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OVERVIEW OF ELECTRICITY MARKET MONITORING

ABSTRACT. The main goal of this paper is to present various aspects of electricity market monitoring and to focus on the monitoring of economic parameters, placing a special emphasis on market power, market performance and behavioral monitoring. This paper provides a view of the monitoring and its components. It presents available monitoring techniques and further it indicates the need to modify the existing structure or to develop a new structure of the monitoring system based on new indices which could be used by both operator and market participants.

JEL Classification: Q4, E03, E37, O10, N70

Keywords: electricity, market monitoring, market power and performance, behavioral monitoring.

Introduction

The monitoring of the electricity market and preventing incorrect usage behavior are well-known issues in the competitive electricity market (see for example Marulanda *et al.*, 2006; Nagypál *et al.*, 2015; Strielkowski and Lisin, 2016; Nagaj, 2016) that are well-embedded into the strategy of sustainable energy development (Streimikiene *et al.*, 2016). The monitoring of the electricity market plays a key role in the free electric energy market (Kasperowicz, 2011; Lisin *et al.*, 2016). Supervisory actions are important for the System Operator and the Regulatory Commissions in order to ensure the efficient market performance. For Federal Energy Regulatory Commission in USA (Haymes, 2000), the market monitoring has been identified as a standard market design component and a basic function in the deregulated electricity market. According to Rahimi *et al.* (2003) and London Economics *et al.* (2007), the electricity market monitoring could be organized as an internal system or an institution in the Independent System Operators (ISO) structures, as well as could function also outside of the ISO structures and can provide service for ISO or other recipients (Goldman and Lesieutre, 2004).

Furthermore, the availability of a well-developed monitoring system would also help agents to optimize their bidding strategies (David and Wen, 2000; Dun-nan *et al.*, 2006; Pires Manso *et al.*, 2015). Currently agents are concentrating on increasing their efficiency in order to maximize profits through a complicated system of product and sales management. Due to the fact that the process of decision making is very complex, whereas complete information is often unavailable, the electricity market monitoring appears to be difficult (London Economics, 2007). Therefore, if the market monitoring system functions properly, the transparency and reliability of the information concerning the electricity market dynamics may be ensured.

The main activities of market monitoring as described in Rahimi *et al.* (2003), London Economics *et al.* (2007), (Dehdashti, 2005) and (Güler *et al.*, 2005) include: 1) Detection of attempts to exercise market power and fraudulent behavioral, 2) Monitoring of market performance, 3) Identification of market design imperfection, 4) Transmission and generation blackout controlling, 5) Market participants' behavioral monitoring (activities and transactions).

After an in-depth analysis of the existing literature devoted to exploring the issue of electricity market monitoring, it is possible to state that the information regarding the general methods of monitoring are available. However, there is a deficit of information related to the monitoring techniques focused on economical parameters of Spanish electricity market. Furthermore, the conducted analyses of the market structure and of the available source data related to Spanish power system have proven that that there is a need for a modification or a creation of new methods and indices, which shall be applied in order to correctly monitor the economical parameters of Spanish electricity market.

This paper firstly introduces the concept and functions of the electricity market monitoring system (section I). Subsequently, the main methods and indices applied to the monitoring (market power, market performance and behavioral monitoring) are outlined (section II). Section III outlines the particularities of Spanish market. Subsequently, section IV presents conclusions.

1. The global overview of the monitoring system

The result of the extensive analysis of the existing literature on market monitoring is represented graphically in *Figure 1*.

The *Figure 1* presents the market monitoring framework: the elements and the correlation between them. This extensive analysis is based inter alia on the following sources: London Economics *et al.* (2007), Goldman and Lesieutre (2004), Dun-nan *et al.* (2006), Chakrabarti *et al.* (2008), Newbery (2004), Asgari *et al.* (2008). The presented paper concentrates on the core aspects of market power, market performance and Behavioral monitoring. The presented elements of monitoring are linked by mutual relations and such relations are crucial for the monitoring of economic parameters in a broader sense. In *Figure 1*, the relations between the elements of the electricity market monitoring system are marked by different colors – red, green and blue. From the global point of view, each of the elements of the system plays a crucial role in the proper monitoring of the free electricity market. Nevertheless, as far as the functionality of the monitoring system from the economical point of view is considered, any detailed analysis of Monitoring of Technical Parameters and Monitoring of Structural Framework is not relevant. All the information acquired on the basis of Monitoring of Technical Parameters might play a vital role in the monitoring of Market Power, Market Performance and Behavioral Monitoring, however, it is not crucial, and often impossible, to obtain very detailed information concerning the technical parameters. In order to monitor economic parameters, basic information regarding transmission congestion or production proves to be sufficient. Due to the fact that changes in the electricity system structure are mostly minor and investments in the electricity sector are relatively time-consuming (on a regular basis they last for years, *e.g.* the construction of a power plant takes about 4-6 years, while the construction of a power line – about 10 years)

(Pérez Arriaga, 2013; Herrero, 2015), Monitoring of Structural Framework has only a secondary impact on the monitoring system (London Economics, 2007).

