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Vertical integration, separation and non-price discrimination: An empirical analysis of German electricity markets for residential customers

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Vertical Integration, Separation and Non-Price Discrimination: An Empirical Analysis of German Electricity Markets for Residential Customers

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Non-technical Summary

Vertical integration of electricity distribution network operator and electricity supplier is a key issue in European energy markets, in particular since the European Commission (EC) has initiated a sector inquiry in 2005. The EC argues that vertical separation of electricity networks from other activities (such as production and retail) increases consumer surplus, while opponents argue that vertical integration enables cost savings due to economies of scope. The European Competition Commission too indicates the disadvantage of vertical integration in energy markets for retail customers caused by potential discrimination of competitors. Aiming at preventing non-price discrimination the EC suggests alternative regulatory approaches to overcome the challenge of vertical integration. Legal unbundling, as an intermediate approach between ownership unbundling and vertical integration, describes a particular type of separation. In this case, the regulation requires legal separation of a grid unit from the retail/production and the operation of the grid by independent management.

In a theoretical model we show that vertically integrated incumbents in the electricity market might have an incentive to favor their own downstream unit over competitors. We distinguish between demand decreasing and cost increasing non-price discrimination. Delaying supplier-switching or withholding important information from competitors are examples for such types of non-price discrimination. This discriminatory behavior might affect the retail prices. Therefore, consumers might be worse off if the distribution network operator and the downstream retail incumbent remain vertically integrated. We further consider the effects that arise from introducing legal unbundling as already implemented in several European Countries. In line with other studies, the results show the legal unbundling regime to be favorable if it works perfectly, i.e. can indeed prevent non-price discrimination.

To test our hypotheses derived from the theoretical model we employ cross-sectional data for geographically separated submarkets for household customers in Germany, each served by one distribution network operator, one downstream retail incumbent and a number of small energy providers. As the vertical structure is heterogeneous across the 850 German electricity submarkets for residential customers (there exist legally unbundled, vertically integrated or fully separated firms), we use firm level data to analyze the effects of different vertical structures and regulation schemes on retail electricity prices. We find significantly higher prices in markets with vertically integrated firms compared to markets with fully separated firms. This finding could indicate non-price discrimination. Furthermore, we find no evidence that legal unbundling eliminates the incentives for non-price discrimination because the prices do not differ from prices in markets under vertical integration. Therefore, we suggest implementing stricter rules for sufficient legal unbundling to prevent potential discrimination against competitors.

Das Wichtigste in Kürze (Summary in German)

Im Gutachten der Europäischen Kommission (2005) über Entwicklung der europaweiten Liberalisierung der Energiemärkte zeigt sich, dass vertikale Integration der Netzbetreiber mit den Stromlieferanten weiterhin ein Problemfeld für die Entwicklung des Wettbewerbs darstellt. Die Europäische Kommission weist daraufhin, dass vertikale Integration Potenzial zur Diskriminierung von Konkurrenten in sich birgt und dadurch die Wettbewerbsentwicklung deutlich hemmt. Deshalb wird einerseits argumentiert, dass eine Separierung der Netzbetreiber vom Stromlieferanten Vorteile für Endkunden haben kann. Andrerseits sind möglicherweise Kopplungseffekte vorhanden, die einen effizienten bzw. kostengünstigen Betrieb gewährleisten. Um einen Mittelweg zu finden wurde ein sogenanntes „Legal Unbundling", eine erweiterte rechtliche Separierung, vorgeschlagen. Dabei sind die Stromlieferanten verpflichtet den Netzbetrieb von anderen Aktivitäten des Unternehmens zu trennen. Dies beinhaltet nicht nur die rechtliche Trennung des Netzes in eine neu gegründete Tochtergesellschaft, sondern auch den Einsatz von einem von der Muttergesellschaft unabhängigen Management. Hierdurch wird versucht sowohl die finanzielle, funktionelle als auch die informationelle Entkopplung zu gewährleisten. Im Gegensatz zur eigentumsrechtlichen Separierung bleibt bei der erweiterten rechtlichen Separierung das Eigentum weiterhin beim Stromlieferanten. Welche Form der Regulierung jedoch die geeignetere ist, wurde bislang nur in wenigen theoretischen Arbeiten untersucht.

Wir knüpfen an die theoretische Literatur an und untersuchen zunächst, ob vertikale Integration Anreize für eine nicht-preisliche Diskriminierung bietet. Dabei unterscheiden wir zwischen zwei Diskriminierungsformen: nachfrage-senkende und kosten-erhöhende Diskriminierung der Konkurrenten. So können beispielsweise absichtliche Verzögerungen beim Kundenwechsel oder Verzögerungen bei der Weitergabe von wichtigen Daten sowohl die Kosten als auch die Nachfrage der Konkurrenten beeinflussen. Wir zeigen, dass solche Anreize für vertikal integrierte Unternehmen theoretisch vorhanden sind. Die Einführung von „Legal Unbundling" könnte jedoch diesen Anreizen effektiv entgegen wirken, wenn diese Form der Regulierung die Abhängigkeit des Netzbetreibers von der Muttergesellschaft tatsächlich reduziert bzw. vollständig beseitigt.

Wir testen unsere theoretisch abgeleiteten Hypothesen mithilfe von Daten für geographisch separierte Haushaltsmärkte in Deutschland. Da in Deutschland etwa 850 Märkte vorhanden sind und diese Märkte unterschiedliche vertikale Strukturen aufweisen, wird der Test unserer Hypothesen hierdurch ermöglicht. Dabei nutzen wir (Angebots-) Daten auf Firmenebene und für Marktnachfrage verwenden wir demographische Daten auf Marktebene. Die Ergebnisse zeigen, dass in Märkten mit vertikal integrierten ehemaligen Monopolisten die Preise für Haushaltskunden im Durchschnitt höher sind als in Märkten mit vollkommen unabhängigen bzw. eigentumsrechtlich separierten Stromlieferanten. Dies könnte auf eine mögliche nicht-preisliche Diskriminierung deuten. Zudem zeigen unsere Schätzungen, dass „Legal Unbundling" nicht notwendigerweise bessere Ergebnisse, in Form von niedrigeren Endkundenpreisen, erzielt. Deshalb sollte eine straffere Regulierung bzw. die strikte Implementierung der Regelungen durch die Regulierungsbehörden auferlegt werden.

Vertical Integration, Separation and Non-Price Discrimination: An Empirical Analysis of German Electricity Markets for Residential Customers

- Vigen Nikogosian[1][2] Tobias Veith[3]

The literature on vertical integration in markets with regulated upstream prices suggests that the integrated upstream firm might engage in non-price discrimination. Several studies provide policy recommendations derived either from case study approaches or based on theoretical modeling which addresses the unbundling issue. In this study we analyze the impact of vertical integration of retail incumbent and network operator on retail prices and upstream charges. As the vertical structure is heterogeneous across the 850 German electricity submarkets for residential customers (there exist legally unbundled, vertically integrated or fully separated firms), we use firm level data to analyze the effects of different vertical structures and regulation schemes on retail electricity prices. We find significantly higher prices in markets with vertically integrated firms compared to markets with fully separated firms. This finding could indicate non-price discrimination. Furthermore, we find no evidence that legal unbundling eliminates the incentives for non-price discrimination because the prices do not differ from prices in markets under vertical integration.

