HOUSTONKEMP
Economists

Investigating wholesale electricity market outcomes

Methodology report

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1. Introduction

On 27 March 2017, the Commonwealth Treasurer directed the Australian Competition and Consumer Commission (ACCC) to undertake an inquiry into the supply of retail electricity and the competitiveness of retail electricity prices. The terms of reference provide the ACCC with wide scope to investigate all aspects of the market that influence retail price outcomes.

The ACCC has asked HoustonKemp Economists (HoustonKemp) to analyse market outcomes in the National Electricity Market (NEM) and associated contract markets to examine the conduct of generators and ascertain whether they may have engaged in behaviour that would constitute the harmful use of market power. To this end, the ACCC has asked HoustonKemp to undertake two related analyses:

1. an assessment of the conduct of wholesale market participants in response to key market events in the NEM; and
2. an assessment of the conduct of gas powered generators, and their changing role in the NEM.

In this methodology report, we outline the approach we have adopted for these analyses. Accompanying this report are two presentations that detail results of our analysis, namely:

- ‘Analysis of NEM events’, which provides the detailed results of our analysis of market events; and
- ‘Impact of gas powered generation on wholesale market outcomes’, which describes the results our analysis of gas powered generation.

The remainder of this report is structured as follows:

- section two describes our approach to investigating the impact of market events on NEM outcomes;
- section three describes our approach to assessing the conduct of gas fired generators on NEM outcomes; and
- section four describes the data sources that have been used to conduct our analysis.

In addition, Appendix A provides a description of our approach to processing bidding data and Appendix B provides a description of our approach to processing price setter data.

2. Approach to analysing NEM events

The wholesale electricity market over recent years has been shaped by several significant market events. These include the closure of major generation assets, acquisitions of generation assets and changes in operational policies and market rules. Each of these events may have changed the strategic decisions facing wholesale market participants and, in turn, the incentive and ability for firms to exercise market power.

In this section, we describe our approach to assessing the response of generators to the most prominent market events that have occurred in recent years. In particular, in this section we:

- describe the framework for our analysis of market events;
- provide an overview of the market events considered in our analysis; and
- describe the metrics we focus on in assessing the response of generators to each event.

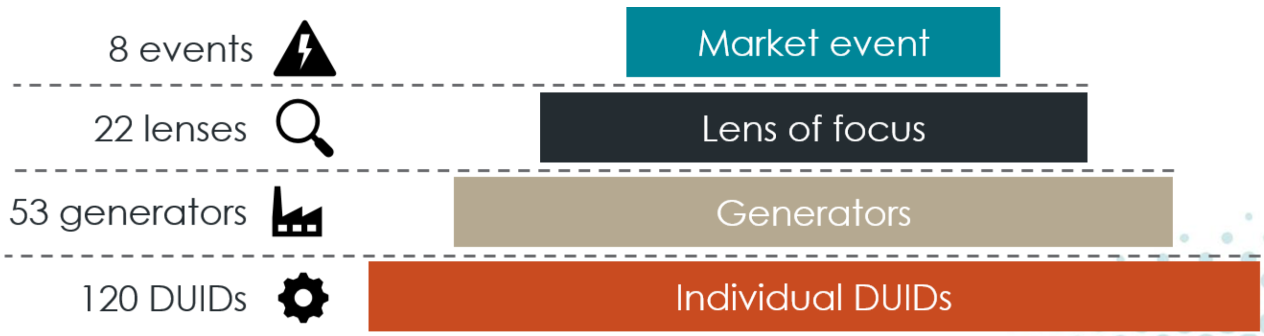
2.1 Framework for analysis

The NEM is a complex system involving a wide range of generation technologies, many participants and varying ownership structures. Therefore, to make our analysis tractable and facilitate the identification of causal links between events and participant conduct, we adopt a systematic approach to identify those participants likely to be materially affected by an event and to assess the conduct of those participants. We analyse each event through the following steps:

1. identify market events that may influence the incentive or ability for generators to exercise market power;
2. identify relevant sets of generators that have been principally affected by the market events, and who are likely to have a changed incentive or ability to exercise market power owing to the event;
3. categorise these generators into groups or 'lenses' consisting of generators with similar characteristics, ie, ownership, location or technology type; and
4. examine behaviour of individual generators and dispatchable units (referred to as 'DUIDs')[1] to identify systematic patterns that may exist in the change in their conduct in response to the events.