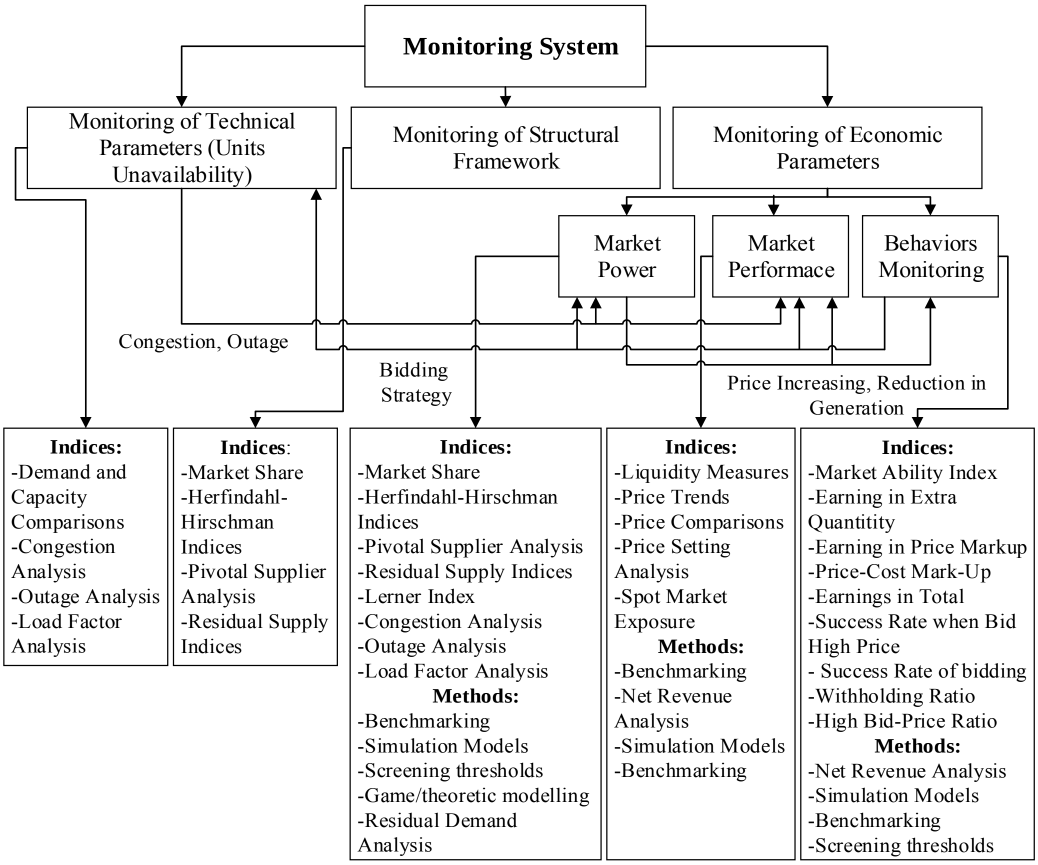

Figure 1. Market monitoring framework
Source: own compilation.

Behavioral Monitoring is the most general monitoring, which aims at detecting changes in the biding strategy. Further, a more precise element of the monitoring is market power monitoring, concentrated on the monitoring of detailed parameters regarding any possible abuses of market power. Market performance monitoring is related to the monitoring of electricity market power by way of monitoring parameters such as the weighted average price, the minimum price, the maximum price, the amount of electricity sold within a particular price range *etc.*

In order to implement the abovementioned elements of monitoring, most frequently a combination of indices and methods are used. The monitoring systems may be applicable to various markets such as day-ahead market, infra-day market or balancing market/balancing mechanisms. All the markets may interact with each other, however, due to the complexity of the issue, this paper focuses only on applying the monitoring to the day-ahead market. After certain modifications and with all the required source data, the presented indices and monitoring methods may be applied also to the monitoring of other types of markets.

The main issue regarding the monitoring systems, in particular the ones implemented as external systems (apart from the market operator structure), is the lack of sufficient publicly available source data with respect to the examined market. Therefore, one of the fundamental challenges and goals of the monitoring is to identify the appropriate indices and methods of monitoring that would allow to characterize the changes in the market on the basis of a limited range of the source data. It shall be noted that the source data availability differs from one EU member state to another. In comparison with other European countries (such as Sweden, Germany, Austria), in the Iberian Peninsula detailed information with respect to the electricity market is being published (London Economics, 2007; OMIE, 2015).

A. Market power

Restructuring and privatization of the energy market leads to the common problem of market power which may result in a lack of the efficient use of energy resources in the market. Consequently, in the literature there are many definitions of market power, however, the quintessence of all the definitions can be found in the American DOJ I FTC's[1] definition of market power: *"The ability profitable to maintain prices above competitive levels for a significant period of time"* (Kaha, 2005). In order to protect the electricity market, a system of monitoring as well as regulatory fines have been introduced to protect the market from unnecessary market influences. These influences can appear in several different markets, like day-ahead market, intraday market, etc.

There are many methods to describe the phenomenon of market power, whereas many scientific journals present information and theories about the abovementioned phenomenon (*e.g.* Marulanda *et al.*, 2006; Arce *et al.*, 2002; Asgari *et al.*, 2008; Chakrabarti *et al.*, 2008; David *et al.*, 2001). All the market power detection methods could be divided into ex-ante and ex-post.

At the same time, we can consider the problem as a behavioral issue and classify it in accordance with behavioral indices, simulation methods and structural indices. Very often behavioral indices are used in processes and are not immediately recognized as the ones concerning market power or even the ones that define the chosen potential of an operator or a group of operators.