JEL Classification: L1, L5, L9
Keywords: Electricity; Regulation; Vertical Integration; Legal and Total Unbundling; Non-Price Discrimination

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Introduction

Vertical integration of energy network operator and supplier is a key issue in European energy markets, in particular since the European Commission (EC) has initiated a sector inquiry in 2005. The EC argues that vertical separation of electricity networks from other activities (such as production and retail) increases consumer surplus, while opponents argue that vertical integration enables cost savings due to economies of scope.[4] In a number of speeches, former European Competition Commissioner Kroes indicates the disadvantage of vertical integration in energy markets for retail customers caused by insufficient unbundling of electricity transmission/distribution and supply activities.[5]

A large number of studies put forward the effects of vertical integration of an upstream monopolist offering an essential input to a competitive downstream market. Without any regulation, the upstream monopolist might favor its own downstream unit either with price-privileges or non-price-privileges. While price discrimination directly affects competitors' input costs, non-price discrimination ("sabotage") might influence quality, customer preferences, cost, and, finally, the demand. To prevent price discrimination upstream price regulation can be installed, but non-price discrimination remains an issue. In general, such non-price discrimination is legally prohibited, but can hardly be detected by the regulation authority (Economides, 1998; Beard et al., 2001).

The literature on non-price discrimination distinguishes between alternative approaches, e.g. raising rivals' costs, in case of information asymmetry, or reducing rivals' quality. Vickers (1995) analyses welfare effects of a vertically integrated upstream monopolist who provides price regulated upstream services and simultaneously acts in the retail market. Furthermore, he assumes the regulator to be imperfectly informed about upstream costs. This fact allows the monopolist to select a wholesale price from a set of prices. Vickers shows that due to information asymmetry, upstream regulation cannot completely prevent discrimination incentives. Sappington (2006) extends Vickers' setup by including economies of scope and

[4] ERGEG Publications: Status Review of DSO Unbundling with Reference to GGP on Functional and Informational Unbundling for DSOs, 2009.

[5] Examples are: Neelie Kroes: Improving Europe's energy markets through more competition SPEECH/07/115), Neelie Kroes: More Competition and Greater Energy Security in the Single European Market for Electricity and Gas (SPEECH/07/212) …" In Germany the market is dominated by vertically-integrated companies, and the retail energy prices for small users are higher than in countries where energy companies have been unbundled, such as the UK."

non-price discrimination. He confirms previous findings concerning higher retail prices due to vertical integration.[6]

Mandy and Sappington (2006) consider an alternative approach of non-price discrimination with an upstream provider able to influence not only competitor's costs, but also demand, by reducing the product quality. The authors show that both cost-increasing discrimination and quality-reducing discrimination are profitable under Cournot competition. However, only cost-increasing discrimination is profitable under Bertrand competition. Our theoretical model, which we use to derive our hypotheses, is related to Mandy and Sappington (2006). Similarly we analyze the effects of cost-increasing and demand-reducing non-price discrimination, and, in contrast, we consider a Hotelling game because we firmly believe the total market demand in energy markets for household customers to be price inelastic in a short run. Furthermore, we believe that the customers' choice on energy supplier depends not only on the energy price, but also on firm preference.

Aiming at preventing non-price discrimination the European Commission suggests alternative regulatory approaches to overcome the challenge of vertical integration. Legal unbundling, as an intermediate approach between ownership unbundling and vertical integration, describes a particular type of separation. Hereby, the regulation requires legal separation of grid unit from the retail/production and the operation of the network by *de jure* independent grid unit management. Cremer et al. (2006) and Bolle and Breitmoser (2006) show that the stronger unbundling is enforced by law, the more network operators try to benefit from higher distribution charges, whereas downstream competition is reduced resulting in higher retail prices. In contrast, Höffler and Kranz (2011a) compare the effects of legal unbundling, ownership unbundling and vertical integration. They find lower retail prices with legal unbundling than with ownership unbundling and vertical integration. A legally separated price-regulated network operator maximizes only its own profit by maximizing the upstream output, therefore the operator has no incentive to discriminate downstream competitors. Thus, retail prices are lower than under vertical integration. By assuming retained informal interdependence between the legally unbundled upstream and downstream units, Höffler and Kranz (2011b) show that discrimination might again occur. We extended our theoretical

[6] The comparison of Vicker's and Sappington's approaches shows that the outcome of a raising rivals' costs strategy does not depend on the type of downstream competition. Other studies on non-price discrimination with Cournot competition are e.g. Crew et al., 2005; Economides, 1998; and Bertrand competition: Beard et al., 2001; Sappington, 2006; Weisman, 1995.

model by adopting several vertical regulation schemes as applied in Höffler and Kranz (2011a and b).

The literature presents a broad range of theoretical evidence of how vertical integration can affect retail prices. Nevertheless, only a very small number of articles provide empirical evidence by considering separation of the transmission networks.[7] In this study we want to take up this challenge by analyzing the impact of vertical integration of retail incumbents (downstream) - mostly former monopolistic electricity suppliers - and distribution system operators (DSOs) (upstream) on retail prices and distribution charges in German household electricity markets. As the vertical structure is heterogeneous across the 850 German submarkets (there exist legally unbundled, vertically integrated or fully separated firms), we are able to analyze the effects of different structures and regulation schemes on electricity prices.

The potential unbundling of distribution networks has received little attention in economic studies so far.[8] As described above, vertically integrated incumbents might have an incentive to favor their own downstream unit over competitors. Delaying supplier-switching or withholding important information (e.g. customers' energy consumption) from competitors are examples for non-price discrimination. Such a discriminatory behavior might affect the retail prices. To test our hypotheses derived from the theoretical model we employ cross-sectional data for about 600 German geographically separated markets, each served by one DSO, one downstream incumbent and a number of small energy providers. Thus, we want to know whether price differences exist in different vertical structures. Using a simultaneous equations approach, we find significantly lower prices in markets with fully separated firms compared to markets with vertically integrated or legally unbundled firms.

I. The German Electricity Sector

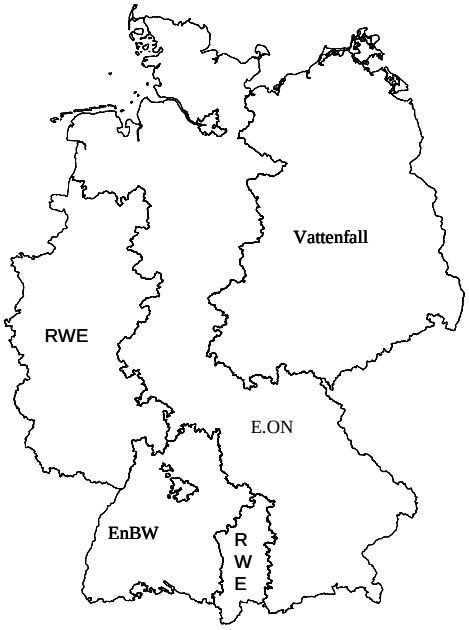
The electricity sector can be subdivided in five interrelated stages: Generation, wholesale, transmission, distribution and retail. In Germany, four electricity producers, EnBW, E.on,

[7]Transmission networks are the highest voltage lines that are used for long distance transmission whereas distribution grid is a regional network to supply end consumers.
E.g. Steiner (2001) and Hattori & Tsuitsui (2001) investigate the effects of unbundling the transmission grid. Copenhagen Economics (2005) estimated the unbundling effects on prices and productivity for 15 European countries (in 1990-2003) finding that unbundling transmission from generation leads to lower prices and higher productivities.

[8]Nillesen and Pollitt (2008) study the effects of unbundling that was implemented in New Zealand for distribution grids.

