On Vertical Integration, Regulation and Non-Price Discrimination in German Electricity Markets

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I. Introduction

Vertical separation is a key issue in European energy markets, in particular since the DG Competition has initiated a sector inquiry in 2005. While the European Commission (EC) argues that vertical separation of electricity networks from other activities (such as production and retail) increases consumer surplus,1 opponents argue that vertical integration enables cost savings due to economies of scope.2 In a number of speeches, former European Competition Commissioner Kroes provides mainly three reasons why a disadvantage of vertical integration in energy markets exists for retail customers: (1) market concentration, (2) lack of cross-border integration and (3) insufficient unbundling of network and supply activities.3 Following Haucap (2007), the first two concerns focus on national market situations and international competition, whereas the last “already addresses a potential policy solution (unbundling) and the lack of its implementation”.4 The common tenor of a multiplicity of recent studies on vertical integration is that unbundling reduces a grid owner’s incentive to discriminate between own units and competitors (Höffler and Kranz, 2007; Pollitt, 2007; Davies and Waddams Price, 2007; Haucap, 2007).

A large number of literature provides policy recommendations derived either from case study approaches or based on theoretical modelling which addresses the unbundling issue. Nevertheless, only a very small number of papers provide evidence from an econometrical perspective by considering separation of transmission network.5 We want to take up this

3 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.”
4 Haucap (2007), p. 302
5 E.g. Steiner (2001) and Hattori & Tsuitsui (2001) empirically examine the effects of unbundling the transmission grid. Nillesen and Pollitt (2008) are the only ones to study effects of unbundling that was implemented in New Zealand for distribution grids.
challenge by analysing 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 and distribution markets. As the vertical structure is heterogeneous across the 850 German submarkets for household customers (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. We focus on the distribution networks, since ownership unbundling of the distribution networks from other activities – in contrast to ownership unbundling of the transmission network – has received little attention in economic studies so far.\(^6\)

In retail energy markets downstream incumbents which are vertically integrated with network operators might have an incentive to favour its 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, which are difficult to detect for the regulator. Such a discriminatory behaviour 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 new energy providers and consider how alternative vertical structures affect retail prices and distribution charges. Using a simultaneous equations approach, we find significantly lower prices in markets with fully separated firms compared to markets with vertical integrated or legally unbundled firms.

II. The German Electricity Sector

Electricity sector consists of the five layers generation, wholesale, transmission, distribution and retail. In Germany, four electricity producers, EnBW, E.on, 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 in the hands of local producers (which are mainly also retailers) or foreign companies. Usually, capacities owned by small retailers 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, the Vattenfall area covers Eastern Germany, the RWE region is in Western Germany and covers mainly the territory of Nord-Rhine Westphalia and Rhineland Palatinate. The remaining territory, which stretches from Northern Germany to Bavaria, belongs to TenneT.\(^7\)

\(^{6}\) For instance: Copenhagen Economics (2005) estimated unbundling effects on prices and productivities for 15 European countries (in 1990-2003) with the results that unbundling transmission from generation leads to lower prices and higher productivities. Unfortunately, effects of unbundling of distribution network could not be estimated due to invariance in the timing of distribution unbundling between the EU-15 countries. A recently published report (2009) on behalf the German Federal Ministry for Environment (BMU) favors the ownership separation of the transmission network: http://www.bmu.de/files/pdfs/allgemein/application/pdf/gutachten_energieuebertragungsnetze.pdf

\(^{7}\) E.on sold the transmission grid in this territory to TenneT in 2010.
In contrast, the distribution layer covers more than 850 geographically separated markets. According to the German Competition Authority (Bundeskartellamt), these are the relevant markets in case of market investigations. The markets differ in distribution areas and in electricity demand. There is only one distribution network operator in each of these markets. Figure 2 provides an overview over the German distribution markets.

In general, vertical integration allows for price and non-price discrimination of competitors. Therefore, in line with the 2005 Energy Act (EnWG), the German regulatory agency (NRA) 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, it has to pay the local distribution charge of the customer’s market. Besides distribution charge regulation, the Energy Act requires the legal separation of grid operators from other activities such as generation and retail, aiming to prevent non-price discrimination. A distinction is made between the following types of vertical separation/integration **Legal unbundling** describes the functional separation of the distribution network operators (DSOs) and other activities in terms of management, information flows and accounting. Since 2007, grid operators with more than 100,000 customers (in terms of tapping points) are obliged to separate their grid operating activity from retail and production units by creating a new legal entity. Operators which have not reached this threshold level of customers need not separate upstream from downstream activities and are, thus, allowed to remain **vertically integrated**. In contrast, **ownership unbundling (full separation)** requires ownership independence of producers, grid operators and retail providers. However, this stricter regulation type has not been implemented in EU member states. About 20 percent of the 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 “fall-back” option for those 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 deleted and customers have not decided where to switch (§§ 36 – 38, Energiewirtschaftsgesetz (EnWG)). This means that after the market liberalization, 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 standard contract which is in general a higher price 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 34 percent of customers chose an alternative incumbent contract, whereas the rest turned to alternative suppliers. Thus, incumbents’ still have high market share after the liberalization.