The issue regarding Market Power is a broad topic, which could be divided into four essential subgroups: Market Power on Ramp-Rate, Physical or Quantity Withholding, Financial or Economical Withholding, Transmission Related Strategies of market power (see *Figure 2*).

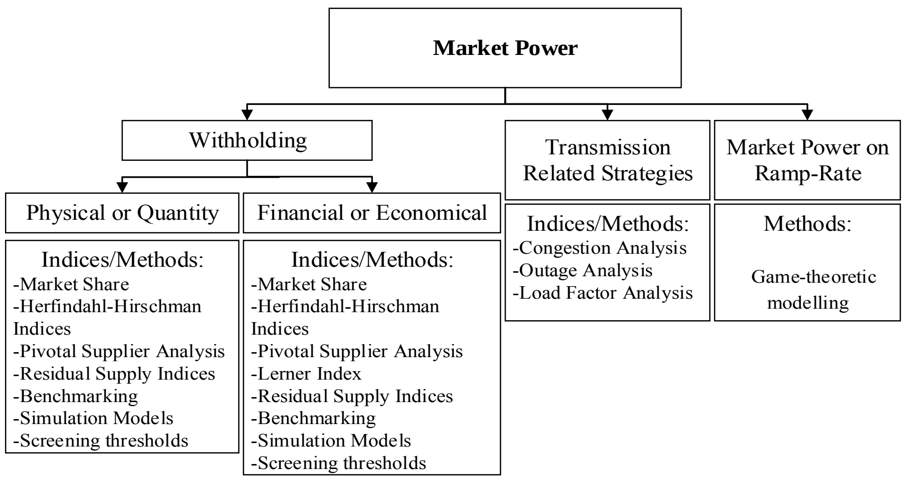

Figure 2. Market Power monitoring framework
Source: own compilation.

a) *Withholding*

There are two different manners of withholding by which companies exercise market power:

[1] United States Department of Justice and Federal Trade Commission.

- *Physical or Quantity Withholding.* The first method implies the change in the amount of energy offered – quantities game. The electricity production companies reduce the amount of energy offered, causing the aggregated supply curve to change so that the electricity price increases. The effect is a rise in the clearing price (Biggar *et al.*, 2014).

- *Financial or Economical Withholding.* The second method of exercising market power is offering the production at a cost higher than the marginal cost of the generation. This one is a more risky strategy because it doesn't guarantee market acceptance. In particular, there are problems because the clearing price is less than the price offered for a given unit (Asgari *et al.*, 2008).

b) Transmission Related Strategies of Market Power. It requires creating a situation in which line capacity is limited (transmission congestion) in order to artificially increase the price in the relevant node or zone. The generators may understate the transmission lines parameters (transmission ratings/capacity) with the aim of delivering less energy to the system. Consequently, due to the fact that less energy is present in the system, the price may artificially increase (Newbery, 2004; Biggar *et al.*, 2014).

c) Market Power on Ramp-Rate.

A recently-observed type of market power is the exercise of market power on ramp rate (Oren *et al.*, 2005). In certain situations companies can manipulate their bid on ramp-rate in order to maintain the production at a profit-maximizing level. The issue is explained in details in "Exercise of Market Power on Ramp Rate in Wind-Integrated Power Systems" (Moiseeva *et al.*, 2014).

1) The summary of the most popular analytical methods and indices *applied to the detection of Market Power*.

The indices and analytical methods, applied to the monitoring of Market Power phenomena could be classified also from the viewpoint of measurement analytical methods (Structural Indices, Behavioral Indices, Simulation Models and Transmission Monitoring). The analytical methods classified in those categories, subject to their characteristics, could be applied also to the ex-ante or ex-post monitoring.

a) The indices, one of the most popular indices falling within the Structural Indices group are Market Share Index and Herfindahl-Hirschman Index (HHI), Pivotal Supplier Index and Residual Supply Index as well as Residual Demand Analysis method. The *Market Share* and *HHI* formulas are straightforward and could be characterized by the fact that their usage does not require any advanced data (requires only sales or capacity data) or any theoretical justification (under certain assumptions) (London Economics, 2007). Nevertheless, due to their uncomplicated formula, they do not include certain aspects pertaining to electricity supply and biding strategies, and even ignore congestion issues, which shall be assumed as the weakest points of those indices. Further, they do not always reflect the dynamics of the market (see *Appendix A*). On the contrary, indices that consider the changes in supply, such as *Pivotal Supplier* Index and *Residual Supply* Index, might capture market dynamics in a much better manner (London Economics, 2007). Due to the availability of empirical support, the abovementioned indices might be widely applied to the monitoring systems on both local and global level. Nonetheless, such indices ignore the possibility that the Behavioral of the market participants might be linked with each other (e.g. collusive behavior and behavior regarding Cournot's theories), which shall be considered as the greatest disadvantage of such indices. Finally, they might be applied to both ex-ant and ex-post analysis (Newbery, 2004; Chakrabarti *et al.*, 2008) (see *Appendix A*).

