Energy competition analysis – which tools to trust?

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ABSTRACT

Continued consolidation in the energy industries means that competition authorities repeatedly need to explore the potential effect of mergers on competition in the industry. Also, ever since the liberalisation process began, regulators and competition authorities have been repeatedly concerned that a number of players in various European power markets have abused market power and have thus needed to investigate whether such abuse has taken place.

In such cases, the authorities are legally required to follow a two stage process in first defining the relevant market in terms of products and geography and then exploring structure and based on this, likely conduct within the market so defined. In an abuse investigation, for example, the finding that a player has market power would lead to

further investigations as to whether he has used it to raise prices, comparing actual prices with some competitive benchmark.

When investigating market structures, authorities tend to rely on traditional tools for market share analysis such as concentration ratios and the Hirschmann-Herfindahl Index (HHI). While to some extent these indices are based on an economic logic they ignore important structural aspects of the market:

- the role of the demand-supply balance in a capacity constrained industry such as electricity or gas; and
- the role of cost structures and their implications for behavioural incentives in the market.

More recently some experience has been gained with more advanced techniques, for example:

- pivot analysis – this analysis relates the capacity controlled by non-strategic players to aggregate demand in order to explore whether one or a few strategic players have a "residual monopoly" over some part of demand.
- market simulations – these go further than pivot analysis and also consider cost structures and potentially demand elasticities, e.g. to explore whether players have commercial incentives to "game the market" independent of whether they are pivotal.

Our paper provides a survey of relevant approaches and through this, addresses a number of questions:

- What are the shortfalls of traditional tools of market share analysis (i.e. to what extent could authorities arrive at wrong conclusions by applying traditional tools alone and not taking into account the experience with more advanced techniques)?

- To what extent does pivot analysis provide a useful development and what are the caveats of this technique?
- To what extent can market simulations – given their complex nature – constitute a credible tool in formal competition investigations?

We illustrate our points using stylised examples for alternative situations of market concentrations and demand-supply balances in the electricity industry.

We reach the following conclusions:

- Traditional tools (such as market share analysis) are insufficient to allow a robust decision in market investigations.
- Pivot analysis provides a useful "ready reckoner" but its inherent simplifications mean caution must be applied in its use.
- If cost information is available, market simulations provide a way forward, if only to explore sensitivities and expose analysis with the other tools to scrutiny.

However, it is not possible to fully capture simultaneously all elements that affect competition with any of the measures assessed in this paper. Therefore, while the tools are useful in building a body of evidence to support authorities' decisions, they should be complemented by aspects of competition less readily parameterised or less readily captured within a single model, e.g. the threat of entry, the threat of regulation and uncertainty.

INTRODUCTION

Competition authorities are frequently required to assess whether a market is characterised by market power or whether market power would be created or increased through a merger.

In other words, competition authorities are primarily concerned about market power. Market power matters as it can convey the ability and incentive to one or a few players to price independently, which may lead to prices in excess of those in a competitive situation.

In order to assess whether market power exists, authorities have traditionally focused on the concentration of an industry. Concentration is measured, for example, by the individual or joint market shares of the largest players in an industry. Concentration matters to the extent that market power is correlated with concentration. Authorities have traditionally relied on concentration analysis as it provides a quick and initial insight into the possible existence of market power.

However, it turns out that the convenience of calculating concentration measures may have led authorities to analyse markets in rather mechanistic ways. New approaches, for example, pivot analysis and market simulations, have emerged to assess market power. These innovations have especially been applied to the energy industry. In this paper we discuss the benefits of these new approaches and also consider the cost and effort required to implement them.

We proceed by:

- providing an overview of the different approaches to competition analysis;
- characterising a stylised model of an electricity market which we use to compare the performance of the different tools;

- providing illustrative results for the different tools for competition assessment; and
- drawing some conclusions.

TOOLS USED IN COMPETITION CASES

Competition authorities have recently used the following approaches to assess whether market power exists:

- The Hirschmann-Herfindal-Index (HHI)[1] – this is a measure of market concentration which considers sales or capacity shares in an industry. By its nature, the HHI ignores demand or overcapacity and does not consider the cost structure of the industry. Typically, certain thresholds and changes in the HHI as a result of a merger will be seen as critical by the European Commission.[2] However, before any meaningful HHIs can be computed, the investigator is first required to define the product and geographic market for which market shares are to be evaluated. The EC has developed a standard

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1 The HHI is the sum of the squares of the market shares of the individual firms in a market. In electricity wholesale markets, it is more common to use capacity shares as opposed to shares of sales or production to calculate the HHI. For an example of the use of the HHI, see EC, *Sector Inquiry under Art 17 Regulation 1/2003 on the gas and electricity markets Preliminary Report*, 16 February 2006.

2 The *Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings* (2004/C 31/03) state:

"*The Commission is unlikely to identify horizontal competition concerns in a market with a post-merger HHI below 1 000. Such markets normally do not require extensive analysis. … The Commission is also unlikely to identify horizontal competition concerns in a merger with a post-merger HHI between 1 000 and 2 000 and a delta below 250, or a merger with a post-merger HHI above 2 000 and a delta below 150, except where special circumstances … are present.*"

The guidelines applied by US authorities are similar. Mergers resulting in post merger HHIs of below 1000 are considered unconcentrated and ordinarily require no further analysis, mergers resulting in HHIs between 1000 and 1800 with an increase in HHI of less than 100 ordinarily require no further analysis and mergers resulting in HHIs of more than 1800 with an increase in HHI of less than 50 ordinarily require no further analysis. See US Department of Justice and the Federal Trade Commission, *Horizontal Merger Guidelines*, April 8, 1997.

procedure for defining the relevant market, the so called SSNIP test. The SSNIP test seeks to identify the smallest market within which a hypothetical monopolist could impose a small but significant non-transitory increase in price (typically 5 to 10%) and defines this as the relevant market. The approach is in practice often difficult to implement as a precise quantitative test. Authorities have therefore often refrained from a proper market definition exercise. However, inappropriate market definition can lead to meaningless concentration measures – for example, if the market is defined too narrowly or too widely and if the resulting market shares of large players within the defined market are too high or too low.

