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Abstract

While liberalization in energy markets has been a widely successful process all over the world, incumbents often still hold a dominant position. Thus, electricity wholesale markets are subject to market surveillance. Nevertheless, consolidated findings on abusive practices of market power and their cause and effect in wholesale electricity markets are scarce and non-controversial market monitoring practices fail to exist. Our application of the established measure of market concentration RSI shows that it serves as a decent indicator for the rents that can be gained in the market but also reveals considerable weaknesses of the RSI. Therefore, we propose and apply the "Return on Withholding Capacity Index" (RWC) representing a measure of the firms' incentive of withholding capacity as a complementary index to the RSI.

Keywords: Market Power, Electric Power Markets, Measurement

JEL classification numbers: L11, L43, L94, K23, C13.

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1. Introduction

Since the 1990s, liberalization of energy markets has been proceeding in many countries worldwide. As an important part of the energy sector, many wholesale markets for electricity have reached a reasonable level of private competitors. Despite to the competitive framework which has been created by this process, incumbents often still hold a dominant position in this market, due to their already existing fleet of power stations. Thus, electricity wholesale markets are typically subject to market surveillance. In particular specialized regulators, competition authorities and service operators are focused on monitoring the market development to deduce substantial information about the degree of remaining market power.[1] The results of this kind of monitoring are important for political and institutional actors for further development of market design. Moreover the cognitions and methods used in market monitoring to assess market power are important in quasijudical investigations, conducted by competition authorities. Hence, it is necessary for all these institutions to enforce a reliable screening method to monitor those markets. In recent years, several indices have been used to determine market power in wholesale electricity markets, including some which have been developed in particular for this type of markets. We have analyzed the most popular among those screening techniques for examining wholesale electricity markets by testing them with German market data. Based on our findings we derive some general valuations about validity of indices and their usability for market monitoring.

Economic research has developed a large set of indices to measure market power, which can generally be used by monitoring units in energy markets.[2] In contrast to other markets, wholesale electricity markets have some distinctive characteristics which have to be taken into account as a key difference for market power measuring. Usually it is assumed that these markets should be accounted as a mean reversion of the price, the sudden fluctuations in load and supply without strong opportunities to storage and low elasticity in demand which is reflected in price spikes (Cartea and Figueroa 2005). Derived from this situation it can be shown, that typical market share indices, which are widespread in market monitoring – i.e. the Herfindahl-Hirschman Index (HHI) – are not perfectly suitable to investigate market power in electricity markets (Newberry 2009).[3] Thus, in recent years market monitoring as well as

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[1] One recent example for such a kind of an important market monitoring unit in the European Union is the Agency for the Cooperation of Energy Regulators (ACER) founded in 2009.

[2] See Twomey, Green, Neuhoff and Newbery (2005) for an overview of possible values for measurement.

[3] Even though HHI and similar values like the concentration rates are still used to determine market concentration on wholesale electricity markets, i.e. Frontier Economics (2010), European Commission (2012).

certain research has been focusing in particular on two methods which seem to be the most prospecting ones: on the one hand emphasis is put on the Residual Supply Index (RSI) which is kind of a structural index and specialized for the needs of electricity markets. On the other hand more complex behavioral analysis is used. The last is typically based on real cost data or cost estimation, such as the price-cost markup.

In fact, it is important to stress that especially the RSI has become a standard method in market monitoring of electricity markets. The RSI has been developed as an extension of the Pivotal Supplier Index (PSI) which has been used for the first time by the US Federal Energy Regulator Commission (FERC) in 2000 as a measure called Supply Margin Assessment (SMA) to determine market power of electricity suppliers. While both PSI and RSI measure how often a power producer is pivotal in terms of its capacity beeing relevant for the market to serve total electricity demand, the RSI is more differentiated as it shows continous values. Measured on an hourly basis, the RSI can be calculated with a decent amount of load and market share data.[4] It was initially introduced by Sheffrin (2002) who showed a strong relationship between the RSI and markups during the California Energy Crisis in 2001. Since its first application the RSI has become an important predictor for market power in electricity markets, which has been used several times in slightly different ways i.e. by Chang (2007), Lang (2007), Asgari and Monsef (2010), Kamiński (2012) or Muldera and Schoonbeek (2013). Even more relevant seems to be the use of the RSI by market monitoring units of US regional transmission organizations (RTO).[5] Additionally, the RSI has gained an important role in market surveillance by European competition authorities. In merger and abuse cases these units have to test for the legal requirements which usually go along with a definition of a certain degree of market power.[6] In Europe the RSI played an important role in assessing European energy markets by DG Competition (2007). On behalf of DG Competition London economics (2007) undertook a study in which the RSI was calculated for several European countries. Their results showed substantial market power of huge electricity suppliers in the observed countries. More recently the German Federal Cartel Office applied an RSI calculation on an hourly basis for the years 2007 to 2008 in its sector enquiry

[4] The Residual Supply Index has reasonable requirements for the data which are necessary for calculation. However, load and other data must be available on an hourly basis. If data is only available on a more aggregated level a lot of explanatory power is lost by this way of RSI calculation.

[5] In RTO the use of PSI/RSI or similar indicators can be intensive as they can be part of local market power mitigation mechanisms. E.g. CAISO applies the “Three Pivotal Supplier Test”. In order to prove the appropriateness of the test a surveillance report is published (CAISO 2013).

[6] For instance Article 102 of the Treaty on the Functioning of the European Union is the central European norm to prohibit abuses by one or more undertakings of a dominant position within the internal market or in a substantial part of it. The “dominant position” marks a certain degree of market power.

(Bundeskartellamt 2011). Furthermore, the German Monopolies Commission conducted an RSI analysis for 2012 in their special report on the German energy sector (Monopolkommission 2013).

As an alternative to the RSI calculation, the Lerner-index as a well established behavioral measure of market power in economic research can be used. The Lerner or likewise the very similar price-cost markup (PCMU) is specified as the proportional price-cost margin of a firm. Although these indices are usually considered as reliable to describe market power their strength as a screening instrument in market monitoring is not yet widely applied because of the limited availability of adequate cost data. Due to the above mentioned characteristics of wholesale electricity markets it would be necessary to gain hourly data – in particular the marginal costs – for each power generation unit. Only in quite extensive sector investigations it might be realistic for a competition authority to obtain this cost data directly from suppliers. Despite the fact that the European Union as well as the German Federal Cartel Office have retrieved this extensive information from power generators once in their sector inquiries this complex procedure seems to be less attractive for continuous market monitoring. An alternative way to obtain real marginal cost values of the suppliers is to estimate costs within a synthetic model of electricity dispatch. These kind of models simulate the market by combining behavioral assumptions with available information about input prices and power generation units. Regarding the measurement of market power only few studies make use of those models (for Germany e.g. Schwarz/Lang (2006), Möst/Genoese (2009)). However, the synthetic simulation of dispatch is usually not used by market monitoring units presumably due to missing confidence in appropriate estimation techniques and lack of empirical work.

While both RSI and behavioral indices are at least prospective ways of measuring market power in wholesale electricity markets there is still little empirical evidence on their appropriate application. Most of the studies using the RSI just assume the reliability of this index. Indeed, there is no fully established calculation procedure[7] and only limited knowledge on how reliable the index is in catching the threat of a possible abuse of market power. Moreover, the thresholds to determine market power which have been used in market monitoring are rules of thumb.[8] Since Sheffrin's initial idea, there have been very few attempts to provide evidence on the quality and appropriate quantification of the RSI. One

[7] I.e. nowadays there is an established way to deal with new phenomena, like the upcoming market integration or the extended supply of subsidized green electricity plants.

[8] In fact, the seminal study of Sheffrin which still is the reference for testing the RSI, has never been published as a paper and Sheffrin has never disclosed or documented her way of dealing with this problem.

exemption is the study of London Economics and subsequent research of the authors (Swinand et al 2010). There, the calculated price-cost markups were used to test the relevance of the Residual Supply Index with a positive result. However, this study has received some criticism in particular about the used model and a possible bias in modeling the market.[9]

In conclusion, there is still a lack of evidence about the correct interpretation of the RSI and the benefit of the application of dispatch models in market monitoring. Our research contributes to this discussion by examining these techniques for measuring market power by using public data for the German wholesale electricity market in 2012. For a better understanding we first describe the data used in our analysis in chapter 2. Building on this, we calculate the RSI on an hourly basis which is described in chapter 3. In chapter 4, a synthetical dispatch model to simulate costs of power supply is designed and verified. By combining the results from our measurements we analyze the validity of the RSI and other market power indices. Thereby we develop a further test – the "Return on Withholding Capacity (RCW) Index" – which could be used for measuring market power in the future.