Residual Demand Analysis is a more advanced tool than the above presented indices, as it requires more specific data pertaining to bids. Its greatest advantage is the fact that it encompasses the elasticity of supply and demand; in addition, a wide range of theoretical justifications is provided therefor. Among the disadvantages are the unavailability of required specific data with respect to many markets, as well as the lack of sufficient practical research with this regard (Newbery, 2004; David *et al.*, 2001).

Some of the indices used in the monitoring of Market Power (most frequently, the indices classified in the group named behavioral indices and analysis) could be applied also to Behavioral Monitoring. One of the primary indices in this group is *Lerner Index*, known also as *Bid-Cost Margins*, which could be applied to both ex-post and ex-ante analyses. Its formula is straightforward, whereas the information obtained on the basis of this index could be useful to construe both ex-ant theoretical models and ex-post analyses. The difficulties in determining the appropriate reference level, problems in interpretation and the fact that margins can be affected by factors other than Market Power are the most significant disadvantages of Lerner Index (Dun-nan *et al.*, 2006; Biggar *et al.*, 2014).

b) *Benchmarking*, as regards Market Power analysis, i.e. *Net Revenue Benchmark* could be applied as an ex-post analytical method. It is focused on investment incentives and entry/exit issues, and appears to be particularly relevant for long-term analyses. The main problems concerning this methods are difficulties in cost estimation and in the interpretation of results, as the revenues may be affected by other factors as well. In the so-called 'Simulation Models' methods group, the Competitive Benchmark Analysis shall be included. It is an ex-post method which covers all the market by virtue of a price-cost margin analysis. Among its advantages is the fact that it could depict the quantitative estimation of the efficiency and welfare loss from Market Operator (Newbery, 2004; Biggar *et al.*, 2014).

Withholding is considered to be one of the core methods of exercising Market Power, therefore, the *Output Gap Analysis* (known also as Withholding Analysis, conducted ex-post) is based on this specific method. Assuming that this type of analysis is based on the appropriate assumptions, the cost estimation will not be required, which is perceived as one of the primary advantages of this type of analysis. Notwithstanding, many imperfections of the output gap analysis could be identified, such as difficulties in the audit of interruptions in manufacturing, all the controversies with regard to empirical results interpretation and problems pertaining to ramp rates for certain technologies (Newbery, 2004; Kaha, 2005).

c) *Screening thresholds*, is a analytical method based on applying thresholds in order to detect certain changes in the analyzed data. Such thresholds may be determined in advance and may have constant values, however, while applying some more advanced algorithms, such thresholds may be defined dynamically on the basis of some other variables.

This analytical method could be applied to Market Power and Behavioral Monitoring. The algorithm of the method is based on detecting the bids which are of the crucial range. If such monitoring is realized by ISO in real time, ISO may order either to change such bids or to eliminate them, such as in the case of ISO New England (Newbery, 2004). If the monitoring is realized in ex-post system, the abovementioned screens could also be applied. While implementing the filters, also the characteristics of each technology (start-up cost, time ramp, fuel cost, etc.) and the functions of each generator (production dedicated to peak hour, main load) shall be taken into account (Güler *et al.*, 2005). One of the primary elements of screening thresholds is also the periodical filters evaluation, related to constantly changing parameters of competitive market. The parameters of competitive market from a couple of months ago, due to some changes of e.g. raw material prices, potential of energy from renewable sources or substantial changes of demand etc., could be outdated and could lead to incorrect results. In some systems of this type, the parameters are being corrected continuously, on the basis of some historical data (e.g. from 90 days ago until yesterday) (Musa, 2014). The key factor of screening thresholds is applying the relevant filter parameters, fully reflecting the market characteristics.

d) *Transmission Monitoring*. At the end of this section it shall be mentioned that the monitoring of transmission in the electricity market monitoring systems is very frequently omitted. The monitoring of transmission parameters could be crucial for detecting Market Power, however, the analysis of transmission parameters requires a great amount of detailed data (such as bids, output, transmission parameters, congestion, etc.) that often is not publicly available. As regards the monitoring of generation outage and the monitoring of electricity transmission outage, several indices could be mentioned, e.g. Transmission congestion index, Risk of Outage Duration and Users Amount Loss, Outage status by unit, Frequency of outage by type, unit, time period, Frequency of unit outages by time period, by demand condition, by system/bus price; a detailed description of the abovementioned indices is presented in (Dunnan *et al.*, 2006; OMIE, 2015; Kaha, 2005). Furthermore, the methods of analyzing outages of generation and transmission shall be noticed, e.g.: Congestion Analysis, Outage Analysis, Load Factor Analysis (Newbery, 2004; Kaha, 2005).

e) *Exercise of Market Power on Ramp* involves gaming on inter-temporal constraints; the static indices are incapable of detecting it. The detection method proposed in paper "Exercise of Market Power on Ramp Rate in Wind-Integrated Power Systems" is the full system game-theoretic modelling. However, this method requires the availability of the data to the system operator and precise modeling of the whole system in every point in time, which can be computationally problematic (Moiseeva *et al.*, 2014).