### III. Related Literature

A large number of theoretical studies consider vertical integration of an upstream monopolist offering an essential input to a competitive downstream market. Without any regulation, the upstream monopolist favours its own downstream unit either with price-privileges or quality-privileges. Including upstream price regulation into these models, non-price discrimination becomes an issue as the upstream provider seeks new approaches to benefit its downstream unit over its competitors. In contrast to price discrimination, “sabotage” is an alternative strategy to influence competitors’ downstream costs which could hardly be detected and legally prohibited (Economides, 1998; Beard et al., 2001). The literature on non-price discrimination differentiates between alternative approaches, e.g. raising rivals’ costs or reducing rivals’ quality.

Vickers (1995) analyzes welfare effects of vertical integration by assuming a regulated upstream monopolist which is the provider of an essential facility being integrated with a downstream company in a competitive retail market. He assumes the regulator to be imperfectly informed about upstream costs, which allows the upstream monopolist to select its wholesale price from a set of prices. Following Vickers’ analysis, regulation hampers upstream price adjustments to affect downstream competition. However, due to information asymmetries, regulation cannot completely absorb discrimination incentive. Sappington
(2006) extends Vickers’ setup by including economies of scope and sabotage (non-price discrimination) and confirms Vickers’ results concerning higher retail prices due to vertical integration. He shows that the link between higher retail prices and vertical integration depends on the level of relative cost efficiencies among downstream competitors and the level of economies of scope which could be passed on to customers. 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.8

Mandy and Sappington (2006) consider an alternative approach where the upstream provider is able to influence the demand for the downstream rivals’ products by reducing its 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.

With a focus on network industries, the literature provides alternative regulatory approaches to overcome the challenge of vertical integration and discrimination by the provider of the essential downstream input. Legal unbundling as an intermediate approach between ownership unbundling and vertical integration describes a particular type of separation in network-based markets where the grid unit and the retail unit are operated by de iure independent managements deciding on prices and investments. Cremer et al. (2006) and also 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, Höfler and Kranz (2007a) compare the effects of legal unbundling, ownership unbundling and vertical integration. They find lower retail prices with (perfect) legal unbundling than with ownership unbundling and vertical integration. As a legally separated, price-regulated network operator maximizes only its own profit by maximizing the upstream output, there is no incentive to discriminate between downstream competitors. Thus, retail prices are lower than under vertical integration. By assuming informal interdependence between the legally unbundled upstream and downstream unit, Höfler and Kranz (2007b) show that discrimination might again occur. If the regulator employs stricter regulatory rules to separate the upstream from the downstream (and the adequate adoption), the outcome leans towards the outcome of perfect legal unbundling.

In a nutshell, the literature provides a broad range of theoretical evidence how vertical integration can affect retail prices. The consideration of legal unbundling as an intermediate approach between ownership unbundling and vertical integration has highlighted some alternative approaches to alleviate the discrimination challenge of vertical integration. As mentioned above, in the liberalized electricity market, non-price discrimination could be delaying customers’ switching activity from the integrated downstream operator to a downstream competitor. Alternatively, a grid operator could deter information about grid characteristics and customer characteristics.

IV. 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

8 Other studies on non-price discrimination with Cournot competition e.g. Crew et al., 2005; Economides, 1998; and Bertrand competition: Beard et al., 2001; Sappington, 2006; Weisman, 1995.
equilibrium in the theoretical model but rather analyze incentives to sabotage and the impact on retail prices. We compare alternative types of non-price discrimination with alternative forms of vertical integration.

a. Vertical Integration

Consider a Hotelling game with uniformly distributed potential customers and two firms located at either end of a line.\(^9\) Firms offer differentiated products which means electricity contracts with a given amount of electricity demand per contract. It is reasonable to assume that firms compete with differentiated contracts since, at least in Germany, the electricity price is not the only factor on which consumers decide. Consumers’ preference for a particular firm is crucial. Furthermore, we assume that the incumbent, located at 0, is vertically integrated with the distribution system operator (DSO) which provides a common input, “access” to the distribution grid, at a cost-based regulated per-unit price \(b\), the so-called 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 \(x\) \(\in [0,1]\) 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 \(\tau_i\), and \(\tau_E\) 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:

\[
U(x) = \begin{cases} 
  v - p_i - \tau_i x & \text{if the customer buys from the incumbent} \\
  v - p_E - \tau_E (1-x) & \text{otherwise.}
\end{cases}
\]

As the distribution charge is regulated, the DSO might be interested in favouring 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, \(s_d\), discriminations. Cost-increasing discrimination might be 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 incumbent but decrease 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,