This approach allows us to narrow the scope of the analysis to market participants that are most likely to be in a position to engage in the harmful use of market power. Figure 2.1 provides a summary of this approach.

Figure 2.1: Summary of framework for analysis



[1] DUID stands for dispatchable unit identifier

2.2 Overview of market events

We have worked with the ACCC to identify eight significant market events for investigation. Table 2.1 outlines the events considered.

Table 2.1: Summary of market events

Event category	Event
Events related to changes in the market structure or significant changes in demand/supply conditions	The closure of Hazelwood Power Station
	Pelican Point returning one dispatchable unit from mothballing
	The closure of Northern Power Station
	Changes to supply due to Snowy Hydro's large-scale generation certificate (LGC) strategy
	Outage of Basslink in 2015 through to 2016
	AGL's acquisition of Macquarie Generation assets
Events related to changes in bidding rules/directives to generators	Queensland government's directive to Stanwell Corporation
	Changes to the bidding-in-good-faith rule

For each of these events, we identify various cross-sections of generators, or 'lenses', that are likely to be materially affected by the event. We describe each event and our approach to assessing it below.

2.2.1 Closure of Hazelwood Power Station

Hazelwood Power Station closed was a 1,600MW brown coal fired generation located in the Latrobe Valley in Victoria. The station closed in March 2017, leading to significant reduction in Victoria's base load electricity supply. Prior to the closure, the generator was operated by Engie. This reduction in base load supply contributed to significant wholesale price increases in Victoria and other NEM regions between 2016 and 2017.

To examine this event, we examine three cross-sections of generators, ie:

- other Victorian brown coal generators;
- other Engie generators; and
- NSW coal generators.

2.2.2 Pelican Point returning one unit from mothballing

In June 2017, Engie secured a long-term gas supply contract that allowed it to return a unit at Pelican Point from mothballing, increasing the capacity of the plant by 240MW up to its maximum capacity.[2] To analyse this increase in supply in the South Australian market, we examine market behaviour through two lenses, in addition to Pelican Point itself, ie:

[2] See https://www.originenergy.com.au/about/investors-media/media-centre/origin-works-with-engie-to-help-boost-energy-security-in-south-australia.html

- other SA Engie generators; and
- other SA non-Engie dispatchable generators.

2.2.3 Closure of Northern Power Station

Northern Power Station was a 540MW coal fired generator located near Port Augusta in South Australia. The closure of the power station in 2016 meant a substantial reduction in supply in the energy, ancillary services and contract markets in South Australia. The generation that has replaced the capacity of Northern in South Australia has largely been from renewable generation which, owing to its technical characteristics, cannot participate in the same manner in these markets.

Our analysis of wholesale market outcomes around the closure of Northern examines the change in dispatch and bidding behaviours by SA gas generators as well as price and volume changes in ancillary services and futures markets and the impact of specific intra-regional constraints.

2.2.4 Changes to supply due to Snowy Hydro's LGC strategy

Under the Large-scale Renewable Energy Target (LRET), new generators that produce power from renewable sources are eligible to create Large-scale Generation Certificates (LGCs). Renewable generators that produced power before 1997 (primarily hydro generators), cannot create renewable energy certificates for output that is less than or equal to the output that they produced historically. Under this scheme, hydro generators can store water, and so can store water inflows from one year (and potentially generate at a level below their baseline) and then increase output in the subsequent year to exceed its baseline and create LGCs.

Snowy Hydro is the largest generator subject to this baseline policy. Snowy Hydro acknowledges that it adopted a strategy of seeking to maximise output in 2016. Reportedly, Snowy Hydro deliberately held back its output in 2015 to enable the higher output in 2016.[3] Snowy Hydro also claims that this period was associated with higher than average inflows, which assisted them in increasing their output over this period.

We examine the changes in dispatch and bidding behaviour by Snowy Hydro by examining the behaviour of the Tumut and Murray hydro generators, as well as Snowy Hydro's gas generators.

2.2.5 Basslink outage

Basslink is the high-voltage transmission cable that connects Tasmania to the rest of the NEM through Victoria. Its outage from December 2015 to June 2016 altered the supply and demand balance in these two regions because under typical conditions when the interconnector is operational we see:

- Tasmania import electricity (typically generated by coal fired generators) from Victoria when the Victorian regional price is low; and
- Tasmania export electricity (typically generated by hydro generators) to Victoria when the Victorian regional price is high.