- The "pivotal supply index"[3] – this approach identifies players that are "indispensable" to satisfy demand on the system. The extent to which a player is pivotal (i.e. its "pivotalness") is measured by assessing whether the entire market demand can be met by all other players apart from the (deemed) dominant player. If this were not the case then competitors may be able to threaten the entire market share of the large player. If, on the other hand, the large player is pivotal to some extent he may enjoy a residual monopoly over part of the market demand which allows the pivotal player the freedom to set prices. Pivotalness can be measured quantitatively e.g. by the size of the residual monopoly at peak demand or by the number of trading intervals (hours in a year) over which a player is pivotal. In contrast to HHI analysis

3 For example, the pivot analysis was used by the Italian competition authority/the Italian energy regulator in an investigation into market power in the Italian electricity wholesale market in 2005 (Autorità per l'energia elettrica e il gas and Autorità garante della concorrenza e il mercato, *Indagine conoscitiva sullo stato della liberalizzazione del settore dell'energia elettrica*, 9 February 2005) and by DTe with respect to the state of competition in the market for gas flexibility services, also in 2005 (Frontier Economics, *Research into Flexibility Services – Final Report*, March 2005). We understand that it was used also by the Danish competition authority in a recent case examining excessive pricing in the electricity wholesale market.

this analysis considers demand information and excess capacity on the system. The main shortcoming of this approach, however, is that it does not consider cost structures in the industry and therefore the extent to which different players and production technologies constitute a competitive restraint on other players.

- Simulation models[4] – these are sophisticated tools which can assess the whole range of profitable strategies available to the different players in a market and thus the wider circumstances under which market power can be exercised. They therefore consider demand profiles and the precise cost structure of the industry.

This description already indicates that pivot analysis and simulation models are superior to the HHI in conveying an understanding of the competitiveness of an industry. The pivotal supply index in particular is a technique which is increasingly used by experts and regulators worldwide. Table 1 summarises the structural aspects of markets that the three approaches consider.

4 For example, NMa commissioned two competition assessments of the Nuon-Relient merger on the basis of merger simulation models (see NMa decision: *3386/ Nuon - Reliant Energy Europe*, 2003). Frontier Economics applied a merger simulation model to the assessment of competition in Austrian wholesale electricity as part of the EC's Phase II enquiry into the Verbund/EnergieAllianz merger (see EC, *Case COMP/M.2947 - Verbund/EnergieAllianz*). Frontier Economics also applied a merger simulation model to the assessment of competition as part of the Veba-Veag merger before the EC (see EC, *Case No COMP/M.1673 – VEBA/VIAG*).

Table 1: Approaches to analysing market power

	Sales / capacity	Demand (relative to capacity)	Cost / profit
Market share analysis	✓		
Pivot analysis	✓	✓	(✓)
Market simulation	✓	✓	✓

A further benefit of simulation approaches is that market definition exercises become obsolete. Simulation models implicitly assess which players and production technologies stand in competition to each other. Traditional approaches require a two-step process where first the relevant product and geographic market is defined and second market shares are analysed within the markets so defined.

ASSUMPTIONS FOR OUR STYLISED ANALYSIS

We use a stylised electricity market model to evaluate the three tools for assessing competition for a number of different market conditions. A stylised model helps use to identify the effect of a change to market conditions on the three measures of competition.

We explain our model in two steps:

- we first describe the structure of the industry which we analyse; and
- we then explain the market simulation model that we employ.

Market structure

Overview

Our stylised model assumes industry structure is characterised by three identical strategic players, who offer their generation capacity into the wholesale electricity market at the marginal cost of production or above, and a competitive fringe that offers its generation capacity into the market at marginal cost. We assume the competitive fringe comprises an infinite number of small players. In analytical terms the fringe has no incentive to offer capacity above marginal cost, is never pivotal in the stylised system and makes no contribution to the numerator of the HHI calculations.

The generation park consists of three plant types, with a low, medium and high short run marginal cost of production respectively. We refer to these plant types as coal, gas and oil respectively. We assume that the cost of production from a power station varies linearly with output, as follows:[5]

- coal: ca. €29/MWh;
- gas: ca. €34/MWh; and
- oil: ca. €59/MWh.

We ignore other production costs, ignore inter-temporal constraints such as limits on the rate of change of output and assume each power station can operate anywhere on the production continuum ranging from zero output to its maximum available capacity.

Demand is assumed to be inelastic and is specified as an average level of power consumption (MW) for a given hour.

We assume a single region with a loss-less and unconstrained transmission system that connects generators to loads. We model the stylised market for a year (8760

5 These indicative costs reflect the efficiency of typical plant as well as fuel prices and prices for emission certificates as of summer 2006.

hours) and clear the market for each hour independently. Demand and generation availability are known in advance.

Variants of market structure explored

Our analysis investigates the effect of:

- three different levels of reserve capacity characterised through different levels of demand; and
- three different distributions of capacity ownership

(i.e. 9 cases in all) on competition, as measured by the three different tools. In all cases, the total net installed generation capacity is held constant at 11000MW, with expected net available capacity held constant at 10000MW – equivalent to a 9.1% expected outage rate. Coal fired generation comprises 50% of available capacity, gas 25% and oil 25%.

Our reserve capacity cases are as follows:

- for our **medium demand** case, we assume demand during the peak hour of the year is such that the system has a 20% installed capacity margin; and
- for our **high** and **low demand** cases, we scale the demand by a uniform multiplier such that the installed capacity margin is 15% and 25% respectively.

The hourly pattern of demand within the year is based on Belgium electricity consumption for 2005.[6]

6 Demand data are available at Elia's website, http://www.elia.be/upload/elia_load/elia_load_2005.xls

The three different cases of capacity ownership, relate to the quantity of the capacity owned by the competitive fringe:

- In the **medium-sized fringe** case, each strategic player's generation portfolio (Player A, Player B and Player C) comprises:
  - 1000MW of available coal fired generation capacity;
  - 500MW of available gas fired generation capacity; and
  - 500MW of oil fired generation capacity.