B. Market Performance

The main goal of market performance monitoring is to identify market inefficiencies and the potential for market abuses. A comparison of existing market performance monitoring and mitigation policies is presented in (Farr, 2002). The analytical methods and indices applied to market performance monitoring are to the great extent convergent with the methods applied to market power monitoring and behavioral monitoring. This stems from the interdependencies between all the groups – any changes of agents strategies almost always would be observed in the market efficiency monitoring, whereas any situations regarding market power would trigger a change of the parameters relevant for market performance. Also some parameters such as: generators concentration, outage or reduction in production or transmission, a change of market structure etc., classified as Monitoring of Technical Parameters and Monitoring of Structural Framework, could be of crucial influence on the market performance (see *Figure 1*). In order to detect the influence of the above parameters on the market efficiency, an individual analysis of each case is required. It is quite a complex process, due to the fact that a lot of factors shape the analyzed situation. In addition, the manner of interpretation of indices and methods for the relevant monitoring is crucial.

- *The core indices applied to market performance monitoring are presented below:*

Liquidity measures index. There are two measures of liquidity. Firstly, in both short term and long term markets, the level of confidence held in the market can be indicated by the number of suppliers and in particular the number of traders who do not have physical positions in the market. This number implies also how easy it is for a market participant to find a counterparty for a trade (Asgari *et al.*, 2008). The second useful measure of liquidity is the volume of trade in a market, relative to the underlying physical demand. Both types of liquidity measures could be implemented straightforward and could be used close-to-real time or ex post and on a daily or monthly basis. Further, the data required in order to implement the measures are bid prices and volumes. It is also highlighted in the literature that the level of output covered by the market participants with long-term contracts is crucial for the proper analysis, while concentrating on spot markets and undue reliance on such markets may hinder the results (Newbery, 2004; Yang, 2006).

Spot Market Exposure index**,** as already mentioned, the conducted research on forward markets leads to a conclusion that undue reliance on spot markets may hinder the results. Therefore, the spot market exposure shall be measured by the percentage of load bought under long term forward contracts and supplied by insufficiently unbundled companies with no use of market mechanisms. Both type of liquidity measures be implemented straightforward and used close-to-real time or ex post and on a daily or monthly basis. Further, the data required in order to implement the measures straightforward are (as in the case of liquidity measures) bid prices and volumes (Newbery, 2004; Bagherpour, 2014).

- *The core analytical methods applied to market performance monitoring are presented below:*

Competitive Benchmark Analysis, the competitive price benchmark proves to be useful in order to obtain a derived Lerner Index. This index (its absolute level) could indicate if there are any problems. Further, it allows to make comparisons with some other markets at different points of time (Galarza *et al.*, 2004).

Net Revenue Benchmark known also as Net Revenue Analysis evaluates the revenue net production costs expected by a particular unit. Practically, the value of the net revenue shall approximate the annual carrying cost of the unit. In order to apply the net revenue analysis, the revenues and estimates of costs shall be compared. Whit regards to the estimates of cost, the data such as entry costs, exit costs and the cost of transmission alternatives to generation shall be considered. Further, this method could be implemented with respect to a plant operating at a range of load factors. Net Revenue Benchmark is perceived in the literature as a useful method, however, the net revenue in a certain year could be subject to various unpredictable system conditions, such as unusual peak load conditions (Newbery, 2004; Patton, 2003). Furthermore, the indices outlined in the subsection C, (Behavioral Monitoring), classified in *Analysis of Earning* group, could be applied also to Market Performance monitoring (London Economics, 2007).

C. participants Behavioral Monitoring

Behavioral Monitoring is one of the most general branches of monitoring, which aims at determining the changes in the market participants behavior as well as at determining current trends. Due to its characteristics, this type of monitoring uses a number of the same methods and indices as both market power monitoring and market performance monitoring (Market Share, PSI, RSI, etc.). If the results of the indices applied to the monitoring of other parameters are properly interpreted, such indices could be applied also to Behavioral Monitoring. Furthermore, on the electricity market various market participants Behavioral could be observed. As a rule, the agents could be classified in two groups: those that are capable of influencing the final price, and those whose actions would not affect the final price – in general, their activity in the market is rather minor. As far as the Behavioral Monitoring methods are concerned, they could be categorized on the basis of the moment of conducting analysis (before biding, during biding and after biding) (Farr, 2002; Dun-nan *et al.*, 2006), or the manner of influencing the market (pricing or withholding); nevertheless, one of the most adequate classification is presented on the *Figure 3*.

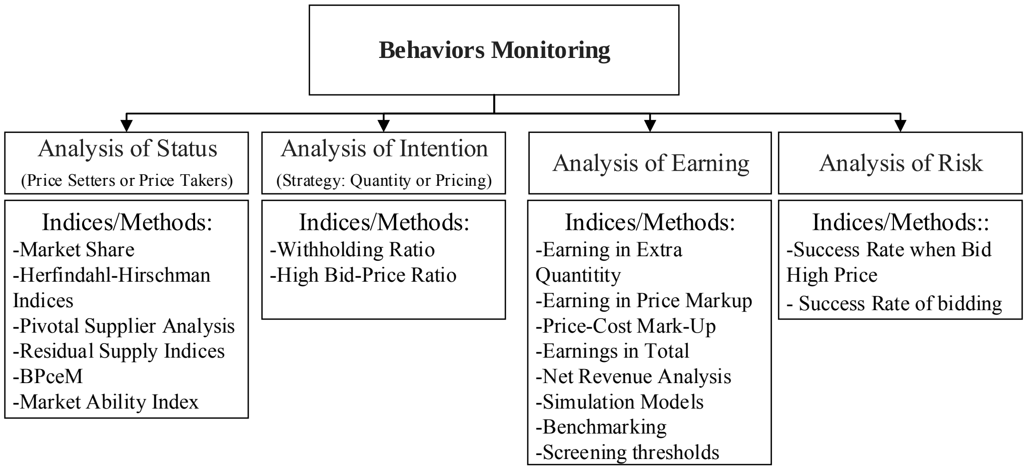

Figure 3. Participants behavioral monitoring framework
Source: own compilation.