2. The Data

Our analysis is based on multiple data sources which are publicly available.[10] Data for the installed capacity in Germany stems from the periodical power plant survey of the German Federal Network Agency.[11] The survey provides information regarding e.g. the normal maximum operating capacity (MW), technical details, energy source, supplier (owner) company and location for all German generation units with a net nominal output of at least 10 MW. According to the Federal Network Agency the survey covers more than 95% of the total installed capacity produced by conventional power plants in Germany or rather in the German control areas.[12] Emphasis should be placed on industrial generation units. They react differently on market signals, such as energy prices since they are operating as required to meet demand of the respective industrial company. Hence, all industrial power plants are discarded from our analysis. In total, we observe 590 generation units of 150 different owner companies with a total installed capacity of 95,417 MW.

[9] A quite detailed discussion about RSI measurement is provided by Swinand (2011a, 2011b) and Arnedillo (2011a, 2011b, 2011c).

[10] While most of the data is available for free, exceptions are the commercial ORBIS database of Bureau van Dijk and information on price data.

[11] Version February 2013. An updated version of the survey can be found here: http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/kraftwerksliste-node.html.

[12] There are generation units not located in Germany, but in the border region of Austria, Switzerland, France and Luxembourg which feed power into the German grid. Hence, they are regarded as part of the German control area.

In order to determine the ownership structure for the generation units, or rather the total installed capacity survey data on the respective owner companies was merged with Bureau van Dijk's ORBIS database. The ORBIS database provides – among others – information about the global ultimate owner for most of our sample firms. This enables us to identify which owner companies in our sample data belong to one of the four big generators in Germany, namely RWE, E.ON, EnBW and Vattenfall. Companies not listed in ORBIS were researched by information gathered through several sources in the internet.

A key issue when calculating the available energy capacities are planned and unscheduled non-usabilities of generating units. They can be caused by e.g. planned maintenance schedules or unscheduled blackouts due to technical malfunctions. The four German transmission system operators are obliged by law to report planned and unscheduled non-usabilities of generation units greater than 100 MW. Information on scheduled non-usabilities of generating units is published on the EEX transparency platform by energy source categories precisely down to the minute. In Germany, around 84% of all conventional installed capacity is produced by generating units with more than 100 MW. In order to take the smaller power generation units also into account we extrapolated our data by calculating the average failure rate of all generating units belonging to a specific energy source (e.g. stone coal, nuclear) on an hourly basis based on the sample generating units with at least 100 MW listed in the survey of the Federal Network Agency and the EEX data[13]. These failure rates were then used to determine the average non-available hourly output of each generating unit in the sample data which in turn was then deducted from each power plant unit.

To model demand for electricity we use the hourly load values for Germany provided by ENTSO-E[14] as a first step. To obtain the residual load which is solely covered by conventional power generators[15] the production by renewable energy sources is subtracted from the hourly load values. While infeed of wind and solar energy is provided by the EEX transparency platform on an hourly basis[16], data on non feature-dependent renewable energies, such as biomass, water, gas and geothermal energy is only available as a monthly average value provided by ENTSO-E. However, since non feature-dependent infeed is barely

[13] For this calculation purposes the industrial generation units were also taken into account since it was not possible to identify single units in the EEX data. Hence, the average failure rates could only be calculated for the full sample, i.e. including industrial generation units.
[14] See entsoe.eu for hourly load data.
[15] Residual load is used since renewables feed in electricity regardless of the market price due to their unlimited priority feed-in and because they are subsidized.
[16] Data is published on the EEX transparency platform, see: http://www.transparency.eex.com

volatile across the day the ENTSO-E data is an adequate measure to take these energy sources into account.

3. The Residual Supply Index

The Residual Supply Index (RSI) is a static concentration measure which monitors market power. The energy market exhibits a number of special features, such as non-storability of electricity, significant daily and seasonal fluctuations as well as a (short-term) price-inelastic demand. For this reason concentration measures solely focusing on the supply side of a market have only limited explanation power. Particularly on energy markets concentration measures which explicitly take the demand side into account are more appropriate. The RSI has been established as a reliable measure and has been used by regulators and competition authorities as a market power indicator in different electricity markets (see e.g. London Economics 2007, Bundeskartellamt 2011, Monopolkommission 2013).[17] Specifically, the RSI measures to which extent the competitors of a given generator can meet the current demand with their installed generation capacities. Thus, the RSI is a measure of the “pivotalness” of firms.

For any particular firm *i* the RSI is defined as follows:

$$RSI_i = \frac{total\ available\ capacity - capacity_i}{market\ demand}$$

As a theoretical foundation of the RSI, an inverse relationship between the RSI and the Lerner-Index (LI) – a well known measure of competition - can be derived.[18] From profit maximization of an oligopoly firm facing residual demand follows that $LI = \frac{p-MC}{MC} = \frac{1}{\varepsilon} - \frac{1}{\varepsilon}RSI$ with ε as the price elasticity of demand. Thus, under this model the Lerner Index is a simple linear function of the RSI such that the RSI is a compelling explanatory variable for price-cost margins.

The RSI is usually expressed as a decimal number. If a generator exhibits a RSI value of one in a given time period (here: one hour) the other competitors would be able to meet 100% of the demand. Hence, a RSI value larger than one indicates that supplier *i* does not have market power and only has little influence on the market price. This on the opposite means that supplier *i* is pivotal if the RSI is less than one.

[17] Justification of the RSI as a measure of market competitiveness has been given by Sheffrin (2002).
[18] See e.g. Swinand et al. (2010).

The calculation of the RSI requires adequate modeling of its components in order to make sufficiently reliable predictions about market power. We generate the required components as follows: calculation of installed capacity or market capacity is based on data as described in chapter 2. Accordingly, the installed capacity of each individual supplier (capacity *i*) is computed by adding up the adjusted installed generation output of all generation units which are majority-owned by the respective supplier.

A further crucial component to consider is the possibility of enhancing the total installed capacity by electricity imports from abroad. The question arises how to tackle this issue adequately. Data on cross border physical flows are provided on the transparency platform of the European Network of Transmission System Operators for Electricity (ENTSO-E) and are available on an hourly basis.[19] Following the approach which was used by the above mentioned market monitoring units, we use the maximum value of the cumulated hourly net import flows in 2012 as a proxy for energy import capacities.[20] This leads to a maximum net import value of 7,682 MW in 2012. However, the data on cross border physical flows is only available on an aggregate level for each of the four German control areas and thus, cannot be linked to each single power generation unit. For this reason the import measure is only taken into account for the calculation of the market capacity, but not for the individual capacities.

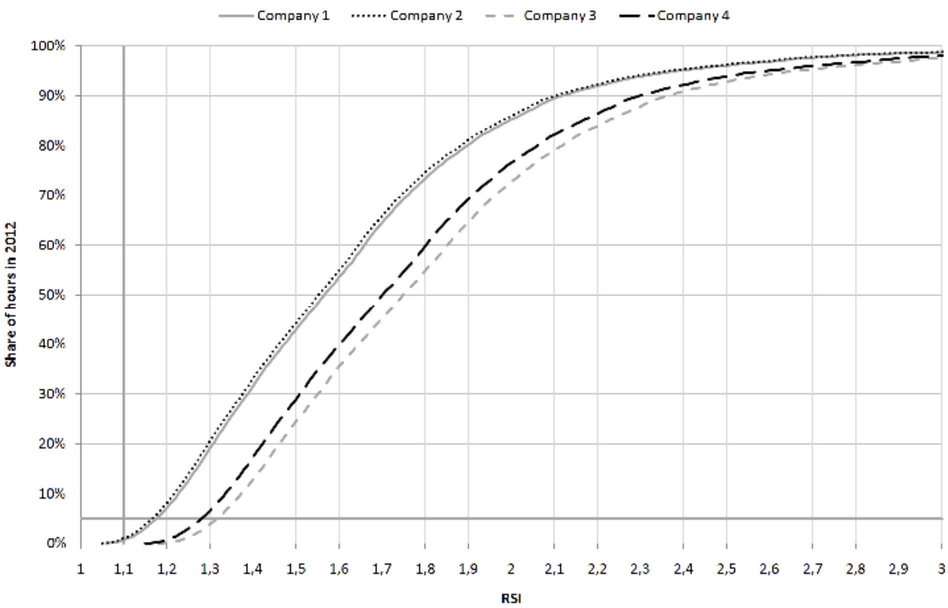
In summary, total installed capacity of conventional generation units is calculated from the aggregated net nominal output of all generation units adjusted for non-available output in the German control areas plus the maximum net import value which is added to the aggregated capacity in every single hour.