RWE and Vattenfall, hold about 85 percent of the electricity generation capacities (with different generation sources). The remaining 15 percent of production capacities are either owned by local producers or foreign companies. Usually, capacities of small producers are used to cover the peak loads. The German transmission grid is geographically divided into four regional transmission grid monopolies covering the following regions: The EnBW area is located in South-Western Germany, Vattenfall in Eastern Germany, RWE in Western Germany. The remaining territory, which stretches from Northern Germany to Bavaria, belongs to E.ON.[9]

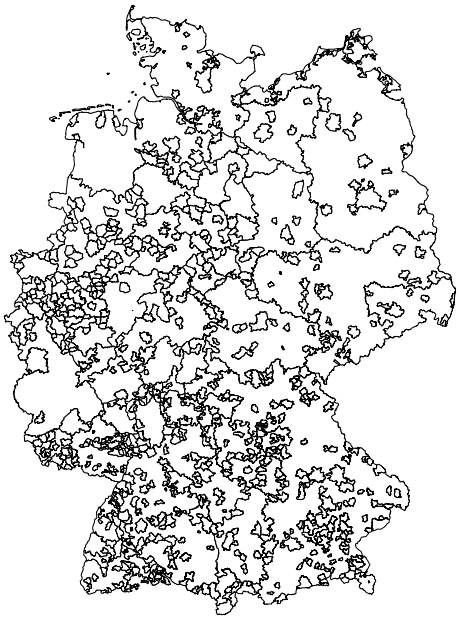
Figure 1: Transmission Grid Areas in Germany



In contrast to transmission, the distribution stage covers more than 850 geographically separated markets, which are, according to the German Federal Cartel Office (Bundeskartellamt), the relevant markets in case of market investigations. The markets have different distribution areas and densities, thus, they differ with electricity demand. Each of these markets has only one distribution network operator and only one retail incumbent (former monopolist). Figure 2 provides an overview over the German distribution markets.

[9] E.ON – forced by European Commission - sold the transmission grid in this territory to TenneT in 2010.

Figure 2: Regional separation of the German Electricity Distribution Market



In general, vertical integration allows for price and non-price discrimination of competitors. Therefore, in line with the 2005 Energy Act (EnWG), the Federal Network Agency (Bundesnetzagentur) started the regulation of the grid access charge, the so-called distribution charge. Until 2009, the distribution charges were cost-based regulated. Recently, a new regulation scheme, incentive regulation (revenue-cap), was implemented. Thus, if a supplier serves a customer in a particular local submarket it has to pay the local distribution charge of the customer's market. Besides distribution charge regulation, the Energy Act requires the legal unbundling of grid operators from other activities such as generation and retail, aiming to prevent non-price discrimination. *Legal unbundling* describes the functional and legal separation of the distribution network operator (DSO) from other activities in terms of management, information flows and accounting. Since 2007, grid operators with more than 100,000 customers are obliged to separate their DSO by creating a new legal entity. Operators with smaller number of customers than the required threshold are allowed to remain *vertically integrated*. In contrast, *ownership unbundling (or full separation)* requires ownership independence of producers, grid operators and retail providers. However, this stricter regulation type has not yet been implemented in EU member states. As mentioned above, Germany has a very unique market structure; about 20 percent of German distribution operators are legally unbundled including voluntary separations, whereas 75 percent are vertically integrated and 5 percent are fully separated.

In addition to network regulation, the largest electricity supplier in each retail market for household customers is obliged to offer one so-called standard (basic) contract. This contract is a "fallback" for customers who decide to switch to an alternative contract. They automatically return to the standard contract either if their new provider leaves the market, or if their contract is cancelled by the supplier and customers have not decided which supplier to switch to (§§ 36 – 38, Energiewirtschaftsgesetz (EnWG)). Moreover, this means that after the market liberalization in 1998, customers who have not yet switched their supplier or contract (about 50 percent on average in each submarket) are supplied under the conditions of the high priced standard contract. Until today, former monopolists are the providers of these standard contracts. Besides the standard contract, former monopolists offer alternative contracts to retain more price-sensitive customers. About 44 percent of customers chose an alternative incumbent contract, whereas the rest (only about 6 percent) turned to alternative suppliers. Thus, incumbents' still have high market share after the liberalization.

II. Unbundling experience from other countries

New Zealand is the first country that has implemented ownership separation of electricity distribution from other commercial activities. The separation, introduced in 1998 after electricity market restructuring in 1992, resulted in no significant retail price reductions. Nillesen and Pollitt (2008) analyze New Zealand's economic effects of unbundling, employing a dataset between 1995 and 2007. They show that prices for commercial customers decreased, whereas residential electricity prices increased after the unbundling intervention.[10] Furthermore, unbundling caused a strong reduction in the number of competitors as energy producers acquired retailers. In their consideration of the unbundling effect on production and distribution costs, the authors find significant operational cost reductions. However, these were not passed on to customers in terms of lower distribution charges.

Currently, the Netherlands is politically debating the ownership separation on the distribution level, which has been legally implemented since 2011. Nooij and Baarsma (2008) summarize the arguments stated in the literature that ownership separation positively affects competition. Among others, they show in a scenario analysis of the Dutch electricity sector that discriminatory activities and cross-subsidization of vertically related companies could appear. In contrast to this theory-based analysis, Mulder et al. (2005) find only a little evidence for a

[10] For commercial customers on average from NZ$ 18,99 to 13,72 cents, and for household customers from NZ$ 14,40 to 18,60 cents after ownership unbundling. The average overall price remained constant (see Nillesen and Pollitt 2007, p. 30f).

price effect due to vertical separation with a broad cross-country analysis of vertical integration strategies.

III. Theoretical Model

With a simple theoretical model, we aim at illustrating the effects arising from non-price discrimination in different vertical structure settings on the downstream prices and derive hypotheses for our empirical analysis. We do not seek the non-price discrimination equilibrium in the theoretical model but rather analyze the incentives to sabotage the competitors and the impact on retail prices. We compare alternative types of non-price discrimination with alternative forms of vertical regulation.

Consider a Hotelling game with uniformly distributed potential customers and two firms located at either end of a line.[11] Firms offer electricity contracts with a given amount of electricity demand per contract. It is reasonable to assume that firms compete with differentiated contracts as, at least in Germany, the electricity price is not the only factor on which consumers decide. Consumers' preference for a particular firm (brand) is also crucial. Furthermore, we assume that the incumbent, located at 0, is vertically integrated with the distribution system operator (DSO). The DSO provides a common input, "access" to the distribution grid at a cost-based regulated per-unit price b, the distribution charge. The DSO faces constant per unit costs c_u, with $b(c_u) \geq c_u$. Each downstream firm demands one unit of network access per contract and each customer x, $x \in [0,1]$ with the reservation price v, buys one contract from the incumbent or the entrant at prices p_I or p_E, with $v \geq p_i^*$, $i = I, E$. Besides distribution charges, both firms bear constant marginal costs per contract c_i, $i = I, E$ for serving customers.

Consumers pay different "transportation costs" which depend on their firm choice. If a consumer buys from the incumbent, transportation costs are τ_I, and τ_E otherwise. In our setting, transportation costs represent the customer preferences for a particular supplier. The utility function of a customer is then defined as follows:

$$U(x) = \begin{cases} v - p_I - \tau_I x, & \text{if the customer buys from the incumbent} \\ v - p_E - \tau_E (1 - x), & \text{otherwise.} \end{cases} \qquad (1)$$

[11] We assume the market demand to be highly price-inelastic in the short run.

Because the distribution charge is regulated, the DSO could be interested in favoring its downstream unit over its competitor by engaging in non-price discriminating activities. We distinguish between two approaches which are cost-increasing, s_c, and demand reducing, s_d, form of discrimination. Cost-increasing discrimination can appear due to delays in (important) information provision e.g. on consumers' energy consumption, whereas demand-reducing discrimination is e.g. due to delays in the contract switching process. While cost-increasing discrimination directly increases the entrant's unit costs, demand-decreasing 'investments' simultaneously increase the preference for the entrant, $\frac{\partial \tau_I}{\partial s_d} < 0$, $\frac{\partial \tau_E}{\partial s_d} > 0$.

