle Anlagen"
`B_kraftw_EF1101U4b`	thermische Engpassleistung (MW) netto - Typ B "kohlenstoffarme Anlagen"
`B_kraftw_EF1101U4b_mean`	thermische Engpassleistung (MW) netto (Jahresdurchschnitt) - Typ B "kohlenstoffarme Anlagen"
`B_kraftw_EF1201U1_mean`	Verfügbare Leistung Anlage (inkl. KWK-Anlagen) insgesamt â€“ Brutto elektrisch Jahresdurchschnitt
`B_kraftw_EF1201U1_sum`	Verfügbare Leistung Anlage (inkl. KWK-Anlagen) insgesamt â€“ Brutto elektrisch Jahressumme
`B_kraftw_EF1201U2_mean`	Verfügbare Leistung Anlage (inkl. KWK-Anlagen) insgesamt â€“ Netto elektrisch Jahresdurchschnitt
`B_kraftw_EF1201U2_sum`	Verfügbare Leistung Anlage (inkl. KWK-Anlagen) insgesamt â€“ Netto elektrisch Jahressumme
`B_kraftw_EF1202U1_mean`	Höchstleistung Anlage (inkl. KWK-Anlagen) â€“ Brutto elektrisch (MW) - Jahresdurchschnitt
`B_kraftw_EF1202U1_sum`	Höchstleistung Anlage (inkl. KWK-Anlagen) â€“ Brutto elektrisch (MW) - Jahressumme
`B_kraftw_EF1202U2_mean`	Höchstleistung Anlage (inkl. KWK-Anlagen) â€“ Netto elektrisch (MW) - Jahresdurchschnitt
`B_kraftw_EF1202U2_sum`	Höchstleistung Anlage (inkl. KWK-Anlagen) insgesamt â€“ Netto elektrisch Jahressumme
`B_kraftw_EF2101U1`	Nettostromerzeugung Anlagen - insgesamt (MWh) - Jahressumme
`B_kraftw_EF2101U1_mean`	Nettostromerzeugung Anlagen - insgesamt (MWh) - Jahresdurchschnitt
`B_kraftw_EF2101U1a`	Nettostromerzeugung (MWh) - insgesamt - Typ A "konventionelle Anlagen"
`B_kraftw_EF2101U1a_mean`	Nettostromerzeugung (MWh) (Jahresdurchschnitt) - insgesamt - Typ A "konventionelle Anlagen"
`B_kraftw_EF2101U1b`	Nettostromerzeugung (MWh) - insgesamt - Typ B "kohlenstoffarme Anlagen"
`B_kraftw_EF2101U1b_mean`	Nettostromerzeugung (MWh) (Jahresdurchschnitt) - insgesamt - Typ B "kohlenstoffarme Anlagen"
`B_kraftw_EF2101U2`	Nettostromerzeugung Anlagen - darunter Kraftwärmekopplung (KWK) (MWh) - Jahressumme
`B_kraftw_EF2101U2_mean`	Nettostromerzeugung Anlagen - darunter Kraftwärmekopplung (KWK) (MWh) - Jahresdurchschnitt