The *Figure 3* presents 4 core participants behavioral monitoring subgroups: (a) Analysis of Status, (b) Analysis of Intention, (c) Analysis of Earning, and (d) Analysis of Risk.

d) Market Participant Status. Analysis of status aims at controlling the market participant status (Price Setters and Price Takers), and is based on comparing the capacity of different market suppliers with the market demand, as well as on one of the primary indices, i.e. *Market Share*. The indices and methods in this subgroup and the indices and methods applied to detecting market power have a number of common features. Further, indices such as *RSI*, *PSI* and *BPceM*, presented in section II and IV, are common for both Market Power and Analysis of Status (London Economics, 2007). On the contrary, *Market Ability* Index (see *Appendix*) is used only for Analysis of Status. It shall be underlined that this index does not illustrate the ability of particular agents to modify the market price. Due to the type of applied source data, the index describes only the group of agents classified as Price Setters and presents its ability to influence the market price (London Economics, 2007; Dun-nan *et al.*, 2006).

b) *Analysis of Intention*. This subgroup focuses on determining whether a particular agent or a group of agents applies a strategy based on quantity or on pricing. The quantity strategy focuses on controlling whether a particular agent limits the volume of energy available on the market in order to trigger a price increase. The primary index applied in this subgroup is *Withholding Ratio* (Dun-nan *et al.*, 2006), which determines (on a scale from 0 to 1) what part of the examined agent capacity is offered on the market, in comparison with the full capacity of the examined agent. If the index value amounts to approximately 1, it could imply that the agent might have attempted to influence the final price. Furthermore, also High Bid-Price Ratio could be useful in determining Price Strategy. *High Bid-Price Ratio* shall be defined as the proportion of quoted quantity when the bid price is around the price cap over the all the quantity. Nevertheless, is shall be noted that this strategy is quite risky and is applied mainly by the agents with significant market shares (Dun-nan e*t al.*, 2006; Kaha, 2005; Mentel *et al.*, 2015).

c) Analysis of Earning. The agents may increase their revenue by increasing the sold electricity volume or by increasing the price or by a combination of both strategies. In order to determine which agent or which group of agents has increased its revenue on the basis of the quantity strategy, *Earning in Extra Quantity* index (see *Appendix*) could be applied. Earning in Extra Quantity index is represented as the ratio of the market share of the sold energy of a particular agent on the market in a particular moment, to the market share of the sold energy of a particular agent on the market in a particular period (one day, one week, one month *etc.*) (London Economics, 2007). Another index, that enables identifying the changes of market participants Behavioral in the aspect of costs maximization, is *Earning in Price Markup*. This index is represented as the ratio of the cleared energy price for a particular agent to the average cleared energy price for all the agent. In addition, the index presents the parameter that describes the change of particular agent price with regard to the whole system (Dun-nan *et al.*, 2006). *Price-Cost Mark-Up* index (see appendix) is very similar to the one presented above (London Economics, 2007). As a rule, Price-Cost Mark-Up index shall be applied at certain time intervals and is defined as the relation of the differences between the market price at certain time and marginal cost, to marginal cost of system. One of the disadvantages of this indices might be the fact that both do not consider the demand parameters, which might affect negatively the results of calculation. Furthermore, Lerner Index, which is broadly described in the literature and presented in the paragraph III (DG COMP), shall be also classified in the same genre of indices. Additionally, *Earnings in Total* index, defined as the product of Earning in Extra Quantity and Earning in Price Markup, describes two core strategies of profits maximization (with regard to price and quantity) in a very complex manner. The higher its indications are, the better and more successful bidding strategy is. If the index value amounts to less than 1, it implies that the adopted strategy incurs losses (London Economics, 2007; Dun-nan *et al.*, 2006; Wang and Xiong 2010).

d) Analysis of success bidding. As a rule, two indexes shall be included in this sub-group: *Success Rate when Bid High Price* and *Success Rate of bidding* (Dun-nan *et al.*, 2006). The first one shall be defined as the relation of bargain's quantity over the total quoted quantity, when the bid price is relatively high. If the index value amounts to approximately zero, it implies that the agent is not capable of increasing the final price, whereas a high value of the index indicates that the agent may successfully submit bids on the market at a high price range and, consequently, increase the final price.

The second index classified in this sub-group is Success Rate of bidding index, which shall be defined as the relation of cleared energy within a particular hour to cleared energy of the particular agent within a fixed timeframe (one day, one week, one month, etc.). The high index value implies that the adopted bidding strategy is highly successful (Dun-nan *et al.*, 2006; David and Wen, 2000; Wang and Xiong 2010).