For calculating market demand - the denominator of the RSI - we make use of hourly load values as described in chapter 2. However, for the RSI analysis, these values have to be adjusted for the feed-in of renewable energy sources and balancing power. Balancing power is used to stabilize the active power balance. Due to the non-storability of energy the balance between generation and consumption has to hold at all times to ensure frequency stability. Hence, balancing power is used when there is either excess demand (positive balancing power) or excess supply (negative balancing power) on the power market. In Germany balancing power is required by the transmission grid operators as a prerequisite for maintaining this demand-supply balance. It is procured in an open and transparent request for

[19] See http://www.entsoe.net/ for more information.
[20] The Federal Cartel Authority in Germany has already explicitly discussed this issue in its sector inquiry (Bundeskartellamt 2011) and used the highest measured net imports during the observation period as a proxy for electricity imports.

proposal process via the internet platform for control reserve tendering.[21] Though the hourly load provided by ENTSO-E includes the effective consumption of balancing power its does not account for positive balancing power that is contracted but not used. In consequence actual demand exceeds the documented load. Therefore, we obtain data on hold but unused balancing power through the internet platform and add this demand to the hourly load values.[22]

Figure 1 Cumulative percentage of RSI levels of the four biggest suppliers in 2012



Using the described setting we calculate the RSI for the four biggest suppliers. The results show relatively high RSI numbers (see Figure 1). In relation to all examined market hours only in the relatively small number, namely 53 (company 1) and 78 (company 2) of 8,782 hours a value below 1.1 results. There are no hours where the RSI is below 1.0 for any supplier. These thresholds (1.1 and 1.0) are usually used in market monitoring analysis indicating market power.

[21] Balancing power is distinguished among primary control, secondary control and tertiary control (minute reserve). There are different weekly auctions for each kind of energy with different prerequisites for bidders (see www.regelleistung.de).
[22] A simple addition of contracted balancing power causes the problem that the effective consumption is included twice in the hourly load values. Hence, we subtract the positive balancing power which can be received by the control area balance measure of the grid control cooperation. The grid control cooperation includes the control areas of the four German transmission system operators, see data for control reserve, RZ_Saldo, https://www.regelleistung.net/ip/action/abrufwert?language=en.

4. Market Power Indices from Modeling the Optimal Dispatch

4.1 Derivation of the price-cost markup

To measure the competitiveness of the market we make use of the normalized hourly price-cost margin. For assessing the relative difference between price and cost we relate the price-cost differential to the cost to obtain the market's price-cost markup that is defined as $PCMU_t = \frac{p_t - MC_t}{MC_t}$ with p_t as the hourly market price and MC_t as the marginal cost of supply. The PCMU is closely related to the Lerner Index (LI) that scales the price-cost margin by the price. As explained below and according to economic theory and empirical evidence the price on short term competitive power markets is set by the marginal cost of the last unit required to meet demand. Thus, when the price is observed above marginal cost such that the price-cost markup and the Lerner Index are positive, this can indicate that the market is less than perfectly competitive.

For determining price-cost margins in electricity supply, it is necessary to analyze this supply in detail. Daily electricity demand on the European Energy Exchange (EEX) is met by a large number of electricity products based on a variety of energy sources. Every type of power plant has different marginal costs – costs that are incurred when the power station is up and running and must at least be earned back. A plant's marginal costs mainly depend on the type of energy source used (nuclear, gas, coal, etc.), but also on other plant individual factors like the energy conversion efficiency. The supply curve of electricity is given by the merit order of available sources of energy. Hereby, the available sources are ranked in ascending order of their short-run marginal costs of production, such that those with the lowest marginal costs are the first ones to be brought on line to meet demand, and the plants with the highest marginal costs are the last to supply power (this is called "merit order"). The last offer that is cleared at the electricity exchange determines the price. Hence, this market clearing price is set by the power station with the highest marginal cost of production that is needed to meet demand. This power station is called the marginal power plant and its cost are the marginal cost of total supply MC_t. Electricity prices are thus the result of the point at which supply and demand intersect. Therefore, to cover high demand, a gas-fired power plant with relatively high marginal costs would tend to determine prices, whereas to cover low demand, a more affordable coal-fired power station would be preferable.

4.2 The Dispatch Model

To calculate price-cost margins in German electricity supply, we need to model the optimal dispatch for every hour. In contrast to several other surveys on marginal costs regarding the energy sector, we do not use a linear programming model to estimate costs. In our approach, we assess the hourly individual marginal costs of all relevant power plants in Germany. Marginal costs are primarily determined by the variable cost of fuel including the cost of carbon plus further variable expenses such as costs for startup or fuel transport. For each firm *i* in every hour *t* its individual marginal costs are given as:

$$Marginal\ Costs_{i,t} = \frac{Fuel\ Price_t}{Fuel\ Value} \cdot Net\ Energy\ Conversion\ Efficiency_i$$

$$+ Carbon\ Price_t \cdot \frac{Fuel\ Emission\ Factor}{Fuel\ Value} \cdot Net\ Energy\ Conversion\ Efficiency_i$$

$$+ Variable\ Operating\ Expenses_{i,t}$$

In principle with this composition we are able to assess hourly marginal costs for each power plant depending on the electricity source, resp. the type of plant – e.g. renewable sources, hard coal, lignite, oil, gas turbine, combined-cycle gas turbine and nuclear power plants. From this we can simulate the optimum dispatch and estimate the system marginal cost using demand data. However, as we are only interested in the cost of the marginal power plant which is setting the market clearing price and not in the entire merit order per se we can ignore some elements on demand and supply side like the supply of renewable generation units which is already subtracted in our residual demand (see chapter 2). Moreover, we subtract hourly import values from hourly demand. Imports of power are that part of demand that is not met by national power supply.[23] Finally we do not include baseload and subtract this hourly supply from the demand side.

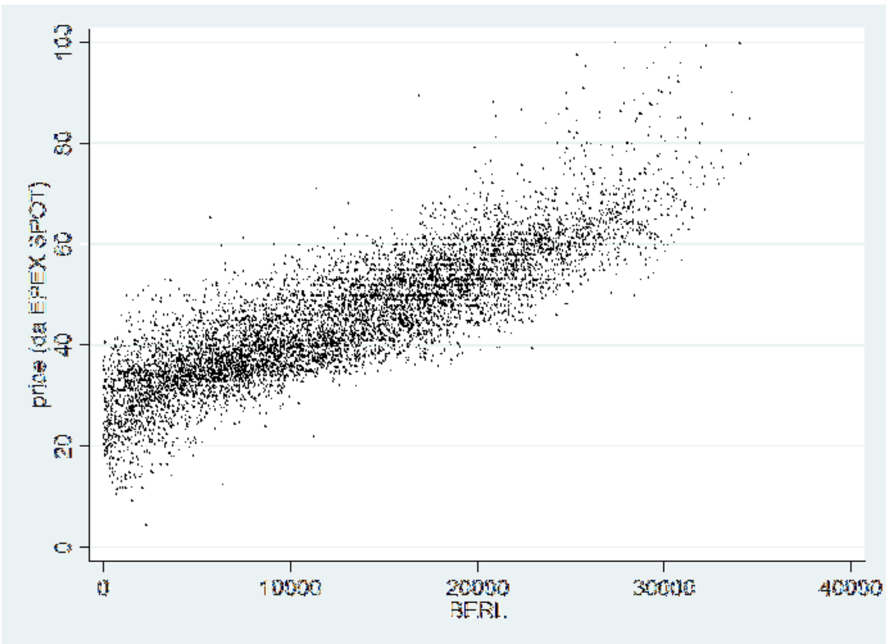
Baseload is the amount of power required to meet minimum demands. According to the merit order logic power plants are designated baseload based on their low marginal cost generation together with their efficiency and safety at aimed output power levels. These baseload power plants typically do not change production to match electricity consumption demands but instead are operated at constant and thus more economical production levels at low marginal costs. In the German power market baseload power plants include nuclear, lignite and run-of-the-river hydropower plants as well as electricity generated from renewable sources that are promoted not only financially but also via unlimited feed-in priority. Thus, to estimate costs

[23] Note that we do not substract net but total import as exported electricity is dispatched by the national plants that are up and running and is therefore essential for merit order consideration.

of the marginal power plant, we subtract baseload supply from total supply as well as from electricity demand and concentrate on assessing costs of generating power from coal, oil, gas and renewable sources that are not promoted like hydroelectricity including pumped-storage (but not run-of-the-river) which we label as baseload exceeding residual load (BERL).[24]

We are able to show that the calculated residual demand or load explains electricity prices to a surprisingly great extent.[25] We also use the correlation of residual load and prices for testing the accuracy of the assumptions made. The better demand explains electricity prices the more accurate is the estimation of BERL. The accordingly simple regression yields a rather high coefficient of determination adjusted R^2 of 0.668.[26] Figure 2 illustrates the correlation of prices and BERL. In our assessment we only consider hours where BERL is positive. This is the case in 88.69% of the observed hours.