We examine changes in generator behaviour through four lenses during and after this outage, namely:

- Tasmanian gas generators;
- Tasmanian hydro generators;
- Victorian gas generators; and
- Victorian coal generators.

[3] For example, see https://www.smh.com.au/business/surging-water-inflows-to-see-snowy-hydro-drive-output-20160930-grrxzp.html

2.2.6 Acquisition of Macquarie Generation by AGL

AGL purchased Bayswater, Liddell and Hunter Valley power stations from Macquarie Generation (MacGen) in 2014. At the time of the acquisition, MacGen represented approximately 27 per cent of NSW capacity. Our analysis of this event focuses on identifying any changes to bidding and dispatch behaviour of the MacGen generators themselves, as well as other generators in the NSW and Victorian regions that may have been affected by this change in ownership. We identified four lenses through which to examine market behaviour, namely:

- MacGen generators;
- non-MacGen coal generators in NSW, including non-vertically integrated generators, such as those owned by Delta Electricity;
- AGL coal and gas fired generators in Victoria; and
- AGL hydro generators in Victoria.

2.2.7 Queensland government directive to Stanwell Corporation

After a period of sustained high wholesale prices, the Queensland government, through the Powering Queensland Plan,[4] directed Stanwell Corporation, a state-owned operator of generator assets in the state, to adopt bidding strategies that place downwards pressure on wholesale prices.

To determine whether this directive had any material effect on Stanwell's bidding behaviour and prices, we examined market behaviour for Stanwell's fossil-fuel and hydro generators. We also examined the same behaviour for the other state-owned generator operator, CS Energy.

2.2.8 Changes to the 'bidding-in-good-faith' rule

In July 2016, the Australian Energy Market Commission (AEMC) introduced a revised 'good faith' bidding rule with the aim of mitigating the number of false or misleading bids made by market participants to improve the accuracy of short-term market forecasts. The rule change came after a Federal Court case between the Australian Energy Regulator (AER) and Stanwell Corporation, after which the South Australian government claimed there was uncertainty with regards to how the previous bidding in good faith rule should be interpreted. We focus our analysis on the bidding behaviour of Stanwell Corporation.

2.3 Description of analysis metrics

In our analysis, we calculate a number of metrics to characterise the conduct of generators before, during and after each market event. Table 2.2 outlines the principal metrics used in our analysis. The results of the analysis of these metrics is provided in the accompanying presentation – 'Analysis of NEM events'.

[4] Queensland Government, Powering Queensland Plan, see https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0008/1253825/powering-queensland-plan.pdf

Table 2.2: Overview of metrics for assessing generator bidding behaviour

Category	Metric
Context metrics – market inputs	Operational demand for each region for each trading and dispatch interval
	Gas prices – daily Short-Term Trading Market (STTM) and Declared Wholesale Gas Market (DWGM) prices
	Coal prices – daily Newcastle free on board (FOB) prices
Context metrics – market outcomes	Dispatch in MW of each generator for each dispatch interval
	Wholesale spot prices for each region for each trading and dispatch interval
	Interconnector flows between regions
Conduct metrics - price setting	Frequency that a generator is marginal based on all dispatch intervals
	Frequency that a generator is marginal based on trading intervals where the wholesale price was greater than $300 per MWh
Conduct metrics - bid offer quantities	Capacity offered across different prices based on all dispatch intervals
	Capacity offered across different prices based on trading intervals where the wholesale price was greater than $300 per MWh
Conduct metrics - rebidding behaviour	Frequency that a generator rebids less than 60 minutes before the start of a dispatch interval based on all dispatch intervals
	Frequency that a generator rebids less than 60 minutes before the start of a dispatch interval based on trading intervals where the wholesale price was greater than $300 per MWh
	Frequency that a generator rebids less than 60 minutes before the start of a dispatch interval based on dispatch intervals when the generator is marginal in at least one NEM region
	Differences in capacity offered between penultimate and final bids

Our assessment also considered further ad-hoc analysis where appropriate. This additional analysis includes an assessment of other factors such as:

- specific instances of binding intra-regional constraints;
- ancillary services prices; and
- the accuracy of pre-dispatch forecasts.

Each of the conduct metrics described above provides information on the behaviour of firms and the extent to which firms have changed behaviour in response to the event. We briefly discuss the interpretation of these metrics below.