  The portfolio of the competitive fringe (Player CF) comprises:
  - 2000MW of available coal fired generation capacity;
  - 1000MW of available gas fired generation capacity; and
  - 1000MW of oil fired generation capacity.
- In the **large fringe** case, the competitive fringe has 2300MW of available coal fired generation, 1150MW of oil fired generation and 1150MW of gas fired generation. The remainder of the capacity is divided equally among the 3 strategic players.
- In the **small fringe** case, the competitive fringe has 1300MW of coal fired generation, 650MW of oil fired generation and 650MW of gas fired generation. The remainder of the capacity is divided equally among the 3 strategic players.

Table 3 in the Annex shows the percentage of installed capacity held by each player for each of the three capacity ownership cases.

Figure 1 below illustrates the market structure for the medium fringe case (also see Table 2 of the Annex). The range of hourly demand during the year for the medium demand case is superimposed over the marginal cost curve – indicating that the system marginal cost (i.e. assuming all players offer their generating capacity into the market at marginal cost) ranges between €29/MWh and €59/MWh.

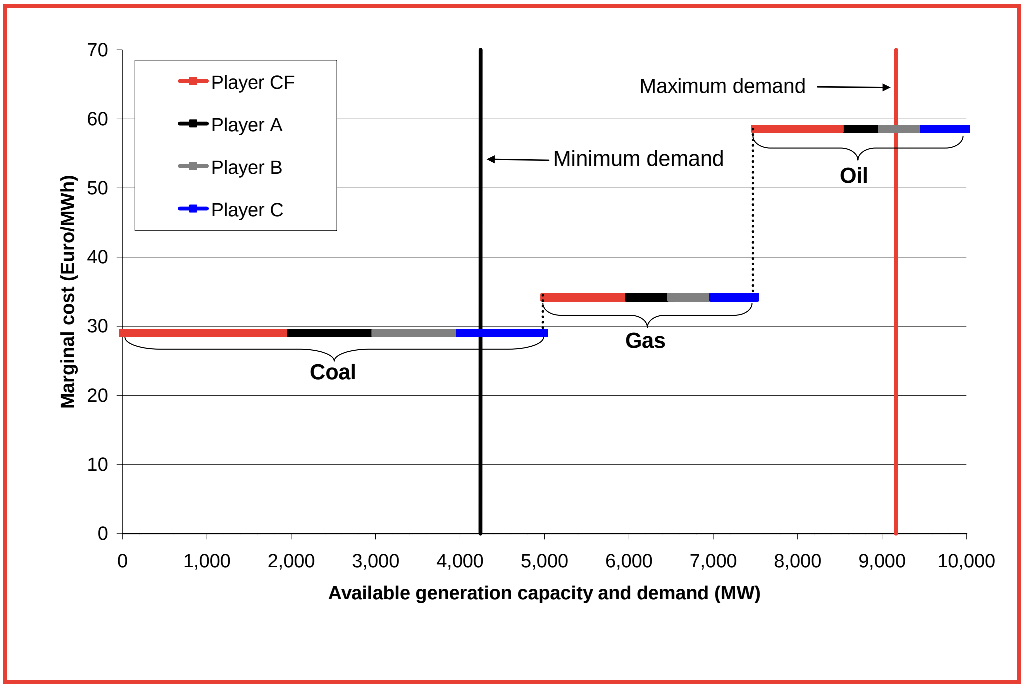

Figure 1: Market structure – medium fringe / medium demand case.

In this case, the HHI based on available capacity is 1200.

Figure 2 below compares available generation capacity, grouped by ownership, to the range of demand during the year for the medium fringe / medium demand case. At peak demand, Player C is shown as being pivotal (i.e. essential to meet demand) although we note that the pivotal player could be any of the strategic players since they are symmetrical. In fact, a strategic player is pivotal whenever demand is 8000MW or above for the medium fringe case, which amounts to 13% of the hours in the year.

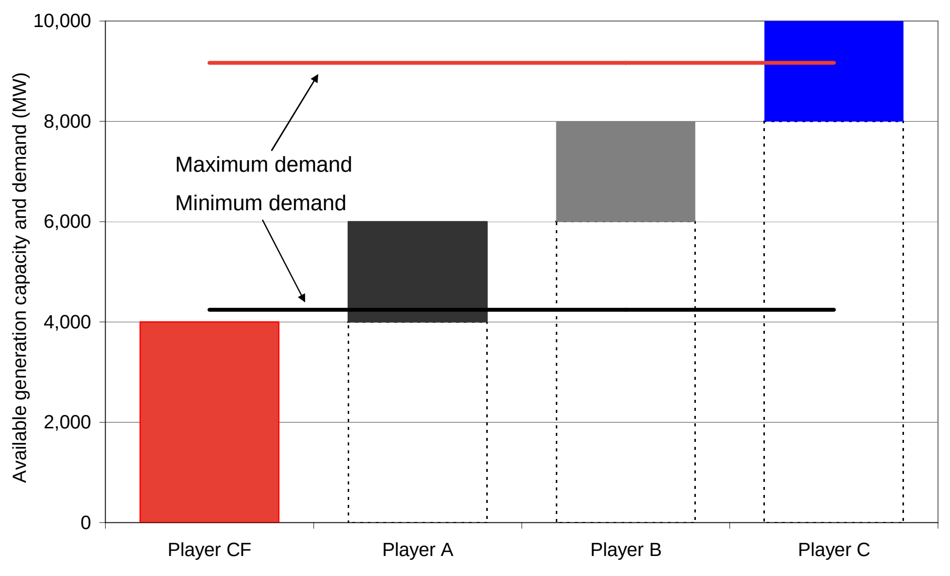

Figure 2: Capacity stack – medium fringe / medium demand case.

Simulation tool for market analysis

The market simulations explore whether the strategic players have a commercial incentive to offer their available capacity to the market above marginal cost. In this section we first compare possible approaches to market simulation and then describe in more detail the specific approach we have adopted for this paper.

Models of competitive interaction

There are basically three models of competitive interaction that could apply: Cournot, Bertrand and supply function equilibria (SFE):

- With a Cournot game, the demand function is known, and the firm bids in the quantity it is willing to supply, taking account of its rivals' behaviour.
- With Bertrand, the demand function is also known, but price is the decision variable, with firms again taking account of each other's behaviour. The

conventional Betrand model presumes flexible output capacities, although that assumption can be changed to reflect capacity constraints as they exist in power production.

