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# Productivity in the Electricity Retail Market: Does Ownership Matter?

A control function approach for Germany

**Preliminary Version<sup>1</sup>**

September 2, 2015

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This paper examines firm-level productivity for German electricity retailers and the role of ownership. An innovative production function for the retail sector is derived with labour and external services as main inputs. We use a proxy function for productivity to overcome the simultaneity bias and control for ownership in the law of motion for productivity. Employing a new dataset on German utilities by the German Federal Statistical Office for the years 2003 to 2012 we find that firm-level productivity increased until 2008 but not afterwards. We do not find any evidence for ownership having an impact on productivity.

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

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<sup>1</sup>The authors acknowledge financial support from Leibniz Association for the research project KOMIED (Municipal Infrastructure Companies against the Background of Energy Policy and Demographic Change). The paper uses restricted data that were analyzed at the German Federal Statistical Office Research Data Center in Berlin. All results have been reviewed to ensure that no confidential information is disclosed.

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# 1 Introduction

In 1998, electricity and natural gas markets in the EU were liberalized. The intention was to lower retail prices and encourage productivity gains by introducing competition (EC 2007). 15 years later, there is little empirical evidence on the impact of liberalization on European utilities with respect to productivity.<sup>3</sup> Only few studies address production explicitly in the retail segment and those which do cast some doubt on expected productivity gains (e.g. DEFEUILLEY 2009). The reason is that the production process within the retailing units changed fundamentally after liberalization. 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 rise accordingly. As a consequence, the net effect of liberalization on productivity in the retail segment is ambiguous.

In many countries including Germany, economic policy is furthermore influenced by an ongoing political debate which links ownership to productivity in the utilities industries. Several municipalities in Germany consider re-municipalization or have already implemented it. Reasons involve dissatisfaction with the quality of private service provision, the wish to have more influence on the energy networks and supply, as well as the absence of substantial tariff reduction after the privatizations of the 1990s. Against the background of re-municipalization, critics claim that public firms are less productive than their private counterparts. They build their arguments on privatization theories in the tradition of the property rights and principal-agent literature (see e.g. LAFFONT/TIROLE 1991, SHLEIFER/VISHNY 1994; BOYCKO et al. 1996). Fundamental assumptions in these models are private rent-seeking behaviour among managers and public officials, soft budget constraints or the absence of transaction costs in regulating private firms. However, most of the theoretical models have only limited explanatory power when applied to a reality which is far more complex. CLÒ et al. 2014 stress that the environment, in which public firms operate, changes. Many public firms have reformed their legal status towards corporatization and state monopolies are replaced by competition between firms with different ownership status. This holds particularly true for German utilities. The share of corporated public utilities in the energy sector has risen from 38% in 1990 to 55% in 2010 (GOTTSCHALK 2012). Likewise, local monopolies were abolished to create competition between more than 870 retailers in Germany. The average consumer can now choose between more than 50 suppliers serving his region. As a consequence, there is reason to believe that the dichotomy between private and public firms nowadays might be exaggerated and that the link between ownership and performance in developed countries is rather weak. Robust empirical support is then needed as an input for policy evaluation. Numerous empirical studies in the past

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<sup>3</sup>Productivity is here defined as the amount of inputs used by the retailer to reach a certain number of customers and sell a subsequent level of energy.

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have tried to establish such a link (see MEGGINSON/NETTER 2001 for a literature review). However, results are not easily transferable. The political institutions between countries differ and the regulatory framework is not the same among different sectors in the economy (see MÜHLENKAMP 2013 for an in-depth discussion).

In addition, econometric estimation poses some challenging issues. First, a well-specified production function is needed. Second, detailed data on the production process of the firms as well as on their ownership structure is needed. Third, to determine firm-level productivity, which is usually unobserved for the econometricians, one has to be aware of potential endogeneity issues resulting from the fact that productivity is not independent from input choices.

To the best of our knowledge, this is the first paper which considers productivity changes in the electricity retail sector in Germany after liberalization. We investigate the existence of productivity differences between public and private firms for a clearly defined subsample of German electricity retailers, which is representative for Germany. The sample is taken from a new and unique dataset on German utilities by the German Federal Statistical Office. It covers the years 2003 to 2012. Due to an increasingly competitive environment and reorganization within the firms, we hypothesize that there is no significant impact of ownership on productivity levels.

To estimate total factor productivity, we derive a new production function framework explicitly for the retail sector, involving a procurement and a marketing decision. Labour and external services are used as main inputs. We address the endogeneity of input choice using the control function approach developed by OLLEY/PAKES 1996 and extended by ACKERBERG et al. 2006. We control for ownership in the law of motion for productivity. A similar setup has been suggested by DORASZELSKI/JAUMANDREU 2013 and DE LOECKER/WARZYNSKI 2012. Our paper differs from DORASZELSKI/JAUMANDREU 2013 in assuming that the ownership status is exogenous to the manager and from DE LOECKER/WARZYNSKI 2012 in the sense that private and public firms face the same demand conditions.