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

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:

\(\text{9 We assume the market demand to be highly price-inelastic in the short run.}\)
\[ D_i = x_i = \frac{p_E - p_I + \tau_E}{\tau_j + \tau_E}. \]

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

The entrant’s, the incumbent’s downstream unit and the incumbent’s upstream unit profit functions \( \pi_E, \pi_{ID} \) and \( \pi_{IU} \) are given as follows:

\[
\begin{align*}
\pi_E &= (p_E - c_E - b - s_c) D_E \\
\pi_I &= \pi_{ID} + \pi_{IU} \quad \text{with} \\
\pi_{ID} &= (p_I - c_I - b) D_I \\
\pi_{IU} &= (b - c_u)(D_E + D_I) - C(s_c, s_d) ,
\end{align*}
\]

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 units engage in Bertrand competition.

Before starting with the analysis of vertical integration, we consider the outcome in the case of total separation as this is our reference structure. In this situation the DSO has no incentives to discriminate. As each firm in our setting maximizes own profits, the profit of the DSO is maximized without engaging in non-price discrimination, since 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.

Let us begin with vertical integration where the incumbent maximizes its total profits, that is \( \max(\pi_{ID} + \pi_{IU}) \). By backward induction, we get the best reply functions:

\[
\begin{align*}
p_i^* &= \frac{1}{2}(b + c_i + p_E + \tau_E) \quad \text{and} \quad p_E^* = \frac{1}{2}(b + c_E + s_c + p_I + \tau_I) .
\end{align*}
\]

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 & Sappington (2006).

Lemma 1:

(i) Cost-increasing discrimination raises the equilibrium downstream prices. The competitor’s price rises more than the incumbent’s price, \( \frac{\partial p_E^*}{\partial s_c} = \frac{2}{3}, \frac{\partial p_i^*}{\partial s_i} = \frac{1}{3} \).
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 induces the competitor to choose a higher price than without discrimination, the competitor loses a fraction of its customers. These customers turn to the incumbent which 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 
\[
\left| \frac{1}{2} \frac{\partial \tau_i}{\partial s_d} \right| < \left| \frac{\partial \tau_E}{\partial s_d} \right| < \left| 2 \frac{\partial \tau_i}{\partial s_d} \right|.
\]
(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, 
\[
c_d = c_e,
\]
and the impact of demand-decreasing discrimination on the competitor’s transportation costs is larger than the impact on the incumbent’s transportation costs, 
\[
\left| \frac{\partial \tau_i}{\partial s_d} \right| > \left| \frac{\partial \tau_i}{\partial s_d} \right|.
\]
With these additional assumptions, the incumbent’s price increases with demand-decreasing discrimination (Lemma 2 (i)).

Following 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 grid unit, cost-increasing discrimination decreases the competitor’s quantity and, thus, the incumbent’s upstream profit. In consequence, the incumbent reaches the optimum discrimination level in the last stage with 
\[
\pi_{ID}'(s_c') + \pi_{IU}'(s_c') = 0,
\]
i.e. where the marginal revenues of discrimination equal its marginal costs. If price regulation is implemented in a very strict way which means 
\[
b(c_u) \approx c_u,
\]
the incumbent neglects the discrimination effect on upstream profits and, therefore, prefers cost-increasing discrimination over non-discrimination as 
\[
\pi_{I}(s_c') \geq \pi_{I}(0).
\]
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. Furthermore, the optimal discrimination level in the last stage is determined by 
\[
\pi_{ID}'(s_d') + \pi_{IU}'(s_d') = 0
\]
and therefore, 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 raises as long as its marginal revenue exceeds the marginal costs of sabotage. In contrast, the competitor tries to keep his 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, have to consider the joint outcome in the next step. The previous findings, \( \pi_i(s_e^*) \geq \pi_i(0) \) 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 derivatives of an incumbent’s equilibrium demand with respect to \( s_d \) and \( s_e \) are positive without additional assumptions. However, introducing demand-decreasing and cost-increasing discrimination simultaneously, total partial derivatives of the incumbent’s profit with respect to \( s_d \) and \( s_e \) become mutually dependent. The mutually dependence appears when we consider the second derivatives for demand effects due to sabotage, so that, given our assumptions, these are negative \( \frac{d^2 D_i}{ds_d s_e} > 0 \). In contrast, the mutual impact of demand-decreasing and cost-increasing discrimination on the incumbent’s profit is positive, since \( \frac{d^2 \pi_i}{ds_d s_e} = \frac{d^2 \pi_i}{ds_s s_d} < 0 \).

Employing both types of discrimination, the boundary condition \( \tau_i \geq s_e \) is reached faster than with singular discrimination as demand-decreasing discrimination reduces \( \tau_i \) and cost-increasing sabotage raises \( s_e \). 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 the further intermediate results we know that also \( \pi_i(s_e^*, s_d^*) \geq \pi_i(0,0) \) holds as long as \( \tau_i \geq s_e \), i.e. employing the optimum combination of both types of discrimination results in a higher total profit than no discrimination.