Price setting

When a generator is marginal and setting the price then it may have a stronger incentive and ability to exercise market power, as it has the potential to directly influence the price it receives. Being the price setter alone is not an indicator of a stronger ability and incentive to exercise market power, as a generator may be facing competition from other generators which would constrain its ability to raise prices. The extent of competitive constraint will tend to reduce as prices increase and the quantity of unutilised capacity decreases and so we also consider the frequency of price setting when prices are greater than $300 per MWh.

Bid offer quantities

A generator seeking to increase profits may withhold capacity from the market to reduce supply, increase price and increase the revenues earned from its remaining fleet of generators. If there is clear evidence that generators are reducing bid offer quantities during high price periods without clear justification, then this may be evidence of harmful use of market power. It follows that we also consider bid offer quantities under periods with prices greater than $300 per MWh, as the benefits from withholding capacity under these conditions would be greater than periods with lower prices.

Rebidding behaviour

Generators can rebid their offered capacity for a dispatch interval up to the start of that dispatch interval. Instances of late rebidding may be evidence of market participants seeking to influence market prices. This behaviour will likely yield higher benefits for a generator during periods with high prices and when the generator is setting the price, and so we report metrics based on these periods separately.

For each of these metrics, an association between a market event and changes in conduct by a market participant does not imply a causal link between them and, in numerous cases, changes that occur over similar timeframes to the market events can be attributed to other factors. We endeavour to identify these factors where relevant in the analysis in the accompanying presentation – ‘Analysis of NEM events’.

3. Approach to analysis of the impact of gas powered generation

In recent years, the east coast gas market has undergone substantial change. The changing mix of technologies in power generation, increasing exports of liquefied natural gas (LNG) and the related increases in the domestic price of gas has affected the role that gas fired generation plays in the wholesale market.

To support the ACCC in understanding the impact of gas powered generation on recent electricity market outcomes, we have conducted a number of empirical assessments of the relationship between gas prices, conduct by gas generators and market outcomes. The purpose of our analysis is to assist the ACCC in understanding the contribution of gas powered generation, and increases in gas prices, to increases in wholesale electricity prices over recent years.

In this section, we:

- describe our framework for analysis; and
- provide additional detail on the econometric analysis of gas and wholesale prices that has been undertaken.

3.1 Framework for analysis

Our analysis of the impact of gas powered generation on wholesale electricity market outcomes considers three distinct aspects of this relationship, namely the:

- impact of gas prices on gas powered generator bidding behaviour;
- impact of gas powered generator bidding behaviour on wholesale electricity price outcomes; and
- relationship between gas prices and gas generator dispatch outcomes.

3.1.1 Impact of gas prices on gas powered generator bidding behaviour

The purpose of this analysis is to assess the response of the bidding behaviour of gas plants to changes in gas prices. To do this, we characterise the bidding behaviour of a plant through constructing the energy bid offer curve for each generator for each dispatch interval – see section 4.1.1 for a description of this data.[5]

In the NEM dispatch process, generators and loads submit bids in the form of ten price-quantity pairs. When the market is cleared, and dispatch directions are issued, generally only a portion of the plant's offered capacity is scheduled for dispatch. This is owing to the typical structure of generator bid functions, where the last units of output, potentially beyond the stable operating range of the plant, are priced very high.

Generators have good information on the amount of output they will be scheduled to provide through pre-dispatch information and outcomes in previous periods. It follows that a bid offer curve includes bids for output levels that are unlikely to occur and so in reality will not influence price or dispatch outcomes. Therefore, the information contained in these portions of the offer curve may not be influenced by underlying cost changes because:

- generators do not face strong incentives to ensure that the portion of the offer curve is reflective of their actual bid decisions; and
- these portions may reflect other considerations such as minimum generation levels and plant commitment decisions.

[5] Generators submit their bids in 10 price and quantity pairs, we do not consider other aspect of the bid of a generator such as minimum generation levels, ramp rates, and bids in ancillary service markets.

In this analysis, we measure the gas cost faced by each gas fired generator by:

- multiplying the spot gas price from the nearest gas spot market by an estimate of the generator's heat rate;
- adding variable operations and maintenance costs; and
- adjusting by marginal loss factors.

Recognising the characteristics of bid offer curves described above, we consider two approaches for empirically assessing the relationship between gas prices and bidding behaviour, namely:

- approach 1 - price-setting bids only; and
- approach 2 - entire bid function.