Empirical results show that firm-level productivity increased during the first years (2003-2008) but not afterwards. We do not find any evidence for ownership having an impact on productivity. The results are policy-relevant for the discussion on re-municipalization and provide new insights on the link between ownership and productivity in modern public enterprises.

The remainder of the paper is as follows: section 3 derives the production function model. Section 5 presents the empirical strategy after the data has been described in section 4. Results are discussed in section 6 along with robustness checks in 7. Section 8 concludes.

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## 2 Literature

Theory on performance differences between public and private firms is abundant. Contributions started with the bureau and property rights literature in the 1960s and peaked during the privatization waves of the 1980s and 1990s employing principal-agent models. There are two main arguments why public firms are conventionally thought to be less efficient than private firms: rent-seeking managers and rent-seeking politicians.

The managerial discretion hypothesis is based on some moral hazard problem. Managers of (public) firms are assumed to put less effort into profit-maximisation and maximise a private agenda (output expansion, leisurely work load, ...) instead (see WILLIAMSON 1963, ALCHIAN 1965, MIGUÉ/BÉLANGER 1974, NISKANEN 1968, 1975). They are free to do so because disciplining mechanisms or incentive schemes in public firms tend to be weak. Reasons involve soft budget constraints (KORNAI 1986), the absence of the market for corporate control (signaling the firm's value and thus the manager's performance, cf. MILLWARD/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/TIROLE 1991).

The pursuit of these further 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 the 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 ('common good' hypothesis, cf. Wintrobe 1987, Florio 2004), more radical contributions assume malevolent governments whose private agenda is of no benefit to society (SHLEIFER/VISHNY 1994, BOYCKO et al. 1996). As a consequence, the production in public firms would inevitably lead to a deadweight loss in efficiency and welfare.

A third strand of literature, by contrast, highlights the role of market structure over ownership in determining performance (e.g. KAY/THOMPSON 1986, YARROW 1986, VICKERS/YARROW 1991). Analyzing the UK privatizations from 1979 to 1991 the authors argue that regulation and market structure are much more relevant for performance than pure transfer of ownership. According to them, empirical studies often fail to compare 'likes with likes' and to disentangle ownership effects from the influence of regulation and market environment.<sup>4</sup> While private firms might 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 conclusion, primacy should then be given to the promotion of competition and effective regulation.

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<sup>4</sup> This holds particularly true for cross-sector and cross-country studies (see MÜHLENKAMP 2013).

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## 3 Model

In the following we derive a production function for electricity retailers which has not been done in the previous literature. We restrict our model to *independent* electricity retailers to provide a clear definition of the firms' production process. We thus exclude vertically integrated firms (generation, transmission, distribution) and horizontally integrated firms (e.g. district heat, water) to ensure the comparability between firms with respect to homogeneous inputs and outputs.<sup>5</sup> In general, retailers are firms which sell electricity to end-consumers. Additionally, some of them might sell electricity to other retailers.

When specifying the production function in detail, it is useful to recap what retailers actually do. They do not produce a physical good but rather provide a service. They are the link between the consumer and the wholesale power plant. Loosely speaking, the consumer does not have to make own contracts with power plants and network operators but asks the retailer to take care of it. In return, he is willing to accept a retail price above the wholesale price, which compensates the retailer for his work. The retailer carries out two main activities which determine the success (i.e. profit) of the enterprise: procurement with electricity and marketing.

### 3.1 Procurement

The retailer must buy electricity from external sources since we exclude vertically integrated firms. He may decide between a variety of contracts, e.g. long-term contracts, procurement on the spot markets etc. Marginal costs of the electricity provided to the end-consumer depend directly on this portfolio choice. A clever portfolio choice can substantially reduce 'production' costs. In addition, retail prices are adjusted only once a year, while wholesale prices fluctuate during the day. The retailer assumes the risk of price volatility, which again can be interpreted as part of the service provided to the end-consumer. As procurement has become more and more complex after liberalization, the manager of the firm must decide whether he wants to hire own experts or outsource procurement. Evidence for Germany shows that in particular small retailers tend to rely on outsourcing. We model the labour choice related to procurement as a decision between own labour force  $L$  and external services  $S$ .

### 3.2 Marketing

The second activity regards the maintenance of customer relations. The overall goal of the retailer is to increase the number of customers and thereby sales. The amount of electricity consumed by a single customer is exogenous to the retailer. He

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<sup>5</sup> *Firms* are defined as the smallest legally independent unit. We cannot exclude that some firms belong to larger holding companies which also own firms at other stages of the supply chain.

