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

Caroline Stiel<sup>1</sup>, Astrid Cullmann<sup>1</sup> Maria Nieswand<sup>1</sup>

## Abstract

Against the background of remunicipalisation trends in European public service sectors this paper estimates firm-level productivity for German electricity retailers and tests whether the ownership type has a significant impact on productivity. We specify a production function for the retail sector with labour and external services as main inputs, which is estimated using a control function approach. Employing a newly constructed dataset on German utilities by the German Federal Statistical Office for the years 2003 to 2012 we find that firm-level productivity generally increased until 2008 but not afterwards. We do not find any evidence for ownership having an impact on productivity.

**JEL Classification:** D24, L11, C23, L94

**Keywords:** Productivity, Retail Electricity, Ownership, Structural Production Function

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# 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 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.<sup>2</sup> 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 paper 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 paper 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](#)).<sup>3</sup> 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](#)).<sup>4</sup> However, the retail electricity sector plays an important

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<sup>2</sup>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.

<sup>3</sup> This paper 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 paper considers technical productivity without taking into account any allocative inefficiencies.

<sup>4</sup> 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

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 [Akerberg et al. \(2015\)](#).<sup>5</sup>

To the best of our knowledge, this paper 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 paper is organised as follows. Section 2 provides some background information on the German retail electricity sector and remunicipalisation trends. Section 3 surveys relevant literature. Section 4 derives the retail production function while Section 5 introduces the dataset, before Section 6 presents the empirical strategy. Section 7 discusses the results along with the robustness checks. Section 8 concludes.

## 2 Electricity supply in Germany

### 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

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productivity in the retail segment remains ambiguous and largely unstudied.

<sup>5</sup> The structural production function framework is well-known and has been applied to other sectors, mainly manufacturing ([De Loecker, 2011](#); [De Loecker and Warzynski, 2012](#); [Doraszelski and Jaumandreu, 2013](#)).

markets until 2007.<sup>6</sup> 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 1, year 2007).

Table 1: Cumulated switching rates (%)

	2007	2008	2009	2010	2011	2012	2013
<hr/> households <hr/>							
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
<hr/> business and manufacturing <hr/>							
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
<hr/> Source: Bundesnetzagentur (BNetzA): Monitoringberichte 2006-2014 (BNetzA, 2006-2014). <hr/>							

In 2005, Germany’s regulatory authority was put in charge of supervising the electricity sector. Centralised regulation and the unbundling reforms<sup>7</sup> 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 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 2).

<sup>6</sup> 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.

<sup>7</sup> 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 1: Consumer switching rates (%), 2006-2014

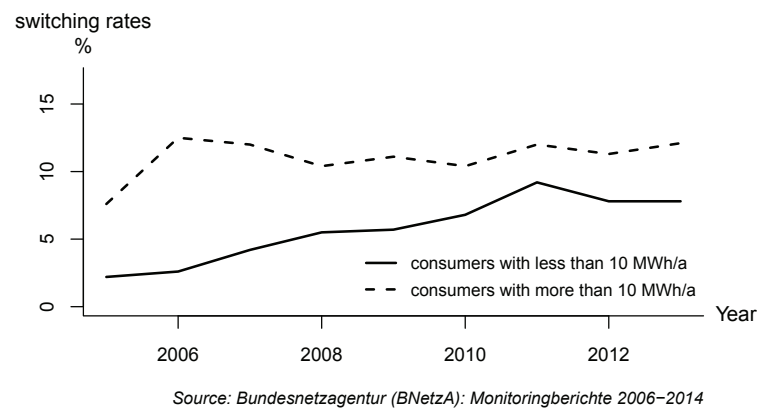
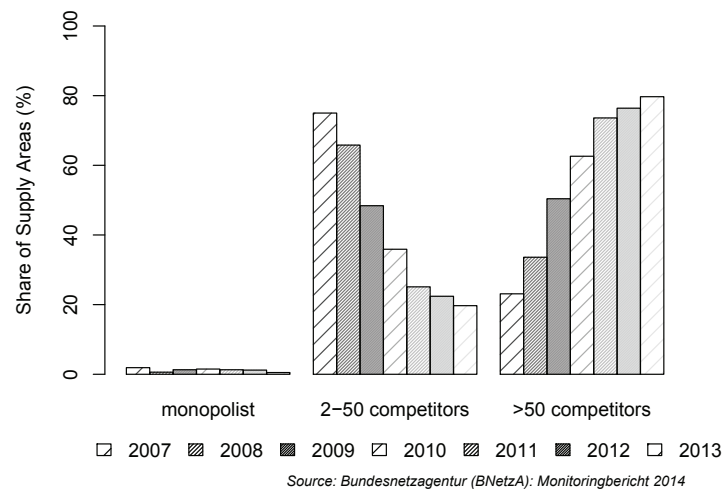


Figure 2: Competition intensity across supply areas, 2007-2013



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.