Discrimination induces costs $C(s_c, s_d)$ to the DSO with increasing rate,

$$C'(s_i) > 0,\ C''(s_i) > 0,\ \frac{\partial^2 C}{\partial s_i s_j} = 0,\ \ i, j = c, d,\ i \neq j.$$

As usual in Hotelling models, the demand split is defined by the marginal consumer x_i who is indifferent between the incumbent's contract and the competitor's contract. Thus, we get the incumbent's demand $D_I = x_i$ as:

$$D_I = x_i = \frac{p_E - p_I + \tau_E}{\tau_I + \tau_E}. \tag{2}$$

and the demand for the competitor's contract as $D_E = 1 - x_i$, with $D_i'(\tau_i) \leq 0$ and $D_i'(\tau_j) \geq 0$ for $i, j = I, E$.

The entrant's profit function, the incumbent's downstream unit and the incumbent's upstream unit profit functions π_E, π_{ID} and π_{IU} are given by:

$$\pi_E = (p_E - c_E - b - s_c) D_E \tag{3}$$

$$\pi_I = \pi_{ID} + \pi_{IU} \text{ with} \tag{4}$$

$$\pi_{ID} = (p_I - c_I - b) D_I \tag{5}$$

$$\pi_{IU} = (b - c_u)(D_E + D_I) - C(s_c, s_d), \tag{6}$$

We assume a two stage game where, first, the vertically integrated incumbent chooses the discrimination strategy $S = S(s_c, s_d)$ and, second, downstream their prices simultaneously.

Vertical integration

We begin with vertical integration and the assumption that the incumbent maximizes the total profit of both units, that is $\max(\pi_{ID} + \pi_{IU})$. By backward induction, we get the best reply functions:

$p_I^R = \frac{1}{2}(b + c_I + p_E + \tau_E)$ and $p_E^R = \frac{1}{2}(b + c_E + s_c + p_I + \tau_I)$.

Cost-increasing discrimination increases the entrant's price, $p_E^{*'}(s_c) > 0$, which confirms the findings of previous studies such as Economides (1998). In contrast, demand reducing discrimination shifts the entrant's best-reply curve inwards and the incumbent's best-reply curve outwards. The results are ambiguous: First, both equilibrium prices may be higher if the (positive) effect on the competitor's transportation costs outweighs the (negative) effect on the incumbent's transportation costs. Second, demand reducing discrimination induces the competitor to respond aggressively by reducing its price, which is also shown in Mandy and Sappington (2006).

Lemma 1:

(i) Cost-increasing discrimination raises the equilibrium downstream prices. The competitor's price rises more than the incumbent's price, $\frac{\partial p_E^*}{\partial s_c} = \frac{2}{3}$, $\frac{\partial p_I^*}{\partial s_c} = \frac{1}{3}$.

(ii) Cost-increasing discrimination raises the incumbent's demand by $\frac{\partial D_I^*}{\partial s_c} = \frac{1}{3(\tau_I + \tau_E)}$ and decreases the competitor's demand by $\frac{\partial D_E^*}{\partial s_c} = -\frac{1}{3(\tau_I + \tau_E)}$.

As cost-increasing discrimination forces the competitor to choose a higher price than without discrimination, the competitor loses a fraction of the customers. As a result, these customers turn to the incumbent. That allows the incumbent to charge a higher price.

Lemma 2:

(i) Demand-decreasing sabotage raises the incumbent's downstream price and decreases the competitor's downstream price if $\left|\frac{1}{2}\frac{\partial \tau_I}{\partial s_d}\right| < \left|\frac{\partial \tau_E}{\partial s_d}\right| < \left|2\frac{\partial \tau_I}{\partial s_d}\right|$.[12]

(ii) Demand-decreasing sabotage raises the incumbent's equilibrium demand $\frac{dD_I^*}{ds_d} > 0$ and decreases the competitor's equilibrium demand $\frac{dD_E^*}{ds_d} < 0$ as long as $(c_I - c_E - s_c + \tau_I)\frac{\partial \tau_E}{\partial s_d} > (-c_I + c_E + s_c + \tau_E)\frac{\partial \tau_I}{\partial s_d}$. This inequality holds for $c_I = c_E$, $\tau_I \geq s_c$.

In contrast to cost-increasing discrimination, the effects of demand-decreasing discrimination are ambiguous and depend on additional assumptions.

We assume that the firms have the same unit costs, $c_d = c_e$, i.e. they pay the same price for electricity at the wholesale level, and the impact of demand-decreasing discrimination on the competitor's transportation costs is larger than the impact on the incumbent's transportation costs, $\left|\frac{\partial \tau_E}{\partial s_d}\right| > \left|\frac{\partial \tau_I}{\partial s_d}\right|$. With these additional assumptions, the incumbent's price increases with demand-decreasing discrimination (Lemma 2 (i)).

In the following we first discus the exclusive effects of both discrimination types. According to Lemma 1 cost-increasing discrimination is profitable for the incumbent as this action increases both the incumbent's price and also its demand. However, taking into account the impact on the incumbent's network operator, cost-increasing discrimination decreases the competitor's quantity and raises operator's costs. As a consequence, the incumbent reaches the optimum discrimination level in the last stage with $\pi_{ID}'(s_c) + \pi_{IU}'(s_c) = 0$. If price regulation is strictly implemented, which means $b(c_u) \approx c_u$, the incumbent neglects the (negative) discrimination effect on upstream profits and, therefore, prefers cost-increasing discrimination over non-discrimination if $\pi_I(s_c^*) \geq \pi_I(0)$.

[12] If this assumption does not hold, the prices can move in the same direction, e.g. if the competitor's price is very sensitive to changes in own transportation cost compared to the effect on the incumbent's transportation cost, both prices increase. See in the appendix Lemma 2.

For the singular effect of demand-decreasing discrimination, i.e. $s_c = 0$, we can derive similar conditions: We know from Lemma 2 (i) that the incumbent's retail price increases and the competitor's price decreases with discrimination. Given our assumptions the incumbent engages in demand-decreasing discrimination if $\pi_I(s_d^*) \geq \pi_I(0)$ holds. The intuition is as follows: An incremental increase in the competitor's transportation cost and, simultaneously, an incremental decrease in the incumbent's transportation cost allow the incumbent to charge higher prices for its contract and, at the same time, to win more customers. The incumbent's profit rises as long as its marginal revenue exceeds the marginal costs of sabotage. In contrast, the competitor tries to keep its customers by reducing its price for the contract but does not win new customers, which, in turn, leads to lower profit.

We know from Lemma 1 that the level of cost-increasing discrimination also affects the profitability of demand-decreasing discrimination and, therefore, we have to consider the joint outcome in the next step. The previous findings, $\pi_I(s_c^*) \geq \pi_I(0)$ and $\pi_I(s_d^*) \geq \pi_I(0)$, show that non-price discrimination can be a preferable strategy for the vertically integrated incumbent. As we have seen, the total partial derivates of an incumbent's equilibrium demand with respect to s_d and s_c are positive without additional assumptions. However, introducing demand-decreasing and cost-increasing discrimination simultaneously, total partial derivates of the incumbent's profit with respect to s_d and s_c become mutually dependent. The mutual dependence appears when we consider the second derivatives for demand effects due to sabotage, so that, given our assumptions, these are negative $\frac{d^2 D_I^*}{ds_d s_c} = \frac{d^2 D_I^*}{ds_c s_d} < 0$. In contrast, the mutual impact of demand-decreasing and cost-increasing discrimination on the incumbent's profit is positive, because $\frac{d^2 \pi_I^*}{ds_d s_c} = \frac{d^2 \pi_I^*}{ds_c s_d} > 0$.