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cannot convince a single consumer to consume more electricity. To increase sales, the retailer must win new customers or at least prevent customers from switching to competitors. He may do so by using different marketing tools. For instance, to attract new customers (and possibly remind existing customers of their lucky choice) the retailer can do some advertisement.<sup>6</sup> An advertisement campaign may be thought up and carried out either by the marketing staff inhouse or by a professional PR agency. Again, we translate the labour choice related to customer relations as a simple decision between using own labour force  $L$  and external services  $S$ .

### 3.3 Capital input

A typical production function contains capital input, so it is useful to think about the relevant capital for service providers. Traditional production functions were designed for the manufacturing sector, where machines (capital) are run by employees (labour). A straightforward extension to the service sector would be to consider computers, office buildings etc. as relevant capital and include them into the production function. However, while a manufacturing firm can potentially increase output through buying a new machine (cf. engine efficiency in a power plant), it is not clear why having a faster computer or adding two grounds to the office building should lead to more customers. Physical capital thus does not seem to be a main driver behind productivity in the service sector. Therefore we abstract from capital in our production function.<sup>7</sup>

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<sup>6</sup> Advertisement is crucial in the electricity sector. New entrants must build up reputation since consumers are scared of current interruption and tend to rely on their local incumbent. Electricity does not differ in its physical appearance, which requires some 'branding'. Consumer do not come across new products by chance and there is switching inertia. Cf. 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>7</sup> One 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 is often subsumed under the term of *human capital*. Accounting for human capital in general is very difficult due to data availability and beyond the scope of the paper.

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### 3.4 Summarizing the production process

Based on the previous ideas we summarize the production process by the following Walras-Leontief production function.

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

where  $Q_1$  is the amount of the retail product in stock (here: procured electricity) and  $Q_2$  is potential market share created by advertisement and a competitive procurement strategy. It is a function of labour and external services  $F(L, S)$  and measured as the number of customers times consumption. Output  $Q$  is the resulting (potential) market share, i.e. the potential amount of electricity supplied adjusted for physical limitations in procurement. While the retailer can substitute within  $F_2$ , he may not substitute between  $Q_1$  and  $Q_2$ . The Leontief condition thus expresses vertical separation between different steps of the supply chain. The independent retailer cannot use labour to take up electricity production. The final output is determined by the limiting factor of both.

In the case of electricity retail,  $Q_1$  is not the limiting factor since demand is always met by production and the retailer is forced to continuously adjust his procurement via the spot market.<sup>8</sup> The total output  $Q$  is then given by the outcome of  $F_2$  and the Leontief function reduces to

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

As usual, realized output finally depends on the interaction with the demand function (which involves the retailer's output price). In equilibrium, much like for a manufacturing production function, the retailer will not produce more output (potential market share) than he can sell at a chosen price.<sup>9</sup>

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<sup>8</sup> Imagine a different retail market, e.g. computer notebooks. A customer enters a local computer store and would like to buy 10 notebooks. Unfortunately, the retailer has only 3 notebooks in stock. Ordering some 7 more takes at least 10 weeks and the customer is unwilling to wait. Clearly, the retailer did enough advertisement to create a potential market share of 10 notebooks. In that case, the limiting factor is the physical procurement. He will only sell 3 notebooks.

<sup>9</sup> We implicitly assume that marketing and prices are independent of each other, i.e. more marketing cannot compensate for higher prices *in the case of identical products*. The sake of marketing is only to get known by the consumers and to enter the set of potential suppliers. The consumer will then select the cheapest offer save for potential product differentiation (preference for green electricity, local incumbent,...). However, a valid marketing strategy could consist in exaggerated product differentiation, cf. footnote 5.



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## 4 Data

We use a new and rich panel dataset on German utilities provided by the German Federal Statistical Office in remote data access. To our knowledge, this is the first time that such an exhaustive dataset has been used to study European utilities. It collects information on various cost components, output and revenue structures and further variables related to the production process. The panel dataset includes all German utilities with more than 10 employees which operate in the sectors electricity, natural gas, district heat, water supply, sewerage or waste treatment. Firms may have different degrees of vertical and horizontal integration. Depending on the year of observation, the data represents 80-90% of true electricity consumption in Germany.

Our subsample consists of independent electricity retailers which are vertically unbundled. We allow for horizontal integration with gas retail, but compute separate inputs between electricity and gas retail. The subsample includes 76 firms which are observed up to 10 years between 2003 and 2012 ( $N = 212$ ).

### 4.1 Inputs

The production function has two inputs, labour  $L$  measured in number of workers and expenditure for external services  $S$ . Expenditure for external services is deflated using the German yearly price index for NACE class M (Professional, scientific and technical activities). The number of workers is reported separately for electricity and gas retail in the data. External services are split between electricity and gas retail proportional to the staff ratio.