- In the SFE model, demand over a particular period is not known with certainty, and firms bid in a supply function for a particular period (again taking account of each other's behaviour), with the actual price and quantity determined by the equilibrium outcome at the out-turn demand.

In the market simulation tool, SPARK, which we employ for our analysis, the firms are assumed to bid a price offer considering cost, capacity constraints and the strategies of other players. Given that price, the price offers of rivals and known demand, the quantity supplied is calculated. Therefore, SPARK is like a Bertrand model which considers capacity constraints and actual cost structures, rather than a SFE model (which assumes uncertain demand) or a Cournot model (which plays a quantity game). However in a capacity constrained Betrand game, the outcomes of SPARK can look like the outcomes of a Cournot game.[7]

Further, multiple equilibria will be a feature of a Bertrand and a Cournot model where individual capacity constraints exist, where the marginal costs of players are different, and where the supply curve for the industry is not smooth, continuous and twice differentiable. Indeed, this is what we observe with SPARK: when demand is low, unit costs are similar across players, and where there are no steps in the cost function, we tend to find a Nash equilibrium at price equal to marginal cost. When

7 For example, compare the equilibria presented in Figure 4 to the Cournot prices of Borenstein, Bushnell and Knittel's analysis of the California market. Borenstein, Bushnell and Knittel. *Market Power in Electricity Markets: Beyond Concentration Measures.* PWP-059. February 1999. See also Burns, Huggins and Lydon. *Generators' Strategies in the England and Wales Electricity Market - A Synthesis of Simulation Modelling and Econometric Analysis.* October 2004. See also Kreps and Scheinkman. *Quantity precommitment and Bertrand Competition yield Cournot outcomes*. Bell Journal of Economics 14(2): 326-337, 1983.

demand is closer to a step in the supply curve, a range of equilibria exists, which may include marginal cost outcomes, but will also include higher price outcomes.

The advantage of the modelling approach of SPARK is that with relatively few strategic players it produces a robust set of equilibria outcomes for a representation of the market that captures many of the real world complexities of electricity systems, i.e. it is able to incorporate the complex nature of electricity markets without compromising the model of competitive interaction. The resultant equilibria do not, for example, depend upon the starting conditions of an iterative game (as they may in a Cournot model). Nor is the model restricted in the representation of demand or supply as, for example, is the case with the SFE approach. As the number of strategic players increases, the solution process applied by SPARK could become very complex and other techniques, such as Cournot, may be preferable. For this reason we have developed a tool with a Cournot model of competitive interaction (which was not applied used this paper) in addition to SPARK.

Frontier's SPARK simulation tool

SPARK first identifies the pay-offs for each strategic player and for each strategy combination for one hour of the year (i.e. for one level of demand). SPARK then searches the strategy space for that hour to identify Nash equilibrium strategies. The process is then repeated for the next hour (level of demand).

In effect, we identify equilibrium strategies on the basis of a grid search of the possible strategy space, as illustrated (for a two strategic player game) by Figure 3. PAi and PBj represent the pricing strategies of players A and B respectively. VAij and VBij represent the pay-offs (contribution to profit) for the strategy combination. SPARK searches the set of possible outcomes of the one-shot game for Nash equilibria without considering how the players arrive at a particular outcome.

PA_n	VA_{n1} VB_{n1}	VA_{n2} VB_{n2}	VA_{n3} VB_{n3}	VA_{n4} VB_{n4}	.	.	.	VA_{nm} VB_{nm}
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
PA_4	VA_{41} VB_{41}	VA_{42} VB_{42}	VA_{43} VB_{43}	VA_{44} VB_{44}	.	.	.	VA_{4m} VB_{4m}
PA_3	VA_{31} VB_{31}	VA_{32} VB_{32}	VA_{33} VB_{33}	VA_{34} VB_{34}	.	.	.	VA_{3m} VB_{3m}
PA_2	VA_{21} VB_{21}	VA_{22} VB_{22}	VA_{23} VB_{23}	VA_{24} VB_{24}	.	.	.	VA_{2m} VB_{2m}
PA_1	VA_{11} VB_{11}	VA_{12} VB_{12}	VA_{13} VB_{13}	VA_{14} VB_{14}	.	.	.	VA_{1m} VB_{1m}
	PB_1	PB_2	PB_3	PB_4	.	.	.	PB_m

Figure 3: Hypothetical example of SPARK's strategy search

In our stylised system, available capacity always exceeds demand. Therefore, the maximum price in the market for a given level of demand is constrained by our arbitrary upper bound on the set of possible pricing actions by each player. The highest price strategy allowed is 10 times the marginal cost of a generator (i.e. a strategic player cannot offer the output from a coal plant at a price higher than €290/MWh, the output from a gas plant at a price higher than €342/MWh and the output from an oil plant at a price higher than €586/MWh).

The cap on the price mark-up could be thought of as the quantification of an implicit regulatory constraint on players' behaviour. We ignore any other implicit or explicit regulatory constraints on behaviour. In addition, we ignore the effect of the threat of entry or other facets of electricity markets that might constrain behaviour.

RESULTS FROM THE MARKET SIMULATION

The market simulation tool estimates the set of possible Nash equilibria for different levels of demand and the associated price outcomes. Figure 4 shows the price outcomes for a SPARK simulation of the medium fringe case. Given the cost structure and ownership structure of the market, the market simulation may result in multiple possible equilibria for a given level of demand. In addition to the possible equilibria price outcomes, Figure 4 shows the system marginal cost, the highest possible price outcome and the minimum Nash equilibrium price for each demand level.

Below about 4000MW of demand, marginal cost strategies are the only equilibrium outcome. Between about 4000MW and 5000MW of demand, the coal plants of strategic players are offered into the market at a price just below the marginal cost of gas generation.

This pattern is then repeated for the range of demand over which gas fired generation is likely to be price setting. For demand between 5000MW and 6000MW marginal cost strategies are the only equilibrium outcome. Then between about 6000MW and 7500MW of demand, the gas plants of strategic players are offered at a price just below the marginal cost of oil generation. The result that generation is priced to just undercut the next step in the supply curve is typical for the outcome of simulated strategic games in electricity markets.