Approach 1 harnesses the information in the price-setter table to describe the relationship between the gas cost for a generator and the wholesale price in periods where the generator is marginal in the region it is located. At this point, the wholesale price is approximately equal to the bid level of the generator for its marginal unit of output, adjusted for losses. The generator's bid is directly influencing the wholesale price and so is likely to reflect the costs faced by the generator or other strategic factors influencing their bid decisions. Figure 3.1 illustrates this concept.

The drawback of this approach is that we may overly restrict the sample size of observations by omitting periods when generators may be reflecting changes in costs in their bids but do not set the price.

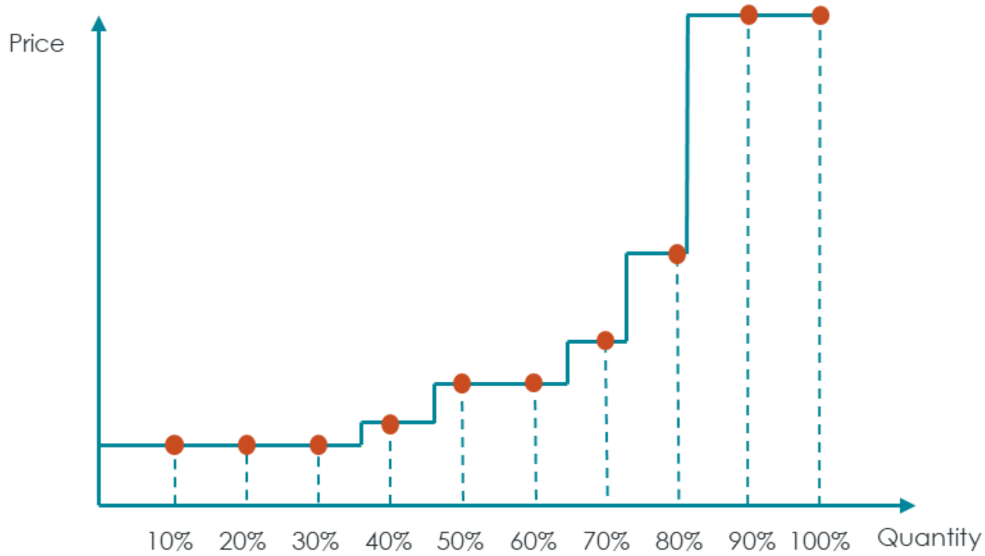
In section 3.2 we describe the approach to undertaking the econometric analysis of this relationship and in appendix A1 we provide a description of our approach to identifying price setting generators.

Figure 3.1: Illustration of analysis of price setting bids only

Approach 2 considers the relationship between gas prices and bidding behaviour of a generator over its entire bid function, rather than focusing exclusively on that part of the bid function that is setting the wholesale price. To implement this approach, we estimate separate regressions for the bid prices for each decile of the generator's capacity for which a bid is placed. In theory, this approach allows us to describe the sensitivity to gas prices of all parts of the bid function. Figure 3.2 illustrates this concept.

The drawback of this approach is that we include a large number of observations of bid price levels that are unlikely to be influenced by gas costs for the generator. The inclusion of these observations negatively influences to explanatory power of the resulting regression models. The result of the inclusion of these additional observations is that this approach did not yield conclusive results.

Figure 3.2: Illustration of analysis of entire bid function



3.1.2 Price outcomes

Using our empirical results obtained by applying approach one, we apply two methods to evaluate the sensitivity of wholesale electricity prices to gas costs.

Under method one, we estimate the monthly average gas cost pass-through. This involves the following steps:

- for each dispatch interval and region, we assign a pass-through value equal to:
  - zero for dispatch intervals where non-gas generators are marginal; and
  - the regression coefficient of gas costs for each gas generator in dispatch intervals when they are marginal.
- for periods where a generator is marginal in a region where it is not located, we adjust the coefficient estimates by estimates of interconnector losses; and
- calculate the average pass-through for each region over the appropriate period, ie, monthly.

The gas cost pass-through calculated under this approach is the average proportion of the changes in generator gas costs (in $/MWh) that are passed through by the marginal generator, eg, a value of 0.2 indicates that a change in average gas costs of $1/MWh would lead to a change in the wholesale energy price of $0.2/MWh

Under method one, we calculate pass-through of gas price to wholesale electricity price by:

- adjusting the average gas cost pass-through calculated under approach one by the heat rate and marginal loss factor for the marginal generator; and
- re-calculate the average pass-through for each region over the appropriate time period, eg, monthly.