Summary statistics are given in table 1. We include labour costs for illustrative purpose to give a better idea of the relative importance of external services in input use. The amounts spent on external services clearly exceed those on internal staff. Outsourcing is therefore an important factor in electricity retailing.

Table 1: 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 w</i>								
<i>public</i>	[€/h]	21	33	34	55	12	-	65
<i>private</i>	[€/h]	16	32	36	73	18	-	147

Labour costs are split between electricity supply and gas supply following the staff ratio. Wages are averaged across employees and computed as total payroll/total hours worked.

## 4.2 Output

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

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

More than one third (39%) of the retailers sell to other retailers ( $Q^{or} > 0$ ). Table 2 provides summary statistics for  $Q$ . 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 incumbants. A few large cities dominate a bunch 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 big city. Altogether, private firms sell 95% of the electricity.

Table 2: Summary statistics for total electricity supplied

		<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

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### 4.3 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>10</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 (*Tarifikunden*) are private households and small businesses that are served based on a two-part tariff. The tariffs are typically adjusted once a year. Large customers (*Sondervertragskunden*) benefit from greater flexibility. Often, prices are more directly linked to fluctuations in wholesale prices and a different tariff scheme applies.<sup>11</sup> Since residential customers usually have lower per-capita consumption levels, controlling for their part is important. Otherwise productivity scores risk to reflect the customer structure instead of providing an isolated measure of productivity.

Likewise, deliveries to other retailers imply much higher volumes than those to end-consumers. Firms with a high portion of electricity supplied to other retailers would thus 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 3 provides summary statistics for both control variables. A significant proportion of private firms does not serve residential customers at all but focuses on large customers instead (27%). Public retailers, in turn, rarely keep out of their traditional segment. The proportion of firms selling to other retailers is balanced and lies around 39%.

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<sup>10</sup>SHEPHARD 1971, for instance, suggests a distance function for modelling multiple outputs in a production framework.

<sup>11</sup>Examples for large customers are manufacturing firms but also government entities, housing associations and (non-energy) retailers.

Table 3: Summary statistics for customer structure

	<i>Q25</i>	<i>median</i>	<i>mean</i>	<i>Q75</i>	<i>sd</i>	<i>zeros (%)</i>
<i>share of residential customers <math>\tau</math></i>						
<i>public</i>	0.25	0.51	0.51	0.73	0.32	9.2
<i>private</i>	0.57	0.77	0.71	0.94	0.27	27.2
<i>share of other retailers <math>\pi</math></i>						
<i>public</i>	0.22	0.85	0.67	0.99	0.36	61.5
<i>private</i>	0.17	0.42	0.44	0.56	0.29	60.5

#### 4.4 Ownership

German electricity retailers may have complex ownership patterns, including mixed ownership between the private and public sector and participation of different government entities. We follow the definition suggested by the European Commission and define public undertakings as firms where public authorities have a dominant influence either by 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% of either shares. It is reported on a yearly basis and taken from the survey *Jahresabschlussstatistik öffentlicher Unternehmen und Fonds* from the Federal Statistical Office. In total we observe 65 public firms and 147 private firms.

### 5 Empirical Strategy and Identification

We approximate the 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 and is standard in the utility sector (e.g. KUMBHAKAR 1996, SAAL et al. 2007, FARSI/FILIPPINI 2009). The estimation equation of the production function is then given by

$$q_{it} = \beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} + \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + \omega_{it} + u_{it} \quad (6)$$

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 (logs),  $s_{it}$  is deflated expenditure for external services (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 productivity and  $u_{it}$  captures measurement errors.

When estimating a production function with unobserved productivity  $\omega_{it}$ , problems may arise from the 'simultaneity bias'. The reason is that productivity is likely to affect input choice, which creates an endogeneity problem. OLLEY/PAKES 1996 were the first to introduce a control function approach meant to overcome that issue. The main idea is to divide the estimation process into two stages. In the first stage, productivity is expressed in terms of observables with the help of the input demand function of a static, flexible input. 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.<sup>12</sup> Our estimation strategy builds on the extension by ACKERBERG et al. 2006 (ACF). The advantage of their approach is that it explicitly allows for modelling labour as a dynamic, non-flexible input, which reflects the legal situation in the German utility sector. Furthermore, it does not rely on investment as a proxy function for productivity. We do not model capital in the production process and thus could not use investment into capital as a proxy.<sup>13</sup>

### First stage estimation

Assume external services  $s_{it}$  to be a static, flexible input without any dynamic implications and with no adjustment costs. We argue that most contracts on external services can be adjusted at least once a year and particularly marketing campaigns are usually more short-term targeted. The input demand function is then determined in a static optimization problem and given by

$$s_{it} = s_t(l_{it}, \tau_{it}, \pi_{it}, \omega_{it}, w_{it}) \quad (7)$$

where  $l_{it}$  is pre-determined and  $w_{it}$  are firm-specific input prices of the substitute (wages of labour staff). 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 modeled.