For levels of demand above 8000MW, the set of equilibria strategies depart from marginal cost. Above about 9500MW, the only equilibrium outcome is the maximum possible price mark-up of €586/MWh.

A question is which equilibria should be chosen as the market outcome on which to base our analysis. It might be possible to base the market outcome on the most “stable” equilibria for each level of demand. For example, an equilibrium might be thought relatively unstable (and therefore unlikely) if a player would incur a large loss in its payoff if it guessed incorrectly about the strategies of its rivals. Likewise, an equilibrium might be thought relatively unstable if a small perturbation in a player's strategy moved the market outcome to a significantly better equilibrium outcome (i.e. one with a better pay-off for all players).

We select as the market outcome the Nash equilibrium with the minimum price outcome at each demand level. This rule is arbitrary and simple and therefore avoids the need for an arbitrary but complex investigation of the most likely (or stable) equilibrium at each demand level. We considered the effect on our results of applying a different rule to equilibrium selection. While the results are not reported here, we confirmed that choosing the equilibria with the highest price outcome at each demand level would not have affected the conclusions of this paper.[8]

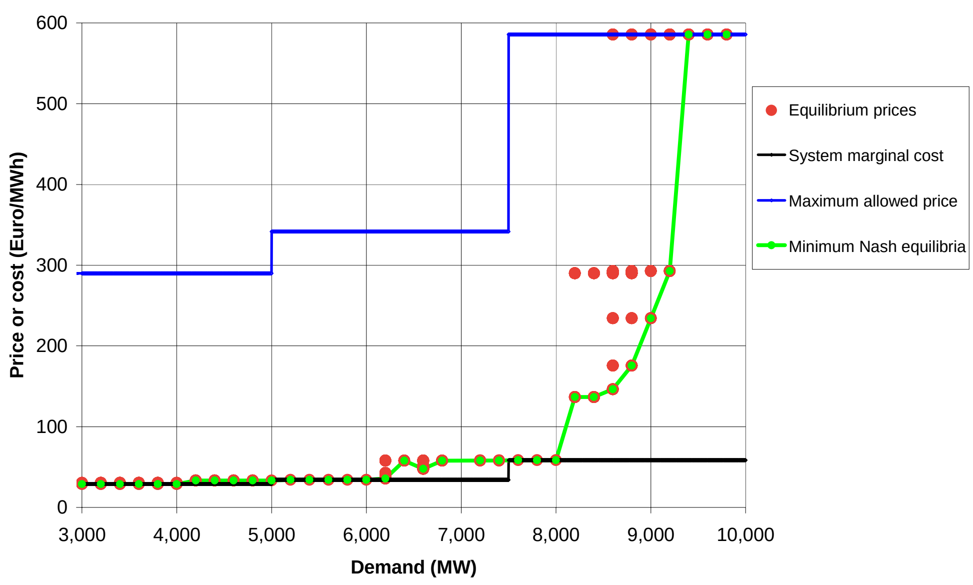

Figure 4: SPARK equilibrium set – medium-sized fringe case.

8 Borenstein, Bushnell and Knittel select the equilibrium with the highest prices at each demand point on the basis that "in a repeated market such as this one, it is reasonable to expect that firms would move towards the most profitable equilibrium point."

Figure 5 uses the output of three SPARK simulation runs, corresponding to the three different capacity ownership cases, to construct three price duration curves assuming the medium demand case. For each case, the chart shows the number of hours for which the given level of price is equalled or exceeded. The graph also shows the system marginal cost – noting that in our stylised model system marginal cost is invariant to capacity ownership and only depends on the level of demand.

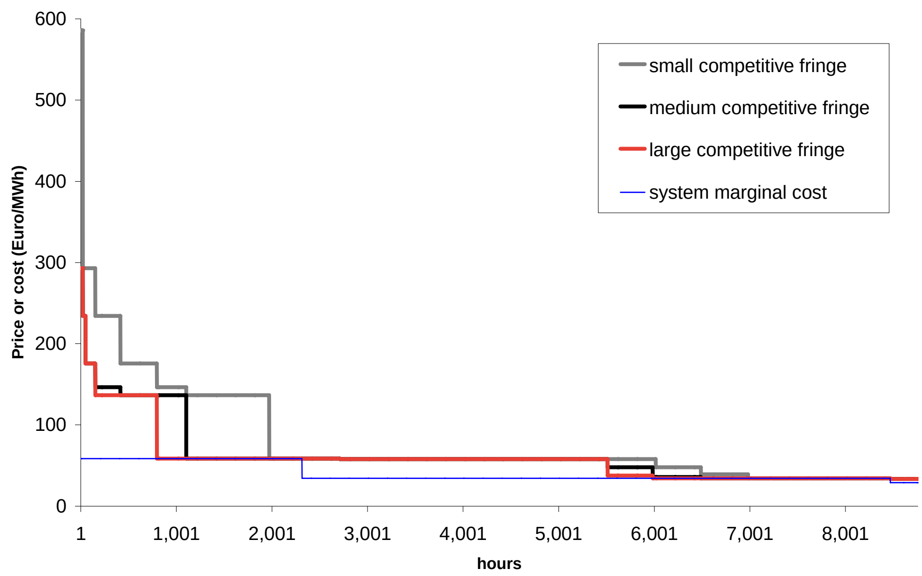

Figure 5: Price duration curve – medium demand case.

As expected, the greater the size of the competitive fringe, the lower the price level.

COMPARISON OF TOOLS

We first compare the level of competition as measured by the HHI of available capacity and a pivot analysis. We then compare the level of competition as measured by the HHI of market shares and the average price mark-up resulting from the market simulations. Finally we compare the level of competition as measured by the pivot assessment and the average price mark-up from the market simulations.

Comparison of HHI and pivot analysis

We first compare the level of competition as measured by the HHI of available capacity and a pivot analysis for two cases:

- low demand and small fringe (Figure 6); and
- high demand and medium fringe (Figure 7).