Figure 2 Relationship of BERL and market price



Additional distinctive characteristics of German electricity markets significantly rising the complexity of the estimation of the merit order need to be considered. Besides the extensive promotion of renewable energy sources this includes electricity sources where estimating marginal costs is not straightforward, like pumped-storage hydroelectricity as well as

[24] It is not possible to reasonable estimate cost of power production from lignite as - different to other energy sources - comparable prices for lignite do not exist. Because of its low energy density and typically high moisture content, lignite is inefficient to transport and is not traded extensively on the world market. It is mostly burned in power stations constructed very close to the mines that are both owned by the same energy company.

[25] The goodness of fit of this regression is higher than the adjusted R2 of the simple regression of residual load on prices. This further indicates that BERL is able to explain electricity prices particularly well.

[26] Table 2 in chapter 5.2 shows further measures for the quality of the relationship.

combined heat and power plants. As a benchmark case we ignore the complex considerations of the operators of these plants and show in the following subsection - when checking for robustness - that this is indeed the most reasonable assumption.

With the described assumptions we assess the above presented determinants of marginal cost for non-baseload power plants and estimate the relevant part of the hourly merit order. To do so, we use daily fuel and carbon prices. In case of coal, we add average transport costs to generation units, calculated by cost data presented by Frontier economics and BAFA.[27]

We calculate average gross energy conversion efficiencies based on the „Energiedaten" of the Federal Ministry of Economics and Technology. To derive the net energy conversion efficiencies we used data provided by VGB PowerTech e.V. However, different efficiencies of plants are the essential driver of differences in marginal costs of plants of the same type such that it is necessary to capture varying efficiencies within our evaluation. As plant specific data is not available we develop distributions of efficiency for each type of plant. With this information we are able to derive efficiency distributions for every power plant in the market depending on its type. In line with information of experts we assume that efficiencies in principal are normal distributed over plants. We use available data for determining the means and variances and further truncate the resulting distributions. Thereby, we take the age of plants into account and assume that the older the plant the lower the efficiency.[28] For every hour and plant we then assign a random efficiency accordingly.[29]

For fuel emission factors we make use of data publicly available from the Umweltbundesamt.[30] Finally, we use estimates of the Organisation for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA) as well as data of Böckers et al. (2013) for the additional variable operating expenses including start-up costs.[31]

We are now able to assess the relevant part of the hourly merit order. For every 8,782 hours of the year 2012, we derive a dispatch model like presented in Figure 3. Making use of the

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[27] The transport costs presented by Frontier economics (2008) show particularly the differences for the main run in transport to certain regions. The Federal Office of Economics and Export Control (BAFA) calculates a price gathered from average costs for the run (to the German border) and more fixed costs like insurances, interim storage, draught measurement, glycosylation and other cost elements: http://www.bafa.de/bafa/de/energie/steinkohle/drittlandskohlepreis.

[28] As this assumption could be important we tested the robustness of our analyses with randomly assigned efficiencies for each type of power plant and every hour.

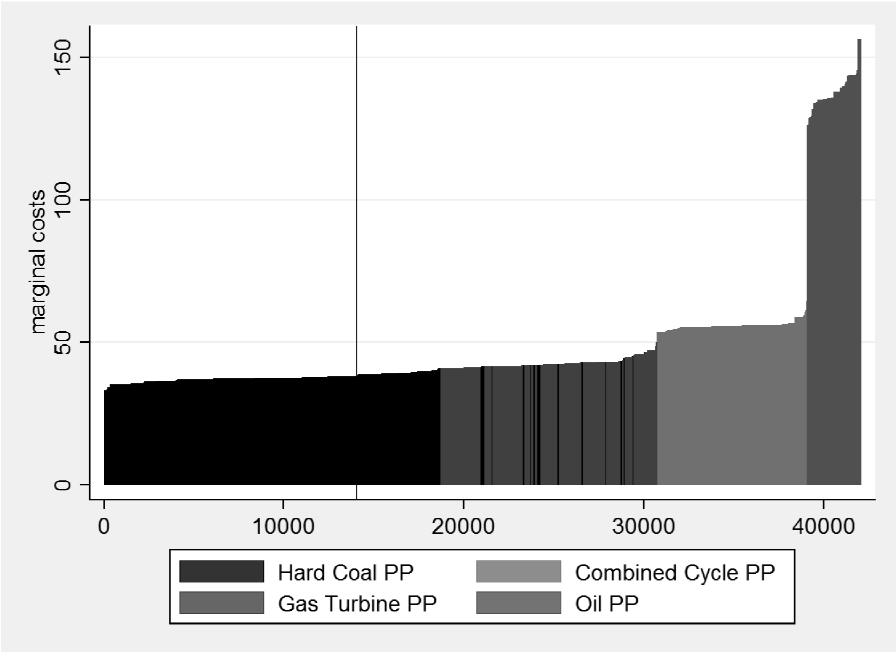
[29] The reason for assigning a new efficiency to each plant every hour although efficiencies are constant for each plant in reality is to utilize the law of large numbers and derive robust results. Alternatively, we would need to simulate the respective year a few thousand times.

[30] As emission factors are given in tonnes of carbon emmission per gigajoule, it is necessary to convert units to kWh by multiplication with the factor 3.6.

[31] OECD, IEA (2010).

residual power demand and the market price, we calculate the market's hourly price-cost markup as a measure for the market's competitiveness.

Figure 3 Merit order of an particular hour in January 2012



4.3 Robustness Checks with Alternative Dispatch Modeling

As described above, estimating the hourly marginal costs of power supply presents particular challenges. To tackle these issues simplifying assumptions are necessary. These may be subject to criticism as the presented analysis as well as all alternative approaches will always incorporate inaccuracies. Nevertheless, by performing the following robustness checks we are able to minimize the remaining imprecision. Besides, even if a significant bias could not be avoided, intertemporal considerations of the development of competition would always remain possible and valid.

As several ways to deal with the distinctive characteristics in the German power market are in principle possible we take different modeling approaches and check robustness of our results. For once, the substantial number of combined heat and power plants in the German market has to be taken into account when estimating marginal cost. These plants might not only run when the electricity price exceeds their cost of supply but also depending on demand for heat. Combined heat and power plants can either be driven by heat or by electricity demand.[32] Different ways to handle these issues within our assessment of the merit order can be

[32] Note that it is not possible to consider profits from heat production just as additional benefits to electricity generation as there is no market for heat and instead demand has to be met independently of a price cost calculation.

justified. As described above, we do not consider demand for heat as an incentive to keep the plant up and running in the benchmark case and focus only on the power side. As an alternative way of modeling we incorporate the demand for heat into the dispatch decision of these plants. Therefore, we assume that a given fraction of electricity generation is dispatched due to the supply of heat during cold periods of the year. According to official heating degree day data for households in Germany about half of the year's heating is demanded within the three coldest months. At these times it is likely that some combined heat and power plants are no longer controlled by electricity but rather heat demand. Thus, we assume some plants are driven according to the demand for heat at times of low temperature. Accordingly, we make use of the average daily temperatures of the cities of Berlin, Hamburg, Munich, Düsseldorf and Frankfurt provided by DWD and assume that a temperature dependent fraction of the combined heat and power plants is running independently of the electricity price. Thus, we treat these plants as baseload (scenario V). In practice, combined heat and power plant show a significantly lower efficiency than ordinary power plants. We additionally incorporate this characteristic in an alternative model (scenario IV).

Additionally, the cost of supply of pumped-storage hydroelectricity are not straightforward to assess. At these plants at times of low electrical demand and hence prices, excess generation capacity is used to pump water into the higher reservoir. When prices are high, water is released back into the lower reservoir through a turbine, generating electricity. With this method not only the costs of pumping water to the high elevation reservoir but rather opportunity costs are the main cost determinant. These opportunity cost depend on actual electricity prices and expectations about future prices. As estimation of these opportunity costs is not worthwhile there are several reasonable ways to deal with these plants within our estimation. We take different approaches to assess the cost of supply of pumped-storage hydroelectricity and test several possible patterns of power supply. For instance, we assume that pumped-storage electricity is baseload supply during peak hours.