Proposition 1: With \( \pi_i(s_e^*) \geq \pi_i(0), \pi_i(s_d^*) \geq \pi_i(0) \) and \( \pi_i(s_e^*, s_d^*) \geq \pi_i(0,0) \), non-price discrimination can be a preferable strategy for the incumbent.

The discussion in line with Proposition 1 provides theoretical evidence that the incumbent’s price is lower without non-price discrimination independent of the discrimination strategy. On the other hand, the competitor’s price choice depends on the magnitude of demand-decreasing discrimination and customers’ loyalty, i.e. the transportation costs.

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

b. Legal unbundling

Let us next turn to legal unbundling. We adopt the ideas of Cremer et al. (2006) and Höffler and Kranz (2007a) and assume that the legally unbundled grid operator considers only its grid activity and maximizes the upstream profit,
\[ \pi_{IU} = (b - c_u)(D_E + D_I) - C(s_e, s_d), \]
whereas the downstream incumbent maximizes overall profit. With perfect legal unbundling the overall profit is given by:
\[ \pi_I = \pi_{ID} + \pi_{IU} = (p_l - c_l - b) D_I + ((b - c_u)(D_E + D_I) - C(s_e, s_d)) \]

As distribution charges are regulated, the only way to affect downstream competition is by changing the firms’ demand and retail prices. However, the grid operator earns the same profit independently of downstream market shares since the total market demand is constant. Therefore, discrimination only negatively affects the DSO’s profit and – with perfect legal unbundling – the grid operator has no incentive to discriminate. This outcome strongly corresponds to the findings of Höffler and Kranz (2007a).

In the next step, it is thus necessary to 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
\[ p_I^* = \frac{1}{3}(3b + s_e + \tau_I + 2\tau_e). \]

**Proposition 2:** With **perfect** legal unbundling, the grid operator maximizes its upstream profit. No incentives for discrimination exist and, therefore, \( S^*(0,0) \) is the equilibrium strategy.

**Hypothesis 2:** **Perfect** 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 dependence of the retail incumbent, the grid operator ignores the downstream effect of its strategic decisions and, thus, has no incentive to act in favour 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. To create such a relation, the retail incumbent needs a sufficient ownership share of the grid operator to exert power (e.g. more than 50 percent). In case of lower shares, conflicts of interests 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 which initiate higher retail prices than with total separation. The incentives increase in ownership fraction.12

**V. Empirical analysis**

We have shown in the previous section that, on the one hand, different types of non-price discrimination are profitable from a theoretical point of view and, on the other hand, 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 only able to analyze price differences for electricity contracts in

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11 See the example for imperfect legal unbundling in the appendix XI.
12 Hypothesis 3 is based on the proposition 3 derived in appendix XI for imperfect legal unbundling.
markets with different vertical structures, when controlling for market and demand characteristics.

Data Sources
We use data from multiple sources to cover the vertical ownership structure, retail prices, distribution charges and customer characteristics. We employ a cross-sectional approach using information as of August 2008 which is aggregated on the distribution grid level. Quantity and price data are selected for an average household consumption level of 4000 kWh per year (3 to 4 persons).

Ownership information is provided by Creditreform, the largest German wholesale commercial credit agency. Price and contract information aggregated on 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. Aggregated information about customer characteristics are taken from the Acxiom database.

Data Adjustments
Because of the particular aggregation level of consideration, we have adjusted our data set to the grid level.

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 also 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.

Total ownership of a grid owner by an electricity provider and vice versa are calculated independently of the number of intermediate owners and of other owners on a higher ownership level. While the link between any grid owner and any electricity provider is undeterred with this approach, it has to be kept in mind that the information for higher level owners might be deterred due to the consideration of a spot of the whole ownership structure. Please 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 fix part, the sum of a fix 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.

Grid regions are not identical with zip code regions, the level of customer information. Moreover, they range over multiple zip code regions and adjoin each other within zip code regions. As customer information covers all regional markets we calculate weights using 3- and-more-person households for the aggregation of customer information to the grid level as they are the corresponding level of consideration in this study.

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13 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.
14 We appreciate inexhaustible support by our colleague Thorsten Doherr.
15 There is a magnitude of approaches of how to calculate ownership shares if one considers more than the first level. Our calculation is based on the actual share values due to even more complex calculation requirements with additional threshold requirements.
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 regionally separated electricity 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 tapping 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 voluntary legal unbundling. We consider the cases with partial ownership, as voluntary separated, since partial ownership indicates that firms chose 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 tapping 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 tapping 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 are voluntary 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 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 estimation.

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.