With the low demand / small fringe case, the HHI based on capacities equals 1875. In addition, a strategic player is pivotal whenever demand is within 1300MW of peak demand.

With the high demand / medium fringe case, the HHI based on capacities equals 1200. In addition, a strategic player is pivotal whenever demand is within 1565MW of peak demand.

An alternative way to present the results of the pivot analysis is to measure the amount of time, or more explicitly, the percentage of time in a year, for which a strategic player is pivotal. For the industry specifications illustrated in Figure 6 and Figure 7, the percentage of time in which a strategic player is pivotal is 16% and 20%, respectively. The capacity based HHIs and the percentage of time for which a strategic player is pivotal, for the 9 different cases are shown in Table 4 and Table 6.

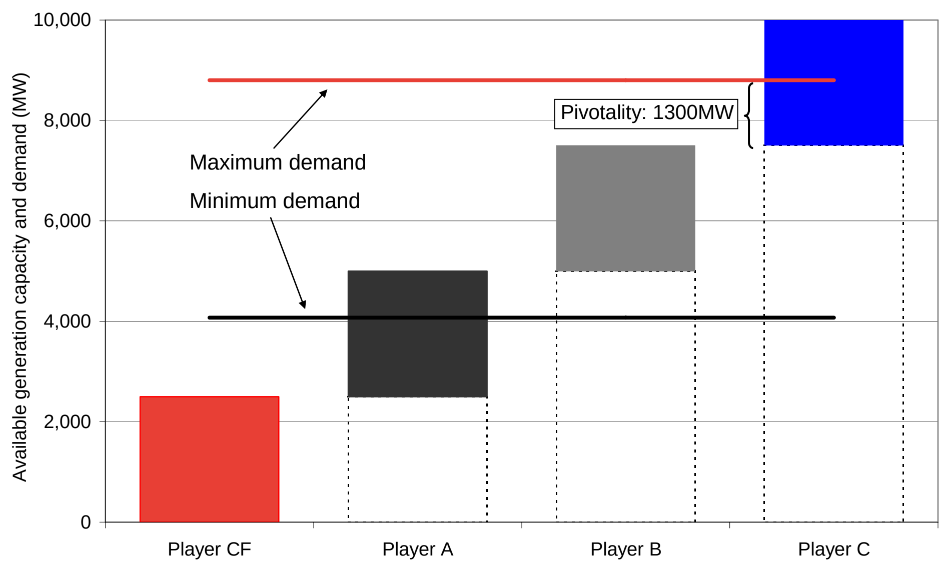

Figure 6: HHI capacity vs pivotal analysis (i) – low demand and small fringe.

The two tools (HHI and pivot) used to evaluate the degree of competition for the two industry specifications shown in Figure 6 and Figure 7 conflict in their assessment as to the direction of change to competition. Based on HHIs, we would conclude that the lower concentration of generation capacity with strategic players shown in Figure 7 gives rise to lesser competition concerns than the industry specification shown in Figure 6. However, the pivot analysis illustrates that as the level of demand increases in moving from the case shown in Figure 6 to that of Figure 7, the likelihood that a player will be necessary to meet demand increases, increasing competition concerns.

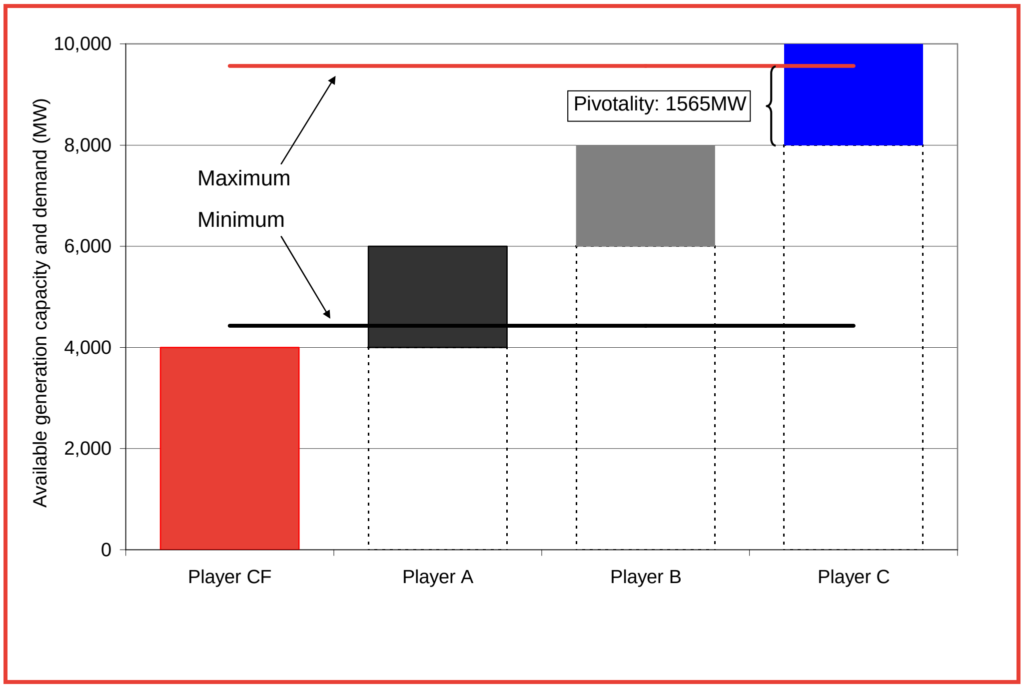

Figure 7: HHI capacity vs pivotal analysis (ii) – high demand and medium fringe.

This perverse result can be explained by the fact that an HHI based on available capacity takes no account of the relative balance between supply and demand and therefore the competitive impact of a possible capacity overhang on competition. In contrast, the pivot analysis does take account of the supply-demand balance since the greater the level of available capacity relative to demand, the lesser the likelihood of a player being pivotal.

Both the HHI based on available capacity and the pivot analysis take account of the structure of capacity ownership. A more diverse capacity ownership would tend to be reflected by both measures indicating a decrease in competitive pressure.