If the monotonicity condition holds,  $s_t(\cdot)$  can be inverted for  $\omega_{it}$  and we get

$$\omega_{it} = h_t(l_{it}, \tau_{it}, \pi_{it}, w_{it}, s_{it}). \quad (8)$$

It is modelled as a polynomial series of degree 2.

The proxy function for productivity (8) is then inserted into the production function (6) to estimate the composite term  $\Phi_{it}(\cdot)$  by OLS. It represents output net of

<sup>12</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. To be more flexibel in our exogeneity assumptions, we will use the control function approach.

<sup>13</sup> LEVINSOHN and PETRIN 2003 do not encounter this problem as they rely on material to proxy for productivity. However, they assume labour to be fully flexible which gives rise to some colinearity problem between  $l_{it}$  and  $s_{it}$  as pointed out in ACKERBERG et al 2006.

the iid error  $u_{it}$ .

$$q_{it} = \underbrace{\beta_0 + \beta_l l_{it} + \beta_s s_{it} + 0.5\beta_{ll} l_{it}^2 + 0.5\beta_{ss} s_{it}^2 + \beta_{ls} l_{it} s_{it} + \beta_\tau \tau_{it} + \beta_\pi \pi_{it} + h_t(\cdot)}_{\Phi_{it}(l_{it}, s_{it}, \tau_{it}, \pi_{it}, w_{it})} + u_{it} \quad (9)$$

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

$$\omega_{it}(\beta) = \hat{\Phi}_{it} - \beta_0 - \beta_l l_{it} - \beta_s s_{it} - 0.5\beta_{ll} l_{it}^2 - 0.5\beta_{ss} s_{it}^2 - \beta_{ls} s_{it} l_{it} - \beta_\tau \tau_{it} - \beta_\pi \pi_{it} \quad (10)$$

### Second stage estimation

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

$$\omega_{it} = c + g(\omega_{it-1}) + \varphi d_{it-1} + v_{it} \quad (11)$$

where we control 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 done elsewhere, for instance in DORASZELSKI/JAUMANDREU 2013 and DE LOECKER/WARZYNSKI 2012.<sup>14</sup> The Markov process is modelled as a polynomial of degree 3.

We then use the law of motion for productivity (11) and regress  $\omega_{it}$  on  $\omega_{ijt-1}$ , ownership and a constant term to obtain the residuals  $\hat{v}_{it}$

$$\hat{v}_{it}(\beta) = \omega_{it}(\beta) - \hat{c} - \hat{\psi}_1 \omega_{it-1}(\beta) - \hat{\psi}_2 \omega_{it-1}^2(\beta) - \hat{\psi}_3 \omega_{it-1}^3(\beta) - \hat{\varphi} d_{it-1} \quad (12)$$

where  $\beta$  is the vector of coefficients from the production function. The parameters  $\beta_0, \beta_l, \beta_s, \beta_{ll}, \beta_{ss}, \beta_{ls}, \beta_\tau$  and  $\beta_\pi$  are identified by the respective moment conditions

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

<sup>14</sup> DORASZELSKI and JAUMANDREU, however, estimate endogenous productivity through R&D expenditure while we assume that the ownership status cannot be influenced by the manager of firm. It is an exogenous shock to productivity. DE LOECKER and WARZYNSKI control for the export status of the firm, but they directly control for it in the input demand function. They assume that exporting firms face different demand conditions from non-exporting firms, e.g. tougher competition on the output market. We argue that public and private firms are both subject to the same degree of competition and face the same demand function.

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The iterative procedure requires first guesses on the vector  $\beta$ . They are taken from an OLS estimation of the translog production function without the productivity term.

## 6 Results

### 6.1 Specification

#### 6.1.1 Production function

The estimates for the coefficients of the production function are given in table 4. All coefficients have the expected sign. Moreover, first-order coefficients from the ACF method are lower than in the OLS estimation. This is in line with previous findings in the literature (e.g. OLLEY/PAKES 1996, ACKERBERG et al. 2006). The intuition is that if productivity is positively correlated with input choice, the OLS estimates will be upward biased. The negative coefficient for the interaction term between labour and external services indicates at the median that the two inputs behave as substitutes, which is what one would expect. Furthermore, after correcting for the upward bias we find constant returns to scale at the median level of inputs.