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B_kraftw_EF2101U2a	Nettostromerzeugung (MWh) - darunter KWK - Typ A "konventionelle Anlagen"
B_kraftw_EF2101U2a_mean	Nettostromerzeugung (MWh) (Jahresdurchschnitt) - darunter KWK - Typ A "konventionelle Anlagen"
B_kraftw_EF2101U2b	Nettostromerzeugung (MWh) - darunter KWK - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF2101U2b_mean	Nettostromerzeugung (MWh) (Jahresdurchschnitt) - darunter KWK - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF2101U3	Nettowärmeerzeugung Anlagen - insgesamt (MWh) - Jahressumme
B_kraftw_EF2101U3_mean	Nettowärmeerzeugung Anlagen - insgesamt (MWh) - Jahresdurchschnitt
B_kraftw_EF2101U3a	Nettowärmeerzeugung (MWh) - insgesamt - Typ A "konventionelle Anlagen" - Jahressumme
B_kraftw_EF2101U3a_mean	Nettowärmeerzeugung (MWh) (Jahresdurchschnitt) - insgesamt - Typ A "konventionelle Anlagen"
B_kraftw_EF2101U3b	Nettowärmeerzeugung (MWh) - insgesamt - Typ B "kohlenstoffarme Anlagen" - Jahressumme
B_kraftw_EF2101U3b_mean	Nettowärmeerzeugung (MWh) (Jahresdurchschnitt) - insgesamt - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF2101U4	Nettowärmeerzeugung Anlagen - darunter Kraftwärmekopplung (KWK) (MWh) - Jahressumme
B_kraftw_EF2101U4_mean	Nettowärmeerzeugung Anlagen - darunter Kraftwärmekopplung (KWK) (MWh) - Jahresdurchschnitt
B_kraftw_EF2101U4a	Nettowärmeerzeugung (MWh) - darunter KWK - Typ A "konventionelle Anlagen" - Jahressumme
B_kraftw_EF2101U4a_mean	Nettowärmeerzeugung (MWh) (Jahresdurchschnitt) - darunter KWK - Typ A "konventionelle Anlagen"
B_kraftw_EF2101U4b	Nettowärmeerzeugung (MWh) - darunter KWK - Typ B "kohlenstoffarme Anlagen" - Jahressumme
B_kraftw_EF2101U4b_mean	Nettowärmeerzeugung (MWh) (Jahresdurchschnitt) - darunter KWK - Typ B "kohlenstoffarme Anlagen"
B_kraftw_EF2201U2	Stromerzeugung (Jahressumme) - Brutto insgesamt (MWh)
B_kraftw_EF2201U2_mean	Stromerzeugung (Jahresdurchschnitt) - Brutto insgesamt (MWh)
B_kraftw_EF2201U3	Stromerzeugung (Jahressumme) - Netto insgesamt (MWh)
B_kraftw_EF2201U3_mean	Stromerzeugung (Jahresdurchschnitt) - Netto insgesamt (MWh)
B_kraftw_EF2201U4	Stromerzeugung (Jahressumme) - Netto darunter KWK (MWh)
B_kraftw_EF2201U4_mean	Stromerzeugung (Jahresdurchschnitt) - Netto darunter KWK (MWh)
B_kraftw_EF2201U5	Nettowärmeerzeugung (Jahressumme) - insgesamt (MWh)
B_kraftw_EF2201U5_mean	Nettowärmeerzeugung (Jahresdurchschnitt) - insgesamt (MWh)
B_kraftw_EF2201U6	Nettowärmeerzeugung (Jahressumme) - darunter KWK (MWh)
B_kraftw_EF2201U6_mean	Nettowärmeerzeugung (Jahresdurchschnitt) - darunter KWK (MWh)
Erhebung über Erzeugung, Bezug, Verwendung und Abgabe von Wärme EVAS No. 43411-064	
TM064_b	Teilnahme Wärmeerhebung

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B_waerme_EF21	Heizwerke - Netto-Wärme-Engpassleistung (MW) des Berichtsjahres im Dezember
B_waerme_EF22	Heizwerke - Eigenverbrauch der Wärmeerzeugung (MWh) im Berichtsjahr
B_waerme_EF1001	Nettowärmeerzeugung (einschl. Wärmebetriebsverbrauch) (MWh)
B_waerme_EF1002	Bezug Inland zusammen (Zeilen 03 bis 05) (MWh)
B_waerme_EF1003	von Energieversorgungsunternehmen (MWh)
B_waerme_EF1004	von VG sowie Bergbau und Gewinnung von Steinen und Erden (MWh)
B_waerme_EF1005	von sonst. Lieferanten (MWh)
B_waerme_EF1006	Bezug Ausland (MWh)
B_waerme_EF1007	Wärmebetriebsverbrauch (MWh)
B_waerme_EF1008	Zur Abgabe verfügbar = (Zeilen 01 + 02 + 06 minus 07) (MWh)
B_waerme_EF1009	Abgabe Inland = (Z. 10+11) (MWh)
B_waerme_EF1010	Abgabe an EVU (MWh)
B_waerme_EF1011	Abgabe an Letztverbraucher = (Z. 12 bis 15) (MWh)
B_waerme_EF1011a	a) an VG sowie Bergbau und Gewinnung von Steinen und Erden (MWh)
B_waerme_EF1011b	b) an private Haushalte (MWh)
B_waerme_EF1011c	c) an sonst. Letztverbraucher (MWh)
B_waerme_EF1011d	d) an Verkehr (MWh)
B_waerme_EF1015	Abgabe Ausland (MWh)
B_waerme_EF1016	Abgabe insgesamt (ohne Netzverluste) = (09 + 16) (MWh)
B_waerme_EF1017	Netzverluste = (08 minus 17) (MWh)
B_waerme_EF2301U3	Brennstoffeinsatz für Wärmeerzeugung (GJ) insgesamt
B_waerme_EF2301U4	Nettowärmeerzeugung (MWh) insgesamt
B_waerme_EF2401U3	Brennstoffbezug im Berichtsjahr (GJ) insgesamt
B_waerme_EF2401U4	Bestand am Jahresende des Berichtsjahres (GJ) insgesamt

KOMIED dataset based on Energiestatistiken der amtlichen Statistik 2003-2012.