The gas price pass-through calculated under this approach is the average proportion of the changes in gas prices (in $/GJ) that are passed through by the marginal generator, eg, a value of 5 indicates that a change in gas price of $1/GJ would lead to change in the wholesale energy price of $5/MWh.

For both of these methods, in cases where a generator is marginal in both the region where it is located and other regions, we adjust the gas cost pass-through by appropriate interconnector loss factors to translate the pass-through to wholesale price changes in these other regions.

3.1.3 Dispatch outcomes

In our analysis of dispatch outcomes for gas powered generation, we principally consider two relationships, ie, between:

- spot gas prices and gas dispatch; and
- wholesale electricity prices and gas dispatch.

These relationships are outcomes of the interactions between supply and demand in the gas and electricity markets respectively and so no causal relationships between these variables can be assumed a priori. Therefore, we focus on describing these relationships and how they have evolved over time in each region. To do this, we consider two principal displays of the data, ie:

- the average proportion of regional dispatch from gas generators aggregated by bands of gas prices; and
- the average proportion of regional dispatch from gas generators aggregated by bands of wholesale price.

The results of these analyses are described in the accompanying presentation - 'Impact of gas powered generation on wholesale market outcomes.'

3.2 Econometric analysis of gas and wholesale prices

This section describes the approach to the econometric analysis undertaken to describe the relationship between gas and wholesale electricity spot prices.

3.2.1 Model estimation

Equation 1 describes the mathematical expression that describes the estimated relationship between wholesale electricity spot prices and spot gas costs under approach one. This equation expresses wholesale prices as a function of the spot gas cost and a series of dummy variables that represent the most relevant set of market events.

Equation 1: Relationship between wholesale electricity spot price and spot gas cost

$$\log \text{spot price}_{g,t} = \alpha_g + \gamma_g \cdot \log \text{spot gas cost}_{g,t} + \sum_{e=1}^{E} \delta_e \cdot \text{event}_{e,t}$$

This equation is evaluated independently for each gas generator, so we are able to examine how the nexus between wholesale prices and gas cost may differ across generator types, owners and regions. Additionally, in this equation:

- g denotes the generator of interest;
- t denotes time;
- e denotes events; and
- event is a set of dummy variables indicating whether a series of events had occurred and include events that are likely to have material effects on the supply-demand balance in the NEM and gas markets, ie:
  - the closure of Hazelwood Power Station;
  - the return of one of Pelican Point's units; and
  - the closure of Northern Power Station.

Rather than estimating this equation in the absolute levels of the wholesale price and gas cost, we evaluate this equation using the log of both values. This means that the coefficient of the $\log \text{spot gas cost}$ variable is interpreted as the expected per cent change in the wholesale price from a one per cent change in spot gas cost.

We truncate prices to between $0 and $1,000 per MWh to:

- reduce the significant amount of ‘noise’ introduced through higher price events; and
- still capture the response of peaking plants to gas prices.

The coefficient of spot gas cost can be interpreted as follows:

- $\gamma = 0$: bids are insensitive to changes in gas costs;
- $0 < \gamma \leq 1$: a proportion of spot gas costs are passed through into bids, either due to direct market exposure or opportunity cost-based pricing; and
- $\gamma > 1$: more than the spot gas cost is passed through into bids.

3.2.2 Tests for model validity and econometric method

For each of the equations we estimate, we undertake a Breusch-Pagan test to evaluate whether the residuals (error terms) of the regression are heteroskedastic. If the test indicates the presence of heteroskedasticity, we re-estimate the equation using a weighted-least squares method. We further correct for any heteroskedasticity or serial-correlation in the residuals by estimating robust standard errors that are not affected by these statistical afflictions.

As we are only examining this relationship when each generator is marginal, our analysis is comprised of a series of nonsynchronous observations and are treated independently without time series components. Indeed, the econometric literature offers few methods to treat time sequential data with irregularly spaced observations besides treating each observation as temporally independent.

4. Data sources

We draw on a number of publicly available data sources to conduct our analysis. This section describes the data sources used in our assessment of NEM market events and the impact of gas powered generation. We principally rely on three publicly available sources of data:

- electricity market data from AEMO's Market Management System (MMS) database and NEM dispatch engine (NEMDE) output files;
- data on prices for gas in the STTM in Sydney, Brisbane and Adelaide and in the DWGM in Victoria; and
- contract data from ASX energy.