VI. 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 cannot fully specify the explanatory equations. However, this latent information might have an effect both on distribution charges and retail prices as described in the theoretical model. We employ a structural estimation approach where the distribution charge enters the standard contract price equation, the incumbent’s most competitive contract price equation and the competitors’ lowest price equation. Ownership variables are used as explanatory variables for both the distribution charge equation and the price equations.
We therefore end up with the following specification:

---

16 Note that voluntary ‘legal unbundling’ is not the same as required ‘legal unbundling’ since in case of voluntary separation, the firms are not obliged to separate the information flows and management.
\[
\log(dc_i) = \text{ownervec}_i \cdot \beta_{dc}^{\text{owners}} + \text{grid characteristics}_i \cdot \beta_{dc}^{\text{grid}} + \text{reg. characteristics}_i \cdot \beta_{dc}^{\text{region}} + \alpha_i^{dc} + \varepsilon_i^{dc}
\]

\[
\log(price_i^\text{ut}) = \text{ownervec}_i \cdot \beta_{ut}^{\text{owners}} + \text{reg. characteristics}_i \cdot \beta_{ut}^{\text{region}} + \beta^{\text{ut}}_i \log(dc_i) + \alpha_i^{ut} + \varepsilon_i^{ut}
\]

\[
\log(price_i^{\text{allow}}) = \text{ownervec}_i \cdot \beta_{allow}^{\text{owners}} + \text{reg. characteristics}_i \cdot \beta_{allow}^{\text{region}} + \beta^{\text{allow}}_i \log(dc_i) + \alpha_i^{allow} + \varepsilon_i^{allow}
\]

\[
\log(price_i^{\text{lowest}}) = \text{ownervec}_i \cdot \beta_{lowest}^{\text{owners}} + \text{reg. characteristics}_i \cdot \beta_{lowest}^{\text{region}} + \beta^{\text{lowest}}_i \log(dc_i) + \alpha_i^{lowest} + \varepsilon_i^{lowest}
\]

We include control variables for grid characteristics and regional characteristics into the distribution charge equation and control variables to characterize regional 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 highly correlated, we consider only the number of tapping 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.\(^{17}\)

Furthermore, we distinguish contracts with and without prepayments, i.e. contracts which have 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.

VII. 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 with vertical separation of the monopolistic upstream provider. The empirical results support the 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

\(^{17}\) We use also the share of voluntarily legally unbundled firms to analyze whether the pricing behavior 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, thus, we do not report the estimation results in the paper.
average higher than in markets with fully separated incumbents. Nevertheless, the prices for lowest-price-contracts of competitors in markets with integrated incumbents do not differ from prices in markets with total separation. However, observing these estimation results, it might 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 since we find no evidence for legal unbundling to be favourable for customers’ surplus. The prices for the standard contract and for incumbents’ low-price competitive contracts are not affected by any regulative unbundling options. 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 has been shown in our theoretical model. The German regulator and the Monopolies Commission also complain about the insufficient realization of operational separation of network activities. In addition, the results show that also 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 since we do not observe any difference in prices between legal unbundling and vertical integration. However, the ownership share has no impact on pricing behaviour. These findings indicate that legal unbundling does not work perfectly.

Considering the distribution charges and the impact of vertical integration, we confirm the results reported by Kwoka (2005) or by Growitsch et al. (2009), showing **economies of scale** in distribution network. We find that a marginal increase in the number of tapping 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.

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. 2) the regulator is not perfectly informed about actual costs.

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18 In specification B (estimation including the number of competitor) 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.

19 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.

20 See also Monopolkommission (2009) p. 94 and Bundesnetzagentur (2008) Monitoring 2008 and the theoretical model shown in the appendix XI.

21 See also Filipini (1996) and Piacenza et al. (2009).

22 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.
Compendiously, 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.”

According to responses to the ERGEG (2009) questionnaire, common shared services are IT, legal services, communication, and 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.”

In line with our previous study (Nikogosian & Veith 2009), 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-price-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. Nevertheless 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 opposed for the incumbents and competitors. That is, the price for the lowest-price-contract is negatively affected by the number of competitors, whereas incumbent’s prices increase with the number of competitors.

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23 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, since retail and distribution are entirely different “products”.

24 ERGEG 2009 p.15
VIII. Concluding Remarks

We consider the impact of vertical relations on retail and distribution prices in the German electricity sector. According to a recent strand of literature, standard wholesale price regulation in markets with an essential input can hamper the influence of the input provider on downstream competition. In a theoretical model, we show that upstream monopolists could use non-price discrimination with regulated wholesale prices (distribution charges) to increase competitors’ marginal costs or to decrease their demand and, thus, to 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 behaviour. Such a regulation is less restrictive than ownership unbundling and, thus, could be advantageous. However, we show that a less restrictive implementation of legal unbundling can still provide incentives for non-price discrimination.