The first stage confirms that a translog specification seems appropriate despite the small sample size. Controlling for the customer structure is important too. A higher share of electricity delivered to residential customers leads at the median to smaller output. By contrast, the more important is the share of electricity supplied to other retailers, the higher is the output. An obvious drawback from the ACF method is that we lose precision in the second stage of estimation due to the numerical optimization and the block-bootstrap of standard errors.

There is a substantial reduction of observations in the second stage, for which lags are required, and which seems to hint at some entry/exit problem in the sample. However, firms that leave our sample are not necessarily driven out of the market. Most of the observations are lost due to missing values in input data. A check in the full dataset revealed that 95% of the firms continue to sell electricity. Some of them take up further lines of products, which is another reason to leave our (narrowly defined) sample. The period (2003-2012) is characterized by massive reorganization within the firms. Firms restructured in response to changing regulation but also to face competition and serve emerging markets such as energy consultancy. Hence, there is no a priori reason why exit should be correlated with (low) productivity values.

Table 4: Estimates for the production function coefficients

variable		first stage (OLS) total supply $q_{it}$	second stage (ACF) total supply $q_{it}$
$\beta_0$	constant	-0.072 (0.173)	0.315 (0.260)
$l_{it}$	labour	1.056*** (0.083)	0.788*** (0.250)
$l_{it}^2$	labour <sup>2</sup>	0.611*** (0.111)	0.188 (0.138)
$s_{it}$	external services	0.445*** (0.056)	0.216 (0.192)
$s_{it}^2$	external services <sup>2</sup>	0.130*** (0.031)	0.179** (0.082)
$l_{it}s_{it}$	labour $\times$ external services	-0.348*** (0.054)	-0.180 (0.136)
$\tau_{it}$	share residential customers	-1.155*** (0.189)	-1.256** (0.591)
$\pi_{it}$	share other retailers	1.203*** (0.218)	2.058*** (0.676)
		N=212	N=118

p-values: 0 '\*\*\*' 0.01 '\*\*' 0.05 '\*' 0.1. 2nd stage: standard-errors block-bootstrapped at firm-level.

### 6.1.2 Autoregressive process

Table 5 shows the results for the estimation of the first-order Markov process for productivity, controlling for public ownership (see equation (11)). Past productivity clearly affects current productivity. Modelling the Markov process as a nonlinear process of degree 3 instead of a linear AR(1) seems to provide a good approximation for the true underlying law of motion for productivity. Note, however, that the ordinary least-squares estimator produces downwardly biased results in small samples for autoregressive processes (see e.g. MARRIOTT/POPE 1954). Hence, the true coefficients might be higher.

Private firms do not seem to have a better strategy of dealing with market opening than public firms. They do not systematically achieve higher productivity gains over the years (or incur less losses). An extensive analysis on the influence of the ownership structure is done in section 6.3.

## 6.2 Productivity time trend

Productivity estimates are computed according to

$$\hat{\omega}_{it} = \hat{\Phi}_{it} - \hat{\beta}_0 - \hat{\beta}_l l_{it} - \hat{\beta}_s s_{it} - 0.5 \hat{\beta}_{ll} l_{it}^2 - 0.5 \hat{\beta}_{ss} s_{it}^2 - \hat{\beta}_{ls} s_{it} l_{it} - \hat{\beta}_\tau \tau_{it} - \hat{\beta}_\pi \pi_{it} \quad (13)$$



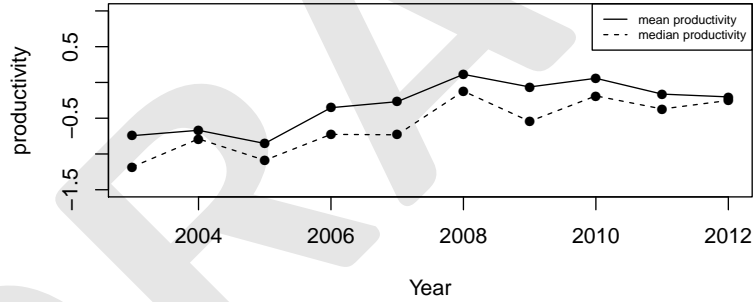
Table 5: Estimates for the autoregression

dependent variable	OLS	std.error
	productivity $\omega_{it}$	
<i>constant</i>	0.057	(0.070)
$\omega_{it-1}$	0.755***	(0.075)
$\omega_{it-1}^2$	-0.295***	(0.059)
$\omega_{it-1}^3$	-0.074***	(0.014)
$d_{it-1}$	0.061	(0.109)

$N = 118$ . p-values: 0 \*\*\*\* 0.01 \*\*\* 0.05 \*\* 0.1.

The evolution of productivity over time is illustrated in figure 1. It shows the mean and median productivity estimates based on all firms in the sample ( $N = 212$ ). As the number of firms used in the second stage of estimation is substantially lower, we reproduce the figure based on the reduced sample to verify robustness of our results (see figure 2 in the appendix). The overall trend is similar.