Many analytical methods applied to the monitoring of market power and market performance could be also used with regard to Behavioral Monitoring (such as benchmarking, screening thresholds, etc.). The reference models as well as the manner of interpreting the results are the key factors in applying any comparative method (such as benchmarking). When applying the methods from screening thresholds group, the selection of appropriate threshold parameters is crucial. The detailed and full description of the abovementioned methods is provided in subsection 1 and 2 of section II

2. Particularities of Spanish market

1) Structure of the electricity market in Spain

The sole transmission agent and operator of Spanish electricity system is Red Eléctrica (Transmission System Operator). It is responsible for the management of an extensive network of electricity infrastructures and facilities. Further, the function of market operator is performed by OMIE. In the year 2013, OMIE managed transactions amounting to over 12 billion euros, accounting for more than 80% of the electricity supplied in Spain and Portugal. The market operates 24/7 and is open to all the buying and selling agents that wish to trade on it. Today there are almost 800 agents operating on markets, being involved in a total of over 11 million transactions per year (OMIE, 2015).

The price and volume of energy are determined on the basis of the offers (bids) of supply and demand. Furthermore, the price and volume of energy are being published after the session is closed (*i.e.* the market is cleared) (OMIE, 2015). It shall be noted that the spot electricity market on the Iberian peninsula consists of 3 basic elements: a) the day-ahead market, b) the intraday market, and c) the procedures for balancing (Electricity market OMIE, 2015).

a) Day-ahead market. The energy price for the next 24
hours is determined one day ahead at 12 (midday). The price and volume of energy are set on account of the intersection of the supply and demand curves, on the basis of the marginal pricing model (such a system of setting the price and volume is implemented in many European countries) (OMIE, 2015).

b) Intraday market. After the closing of the daily market, the agents may enter into transactions on the intraday market, which has high liquidity. The transactions take place on the same day up to four hours ahead of real time (OMIE, 2015).

c) Balancing procedure supports the functioning of the market after closing of the day-ahead market and intraday market, through the following functions: technical and security of supply constraints management, secondary reserve, tertiary reserve, deviation management, and additional upward reserve (Red Eléctrica de España, 2015). Bids submitted in the day-ahead market and intraday market are not technically restricted. Nevertheless, one of the main aims of the technical security of supply constraints management is controlling whether a particular offer could be introduced into production (*e.g.* whether the transmission capacity is sufficient). Consequently, if some bids are modified or the energy demand changes, such a correction is made first on the secondary reserve and then, in case it is necessary, on the tertiary reserve. The last element is deviation management, which aims at detecting differences between the forecasted and actual demand (Bratu, 2012). If it is necessary, relevant information is sent from deviation management to additional upward reserve for the purpose of satisfying the actual demand (Red Eléctrica de España, 2015; Electricity market OMIE, 2015).

2) Public data

Publicly available source data regarding electricity market could be divided into two groups:

a) Data published in real time or close to real time (a few hours after its creation);

b) Data published 3 months after its creation – such data is more detailed, it includes strategic information for market participants (e.g. the parameters of bids related to particular agents).

Due to the service of transmission system operator and market operator it is possible obtain about the day ahead market current information regarding market prices of electricity and hourly values energy in time intervals for the whole day ahead market, without making any distinctions as regards agents. The abovementioned service presents also information relating to the planned production, with regard to different the technology types (hydro, nuclear, etc.), 48 hours in advance. The data is being updated in the moment of the closing of each session for the relevant market (the day ahead and the intraday market), as well as after the introduction of changes by balancing mechanisms. Balancing mechanisms are being launched at 2-4 hours intervals and are being published in real time (Datos OMIE, 2015; Red Eléctrica de España, 2015).

After conducting a proper analysis of the abovementioned data, the differences between relevant markets could be observed, as well as the influence of the technical parameters on the final energy production. The detailed data regarding day ahead market is being published on the market operator website, however, such information is available there with a delay of 3 months. Among the most important pieces of information are those regarding bids (price, energy value, data and time related to the bid, the agent submitting the bid, bid status: sale/purchase, accepted for sale/purchase, rejected) (Datos OMIE, 2015).

Conclusion

In this paper, the indices and methods for electricity market monitoring are categorized and listed. The in-depth analysis of the literature presented in this paper could be also highly important for projecting a new monitoring system. In addition, the analysis describes the most important issues related to electricity market monitoring from the point of view of the economic parameters.

Further, the conducted analysis of the available publications related to electricity market monitoring demonstrates a deficit of effective methods and indices that could be applied to electricity markets monitoring in Europe.

As regards the presentation of the structure and analytical methods of a monitoring system, future research will focus on redesigning or developing a new structure of the monitoring system characterised by more effective monitoring of inappropriate behaviours of market participants. Due to the constant changes on electricity markets, proposing a new structure might require also proposing new indices.