We test the findings of our theoretical model using data for nearly 600 regional German electricity markets and find central differences in the retail pricing behaviour 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. However, we find no evidence for legal unbundling being the preferable regulatory instrument, since prices in markets with legally unbundled firms do not differ from prices in markets with vertically integrated firms. These results partially underline the findings of our theoretical model that legal separation might not work perfectly since firms might elude the rules that ensure independence. In consequence, our results raise the question whether legal unbundling, as it is implemented in European electricity markets, meets the aims originally intended for this regulatory instrument.

However, it should not be ignored that we only focus on pricing aspects in our analysis. In particular, we cannot consider any costs or investment aspects which have been brought forward in a range of theoretical papers due to missing data. Nevertheless, our results provide a first empirical indication about the role of alternative forms of ownership unbundling regulations and their impact on downstream competition.
References:


Appendix

Table 1: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observations</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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<td>lowest price (without prepayment)</td>
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<td>26.54</td>
<td>617.88</td>
<td>824.00</td>
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<tr>
<td>lowest incum. price</td>
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<td>832.18</td>
<td>40.07</td>
<td>680.00</td>
<td>958.44</td>
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<tr>
<td>standard contr. price</td>
<td>572</td>
<td>876.70</td>
<td>42.33</td>
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<td>0.26</td>
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<td>1</td>
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<td>0.29</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
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<td>3410000</td>
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<td>164800.10</td>
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<td>2322236</td>
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<td># of owner of retail incumbent</td>
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<td>7.88</td>
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<td># of owner of DSO</td>
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<td>0.39</td>
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</table>
Table 2: Estimation Results

A) Estimation without the number of competitors

<table>
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<tr>
<th>Prices without prepayment</th>
<th>(1) log (lowest price)</th>
<th>(2) log (lowest incum. price)</th>
<th>(3) log (standard contr. price)</th>
<th>(4) log (distribution charge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Legal Unbundling</td>
<td>0.008</td>
<td>0.012</td>
<td>0.001</td>
<td>-0.029</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Voluntary Legal Unbundling</td>
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<td>0.005</td>
<td>0.007</td>
<td>0.031*</td>
</tr>
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<td>(0.006)</td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Ownership unbundled</td>
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<td>-0.018**</td>
<td>-0.014*</td>
<td>0.002</td>
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<td></td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>log(distribution charge)</td>
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<td>0.276***</td>
<td>0.249***</td>
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</tr>
<tr>
<td></td>
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<td>(0.036)</td>
<td>(0.036)</td>
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<td>log(population)</td>
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<td>0.007</td>
<td>0.006***</td>
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<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.003)</td>
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<td>0.001</td>
<td>-0.004</td>
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<td></td>
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<td>(0.003)</td>
<td>(0.003)</td>
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<tr>
<td>log(# of owner of retail incumbent)</td>
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<td>0.009***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>(0.002)</td>
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</tr>
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</tr>
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*** p<0.01,  ** p<0.05,  * p<0.1
<table>
<thead>
<tr>
<th>Prices without prepayment</th>
<th>(1) log (lowest price)</th>
<th>(2) log (lowest incum. price)</th>
<th>(3) log (standard contr. price)</th>
<th>(4) log (distribution charge)</th>
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</thead>
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<td><strong>Legally Unbundled</strong></td>
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</tr>
<tr>
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<tr>
<td>Voluntary Legal Unbundling</td>
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<td>0.031*</td>
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<td>(0.007)</td>
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<tr>
<td>(0.022)</td>
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<tr>
<td>hv zone Vattenfall</td>
<td>0.162***</td>
<td></td>
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<tr>
<td>(0.024)</td>
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<tr>
<td>Constant</td>
<td>4.747***</td>
<td>5.071***</td>
<td>4.981***</td>
<td>5.554***</td>
</tr>
<tr>
<td>(0.157)</td>
<td>(0.218)</td>
<td>(0.217)</td>
<td>(0.042)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>572</td>
<td>572</td>
<td>572</td>
<td>572</td>
</tr>
</tbody>
</table>

*** p<0.01,  ** p<0.05,  * p<0.1
IX. Unbundling experience from other countries

New Zealand is the first country that has legally implemented ownership separation of electricity distribution from other commercial activities such as generation or retail. The separation was introduced in 1998 after electricity market restructuring in 1992 resulted in no significant retail price reductions. Nillesen and Pollitt (2008) analyze the economic effects of unbundling, employing a dataset between 1995 and 2007, and show that prices for commercial customers decreased whereas household prices increased after the unbundling intervention.25 On the other hand, liberalization 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, Nillesen and Pollitt find significant operational cost reductions. However, they were not passed on to customers in the form of lower distribution charges.

Currently, a political debate is going on in the Netherlands about ownership separation on the distribution level which will be legally implemented in 2011. Nooij and Baarsma (2008) summarize the arguments of a strand of 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 are prohibited. In contrast to this theory-based analysis, Mulder et al. (2005) find only little evidence for a price effect due to vertical separation with a broad cross-country – cross-market analysis of vertical integration strategies.