As stated before for testing the accuracy of our assumptions we use the correlation of residual load or demand and prices. The better demand explains electricity prices the more accurate is the estimation of residual load. Regarding all our alternative assumptions as well as with every possible combination of alternative assumptions regarding run-of-the-river and combined heat and power plants, the coefficient always significantly declines with alternative dispatch modeling compared to the benchmark case.

5. A Discussion of Established and New Measures of Competitiveness of Power Markets

5.1 The RSI as a Proxy for the Price-Cost Margin

Based on our calculations of the hourly RSI and price-cost markup this analysis aims at providing further details on the quality of these measures as market power indicators in electricity supply. Although the Lerner Index is an established measure of the competitiveness of markets the RSI has been frequently used by market monitoring units as its calculation requires less data and is based on fewer critical assumptions. As we have calculated both, RSI and price-cost margin, within our analyses we are able to test whether the RSI is a reliable proxy for the Lerner Index, respectively the PCMU. If our results suggest a strong relationship between these two measures the value of the RSI as a monitoring instrument for wholesale electricity markets will be validated.

Surprisingly, although the RSI is considered as a standard technique in market power analysis, there is only limited empirical evidence on the relationship between the RSI and market power measures such as the Lerner Index. The most prominent work is the study of Sheffrin (2002) finding a negative relationship between the developed RSI and the Lerner Index. Furthermore, the study conducted by London Economics in 2007 also confirmed the link between RSI and the PCMU. With the following analysis we contribute to these findings by using data for the German market in 2012.

In order to investigate the previously discussed relationship between RSI and PCMU we estimate the following regression using OLS:

$$PCMU_t = \propto + \beta X_t' + \mu_t$$

where $PCMU$[33] is the dependent variable and μ_t the usual random error term. The set of regressors X_t include our main variable of interest RSI[34] and a number of control variables, such as the daily temperature as well as relevant fuel prices for coal, uran, gas and $CO2$. The parameters to be estimated are denoted by the vector β, whereas α is the intercept.

In order to produce consistent and efficient estimators we first test whether the time series used in our regression model are stationary by conducting augmented Dickey-Fuller tests. It

[33] It is an advantage to use the PCMU instead of the Lerner index since prices can become zero or negative in some situations.
[34] In fact there is a RSI for all of our four observed suppliers, however, we only include the RSI of the company with the highest average RSI value in our regression model.

turns out that the fuel prices for coal, gas, uran and CO_2 show a unit root and hence are non-stationary. Consequently they enter the regression model as first differences.[35]

Since autocorrelation was detected in the residuals by using the Breusch-Pagan test OLS estimates are still unbiased, but no longer efficient. However, we believe that serial correlation is no serious problem in this case. While load is a key component of the RSI the PCMU is also determined by the electricity price. The electricity day-ahead spot price we use in our models is calculated for the next operating day on the basis of generation offers, demand bids and scheduled bilateral transactions by the energy exchange EPEX SPOT. However, biddings are based on expectations for load which depend on several imperfectly predictable demand and supply factors (i.e. supply of weather dependent renewable power plants). Flawed expectations may yield to under- or overestimation of load and therefore to several consecutive positive or negative residuals in our regression model. To address the problem of serial correlation we estimate OLS with Newey-West standard errors which are robust to autocorrelation as well as to heteroscedasticity.

As we expect a much higher influence of the RSI during times of high and very high demand compared to hours in which demand is rather low we also estimate sub-samples for peak (model II) and off-peak (model III) hours. Furthermore, as a robustness check we also present regressions for additional scenarios where the production of hydro (model IV) and combined heat and power plants (model V) are taken into account (see chapter 4.2 for a discussion).

[35] However these variables became insignificant in our analysis. As a robustness check, we tested several different specifications, e.g. without differences, lags and without fuel variables at all. All these tests did not yield to a rejection of the main relationship between RSI and PCMU.

Table 1: Regression Results for PCMU on RSI

	I full sample	II peak	III off-peak	IV full sample	V full sample
RSI (Comp2)	-0.615***	-0.219***	-0.938***	-0.725***	-0.753***
	(-4.75)	(-7.57)	(-3.50)	(-5.25)	(-5.43)
temperature	-0.000688	-0.00258***	-0.00216	-0.00101	-0.00346**
	(-0.56)	(-2.84)	(-1.62)	(-0.76)	(-2.35)
$\Delta uran_{t-24}$	0.0968	-0.0129	0.205	0.0775	0.0785
	(0.96)	(-0.47)	(1.10)	(0.76)	(0.77)
$\Delta coal_{t-24}$	0.00921	0.00621	0.00579	0.0107	0.00766
	(1.07)	(0.78)	(0.54)	(1.17)	(0.80)
Δgas_{t-24}	-0.00386	-0.00689	0.00192	0.00539	0.0196
	(-0.51)	(-0.73)	(0.24)	(0.47)	(0.98)
$\Delta CO2_{t-24}$	0.00719	0.0174	-0.0165	0.00562	0.0163
	(0.17)	(0.42)	(-0.36)	(0.12)	(0.33)
Constant	1.133***	0.585***	1.663***	1.331***	1.415***
	(5.93)	(12.97)	(3.84)	(6.57)	(6.97)
Observations	8734	4732	4002	8734	8734
ar2	0.366	0.306	0.439	0.385	0.399
aic	6251.5	-1419.3	4469.2	6759.9	7020.1
bic	6308.1	-1367.6	4519.6	6816.5	7076.7

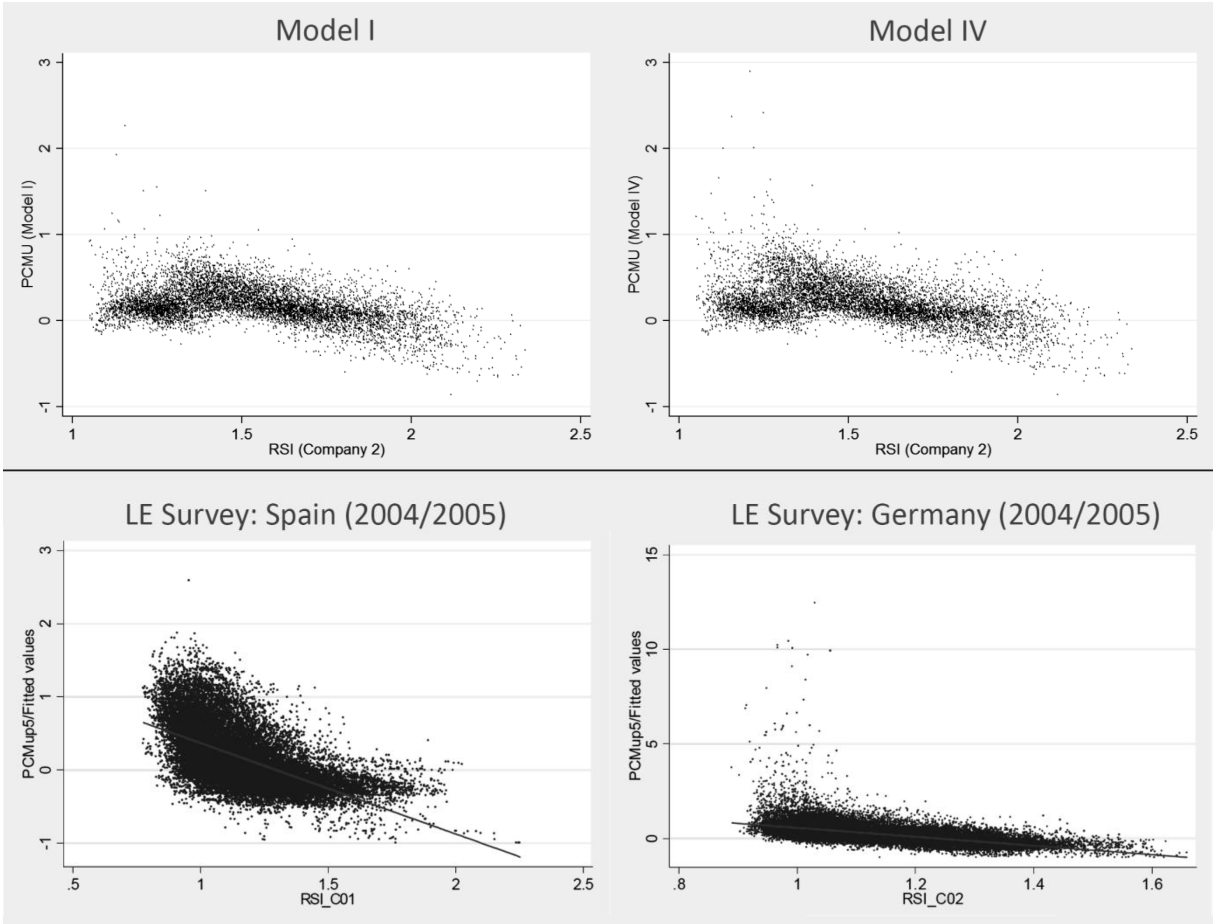
Notes: Standard errors in parentheses (Newey-West HAC standard errors with lag length parameter equal to 24); * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; for peak and off-peak hours number of lags was also reduced accordingly.