## 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 Literature survey

### 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.<sup>8</sup> 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 and effective regulation.

### 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.<sup>9</sup> 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

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<sup>8</sup> This is particularly true for cross-sector and cross-country studies (see [Mühlenkamp, 2013](#)).

<sup>9</sup> 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.



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.<sup>10</sup> In summary, despite the attention that economic theory 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-intensive segments, generation and distribution, or analyse vertically integrated utilities. However, production processes fundamentally differ between the capital-intensive 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 paper 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.

## 4 Model

A novel contribution of this paper 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 paper 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.<sup>11</sup> 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

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<sup>10</sup> 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 failing to disentangle the effect of ownership from the changes in regulation and market structure.

<sup>11</sup>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.

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 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.

## 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  $S$ .

## 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.<sup>12</sup> To increase

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<sup>12</sup> 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.

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 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.<sup>13</sup> 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  $S$ .

### 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.<sup>14</sup>

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<sup>13</sup> 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."

<sup>14</sup> 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 paper.

## 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

$$Q = \min(Q_1, Q_2) \quad (1)$$

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  $Q_1$ .<sup>15</sup> 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.<sup>16</sup> 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

$$Q = Q_2 = F_2(L, S). \quad (2)$$

## 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

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<sup>15</sup> 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.

<sup>16</sup> 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.

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 (Stiel, 2015). 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 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 2 gives an overview of the number of observations per year.<sup>17</sup> Intensified competition for residential customers can explain the strong increase of private firms after 2011 (see Section 2).

Table 2: Number of observations

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

## 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 technical activities).<sup>18</sup> Table 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.

<sup>17</sup> 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.

<sup>18</sup> 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: Summary statistics

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

$$Q = Q^e + Q^{or}. \quad (3)$$

We observe that 39 per cent of the retailers sell to other retailers ( $Q^{or} > 0$ ). Table 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.

Table 4: Summary statistics for total electricity sold

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

## 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.<sup>19</sup> 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

$$\tau = \frac{\text{supply to residential customers } Q^r}{\text{supply to end-consumers } Q^e}. \quad (4)$$

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

$$\pi = \frac{\text{supply to other retailers } Q^{or}}{\text{total supply } Q}. \quad (5)$$

Table 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.

Table 5: Summary statistics for customer structure

	<i>Q25</i>	<i>median</i>	<i>mean</i>	<i>Q75</i>	<i>sd</i>	<i>nonzeros (%)</i>
<i>share of residential customers <math>\tau</math></i>						
<i>public</i>	0.25	0.51	0.51	0.73	0.32	90.8
<i>private</i>	0.57	0.77	0.71	0.94	0.27	72.8
<i>share of other retailers <math>\pi</math></i>						
<i>public</i>	0.22	0.85	0.67	0.99	0.36	38.5
<i>private</i>	0.17	0.42	0.44	0.56	0.29	39.5

### 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).

<sup>19</sup> 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).

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.<sup>20</sup>

$$d_i = \begin{cases} 1 & \text{if company has more than 50 per cent public shares} \\ 0 & \text{if company has more than 50 per cent private shares} \end{cases} \quad (6)$$

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.<sup>21</sup>

## 6 Empirical strategy

We approximate the retail production function in (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 5.2). The estimation equation of the retail production function is then given by

$$q_{it} = \beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} + \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + \omega_{it} + \epsilon_{it}, \quad (7)$$

where  $i$  is the firm in the year  $t$ ,  $q_{it}$  is total supply (logs),  $\beta_0$  is a constant,  $l_{it}$  is the number of employees (in logs),  $s_{it}$  is deflated expenditure for external services (in logs),  $\tau_{it}$  controls for the share of electricity delivered to residential customers,  $\pi_{it}$  is the share of electricity supplied to other retailers,  $\omega_{it}$  denotes unobserved technical productivity, and  $\epsilon_{it}$  captures iid errors.

When estimating a production function with unobserved productivity  $\omega_{it}$ , productivity is likely to affect input choice, which leads to an endogeneity problem, the so-called simultaneity bias.<sup>22</sup> Olley and Pakes (1996) were the first to introduce a

<sup>20</sup> 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.