X. Mathematical Derivations

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 by the contract from the incumbent:

\[ D_I = \frac{P_E - p_i + \tau_E}{\tau_I + \tau_E} \]

The demand for the competitor is then:

\[ D_E = 1 + \frac{p_I - P_E - \tau_E}{\tau_I + \tau_E} \]

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:

---

25 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).
\[
\pi^*_i = \frac{1}{3}(b - c_j)(c_j - c_E - s_c + 2\tau_j + \tau_E)
\]
\[
\tau_j + \tau_E
\]
\[
+ \frac{(c_E - c_j + s_c + \tau_j + 2\tau_E)(3b + c_E - c_j - 3c_u + s_c + \tau_j + 2\tau_E)}{3(\tau_j + \tau_E)} - C[s_c, s_c]
\]

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

\[
\frac{\partial p^*_E}{\partial s_d} = \frac{1}{3}(2 \frac{\partial \tau_j}{\partial s_d} + \frac{\partial \tau_E}{\partial s_d})
\]
\[
\frac{\partial p^*_E}{\partial s_d} = \frac{1}{3}(\frac{\partial \tau_j}{\partial s_d} + 2 \frac{\partial \tau_E}{\partial s_d})
\]

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

b. increases both equilibrium downstream prices given that our assumptions hold and if \(\frac{\partial \tau_E}{\partial s_d} > 2 \frac{\partial \tau_j}{\partial s_d}\), 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
\[
\frac{\partial \tau_E}{\partial s_d} < \frac{1}{2} \frac{\partial \tau_j}{\partial s_d},
\]

\[
\frac{dD^*_E}{ds_d} = \frac{(c_E - c_j + s_c + \tau_j) \frac{\partial \tau_j}{\partial s_d} + (c_E - c_j + s_c - \tau_j) \frac{\partial \tau_E}{\partial s_d}}{3(\tau_j + \tau_E)^2} = - \frac{dD^*_I}{ds_d}
\]

a. Demand-reducing sabotage increases incumbent’s equilibrium demand \(\frac{dD^*_I}{ds_d} > 0\) and decreases competitor’s equilibrium demand \(\frac{dD^*_I}{ds_d} < 0\) given that our assumptions hold and \((c_j - c_E - s_c + \tau_j) \frac{\partial \tau_E}{\partial s_d} > (c_j - c_E + s_c + \tau_j) \frac{\partial \tau_j}{\partial s_d}\).

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, \(\tau_j \geq s_c\).
XI. Imperfect Legal Unbundling

Assuming perfect legal unbundling in our theoretical model in Section IV eliminates the grid operator’s legal dependence of the retail incumbent. Consequently, the grid operator ignores the downstream effect of its strategic decisions and, thus, has 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.

To illustrate how such a manipulation could work, we take this imperfect legal unbundling situation into account by adjusting our model as follows:

Again, assume that the legally unbundled grid operator considers only its grid activity and maximizes the upstream profit, whereas the downstream incumbent fully or partially owns the grid operator, \( \lambda \in [0,1] \), and aims at maximizing the overall profit \( \pi_t = \pi_{ID} + \lambda \pi_{IU} \). A fraction \( \lambda \) of upstream gains is transferred to the downstream incumbent.

Modelling the internal dependence, we assume that the downstream firm owning the network, but forced to legal unbundling, might lease the network to upstream subsidiary by charging a particular leasing rate \( r_u \) which is a function of the network costs. In addition, assume that this leasing rate is also affected by the sabotage strategy of the upstream, \( r_u(c_u, S(s_c, s_d)) \), but in contrast to regular costs that emerge from operating the network, engaging in sabotage in upstream lowers the leasing rate, \( \frac{\partial r_u}{\partial S_j} < 0 \) with \( i = c, d \), and \( r_u \in \left[ r_u(c_u, S(s_c, s_d)), \bar{r}_u(c_u, 0) \right] \).

In contrast, the sabotage strategy of the upstream affiliate, \( S(s_c(r_u), s_d(r_u)) \) depends on the leasing rate \( r_u \) to be paid to parent company. This setting or the internal structure is based on principal-agent problem with the landlord (incumbent) as the principal and the tenant (DSO) as the agent.