Our results clearly show a significant negative relationship between the RSI and the price-cost markup irrespective of how pump-storage and combined heat and power plants are taken into account in the dispatch model. Figure 4 shows the relationship between the RSI and the price-cost markup. Remarkably, in case of treating hydro storage generation and combined heat and power plants partly as baseload within the dispatch model (model IV, see section 4.2) the slope becomes steeper. Nevertheless model I represents the benchmark model providing the best explanation of prices.

Nevertheless, in detail our findings differ from to the results of London Economics illustrated in Figure 4. Obviously, the scatter plot of our analysis shows lower markups for low RSI such that the linear relationship between RSI and PCMU is less rigorous. This can be observed in particular for scenario I. The reason for this result is that at a certain value of residual load the type of the marginal power plant changes such that there is a discontinuity in marginal costs. This again causes a discontinuity in the relationship of RSI and PCMU such that a relatively low RSI is not necessarily linked to a high PCMU and hence market power of the suppliers.

For the German market especially power generation from coal and gas need to be distinguished since whenever demand exceeds base load, i.e. the hours which are analysed in our dispatch model, the marginal power plant is either hard coal or gas fired. As producing power by use of coal was significantly cheaper than by gas during most of the year, due to relatively low coal prices coal fired plants could generate a higher markup. Thus, a supplier providing capacities by gas fired power plants gains lower markups than a supplier running base-load power plants. Thus, a residual supplier of power generated from gas exhibits less market power.

Figure 4 Relationship between RSI and markup measures in comparison to London Economics (2007)



To conclude, when the type of the marginal power plant changes frequently within the analyses the interpretation of the RSI has to take this into consideration. This shows the importance of taking into account the technology mix of a supplier when the RSI is interpreted.

Moreover, this analysis contributes to the discussion whether there is a general mismeasuring of market power by the RSI during hours with extremely high prices. For instance Brennan (2003) argued that markups at price spikes are not a stringent signal for lack of competition. By contrast, we find that the linearity of the relationship of PCMU and RSI also holds for high price-cost margins. This is illustrated in Figure 4 especially when only considering cases where the coal fired generation units are the marginal power plant.

5.2 Return on Withholding Capacity (RWC) Index as an Alternative Measure of Market Power

Our previous results highlight a major drawback of the RSI: it does not distinguish between different types of power generation. Although a market can be distorted in several ways, generally two strategies are considered as important for abusive practices in power generation (Twoney et al 2005, Helman 2006, Biggar 2011). Both strategies aim at rising prices by reducing supply such that the cost of the marginal power plant increases: on the one hand this can be achieved by physical withholding of capacity (reducing output), e.g. a supplier temporarily reduces its capacity by claiming a unit is not operational. On the other hand market power is exercised by financial withholding (raising the price of output), i.e. a supplier raises its bidding price above the marginal cost of a generation unit. Either strategy generates specific cost and price effects depending on the technology mix of the electricity supplier. For the evaluation of market power the incentives for abusive behavior are essential.

The consideration of abuse techniques points out an advantage of behavioral indicators: those measures are more suitable to capture the possible application of withholding strategies. Thus, the applied model of market dispatch allows for conducting such an extended analysis. For instance, the dispatch model reveals further details about the marginal cost structure of the analyzed coal and gas fired power plants. With the information on the ownership structure of each generating unit we were able to calculate markups for the total installed capacity of every supplier. A weakness of dealing with this information is that the results are decisively depending on the accuracy of the estimated cost level. This highlights a crucial point as our dispatch model is based on synthetic assembling of several cost elements. As a consequence of limited availability of current cost data interpretation of the absolute values of the calculated marginal costs has to be done with caution. Therefore, a market power index such as the Lerner which is sensitive to the absolute cost level is more vulnerable to possible impreciseness.

In fact this is a serious problem, because market monitoring and even more investigations by competition authorities need feasable and reliable monitoring techniques. Hence, we develop an indicator for market power which is more suitable for practical use. It is important that it addresses the incentive for capacity withholding and is not sensitive to the absolute level of costs. Therefore, we make use of the linear relationship between baseload exceeding residual load (BERL) and the price level found in chapter 4. In order to further quantify this effect we estimate a regression model using the method described in the previous chapter with wholesale electricity price as the dependent variable and BERL as a regressor. The augmented Dickey-Fuller test reveals that the two time series do not show a unit root, i.e. they are stationary and consequently enter the regression model in levels. Furthermore, we used the same control variables as in our previous model, namely the daily temperature as well as relevant fuel prices for coal, uran, gas and CO2[36].

One could argue that our model suffers from an endogeneity bias due to reverse causality since usually demand and price are simultaneously determined. However, in this case the BERL is highly price inelastic since electricity consumers are not aware of the real-time fluctuations in the wholesale price of electricity. Hence, they have no incentive to adjust their consumption accordingly that is they only react on price changes in the long run.

Our results show that in the full sample only the coefficient of BERL is significant while the other control variables are insignificant. We also found that they are jointly insignificant by performing an F-test (F=0.76, p-value=0.578). Hence, in a further specification we simplify our model by omitting all control variables (see specification IV). As Table 2 shows this only led to a small decline in the goodness of fit measure and - even more important - it does obviously not affect the coefficient value of BERL. Since our goal is to develop a very simple measure of market power that can be calculated and applied easily this simplified model provides a very sound foundation. Although using the coefficient value of BERL of the simplified model might come at the cost of a small bias it has the huge advantage that considerable less data is necessary. Besides, omitting control variables allows for defining a standard procedure. Thus, we propose using the result of the simple regression model as the foundation of the RWC and build on this within the following analysis.

[36] Some of our observations (around 13% of the observed hours) show negative values for BERL since during these time periods demand is already met by baseload power plants (see chapter 4.2). Since we want to avoid gaps in the time series we set BERL to zero in these cases. As commonly done in the literature (e.g. Hall and Ziedonis 2001, Czarnitzki et al. 2009), we capture the arising bias from that by including a dummy variable that captures the negative values in BERL. As a result, we do not have to discard these observations. However, as the estimated coefficient of this dummy has no interpretation in itself we do not show the regression coefficient in Table 2.

Table 2: Regression Results of spot price on load

	Full sample I	Peak hours II	Off-peak hours III	Full sample IV
BERL	0.00148***	0.00140***	0.00136***	0.00148***
	(32.19)	(21.39)	(30.25)	(27.97)
temperature	0.055	-0.053	0.101*	
	(1.15)	(-0.66)	(1.91)	
$\Delta uran_{t-24}$	3.661	0.824	7.220	
	(1.18)	(0.93)	(1.09)	
$\Delta coal_{t-24}$	0.055	-0.690	-0.142	
	(1.15)	(-1.63)	(-0.44)	
Δgas_{t-24}	0.751	1.131	0.406	
	(1.00)	(0.97)	(0.96)	
$\Delta CO2_{t-24}$	0.721	1.131	0.072	
	(0.52)	(0.97)	(0.05)	
Constant	26.30***	29.83***	25.58***	26.84***
	(47.72)	(34.77)	(38.28)	(45.27)
Wald-test on $\beta_{BERL}^{PEAK} = \beta_{BERL}^{OFFPEAK}$		0.82		
Observations	8734	4732	4002	8782
Adjusted R2	0.592	0.692	0.434	0.591
aic	68075.0	34106.0	32647.0	68493.7
bic	68131.6	34157.7	32697.4	68514.9

Notes: Standard errors in parentheses (Newey-West HAC standard errors with lag length parameter equal to 24);
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All our results show a highly significant positive relationship between BERL and the spot market price. In the simple regression model (IV) this indicates that an increase of BERL by one MWh raises the spot market price by 0.148 Eurocent. At the same time this also means that withholding of one MWh (profitable) capacity leads to an increase in energy prices of 0.148 Eurocent.

The results for the subsamples reveal that during peak hours another unit of BERL leads to a price increase of 0.140 and during off peak hours to 0.136 Eurocent. However, a Wald test on the difference of the coefficients of BERL during peak and off-peak hours clearly shows that the coefficients are not significantly different from each other making the full sample model the preferred specification.