Employing both types of discrimination, the boundary condition $\tau_I \geq s_c$ in Lemma 2 ii is reached faster than with singular discrimination as demand-decreasing discrimination reduces τ_I and cost-increasing sabotage raises s_c. Thus, the higher the maximum level of cost-increasing discrimination, the lower the maximum level of demand-decreasing discrimination and vice versa. With the positive second derivatives and further intermediate results, we know that also $\pi_I(s_c^*, s_d^*) \geq \pi_I(0,0)$ holds as long as $\tau_I \geq s_c$. Therefore, employing the optimum

combination of both types of discrimination can result in a higher total profit than no discrimination.

Proposition 1: With $\pi_I(s_c^*) \geq \pi_I(0)$, $\pi_I(s_d^*) \geq \pi_I(0)$ and $\pi_I(s_c^*, s_d^*) \geq \pi_I(0,0)$, non-price discrimination can be a profitable strategy for the incumbent.

The discussion in line with Proposition 1 provides theoretical evidence that incumbent's price is always lower without non-price discrimination. Therefore, given our assumptions, the upstream firm has incentives to engage in non-price discrimination, which always results in a higher price than without any discrimination. In contrast, the competitor's price choice depends on the magnitude of demand-decreasing discrimination and customers' loyalty, i.e. the transportation costs.

Fully separated firms

We consider the outcome in the event of total separation as this is our reference structure for the hypotheses. Given our assumptions, the equilibrium outcome is straightforward: In case of total (full) separation the DSO has no incentives to discriminate. As each firm in our setting maximizes its own profits, the profit of the DSO is maximized without engaging in non-price discrimination, because discrimination is costly and market demand is constant, $(b - c_u)(D_E + D_I) - C(s_c, s_d) < (b - c_u)(D_E + D_I) - 0$. Therefore, downstream prices are not affected by discrimination because the DSO does not take into account the discrimination effects on downstream profits.

Hypothesis 1: In markets with vertically integrated firms, non-price discrimination results in higher retail prices of the incumbent compared to markets with fully (ownership) separated firms.

Legal unbundling

We adopt the ideas of Cremer et al. (2006) and Höffler and Kranz (2011a) and assume that the legally unbundled grid operator considers (or is forced to consider) only its grid activity and maximizes only the upstream profit,

$$\pi_{IU} = (b - c_u)(D_E + D_I) - C(s_c, s_d), \quad (7)$$

whereas the downstream incumbent maximizes total profit, upstream and downstream. With perfect legal unbundling the total profit is given by:

$$\pi_I \equiv \pi_{ID} + \pi_{IU} = (p_I - c_I - b)D_I + \left((b - c_u)(D_E + D_I) - C(s_c, s_d)\right). \quad (8)$$

Given our assumptions, the grid operator earns the same profit independently of downstream market shares because the total market demand is constant and distribution charges are regulated. Therefore, discrimination only negatively affects the DSO's profit and – with perfect legal unbundling – the grid operator has no incentive to discriminate. This outcome is in line with the findings of Höffler and Kranz (2011a).

We check whether the partial consideration of grid profits affects the retail providers' profit maximization strategies. Deriving the incumbent's optimum retail price strategy brings us to $p_I^* = \frac{1}{3}(3b + s_c + \tau_I + 2\tau_E)$.

Proposition 2: With <u>perfect</u> legal unbundling, the grid operator maximizes its upstream profit with the equilibrium strategy $S^*(0,0)$. Therefore, the implementation of legal unbundling provides no incentive for non-price discrimination, in case it works perfectly.

Hypothesis 2: <u>Perfect</u> legal unbundling provides the same results as total separation (ownership unbundling). Therefore, incumbents' prices in markets with legal unbundling do not significantly differ from incumbents' prices in markets with total (ownership) separation.

Assuming that perfect legal unbundling eliminates the grid operator's legal relationship in the retail incumbent, the grid operator ignores the downstream effect of its strategic decisions, thus having no incentive to act in favor of its retail parent firm. However, according to the special report (Sondergutachten, 2009) of the German Monopolies Commission on issues in German energy markets, the dependence of former vertically integrated operators remains strong even with legal unbundling. In particular, it is stated that upstream management decisions seem to be influenced by requirements of the retail incumbent. This might happen when the parent company is able to create an incentive-based relation to its affiliate.[13] To create such a relation, the retail incumbent needs sufficient ownership shares in the grid

[13] See also Höffler and Kranz 2011b

operator to exert power (e.g. more than 50 percent).[14] In case of lower shares, conflicts of interest might appear if other owners follow different aims. Thus, we formulate Hypothesis 3:

Hypothesis 3: With imperfect legal unbundling, incentives for non-price discrimination exist(s) which initiate higher retail prices than with total separation. The incentives increase in ownership fraction.

IV. Data Description

In the previous section we have shown that cost-increasing and demand-reducing non-price discrimination types are profitable from a theoretical point of view and, that they both increase the incumbent's electricity contract price. As sabotage is not observable (and difficult to detect by regulatory authorities), we are not able to test the theoretical model as such. However, we are able to analyze price differences for electricity contracts in markets with different vertical structures, controlling for market and customer characteristics. Thus, price differences could indicate non-price discrimination, as discussed in the theoretical model.

Data Sources

We use data from multiple sources to cover the vertical ownership structure, retail prices, distribution charges and customer characteristics. Ownership information is provided by Creditreform, the largest German wholesale commercial credit agency. Price and contract information aggregated at the zip code level stems from the internet platform Verivox which collects information on electricity contract offers. Low-voltage grid information and grid-related information is provided by E'net, the database for network characteristics. Aggregated information about customer characteristics are taken from the Acxiom database, which provides global information for marketing services.

We employ a cross-sectional approach using Data as of August 2008 that we aggregated at the distribution grid level.[15] Quantity and price data are selected for an average household consumption level of 4000 kWh per year (3 - 4 persons).

[14] Of course, imperfect legal unbundling depends strongly on corporate governance. The discussed outcome is not the only equilibrium.

[15] According to the Federal Cartel Office (Bundeskartellamt), the relevant market for end consumers without real-time-metering is the low-voltage grid area of a DSO.

Data Adjustments[16]

The most comprehensive calculations concern the calculation of ownership shares. The Creditreform database offers information about the ownership structure of each company in our sample. This information comprises both direct owners of the retail company and the grid operator, and additionally the complete link between the dependent company and the ultimate owners. Based on this information, we can calculate the individual share of an ultimate owner for each electricity company. However, what we finally need is the direct and the indirect ownership link of intermediate owners as we consider (only) the ownership structure of the retail provider and the grid owner.[17] Total ownership of a grid owner by an electricity provider and vice versa are calculated independently of the number of intermediate owners. It is important to note that we consider markets individually, i.e. we ignore cross-ownerships between alternative incumbents and alternative grid owners. However, what cannot be taken into account in this study is the aspect of common owners on a higher level.

The grid access charge consists of a fixed part, the sum of a fixed usage charge and the meter charge, and a variable part which depends on the usage level. Thus, the grid access charge for a particular usage level is the sum of these components.

Our market definition is the same as suggested by the German Regulation Authority. Since incumbents' standard contract prices apply in the area where only one incumbent or DSO serves, we use that as the relevant market. Usually areas served by only one DSO are not identical with zip code areas - the level at which we have customer information. Therefore, we have first to aggregate the information at the grid area level. To do this we calculate weights using three- and four-person households for the aggregation of customer information to the grid level.

Data Description of the Key Variables

The descriptive information is summarized in Table 1 in the appendix. The information used in the estimations covers about 600 geographically separated electricity (relevant) markets.