<sup>21</sup> 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.

<sup>22</sup> 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.



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 [Akerberg 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.

## 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

$$s_{it} = s_t(l_{it}, \tau_{it}, \pi_{it}, \omega_{it}, p_{Lit}), \quad (8)$$

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  $\omega_{it}$ . The index  $t$  conveys that  $s_t(\cdot)$  depends on further firm-invariant variables, such as the price-level of external services, which are not explicitly modelled. Except for  $\omega_{it}$ , all variables are observed.  $s_t(\cdot)$  is then inverted for  $\omega_{it}$ , giving

$$\omega_{it} = h_t(l_{it}, \tau_{it}, \pi_{it}, p_{Lit}, s_{it}), \quad (9)$$

where  $h_t(\cdot)$  is modelled as a polynomial series of degree 2. The proxy function for productivity (9) is inserted into the retail production function (7) to estimate the prediction  $\Phi_{it}(\cdot)$  by OLS.  $\Phi_{it}(\cdot)$  represents the predicted output net of the iid error  $\epsilon_{it}$ .

$$q_{it} = \underbrace{\beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} + \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + h_t(\cdot)}_{\Phi_{it}(l_{it}, s_{it}, \tau_{it}, \pi_{it}, p_{Lit})} + \epsilon_{it} \quad (10)$$

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

$$\omega_{it}(\beta) = \hat{\Phi}_{it} - \beta_0 - \beta_l l_{it} - \beta_s s_{it} - 0.5\beta_{ll} l_{it}^2 - 0.5\beta_{ss} s_{it}^2 - \beta_{ls} s_{it} l_{it} - \beta_\tau \tau_{it} - \beta_\pi \pi_{it}. \quad (11)$$

## 6.2 Second-stage estimation

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

$$\omega_{it} = c + g(\omega_{it-1}) + \varphi d_{it-1} + \xi_{it} \quad (12)$$

where  $\xi_{it}$  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 3.1). 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  $\omega_{it}$  on  $\omega_{it-1}$ , ownership and a constant term to obtain an estimate for the innovation in productivity  $\hat{\xi}_{it}$

$$\hat{\xi}_{it}(\beta) = \omega_{it}(\beta) - \hat{c} - \hat{\psi}_1 \omega_{it-1}(\beta) - \hat{\psi}_2 \omega_{it-1}^2(\beta) - \hat{\psi}_3 \omega_{it-1}^3(\beta) - \hat{\varphi} d_{it-1} \quad (13)$$

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

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

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  $\beta$  which we take from an OLS estimation of the production function without the productivity term.

## 7 Results

### 7.1 Production function estimates

Table 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.

Table 6: Production function coefficients

		<i>OLS</i>	<i>ACF</i>
variable		<i>total supply</i> $q_{it}$	<i>total supply</i> $q_{it}$
$\beta_0$	<i>constant</i>	0.315* (0.159)	0.315 (0.260)
$\beta_l$	<i>labour</i>	0.730*** (0.062)	0.788*** (0.250)
$\beta_{ll}$	<i>labour</i> <sup>2</sup>	0.296*** (0.072)	0.188 (0.138)
$\beta_s$	<i>external services</i>	0.421*** (0.034)	0.216 (0.192)
$\beta_{ss}$	<i>external services</i> <sup>2</sup>	0.091*** (0.019)	0.179** (0.082)
$\beta_{ls}$	<i>labour</i> $\times$ <i>external services</i>	-0.143*** (0.031)	-0.180 (0.136)
$\beta_\tau$	<i>share residential customers</i>	-1.584*** (0.199)	-1.256** (0.591)
$\beta_\pi$	<i>share other retailers</i>	1.119*** (0.226)	2.058*** (0.676)
$\varphi$	<i>public ownership</i>		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.			

The estimate for  $\varphi$  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 7.3 analyses the influence of ownership structure in more detail.