Furthermore, the dispatch model enables us to derive the total capacity each power supplier provides per hour. Hence, multiplying these values yields the profits any supplier can gain by withholding a capacity of one MWh. This value can be considered as the incentive for this abusive strategy of withholding physical capacity to increase prices. For interpretational reasons it is helpful to relate this rent to the actual market price. This yields an alternative measure of market power as firms' incentive for abusive behaviour which we label as return on withholding capacity (RWC) index.

It is defined as follows:

$$RWC_{i,t} = \frac{\beta^{berl} \cdot (running\ capacity_{i,t} - 1)}{market\ price_t}$$

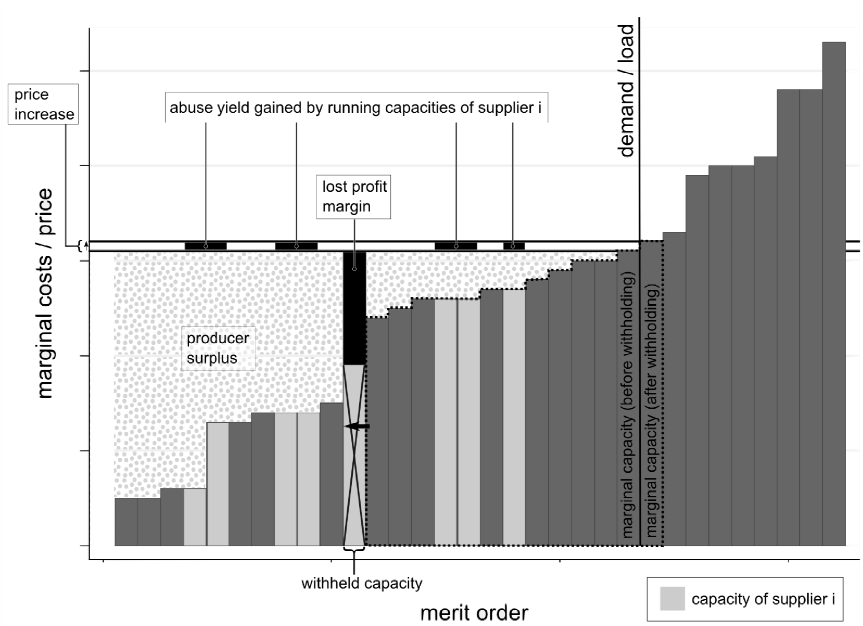
with β^{BERL} as the coefficient of BERL from our described estimation results.

The RWC constitutes as a standardized indicator for the incentive of a certain power supplier to apply capacity withholding. However, to interpret the results of RWC calculation some aspects have to be taken into account. Note that the calculated return on withheld capacity has to be compared to the lost profit margin due to reduced production (see Figure 5). An incentive for strategic withholding is given if the RWC is higher than the proportional profit margin for withheld capacity. In its maximum the proportional profit margin is one if the withheld capacity has marginal costs of zero.

Thus, the following rule can be applied:

- RWC ≥ 1; supplier i has a strong incentive to withhold capacity since the lost profit margin is always smaller than the abuse yield gained if supplier i runs other capacities.
- RWC < 1; interpretation of this indicator is limited since it can solely provide information on the relative likelihood of strategic withholding (e.g. by inter-temporal, inter-market or inter-firm comparison). For further interpretation of an RWC below one, extended in-depth data about the hourly profit margins of generation units would be necessary.

Figure 5 Rational Calculation for Capacity Withholding



In this context, it is important to highlight the relevance of suppliers' running capacity estimation for calculation of the RWC. In our example for Germany in 2012 we have used the dispatch model for estimating marginal cost data of all potential marginal power plants in the market in order to derive this information for every hour of the year.[37] Our results for the RWC during 2012 are presented in Table 3. As parts of our estimations are based on distributions of efficiency for each type of plant, repeated random sampling enables us to obtain reliable numerical results on average. Thus, for further analyzing the RWC we suggest to use yearly mean as well as yearly percentile values to indicate the degree of market power. This approach is suitable for market monitoring as it leads to reasonable approximations of RCW values. The RWC results for Germany in 2012 are presented in Table 3 and reveal a substantially higher difference in measured market power between company one and two compared to the RSI measures (see Figure 1 for RSI evaluation).

[37] As an alternative approach, real time data for running capacities could be obtained directly from the suppliers (i.e. during competition authority investigations) or purchased at specialized data dealers. If a very easy to calculate but less reliable and less valid indication of market power is needed it is also possible to abstain from using exact data about the running capacity of each supplier. Instead a very rough estimation of running capacity could be used (i.e. multiplying market share with hourly BERL values).

Figure 6 RWC for the 19th hour of a particular day in 2012

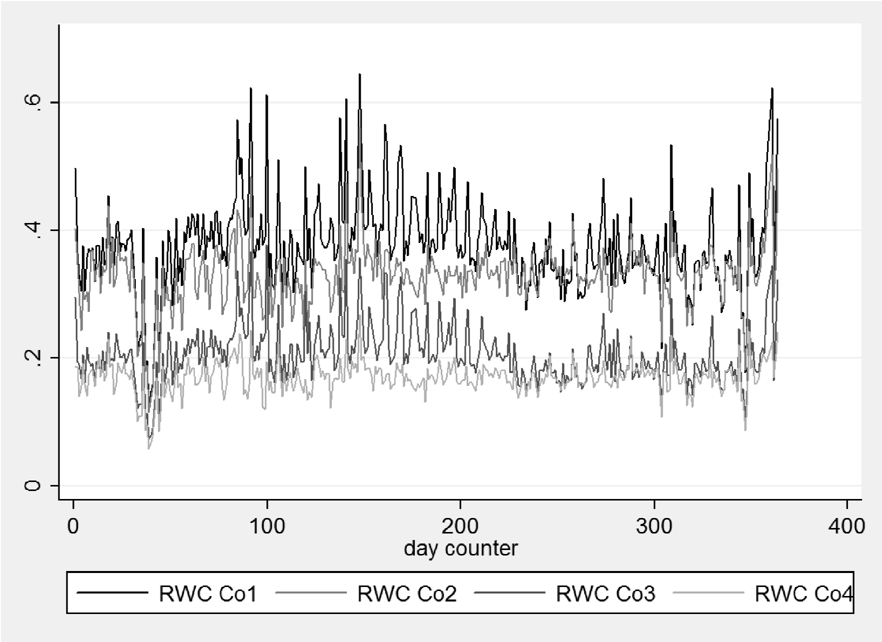


Table 3 Mean and fringe values of RWC for the four biggest suppliers in 2012

	Company 1	Company 2	Company 3	Company 4
Mean	0.412	0.340	0.229	0.176
90 % Percentile	0.520	0.405	0.300	0.216
95 % Percentile	0.564	0.436	0.329	0.262

5.3 Relevance and Thresholds for Market Power Indices

The indices we have carved out from our previous analyses – RSI and RWC – are both suitable for being applied on either one or a group of suppliers. However, it has to be emphasized that these two indices do not serve as substitutive but rather complementary measures of market competitiveness. The RWC can measure the incentive for capacity withholding in regular hours only. Especially during price spikes there is no linear relationship between residual load and market price. Consequently, at these times the RWC will be imprecise as it is based on the linearity of this relation. In contrast, the RSI usually shows low values in hours with high demand and hence price. The importance of price spikes as evidence of market power abuse has been the subject of lively debates.[38] While the ordinary RSI application is sensitive to price spikes as long as only values under a certain

[38] On the one hand in times of price peaks the price level generally exceeds marginal costs which could be evidence of market power (Bundeskartellamt 2011). On the other hand it is argued that these peaks in price level are necessary for covering the costs of marginal power plants and should be rated as in line with functional market (Brennan 2003, Böckers et al. 2013).