In addition, assume that the incumbent first sets the boundaries (or a schedule) for the leasing rate \( r_u \in [\underline{r}_u, \bar{r}_u] \) and afterwards the upstream affiliate chooses the sabotage level and the corresponding leasing rate, respectively. Given our assumptions, this setting enables the incumbent to influence decisions in upstream even though the upstream firm is legally separated. Now, we slightly change the profit functions faced by the upstream subsidiary and the downstream incumbent:

\[
\pi_{IU} = (b - r_u)(D_c + D_d) - C(s_c, s_d) \\
\pi_t = \pi_{ID} + \lambda \pi_{IU} = (p_t - c_t - b)D_t + (r_u - c_u)(D_c + D_d) + \lambda \left( (b - r_u)(D_c + D_d) - C(s_c, s_d) \right)
\]

In the equilibrium the affiliate will always set the sabotage level that corresponds to the lower bound of the leasing rate since the lower the leasing rate, the higher the upstream profit,

\[
\pi_{IU} \left( S^*(s_c(r_u^*), s_d(r_u^*)) = \underline{r}_u, r_u^* = \underline{r}_u \right) > \pi_{IU} \left( \hat{S}(s_c(\hat{r}_u), s_d(\hat{r}_u)) \neq \underline{r}_u, r_u^* \neq \underline{r}_u \right).
\]

Deviation to a lower sabotage level would induce a higher leasing rate and is therefore not the optimal decision.
Without engaging in sabotage the upstream firm receives 0 upstream profits, \( \pi_{iu} \equiv (b - r_u^*)(D_c + D_d) - 0 = 0 \).

In case we have the limit \( \lambda \to 1 \), the incumbent’s overall profit collapses to:
\[
\pi_{id} + \lambda \pi_{iu} = (p_l - c_l - b) D_l + (b - c_i)(D_e + D_f) - C(s_e, s_i),
\]
which is exactly our initial objective profit function. Moreover, in this case \( r_u^* \) acts as a steering tool for upstream affiliate but has no direct impact on upstream profit in incumbent’s objective function.

Proposition 3.: Incentive to sabotage increases in ownership share \( \lambda \) of downstream incumbent on upstream affiliate. The DSO will undertake sabotage since there exist a subgame-perfect equilibrium with \( r_u^*, S^* \), \( \pi_{id}(r_u^*(c_u, S^*)) \geq \pi_{id}(\tilde{r}_u(c_u, \tilde{S})) \geq \pi_{id}(\tilde{r}_u(c_u, 0)) \) and \( \pi_{iu}(S^*(s_r(c_r^*), s_d(r_u^*))) \geq \pi_{iu}(\tilde{S}(s_r(\tilde{r}_u), s_d(\tilde{r}_u))) \geq \pi_{iu}(S(s_r(\overline{r}) = 0, s_d(\overline{r}) = 0)) \) that maximize firms’ objective functions.

Proof: In this case, the outcome is obvious since \( S^*(s_r, s_d) \) with \( s_r \lor s_d \neq 0 \) maximizes the incumbent’s profit function as already derived in prop 1. This implies that the downstream incumbent will set the corresponding lower bound for the leasing rate to \( r_u^* = 0 \leq \overline{r} \). Accordingly, the upstream firm maximizes the profit by undertaking sabotage as long as the gain from lower leasing rate corresponding to sabotage level exceeds sabotage costs so that \( \pi_{iu}(S^*(s_r(c_r^*), s_d(r_u^*))) \geq \pi_{iu}(S(s_r(\overline{r}) = 0, s_d(\overline{r}) = 0)) \) with \( s_r \lor s_d \neq 0 \).

Consider two different ownership shares \( \lambda_a \) and \( \lambda_b \) with \( \lambda_a < \lambda_b \), in which \( p_l^b \) and \( r_u^b \) (\( p_l^a \) and \( r_u^a \)) denote downstream incumbent’s optimal choice given \( \lambda_b (\lambda_a) \). \( S \) denotes the optimal sabotage strategy given the market share. DSO’s optimal choice implies:
\[
\begin{align*}
\pi_{id}(p_l^a, r_u^a(S^a)) + \lambda_a \pi_{iu}(S^a(r_u^a)) & \geq \pi_{id}(p_l^b, r_u^b(S^b)) + \lambda_a \pi_{iu}(S^b(r_u^b)) \\
\pi_{id}(p_l^a, r_u^b(S^b)) + \lambda_b \pi_{iu}(S^b(r_u^b)) & \geq \pi_{id}(p_l^a, r_u^a(S^a)) + \lambda_b \pi_{iu}(S^a(r_u^a))
\end{align*}
\]

Adding the two inequalities and dividing by \( (\lambda_b - \lambda_a) \), we find that \( \pi_{iu}(S^b(r_u^b)) \geq \pi_{iu}(S^a(r_u^a)) \). Since upstream profit increases with lower leasing rates and higher sabotage levels, this result implies that sabotage is increasing in ownership share.

The intuition for this finding is obvious: The higher the ownership share, the higher the share of downstream firm receiving upstream profit. This profit, in turn, covers the losses that arise from lowering \( \overline{r} \). In limit, \( \lambda \to 1 \), this leasing rate is an internal transfer to rise upstream’s sabotage incentives. In contrast, lower ownership share only partially covers the losses from lower leasing rate. This outcome is in line with our assumption that the network is strictly regulated, \( d \approx c_u \). Consequently, equilibrium leasing rate \( r_u^* \) might be even less than the network costs \( c_u \).