However, neither the HHI based on capacity shares nor the pivot analysis take full account of the competition to deliver to the market. In other words these two measures of competition ignore information about the relative cost of production and about commercial incentives to price output above marginal cost. For example, a large price step low in the supply curve combined with a competitive fringe that only owns oil fired plant may give a strategic player some incentive to mark up prices low in the merit order. The lack of competition along a specific part of the supply curve would not be captured by the HHI based on installed capacity or the pivot analysis.

We include information about the relative cost of production in the analysis of competition by applying a further measure of competition: the HHI based on production shares. In addition, we include information about the relative cost of production and the commercial incentives to price above marginal cost by applying a fourth measure of competition: the average of the system price mark-up over system marginal cost for each hour the year (expressed as a percentage of cost) as derived from our market simulation.

It should be noted that generators will typically require some margin over their variable cost of production – and therefore possibly also over system marginal cost – in order to recover the fixed cost of their plants. Mark-ups therefore do not *per se* imply the exercise or existence of market power.

Comparison of HHI and price mark-up

Figure 8 below compares the HHI based on annual output shares[9] and the average system price mark-up over system cost resulting from the market simulation for each of the 9 cases. The numerical results for both tests can be found in Table 5 and Table 7 below.

We observe in Figure 8 that the average system price mark-up increases with the degree of market concentration, for a given demand specification. However, as with

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9 The choice of output levels of each strategic player used in the calculation of the output based HHI is derived from the set of minimum Nash equilibria. In this respect the market share based HHI does include some limited information about the incentive to raise price above marginal cost.

the analysis presented in Figure 6 and Figure 7, we find that the direction of change to the level of competition implied by the two measures sometimes conflicts when moving between two industry specifications.

The same two industry specifications from Figure 6 and Figure 7 illustrate this perverse result. In moving from a system characterised by a small fringe and a low demand to a system characterised by medium fringe and high demand, the HHI based on market shares *falls* from 1653 to 1008. However, the average system price mark-up over system cost *increases* from 57% to 66%.

Based on the HHI of market shares we would conclude that the first industry specification gives rise to higher competition concerns than the second industry specification. However, the market simulation suggests that the second industry specification gives rise to greater competition concerns.

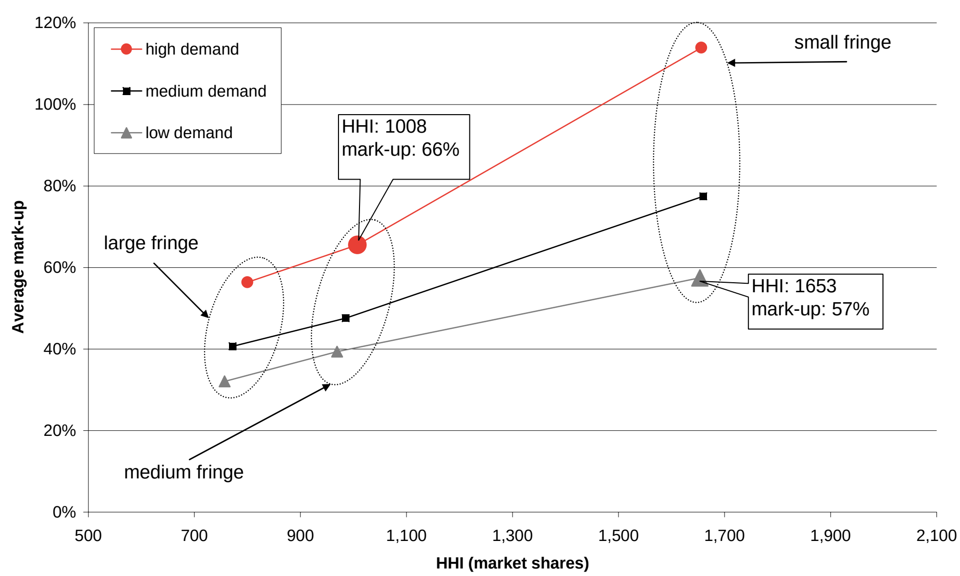

Figure 8: HHI based on market shares and average system price mark-up

The perverse result is because the HHI based on market shares takes very limited account of information about the incentive to exert strategic behaviour. For example, with those levels of demand for which the application of strategic behaviour does not affect the merit order, the HHI based on market shares will not distinguish between a strategy whereby all players bid at marginal cost and a strategy whereby prices are marked up to be just below the marginal cost of production of the next technology step up in the supply curve. In contrast, the measure of average price mark-up would distinguish between the two strategies.

The potential inconsistency between HHI and the measure of price mark-up is confirmed by a more detailed analysis of individual demand levels. Holding the ownership structure constant (for the medium fringe case) and looking at all of the different levels of quantity demanded (for the medium demand case) we compared output-based HHIs to the price-cost mark-up. The comparison revealed that the relationship between HHI and mark-up is weak. For example, at levels of demand below 5000MW, the mark-up is low but conversely the HHI is high. At very high levels of demand where the ability and incentive to mark-up is high, the HHI is relatively low. This result is somewhat similar to that obtained by Borenstein, Bushnell and Knittel's comparison of the HHI and Lerner Index resulting from a Cournot analysis of the California power market.[10]

Comparison of pivot analysis and price mark-up

Figure 9 compares the measure of competition based on the pivot analysis with the average price mark-up for the 9 possible industry specifications considered. Both tests produce similar (and therefore largely consistent) results. A 1:1 mapping of

10 Borenstein, Bushnell and Knittel.

average system price mark-up to the percentage of time that a player is pivotal would indicate perfectly consistent results for the two measures of competition. Therefore, while the band of results is narrower than with Figure 8 (indicting more consistent results) there remains the possibility of ambiguity between the two measures of competition illustrated in Figure 9.