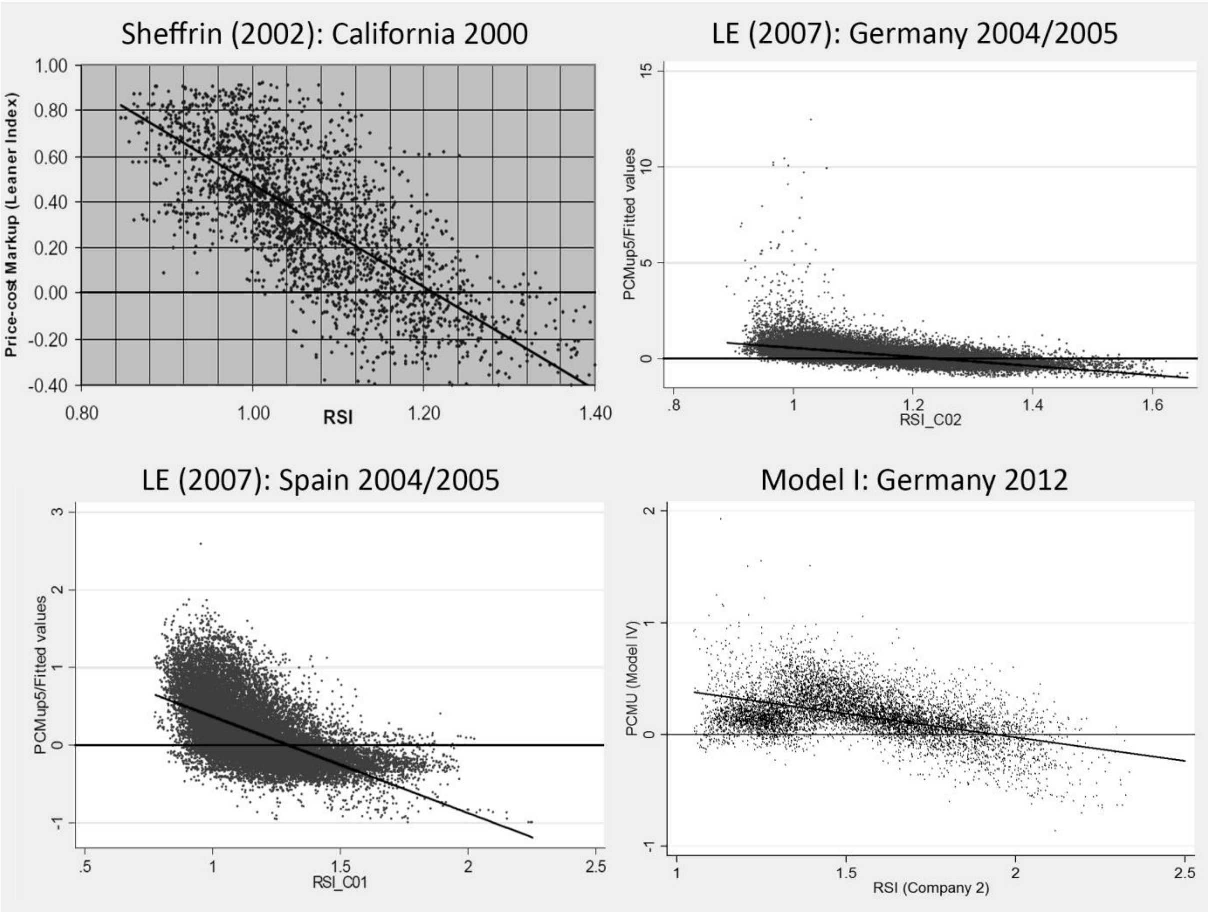
threshold are taken into account, the RWC serves as a reliable measure of the incentive of market power abuse. As long as there is no clear evidence about the nature of the abuse of market power the described measures, namely RSI and RWC should be used as complements in market monitoring.

One difficulty for the application of the examined market power indices is the interpretation of derived values for practical use. A typical task of market monitoring is tracing changes of market competitiveness. Therefore a set of continuously measured RSI and RWC values could be monitored. While such an application of RSI and RWC to identify changes in market power over time is rather straightforward, other practical applications are more challenging. Notably is the determination of market dominance. Market dominance is a legal concept that indicates a certain minimum level of market power by one or a group of firms. Defining thresholds for a certain degree of market power like market dominance is particular necessary in cases of quasijudical investigations conducted by competition authorities. Defining appropriate measures and thresholds accordingly for the assumption of dominance is usually a difficult task regardless the market under consideration.[39] However, the market power indicators considered here are highly specialized for their application in wholesale electricity markets, though there is limited experience available, in particular for the suggested RWC.

Regarding the RSI market monitoring units (e.g. Bundeskartellamt 2011) usually refer to the study of Sheffrin (2002) who suggested that RSI values below 1.1 in more than 5% of all observed cases indicate some kind of market dominance. The threshold of 1.1 is based on her regression analysis and the value where the RSI corresponds to positive Lerner indices. However, the usage of this threshold as an indicator of dominance remains arguable. Usually, within a certain time frame both - positive markups corresponding with low RSI values and losses corresponding with higher RSI values - can be observed. Thus, it seems to be questionable to use positive markups as an indicator for the abuse of market power in general. Regarding the results of existing studies the point of intersection differs significantly. While Sheffrin finds that RSI values of around 1.2 correspond to zero margins[40], London Economics observes values of around 1.25 for Germany and 1.3 for Spain. In our own analyses the respective value of the RSI is even higher at around 1.9 (see Figure 6).

[39] In certain competition laws there are presumption thresholds for the market shares for assuming individual or collective market dominance, such as § 19, para. 3 of the German law against restraints of competition (Gesetz gegen Wettbewerbsbeschränkungen GWB). These values are usually rules of thumb.

Figure 6 Relationship of RSI and price-cost margin/markup



These quite different results regarding the intersection of the RSI with zero markups show the essential problem of defining reliable thresholds for market power analysis.

Differences can be caused by several reasons. For once, different characteristics of competition will result in different intersection points. While the price-cost markup is a measure based on the market outcome, the RSI is only based on financial numbers of one company (usually the market leader). Hence, across countries the position of the market leader compared to the rest of the market will have a considerable effect on the intersection of the market leader's RSI with the market's price cost margin.[41]

Different intersection points may also be caused by the different methods of determining costs and thus markups. Hence, as the markup mainly depends on costs a general over- or underestimation can have substantial consequences for the point of intersection. Such a general estimation bias can easily arise if e.g. start-up costs are not calculated correctly.

[41] This effect is already apparent in the study by London Economics (2007) where e.g. for the German market the intersection points of the RSI with zero markup significantly differ depending on the company considered.

Therefore, the thresholds for the RSI proposed by previous studies should not be taken as given but used with caution.[42]

In case of the RWC it is also necessary to define thresholds indicating market dominance. The RWC is calculated as the proportional benefit for abusive capacity withholding. In general, a RWC equal or bigger than one is problematic. This does not imply, however, that at values below one the competitiveness of the market is sufficient. Thus, the correspondence of certain values of RWC with market power needs to be evaluated. This could be done by examining the actual cost of power generation within market monitoring. Therefore, power plants that seem to have a rather high likelihood of being withheld could be chosen for a more detailed analysis.[43] The determined proportional profit margin of these plants could be cautiously used as an indicator to set the threshold for the RWC. Hereby the market monitoring unit can accumulate knowledge and experience in estimating cost and profit margins.

6. Conclusion

Despite numerous studies of electricity markets and many years of market monitoring, consolidated findings on abusive practices of market power and their cause and effect in wholesale electricity markets are scarce. Nevertheless, indicators or measures of market competitiveness are important for market monitoring where standardized methods are necessary for evaluating the effect of changes in a certain framework – e.g. the rapid expansion of renewable energies.

Our application of the established measure of market concentration, namely the RSI shows that it serves as a decent indicator for the rents that can be gained in the market. Complementary to the few empirical studies on the practical value of the RSI our results for the German electricity market in 2012 support the correlation of the RSI and the price-cost margins of the largest German energy suppliers. Specifically, the results show a linear relationship of these two values not only for margins below a certain threshold, i.e. off-peak prices, but for the entire range of margins. Thus, the firms' market power and influence on the market outcome continuously increases with declining RSI values.

Nevertheless, the analysis here reveals considerable weaknesses of the RSI. In particular, the index does not account for the actual type of capacity a particular company owns although

[42] For this reason the German Monopolies Commission suggested to use the threshold of 1.0 that is derived from the theoretical foundation of the relation of RSI and price-cost margin.
[43] This seems to be likely for plants which are either baseload or up and running most of the time and still incur high marginal cost.

these capacities are essential for the rents and thus incentives of abusive behavior like withholding capacity. Hence, for a deeper understanding and productive analyses of market power and abusive practices it is necessary to take behavioral indicators into account. Therefore, we propose the "Return on Withholding Capacity Index" (RWC) that represents a standardized measure of the firms' incentive of withholding capacity. This index could be used complementary to the RSI by market monitoring units.

However, the proposed index does not account for further specific characteristics of energy markets and their effect on prices. For example, the correct way of incorporating combined heat and power plants as well as pumped-storage hydroelectricity into the optimal dispatch model remains unclear. Besides, although several methods to consider imports are generally possible this issue has not been subject to extensive studies yet. Another increasingly discussed aspect is the consideration of forward contracts and their impact on market power of suppliers. These issues leave room for future research.

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