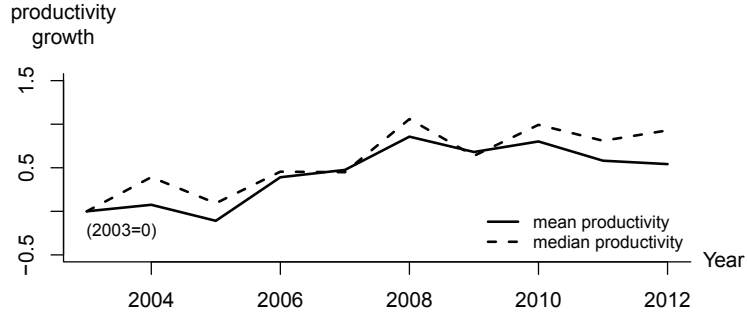
## 7.2 Productivity time trend

Firm-level productivity estimates are computed according to

$$\hat{\omega}_{it} = \hat{\Phi}_{it} - \hat{\beta}_0 - \hat{\beta}_l l_{it} - \hat{\beta}_s s_{it} - 0.5 \hat{\beta}_{ll} l_{it}^2 - 0.5 \hat{\beta}_{ss} s_{it}^2 - \hat{\beta}_{ls} s_{it} l_{it} - \hat{\beta}_\tau \tau_{it} - \hat{\beta}_\pi \pi_{it} \quad (14)$$

Figure 3 illustrates the evolution of productivity over time and shows the mean and median productivity growth using 2003 as the reference year.

Figure 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 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 driven 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.<sup>23</sup> 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 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.

### 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 produc-

<sup>23</sup> 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.

tivity 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

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

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  $\{\tilde{\omega}_1\}$  and  $\{\tilde{\omega}_2\}$  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  $\tau_b$  is the test statistic from the bootstrapped sample,  $\tau_{obs}$  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.

## 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.

### 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  $\omega_{it}$  would then capture demand shocks rather than productivity (see critique in [De Loecker, 2011](#)). 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 8, column 1, in the section Appendix 9).<sup>24</sup>

#### 7.4.2 Technology

Public firms can also differ in technology and customer structure. As a consequence, the pooled estimation in Section 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  $\tau_{it}$  and  $\pi_{it}$  with the ownership dummy to verify this hypothesis. Based on the results listed in column 2 of Table 8, we find no systematic difference in technology and customer structure for both groups.

#### 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 6). Although the technology coefficients in Section 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 8, column 3). We find that the coefficient  $\beta_\pi$  decreased by one half compared to its original value and was more in line with  $\beta_\tau$ . The group mean tests were unaffected.

#### 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 P  rotin, 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 7). We control for time effects.

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<sup>24</sup> The limited sample size restricts the study of additional variables to the OLS regression.

Table 7: Governance structure and productivity

	<i>pooled OLS</i>	<i>std.error</i>
dependent variable	<i>productivity</i>	
(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*.<sup>25</sup> 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.<sup>26</sup>

## 8 Conclusions

Based on a robust structural model, this paper 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 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

<sup>25</sup> *Gesellschaft mit beschränkter Haftung* is a company with limited liability comparable to *Ltd.* in the UK or *LLC* in the US.

<sup>26</sup> 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.

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.



## 9 Appendix

Table 8: Robustness checks

		<i>I</i>	<i>II</i>	<i>III</i>
		<i>OLS</i>	<i>OLS</i>	ACF
$\beta_0$	<i>constant</i>	−1.968 (3.539)	−0.088 (0.200)	0.294 (0.256)
$l_{it}$	<i>labour</i>	1.055*** (0.083)	1.000*** (0.112)	0.427 (0.277)
$l_{it}^2$	<i>labour</i> <sup>2</sup>	0.607*** (0.111)	0.612*** (0.113)	0.187 (0.126)
$s_{it}$	<i>external services</i>	0.443*** (0.056)	0.463*** (0.060)	0.432* (0.229)
$s_{it}^2$	<i>external services</i> <sup>2</sup>	0.129*** (0.031)	0.133*** (0.031)	0.090 (0.076)
$l_{it}s_{it}$	<i>labour</i> × <i>external services</i>	−0.345*** (0.055)	−0.338*** (0.057)	−0.126 (0.109)
$\tau_{it}$	<i>share residential customers</i>	−1.164*** (0.190)	−1.327*** (0.267)	−0.949** (0.439)
$\pi_{it}$	<i>share other retailers</i>	1.217*** (0.219)	1.176*** (0.329)	0.795 (0.594)
	<i>German electricity demand</i>	0.004 (0.007)		
$d_{it}$	<i>public</i>		0.115 (0.276)	
$d_{it}l_{it}$	<i>labour</i> × <i>public</i>		0.124 (0.141)	
$d_{it}s_{it}$	<i>external services</i> × <i>public</i>		−0.027 (0.069)	
$d_{it}\tau_{it}$	<i>share residential customers</i> × <i>public</i>		0.300 (0.419)	
$d_{it}\pi_{it}$	<i>share other retailers</i> × <i>public</i>		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.

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