In about 6 percent of all retail electricity markets in our sample network operators and retail incumbents are fully separated (ownership unbundling). In 16 percent, companies are legally unbundled. As there are also voluntary legal separations, we take the number of meter points as a proxy for the number of connected customers, thus, as a proxy for the threshold required for legal unbundling. Therefore, we can distinguish between required legal unbundling and

[16] Because of the particular aggregation level of consideration, we have adjusted our data set to the market level instead of zip code level.

[17] We appreciate inexhaustible support by our colleague Thorsten Doherr.

voluntary legal unbundling.[18] We consider the cases with partial ownership (for example with 70 percent share in DSO) as voluntarily separated, because partial ownership indicates that firms choose to hold stake in DSO without being obliged to separate their activities as they are not fully integrated. These firms might have more than 100,000 meter points (the threshold level for legal unbundling required by the German regulator). About 7 percent of the firms in our sample have more than 100,000 meter points, are legally unbundled but are fully owned by the parent company, so that they were obliged to separate the DSO (required legal unbundling). On the other hand, nearly 9 percent of the firms have voluntarily unbundled. These firms have either more or less customers than the threshold level. If they have more than the threshold, they are not fully owned by the incumbent. In 78 percent of markets, retail incumbents and distribution grid operators are one company, i.e. they are fully integrated and not legally separated. Thus, in these regions the standard contract provider has a strong information advantage over its competitors. It has knowledge of the quantities provided by competitors and, moreover, it knows exactly the customers served by its competitors. Note that we do not consider the ownership direction (who owns whom) because only in 3 cases out of 42, the DSO owns the retail incumbent. Therefore, we neglect the analyses of ownership direction in our estimates.

Turning to dependent variables, we find the standard contract price to be on average 44 Euros more expensive than the incumbent's lowest price offer. However, the lowest price offer of competitors which is comparable to the incumbent offers is on average more than 120 Euros cheaper than the standard contract. Taking into account pre-payment offers, the reduction is about 170 Euros for household customers. In line with the explanations in the Monitoring Report of the Federal Network Agency (Bundesnetzagentur), the distribution charge determines about 26.0 percent of the standard contract price in our sample.

V. Econometric Model

Due to missing information about company specific incentive schemes and internal information on vertical relations between the grid owner and the retail incumbent, we are unable to fully specify the explanatory equations. However, this latent information might have an effect on both the distribution charges and retail prices as described in the theoretical

[18] Note that voluntary 'legal unbundling' is not the same as required 'legal unbundling' because in case of voluntary separation, the firms are not obliged to separate the information flows and management.

model. We therefore employ a simultaneous equation model, where the distribution charge enters the standard contract price equation, the incumbent's most competitive contract price equation, and the competitors' lowest price equation. Along with the standard contract price we also consider incumbents' competitive prices to count for effects caused by price discrimination and competitors' prices (the lowest market price) to capture the cross-prise effects. These are equilibrium prices. Ownership variables are used as explanatory variables for both the distribution charge equation and the price equations. We use the three stage least squares estimation method because we assume that the error terms correlate across the specified equations due to "shocks" that affect all endogenous variables.

We therefore end up with the following specification:

$$\log(price_i^{st}) = ownervec_i' \beta_{owners}^{st} + reg.\ characteristics_i' \beta_{region}^{st} + \beta_{dc}^{st} log(dc_i) + \alpha_i^{st} + \varepsilon_i^{st}$$

$$\log(price_i^{stlow}) = ownervec_i' \beta_{owners}^{stlow} + reg.\ characteristics_i' \beta_{region}^{stlow} + \beta_{dc}^{stlow} log(dc_i) + \alpha_i^{stlow} + \varepsilon_i^{stlow}$$

$$\log(price_i^{lowest}) = ownervec_i' \beta_{owners}^{lowest} + reg.\ characteristics_i' \beta_{region}^{lowest} + \beta_{dc}^{lowest} log(dc_i) + \alpha_i^{lowest} + \varepsilon_i^{lowest}$$

$$\log(dc_i) = ownervec_i' \beta_{owners}^{dc} + grid\ \ characteristics_i' \beta_{grid}^{dc} + reg.\ characteristics_i' \beta_{region}^{dc} + \alpha_i^{dc} + \varepsilon_i^{dc}$$

We include control variables for grid characteristics and regional characteristics into the distribution charge equation, and control variables to characterize relevant markets in the price equations. Grid characteristics are proxied by grid area, the size of the distribution region, supply density (population divided by grid area) and population density. As some variables for grid characteristics are correlated, we consider only the number of meter points (correlated with grid area) and supply density in our estimations. Regional characteristics include information about customers such as total population and regional purchasing power.

For reasons of comparison, we employ alternative ownership measures and different specifications of the equations. First, we estimate the model including dummy variables for markets with fully separated, fully integrated and legally unbundled incumbents. In the case of legally unbundled firms, we distinguish between required and voluntary legal unbundling (specification A). Second, we take into account the number of competitors which have

entered the markets (specification B) because we assume that the number of competitors, which is a proxy for competition intensity, has an impact on market prices.[19]

Furthermore, we distinguish contracts with and without prepayments, i.e. contracts which have or have not to be completely paid in advance, and estimate our model twice including contracts without prepayment and contracts with prepayment as we assume both types of contracts to address alternative customer groups. As the results with regard to our hypotheses do not differ, we only report the results for contracts without prepayment.

There might be concerns about the endogeneity of ownership structure. For example, if the error term captures an important variable that influences the price setting of firms and at the same time this variable was the driving force for integration or voluntary separation. However, the ownership structure, in particular the integration, of German incumbents are mostly the same as it was before market liberalization. Firms serving less than 100,000 customers were historically integrated and mostly remain integrated. For example, the number of business and industry customers in the area could influence the decision to integrate but do not necessarily affect the retail prices for household customers since these are different markets. The voluntary separation of incumbents with fewer customers than the threshold for the required separation occurred, as we presume, for reasons of taxation or simply for financial separation and regulation. Beside that some of the incumbents merge their network operators to take advantage of economies of scale. We control for that in our estimation by considering the grid characteristics.

VI. Estimation Results and Discussion

The estimation results are displayed in Table 2 in the appendix. In specification A, we examine the vertical structure ignoring the number of competitors in a market. In contrast, in specification B the number of competitors is taken into account. Full vertical integration is the reference category for the vertical structure dummy variables.

Following the theoretical model in line with *Hypothesis 1*, incumbent contract prices are expected to be lower in markets with ownership separated upstream monopolists compared with markets where the incumbents are vertically integrated. The empirical results support the

[19] As, for example, used in Bresnahan and Reiss (1991) in the entry game, where the authors consider the price effects depending on the number of competitors.
We also use the share of voluntarily legally unbundled firms to analyse whether the pricing behaviour is affected by the control of the parent company. In contrast to our conjecture (in hypothesis 3) that higher shares might have a stronger influence on prices, we find no significant results and therefore refrain from reporting the estimation results in the article.

expectations. Thus, Hypothesis 1 cannot be rejected. The findings suggest that in markets where the downstream incumbent and the DSO are either fully integrated or legally separated, prices for contracts offered by the incumbent are on average higher than in markets with fully separated incumbents. [20] Nevertheless, the prices for lowest-priced-contracts of competitors in markets with integrated incumbents do not differ from prices in markets with total separation. However, observing these estimation results, it could be concluded that higher incumbent prices in vertical integrated markets indicate non-price discrimination.