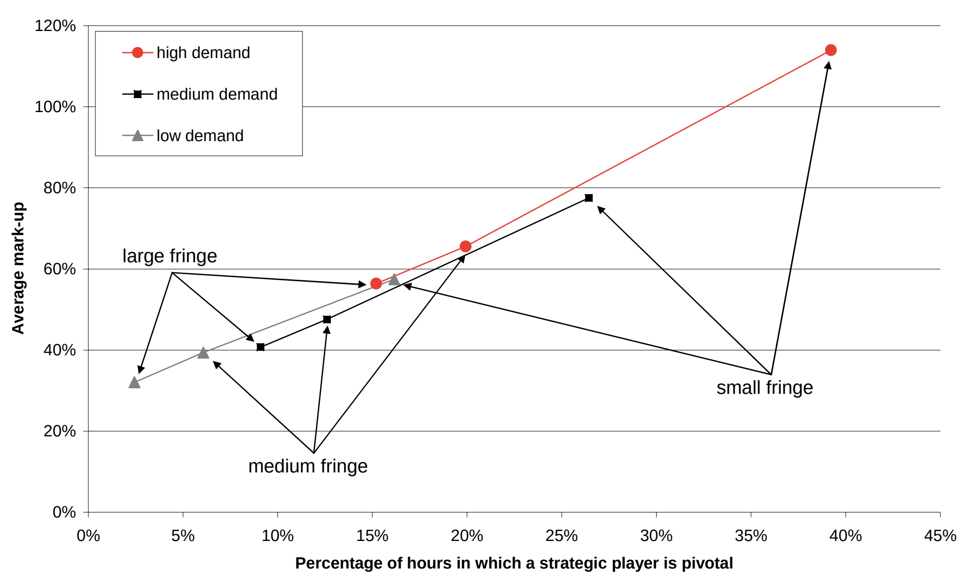

Figure 9: Pivotal analysis and average system price mark-up

The close alignment of the two measures of competition is partly the result of the shape of the supply curve limiting the incentive and / or ability to raise price at low and medium levels of demand. However, at high levels of demand, which largely coincides with those periods for which a strategic player is pivotal, the incentive and ability to raise price is only constrained by the maximum mark-up allowed above marginal cost (900%).

If we had designed the stylised system with a larger cost step between technologies, there would have been a greater incentive and ability to mark-up prices during periods when no player was pivotal. This would have driven a greater "wedge" between the results from the market simulation and the pivot analysis, i.e. the results of the two methods would probably not have been as consistent with one-another as indicated by Figure 9.

CONCLUSIONS

We have highlighted the shortfalls of competition analysis that draws on market share (or HHI) analysis as an indicator of competitive conduct and market outcomes, complemented by qualitative evaluations of, for example, the possibility of entry or other effects that are difficult to quantify. We have shown that a focus on HHI (or market share) may lead to misguided judgements of competitive situations.

One key shortfall of HHI and market share analysis is that it does not consider the importance of reserve capacity or the tightness of the demand-supply balance as a key driver of the potential to exercise strategic behaviour which may in some cases correspond to market power. We have demonstrated that pivot analysis allows the analysis of capacity shares and capacity reserve over demand in a consistent manner. Pivot analysis can be straightforward to perform as it only requires knowledge of demand levels in addition to the capacity information often used for HHI analysis.

However, the main shortcoming of pivot analysis is that it ignores information about cost structures and therefore also behavioural incentives. These aspects can be accounted for through market simulations. The benefit of including all possible information about the structure of the industry by way of market simulation in the competitive assessment is potentially very high if it prevents an authority from drawing an incorrect conclusion about the intensity of competition in a market or the change in the intensity of competition as a result of a change in market structure. We assume that the potential benefit would outweigh the cost of the additional analysis required to under-take a market simulation if it were possible to obtain the relevant information about industry structure (i.e. production costs) with reasonable effort.

However, it is not possible to fully capture simultaneously all elements that affect competition with any of the measures assessed in this paper. Therefore, while all of the measures discussed have a role to play in competition assessment and can help authorities build a body of evidence to support a conclusion, they need to be complemented by careful consideration of further aspects that are less easily parameterised or less readily captured within a model, e.g. the threat of entry, the threat of regulation and uncertainty.

On the other hand, market simulation does allow authorities to parameterise many aspects of the market that could only be considered qualitatively under a more conventional approach that focuses on HHI or market shares. While we have not reflected these in our stylised model, further aspects that could have been considered quantitatively include must-run characteristics of certain plant, seasonal variations in market structures and cost, contract coverage, elastic demand, import capacity from neighbouring power systems, repeated interactions etc. For simplicity our paper has focussed on relatively symmetric market structures and we have not explored the analysis of mergers. These would be straightforward extensions to our analysis presented here.

A further benefit of simulation approaches is that market definition exercises become obsolete. Simulation models implicitly assess which players and production technologies stand in competition to each other. Traditional approaches require a two-step process where first the relevant product and geographic market is defined and second market shares are analysed within the markets so defined.

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ANNEXE

Table 2: Generation structure – medium fringe case

Owner	Plant type	Available capacity (MW)	Marginal cost (€/MWh)
Player A	Coal	500	29.00
Player A	Coal	500	29.00
Player A	Gas	500	34.17
Player A	Oil	500	58.57
Player B	Coal	500	29.00
Player B	Coal	500	29.00
Player B	Gas	500	34.17
Player B	Oil	500	58.57
Player C	Coal	500	29.00
Player C	Coal	500	29.00
Player C	Gas	500	34.17
Player C	Oil	500	58.57
Player CF	Coal	1000	29.00
Player CF	Coal	1000	29.00
Player CF	Gas	1000	34.17
Player CF	Oil	1000	58.57

	large fringe	medium fringe	small fringe
Player A	18%	20%	25%
Player B	18%	20%	25%
Player C	18%	20%	25%
Player CF	46%	40%	25%

Table 3: Percentage of installed capacity for each player

	large fringe	medium fringe	small fringe
high demand	972	1200	1875
medium demand	972	1200	1875
low demand	972	1200	1875

Table 4: Market concentration analysis. Capacity HHIs

	large fringe	Medium fringe	small fringe
high demand	800	1008	1656
medium demand	772	985	1660
low demand	757	969	1653

Table 5: Market concentration analysis. Output HHIs

	large fringe	medium fringe	small fringe
high demand	15%	20%	39%
medium demand	9%	13%	26%
low demand	2%	6%	16%

Table 6: Pivotal analysis. Percentage of hours in which a strategic player is pivotal

	large fringe	medium fringe	small fringe
high demand	56%	66%	114%
medium demand	41%	48%	77%
low demand	32%	39%	57%

Table 7: Market simulation results. Average mark-ups