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Appendix

Nr	Index name	Mathematical formula	Input data
1	System available committed capacity reserve margin (CRM)	$CRM = \frac{(AC-Lo)}{AC} \times 100\%(1)$	*AC* – AvailableCapacity *Lo* – Load
2	Transmission congestion index TCI in $/MWH	$TCI = \frac{TCC}{TSE}$	*TCC* – Total transmission congestion cost, *TSE* – total system energy
3	Transmission congestion index in Percentage (TCIP)	$TCIP = \frac{TCI}{SAMCP} \times 100\%$	*SAMCP* – SystemAverageMarketClearing Price, *TCI* – Transmission congestion index
4	Market clearing price monitoring index (CPMI)	$CPMI = \frac{(MaxMCP - MaxCost \times RPM)}{(MaxCost \times RPM)} \times 100\%$	*MaxMCP* – highest market clearing price is abbreviated, RPM-reasonable profit margin is abbreviated, *MaxCost* – ISO estimated equivalent generation cost (variable and distributed fixed cost) in $/MWH for the highest accepted bidder
5	Market clearing price deviation (CPD)	$CPD = \sqrt{\frac{\sum_i^L (MCP_i - AvgMCP)^2}{L}}$	*AvgMCP* – average market clearing price, L – number of LMP locations. LMP(Locational Marginal Prices (LMP) or Spot Prices (SP), *MCP* – market clearing price
6	Market clearing price distribution index (CPDI)	$CDPI = \frac{CPD}{\lvert AvgMCP \rvert} \times 100\%$	*AvgMCP* – system average market clearing price, *CPD* – Market clearing price deviation
7	Hertlndahl – Hirschman Index (HHI)	$HHI_c = \sum_{i=1}^{m} \left(\frac{MWH_i}{Total_c} \times 100\right)^2$	$Total_c$ – the generation (energy), MWH_i – generation of i company
8	System HHI	$HHI_s = \sqrt{\sum_{j=1}^{n} \left(\frac{MWH_j}{Total_s} \times HHI_{c_j}^2\right)}$	MWH_j – generation of j company (energ), $Total_s$ – total generation
9	Market power monitoring index (MPMI)	$MPMI_{yr} = \sqrt{\sum_{k=1}^{H} \left(\frac{MWH_k}{Total_{yr}} \times MPMI_k^2\right)}$	*H* – hours in a year, System MPMI – system HHI every hour, MWH_k – generation of k company
10	Residual Supply Index	$(RSI)_i = \frac{TC - Cr}{TD}$	Total capacity – the total supply *TSCi* – total supply capacity of company i *TD* – total demand
11	Market Share of supplier i	$MS = \frac{q_i}{Q}$	qi – Quantity supplied by company i, Q – Total volume of the market
12	Lerner Index (LI) and Price – Cost Margin Index (PCMI)	$LI = \frac{p-\lambda}{p}$; $PCMI = \frac{p-\lambda}{\lambda}$; t	λ – Marginal cos p – price
13	Earnings in Price Markup	$EP = \frac{p_i}{P_{Ave}}$	*pi* – is the deal price of *i* *PAve* – average deal price of all the generators
14	Earnings in Extra Quantity (EQ)	$EQ = \frac{MS_i}{MSu_i}$	*MSi* – Market share of qi is calculated based on the supplier's bargains, *MSui* – Market share of ci is based on their usable capacity

15	Earnings in Total Income	$EI = \frac{I_i}{DI_i}$	I_i – the total income of supplier i, DI_i – average income of supplier i
16	Available Capacity (AC)	$AC_{i,t} = AIC_{i,t} - RES_i + LTC_i$	RES_i – system reserve requirements *LTC* – net position of the company in the long-term contract market $AIC_{i,t}$ – Available Installed Capacity
17	Benchmarking cost for company i in year t	$C_{i,t} = \alpha_i C_{i,t} + (1-\alpha_i)\sum_{j=1}^{n} f_j C_{j,t}$	α_i – share of company i $C_{i,t}$ – cost of comany i in year t f_j – weights for peer group companis $C_{i,t}$ – cost for peer group companies year t n – number of peer group companies
18	Pivotal Supplier Index (PSI)	$PSI_j = 0\ if \left(\sum_{i=1}^{N} AIC_i - AC_j - \sum_{i=1}^{N} hG_i\right) \geq 0$ $PSI_j = 1\ if \left(\sum_{i=1}^{N} AIC_i - AC_j - \sum_{i=1}^{N} hG_i\right) < 0$	AIC_i – Available Installed Capacity AC_j – Available Capacity *hGi* – hourly generation of supplier i
19	Load weighted average prices and costs	$wP = \sum_{t=1}^{T}\left[\left(\frac{hGi}{\sum_{i=1}^{T} hG_1}\right) * P_t\right]\ where = 1,2 \ldots\ldots,26,30$ $MC = \sum_{t=1}^{T}\left[\left(\frac{ht}{\sum_{i=1}^{T} hG_t}\right) * MC_t\right]\ where; t = 1,2 \ldots\ldots,26$	P_t – price MC_t – marginal cost, *hGi* – hourly generation of supplier i
20	Contribution to Fixed Cost	$CFC_i = \sum_{t=1}^{T}[(MC_{system,t} - MC_{it}] * mg_{it}]\ where; t = 1$	MC_{it} – subtracted from the hourly system marginal cost $MC_{system,t}$ – equivalent to the market price in a perfectly competitive market, *mgit* – the hourly optimal unit dispatch specific to each unit (*i*)
21	Price-Cost Mark-Up (based on load weighted avarage proces and costs)	***wPC Mark – Up*** = $\frac{wP - wMC}{wMC}$	*wP* – weighted average price *wMC* – weighted average marginal cost
23	Markup Ability	***MA*** = $(P_{Max} - P_0)/P_0$	P_0 – market clearing price in the case the generator does not intent to raise the price, P_{Max} – represent the max value of market clearing price while the generator try its best to raise the price