Figure 1: Evolution in productivity 2003-2012



We observe an initial upward trend in mean productivity between 2003 and 2008. During that period, a lot of firms decided to reorganize units, which could have let to better input use. After 2008, both mean and median productivity remain stable. The results indicate that productivity gains are probably more driven by reorganization within the firms than by active competition. Note that active competition only started in 2008 after the unbundling reform had reduced discrimination in network access. Although markets were liberalized in 1998, competition, in particular for residential customers, thus took some time to develop.

With the start of active competition, input intensity in the retailing unit of the firms steadily increased without a considerable increase in *overall*, i.e. industry-wide output. The overall number of electricity consumers in Germany remained constant since coverage was already at 100%. Also, the amount of electricity consumed remained fairly stable. In contrast, the production process at the retailing

stage changed fundamentally (see section 3). Competition introduced a need for additional activities in marketing, advertisement and customer relations. Furthermore, procurement became much more complex and required additional expertise. Since all firms have to engage in these additional activities, potential productivity gains from competitive pressure could have been outweighed by higher input requirements.

## 6.3 Ownership

### 6.3.1 Group means test

The autoregressive 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 productivity levels evolve at the same rhythm as for private firms, than much of the ownership variation will be captured by past productivity. We first check for an overall effect of ownership on productivity with an equality of means test. Since we have very small group sample sizes and are unwilling to make any distributional assumptions, we use bootstrap. The following test is standard and based on EFRON/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. We estimated a p-value of  $\hat{p} = 0.663$  and conclude that the null hypothesis cannot be rejected.<sup>15</sup>

<sup>15</sup> We also calculate the test for the reduced sample  $N = 118$  from the second stage estimation and get  $\hat{p} = 0.711$ .

### 6.3.2 Governance structure

It might not only be the shareholders themselves who matter but also the degree up to which they can influence decisions taken within the firm (cf. e.g. ESTRIN/PÉROTIN 1991). In Germany, governance differs with the legal form of the firm. The difference is particularly pronounced for public firms organized 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 are usually head of the firms. Over the last decade, many utilities in Germany decided to reform their legal status and reorganized under private law (e.g. AG, GmbH, GmbH & Co. KG, KG). The share rose from 38% in 1990 to 55% in 2010 (GOTTSCHALK 2012). The governance structure is now much closer to that of a private firm and stricter accounting rules apply. As a consequence, we hypothesize that the difference 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 6).<sup>16</sup> We control for time effects.

Table 6: Governance structure and productivity

dependent variable	pooled OLS productivity		std.error
(Intercept)	-0.512	***	(0.116)
public GmbH	0.107		(0.187)
private AG	0.569	***	(0.210)
public AG	-0.783	**	(0.308)
private GmbH & Co. KG	-1.045	***	(0.308)
public GmbH & Co. KG	1.120	**	(0.457)
Eigenbetrieb (public)	-1.077		(0.709)
Genossenschaft (private)	-0.058		(0.289)
private KG	-1.395	**	(0.582)
other private firms	-1.060	***	(0.298)
time effects	yes		
N = 212. p-values: 0 '***' 0.01 '**' 0.05 '*' 0.1. Reference group: private GmbH.			

In the sample, roughly two third (46) of the public firms and 50% of the private firms are organized as GmbH. As we only observe 65 public firms in total, we focus on the results for *public GmbH* in relation to the reference group *private GmbH*. The reason is that we do not observe enough firms in the remaining subgroups to clearly identify the legal form as the main driver behind the results. Coefficients might be driven by unobserved individual characteristics.

We do not find any difference between public and private firms organized as GmbH. GmbH is by far the most common legal form in the electricity retail sector

<sup>16</sup> Table 7 in the appendix shows again results for the reduced sample from the GMM estimation.

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and these firms do not seem to behave fundamentally different under competition whether they are publicly or privately owned.

## 7 Robustness checks

We conduct several robustness checks to verify the validity of our specification.

*Demand.* Problems could arise from output being measured as electricity supplied instead of the number of customers. Fluctuations in electricity supply might be driven by demand-side shocks which are beyond control for the firm. The residual  $\omega_{it}$  would then capture demand shocks rather than productivity (cf. critique in DE LOECKER 2011). We test for the impact of aggregate demand-side shocks, in particular the economic crisis in 2009, by including yearly German electricity consumption as a control variable in the production function. The results for the first stage (OLS) are given in the first column of table 8 in the appendix and suggest that the average productivity trend over time is not driven by demand-side shocks.<sup>17</sup>

*Technology.* Public firms might not only differ in productivity but also in technology and customer structure. As a consequence, the pooled estimation in section 5 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. Column 2 of table 8 reproduces the results. We do not find any systematic difference between both groups in technology nor customer structure.