4.1 Electricity market data from AEMO

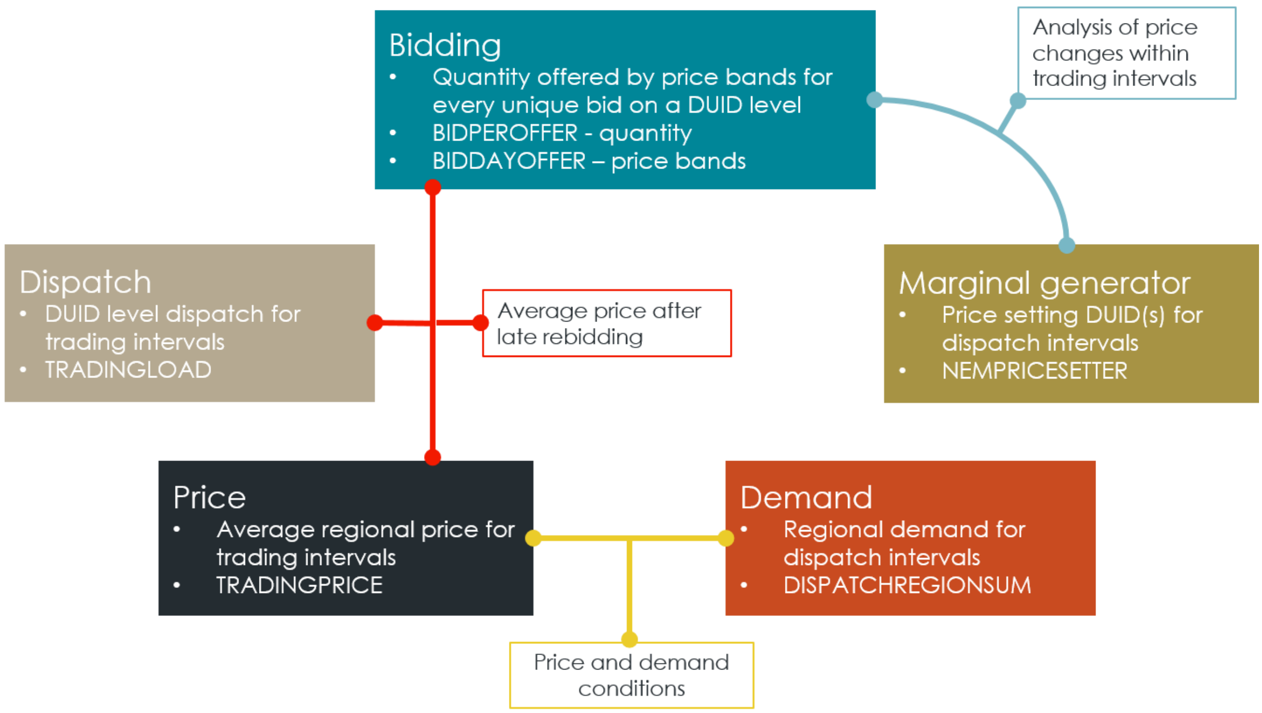
Our analysis makes use of historical data on bidding and market outcomes in the NEM data from AEMO's databases. Table 4.1 outlines the tables we have relied upon.

Table 4.1: Summary of relevant tables from the MMS database and NEMDE output files

Data type	MMS/NEMDE table name
Marginal DUID and dispatch interval price	NEMPRICESETTER
Trading interval price forecasts	PREDISPATCHPRICE
Interconnector flows	DISPATCHINTERCONNECTORRES
Trading interval prices	TRADINGPRICE
Trading interval generation by DUID	TRADINGLOAD
Dispatch interval prices	DISPATCHPRICE
Dispatch interval generation by DUID	DISPATCHLOAD
Trading interval demand by region	DISPATCHREGIONSUM
Quantity bid by DUID	BIDPEROFFER
Daily price band bids by DUID	BIDDAYOFFER

For our analysis of market events, we combine data from the various tables to establish and examine a holistic picture of the market conditions during each event. Figure 4.1 shows a high-level schematic of how we collate the data to undertake some of the more complex analysis, as explained in further detail below.

Figure 4.1: Relationships in the MMS database



We note that two of the data tables required non-trivial processing to be arranged in a format useful for the analysis. These two sets are:

- bidding data, ie, the BIDPEROFFER and BIDDAYOFFER tables; and
- price setter data, ie, the NEMPRICESETTER table.