Hypothesis 2 - lower incumbent prices in markets with perfectly working legal unbundling - must be rejected because we find no evidence for legal unbundling to be favorable for customers' surplus in terms of retail price. The prices for the standard contract and for incumbents' low-price competitive contracts are not affected by any regulative unbundling options.[21] One reason might be that major vertically integrated firms which were obliged to legally separate their distribution activities might lease back the network by charging sabotage-conform leasing rates (as argued in Sondergutachten, 2009 of German Monopolies Commission).[22] The German Federal Network Agency and the Monopolies Commission also complain about the insufficient realization of operational separation of network activities. In addition, the results show that too competitors' prices are not significantly lower in markets with legally unbundled firms. Moreover, we do not observe any price difference in markets with required and voluntarily legal unbundling. In contrast, the alternative *Hypothesis 3* - in the case of imperfect legal unbundling prices do not differ from prices under vertical integration - cannot be rejected because we do not observe any difference in prices between legal unbundling and vertical integration. However, the ownership share has no impact on pricing behavior. According to the theoretical results our empirical findings indicate that legal unbundling does not work perfectly. Therefore, the European Regulators need to force further legal unbundling and, besides the charge regulation, to be aware of possible non-price discrimination effects that arise from imperfect legal unbundling. In particular, we suggest

[20] In specification B (estimation includes the number of competitors) the coefficient of ownership unbundling in our standard contract price equation is not significant at confidence interval of 95 %. However, the threshold of the p value to be significant at * $p<0.1$is just failed. Thus, we argue that the price for incumbent's standard contract is lower in markets with totally separated firms. The findings in specification A and the significance of the coefficient for ownership unbundling in the equation for incumbent's lowest price in specification B enforce our argument.

[21] Although the lowest market price is significantly negative in voluntary legally unbundled markets, in specification B, the coefficient is negligibly small. Thus, we argue that the prices are de facto equal in case of vertical integration and voluntary legal unbundling.

[22] See Monopolkommission (2009) p. 94 and also Bundesnetzagentur (2008) Monitoring 2008.

implementing rules that control and standardize the switching process. Furthermore, the Regulators must be sensitive to customers' and competitors' complaints.

Considering the *distribution charges* and the impact of vertical integration, we confirm the results reported by Kwoka (2005) and by Growitsch et al. (2009)[23], showing *economies of scale* in distribution network. We find that a marginal increase in the number of meter points (and total distributed electricity) marginally decreases distribution charges for household customers. The vertical structure and regulatory unbundling options, among others, are also used to examine the factors that determine the distribution charges. While we have expected a positive effect of vertical integration on distribution charges due to potential *economies of scope* (retail activity and distribution), we find no support for this argument.[24] In contrast, in markets with voluntarily legally unbundled electricity providers we find significantly higher distribution charges compared to markets with fully integrated or ownership-unbundled providers. This result provides evidence that potential economies of scope do not decrease distribution charges. The implications are: 1) vertical integration indeed does not provide economies of scope, thus, distribution charges remain unaffected regardless of the vertical structure, and 2) the regulator is not perfectly informed about actual costs. Consequently, if economies of scope in fact exist, this outcome indicates raising rivals' costs, according to Vickers (1995).

> "Economies of scale [scope] are frequently cited as the major reason to allow shared services and sharing of personnel. In 80% of responding countries, shared services, i.e. services performed by the integrated company for the DSO, are permitted and regulators have access to the underlying contracts. However, in about 4 out of 5 [European] Member States it has not been demonstrated that sharing services leads to lowering costs. It might be interesting for regulators to investigate this area in order to have a clear idea on the benefits of shared services." [25].

[23] See also Filipini (1996) and Piacenza et al. (2009).
[24] A limitation of the study is that we only consider distribution charges for household customers and disregard distribution charges for industrial customers with real-time.
[25] European Energy Regulators (ERGEG), 2009 p.9. In this status report of ERGEG, economies of scale are defined as synergies that arise from sharing services between retail activities and electricity distribution. However, we define these synergies as economies of scope, because retail and distribution are entirely different "products".

According to responses to the European Energy Regulators [ERGEG (2009)] questionnaire, common shared services are IT, legal services, communication, human resources, accounting, and financial services. However, sharing services apparently does not lead to economies of scope. Observing our estimation results, we recommend quantifying potential economies of scope that arise from shared services. Similarly, ERGEG (2009) argues that "shared services could lead to cross-subsidization and indicates the need to further investigate this issue."[26]

In line with our previous study (Nikogosian and Veith, 2011) we find a significant impact of distribution charges on standard contract prices. The extension to the incumbent's low-price competitive contract and competitors' contracts shows also a significant impact of distribution charges on competitive prices. Comparing the size of distribution charges across the four high voltage zones, we find the highest distribution charges in the Vattenfall area in east Germany. The significant deviation is mainly caused by higher depreciation rates due to network investments during the 1990s.

We find no significant effect of the number of ultimate owners-measure on prices and distribution charge. Considering the outcome for variables representing the demand side in submarkets, we find that lowest-priced-contract prices are higher in regions with a higher *purchasing power*. However, the effect is negligibly small. Furthermore, there is no significant effect on the standard contract price induced by purchasing power. In markets with a higher *population* higher price for standard contract are found. Also in this case the coefficient is close to zero.

As we also consider the number of competitors in distinct markets (in specification B), the results show a significant impact of the number of competitors on market prices. Surprisingly, the effects are opposite for the incumbents and competitors. That is, the competitors' prices for the lowest-priced-contract are negatively affected by the number of competitors, whereas the incumbents' prices increase with the number of competitors.

VII. Concluding Remarks

We consider the impact of vertical relations on retail and distribution prices in the German electricity sector. According to a recent research, price regulation of an input product in a market with upstream monopolist can only partially prevent discrimination of downstream

[26] ERGEG, 2009 p.15

competitors. In a theoretical model, we show that upstream monopolist with regulated distributed charges prices could use non-price discrimination to increase competitors' marginal costs or to decrease their demand and, thus, affect downstream prices. Legal unbundling is brought forward in political debates as well as in the literature as a regulatory option to prevent non-price discriminatory behavior. Such a regulation could be advantageous because it is less restrictive than ownership unbundling or total separation. However, we show that a lax implementation of legal unbundling can still provide incentives for non-price discrimination.

We test the findings of our theoretical model using firm level data for nearly 600 regional German electricity markets for household customers. We find significant differences in the retail pricing behavior of incumbents based on alternative vertical ownership structures. In markets with fully separated incumbents (equal to ownership unbundling), retail prices for incumbents' contracts are lower than in markets with fully integrated incumbents. Furthermore, we find no evidence for legal unbundling being the preferable regulatory instrument, because prices in markets with legally unbundled firms do not differ from prices in markets with vertically integrated firms. These results show that legal unbundling might not work perfectly because firms could circumvent the rules that ensure independence. To prevent non-price discrimination stricter regulation of legally unbundled incumbents can be implemented.

One shortcoming of our study is that we only focus on pricing aspects in our analysis. In particular, we do not consider any costs or investment aspects which have been brought forward in a range of theoretical articles. Nevertheless, our results provide empirical indications about the role of alternative forms of vertical unbundling regulation and their impact on downstream competition.