*Economies of 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 (cf. table 4). Although the technology coefficients in section 6 suggest constant returns to scale *at the median* level of inputs, this does not exclude very large firms to benefit from economies of scale and thus have higher productivity values. There are 13 extraordinary large observations in the sample whose output is 200 times that of the median firm. To avoid any systematic bias in the productivity values we run a sensitivity analysis and exclude all firms whose output exceeds 20TWh. The results are given in column 3 of table 8. The coefficient  $\beta_\pi$  decreased by one half compared to its original value and is now more in line with  $\beta_\tau$ . The group mean tests remain unaffected.

## 8 Conclusion

Based on a robust structural model, this paper investigates the evolution of productivity for independent electricity retailers in Germany after liberalization between

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<sup>17</sup> The limited sample size unfortunately restricts the study of additional variables to the OLS regression.

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2003 and 2012. It is the first study to analyze productivity trends and the influence of ownership in the German retail market after liberalization.

A new production function for the retail sector is derived, which involves a procurement and a marketing decision. Labour and external services are used as main inputs. The production function is then estimated in a structural model to control for the simultaneity bias, which arises when unobserved productivity is correlated with input choice.

We do not find any evidence for ownership having an impact on productivity. One of the reasons could be the increasing degree of corporatization among public utilities and the competitive environment. The theoretical dichotomy between public and private firms in that context might be exaggerated. Productivity differences between firms seem to result from more complex sources and further research should concentrate on precise firm strategies instead (e.g. offering green electricity, branding).

There is a steady increase in mean productivity up to the year 2008 but not afterwards. The results suggest that productivity gains are more driven by reorganization within the firms in response to changing regulation and technology (e.g. procurement) than by direct competitive pressure. When active competition started in 2009, average productivity remains stable. The stop in productivity growth cannot be explained by demand-side shocks alone and suggests a different interpretation based on two countervailing effects. After liberalization, retail firms had to engage in marketing activities and complex procurement decisions. This required additional inputs (e.g. labour force or external services) while the overall industry output, the number of customers and the amount of electricity consumed, did not change. Since all firms have to engage in these additional activities, productivity gains from competitive pressure might be countervailed by increasing input requirements.

Our sample was restricted to independent electricity retailers while most of the electricity in Germany is actually served by vertically and horizontally integrated firms. Further research should extend the analysis to integrated firms since economies of scope might play an important role in the determination of productivity.

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## 10 Appendix

Figure 2: Evolution in productivity 2004-2012: GMM sample

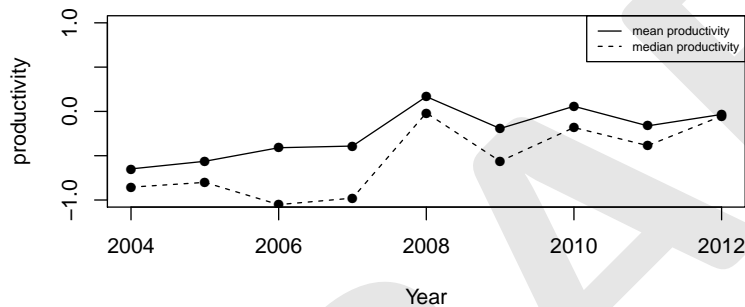


Table 7: Governance structure and productivity: GMM sample

dependent variable	pooled OLS productivity		std.error
(Intercept)	-0.605	***	(0.159)
public GmbH	0.213		(0.253)
private AG	0.634	**	(0.282)
public AG	-0.565		(0.401)
private GmbH & Co. KG	-1.021	**	(0.454)
public GmbH & Co. KG	1.724	**	(0.754)
Eigenbetrieb (public)	-	-	-
Genossenschaft (private)	0.511		(0.545)
private KG	-1.252	*	(0.754)
other private firms	-1.180	**	(0.492)
time effects	yes		

N = 118. p-values: 0 \*\*\*\* 0.01 \*\*\* 0.05 \*\* 0.1 \*. Reference group: private GmbH.



Table 8: Robustness checks

		<i>I</i>	<i>II</i>	<i>III</i>
		<i>OLS</i>	<i>OLS</i>	<i>ACF</i>
$\beta_0$	<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=110
Group mean test				
$\hat{p}$				0.474
$\hat{p}$	GMM sample			0.288

p-values: 0 '\*\*\*\*' 0.01 '\*\*\*' 0.05 '\*\*' 0.1 '\*'. 2nd stage: standard-errors block-bootstrapped at firm-level. Model I: controls for German electricity demand in the production function. Model II: controls for ownership in technology and customer structure. Model III: excludes firms with more than 20TWh/a supply.