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Appendix A

Table 1: Descriptive Statistics

Variable		Observations	Mean	Std. Dev.	Min	Max
lowest price without prepayment)		572	754.67	26.54	617.88	824.00
lowest incum. price		572	832.18	40.07	680.00	958.44
standard contr. price		572	876.70	42.33	734.60	999.61
Legally Unbundled	Required Legal Unbundling	572	0.07	0.26	0	1
	Voluntary Legal Unbundling	572	0.09	0.29	0	1
Ownership unbundled		572	0.06	0.24	0	1
number of competitors		572	43.83	6.49	12	73
distribution charge		572	228.39	30.01	149.71	314.20
population		572	92407.43	279465.50	947	3410000
purchasing power		572	104.59	81.93	0.24	490.90
population/area		572	2257.82	2202.05	2.97	33220.43
meter points		572	52215.05	164800.10	3	2322236
number of owner of retail incumbent		572	5.46	7.88	1	61
number of owner of DSO		572	5.60	7.87	1	61
hv zone EnBW		572	0.14	0.35	0	1
hv zone TenneT		572	0.41	0.49	0	1
hv zone RWE		572	0.24	0.43	0	1
hv zone Vattenfall		572	0.18	0.39	0	1

Table 2: Estimation Results

A) Estimation without the number of competitors					
Prices without prepayment		1) **log lowest price)**	2) **log lowest incum. price)**	3) **log standard contr. price)**	4) **log distribution charge)**
Legally Unbundled	Required Legal Unbundling	0.008 0.007)	0.012 0.009)	0.001 0.009)	-0.029 0.021)
	Voluntary Legal Unbundling	-0.008 0.006)	0.005 0.007)	0.007 0.007)	**0.031*** 0.017)
Ownership unbundled		-0.002 0.007)	**-0.018**** 0.008)	**-0.014*** 0.008)	0.002 0.020)
Log(distribution charge)		**0.357***** 0.026)	**0.276***** 0.036)	**0.249***** 0.036)	
Log(population)		0.000 0.001)	-0.000 0.002)	**0.006***** 0.002)	
Log(purchasing power)		**0.004**** 0.002)	0.001 0.003)	-0.004 0.003)	
Log(# of owner of retail incumbent)			**0.006***** 0.002)	**0.009***** 0.002)	
Log(# of owner of DSO)					**0.007**** 0.003)
log (population/area)					-0.006 0.004)
log (meter points)					**-0.015***** 0.003)
hv zone EnBW					-0.006 0.023)
hv zone TenneT					0.011 0.022)
hv zone RWE					0.031 0.022)
hv zone Vattenfall					**0.162***** 0.024)
Constant		4.668*** 0.150)	5.215*** 0.203)	5.373*** 0.203)	5.556*** 0.042)
Observations		572	572	572	572

*** p<0.01, ** p<0.05, * p<0.1

B) Estimation including the number of competitors					
Prices without prepayment		1) **log lowest price)**	2) **log lowest incum. price)**	3) **log standard contr. price)**	4) **log distribution charge)**
Legally Unbundled	Required Legal Unbundling	0.009 0.007)	0.012 0.009)	-0.000 0.009)	-0.030 0.021)
	Voluntary Legal Unbundling	**-0.009*** 0.006)	0.006 0.007)	0.009 0.007)	**0.031*** 0.017)
Ownership unbundled		-0.003 0.007)	**-0.017**** **0.008)**	-0.012 0.008)	0.003 0.020)
Log(# competitors)		**-0.022***** 0.008)	**0.019*** 0.012)	**0.054***** 0.012)	
Log(distribution charge)		**0.358***** 0.026)	**0.289***** 0.036)	**0.282***** 0.036)	
Log(population)		0.001 0.001)	-0.000 0.002)	**0.005***** 0.002)	
Log(purchasing power)		**0.003*** 0.002)	0.002 0.003)	-0.001 0.003)	
Log(# of owner of retail incumbent)			**0.005***** 0.002)	**0.008***** 0.002)	
Log(# of owner of DSO)					**0.007**** 0.003)
Log(population/area)					-0.005 0.004)
Log(meter points)					**-0.015***** 0.003)
hv zone EnBW					0.005 0.023)
hv zone TenneT					0.008 0.022)
hv zone RWE					0.027 0.022)
hv zone Vattenfall					**0.162***** 0.024)
Constant		4.747*** 0.157)	5.071*** 0.218)	4.981*** 0.217)	5.554*** 0.042)
Observations		572	572	572	572

*** p<0.01, ** p<0.05, * p<0.1

Appendix B

Mathematical Derivations

Equilibrium Prices

Incumbent's profit in case of vertical integration is composed of downstream profit and upstream profit and is given by:

$$\pi_I = (p_I - c_I - c_u) D_I + (d - c_u) D_E - C(s_c, s_d)$$

The demand for one contract offered by incumbent is characterized by the marginal consumer who is willing to buy the contract from the incumbent:

$$D_I = \frac{p_E - p_I + \tau_E}{\tau_I + \tau_E}$$

The demand for the competitor is given by:

$$D_E = 1 + \frac{p_I - p_E - \tau_E}{\tau_I + \tau_E}$$

Given this information we can calculate the equilibrium prices:

$$p_I^* = \frac{1}{3}(3b + 2c_I + c_E + s_c + \tau_I + 2\tau_E)$$

$$p_E^* = \frac{1}{3}(3b + c_I + 2c_E + 2s_c + 2\tau_I + \tau_E)$$

and the profit function before choosing the sabotage strategy:

$$\pi_I^* = \frac{1}{3}\left(\frac{(b - c_u)(c_I - c_E - s_c + 2\tau_I + \tau_E)}{\tau_I + \tau_E} + \frac{(c_E - c_I + s_c + \tau_I + 2\tau_E)(3b + c_E - c_I - 3c_u + s_c + \tau_I + 2\tau_E)}{3(\tau_I + \tau_E)}\right) - C[s_c, s_e]$$

Comparative Statics

Lemma 2 is derived from the derivates of equilibrium prices and equilibrium demand with respect to demand-decreasing sabotage in the last stage i.e. before the sabotage strategy is chosen):

$$\frac{\partial p_E^*}{\partial s_d} = \frac{1}{3}\left(2\frac{\partial \tau_I}{\partial s_d} + \frac{\partial \tau_E}{\partial s_d}\right)$$

$$\frac{\partial p_I^*}{\partial s_d} = \frac{1}{3}\left(\frac{\partial \tau_I}{\partial s_d} + 2\frac{\partial \tau_E}{\partial s_d}\right)$$

a. Demand-decreasing sabotage increases incumbent's downstream price and, at the same time, decreases competitor' downstream price given that our assumptions hold and if $\left|\frac{1}{2}\frac{\partial \tau_I}{\partial s_d}\right| < \left|\frac{\partial \tau_E}{\partial s_d}\right| < \left|2\frac{\partial \tau_I}{\partial s_d}\right|$.

b. increases both equilibrium downstream prices given that our assumptions hold and if $\left|\frac{\partial \tau_E}{\partial s_d}\right| > \left|2\frac{\partial \tau_I}{\partial s_d}\right|$, i.e. competitor's price is very sensitive to changes in own transportation cost compared to the effect on incumbent's transportation cost,
c. vice versa, decreases both equilibrium downstream prices given that our assumptions hold and if $\left|\frac{\partial \tau_E}{\partial s_d}\right| < \left|\frac{1}{2}\frac{\partial \tau_I}{\partial s_d}\right|$,

$$\frac{dD_E^*}{ds_d} = \frac{(c_E - c_I + s_c + \tau_E)\frac{\partial \tau_I}{\partial s_d} + (c_E - c_I + s_c - \tau_I)\frac{\partial \tau_E}{\partial s_d}}{3(\tau_I + \tau_E)^2} = -\frac{dD_I^*}{ds_d}$$

a. Demand-reducing sabotage increases incumbent's equilibrium demand $\frac{dD_I^*}{ds_d} > 0$ and decreases competitor's equilibrium demand $\frac{dD_E^*}{ds_d} < 0$ given that our assumptions hold and $(c_I - c_E - s_c + \tau_I)\frac{\partial \tau_E}{\partial s_d} > (c_E - c_I + s_c + \tau_E)\frac{\partial \tau_I}{\partial s_d}$. This inequality is true when the companies are comparably efficient, $c_d \approx c_e$, and incumbent's transportation cost is lower than the competitor's sabotage cost, $\tau_I \geq s_c$.