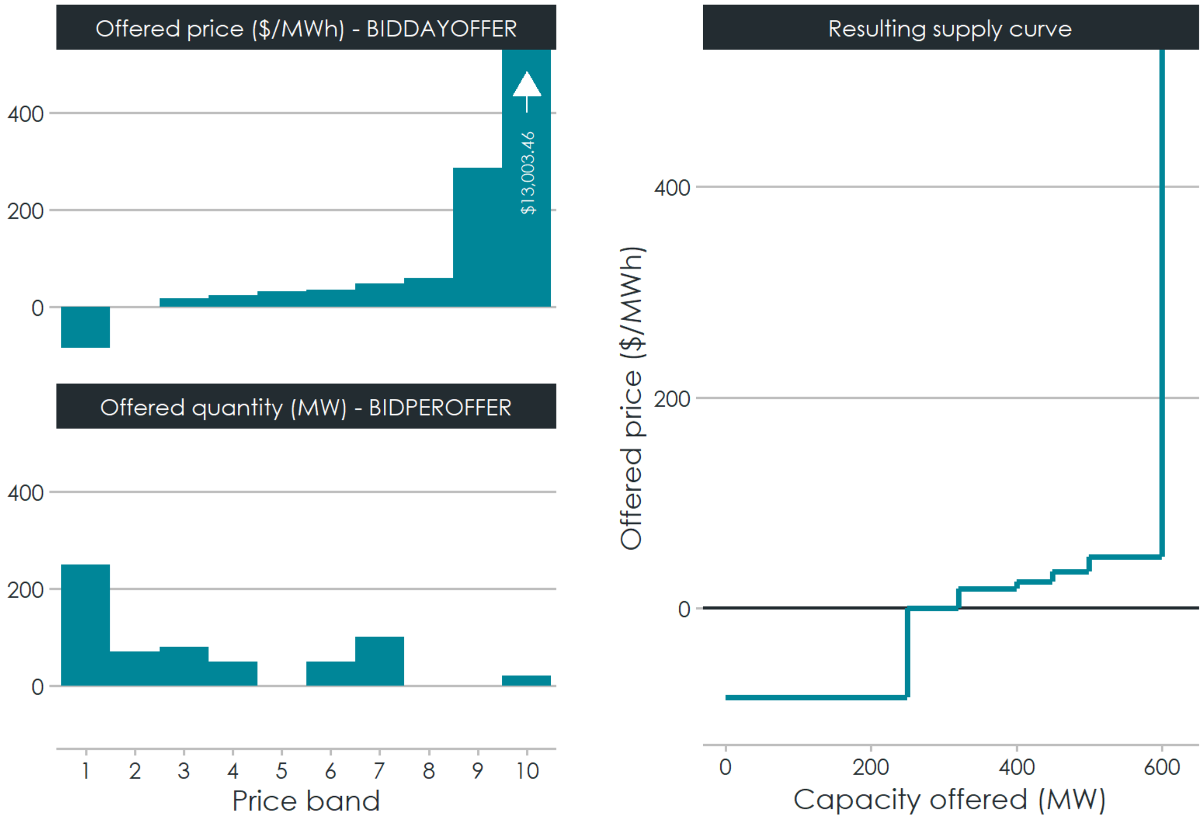
These tables required further manipulation, which we describe further below.

4.1.1 Bidding data

We use the BIDPEROFFER and BIDDAYOFFER tables from the MMS database to obtain a set of energy-only bids into the NEM. The BIDPEROFFER table contains each capacity bid in ten price bands for each dispatch interval. The BIDDAYOFFER table contains the price for each of the ten bands, which apply for the entire trading day for which they are placed.

The combination of these two data tables can be used to create the short-run supply curve for each DUID, ie, a curve representing the price at which the DUID is willing to sell each unit of its capacity into the market. Figure 4.2 provides an illustrative example of the development of bid supply curves.

Figure 4.2: Bayswater Unit 1 bids and supply curve on 1 September 2015



Description of bidding process

AEMO determines the optimal dispatch combination on a five-minute, 'dispatch interval', basis and the market is financially settled on a 30-minute, 'trading interval', basis containing six dispatch intervals. A trading day is a 24-hour period that begins at 4am of each day.

For each trading interval, a DUID submits two corresponding bids, ie:

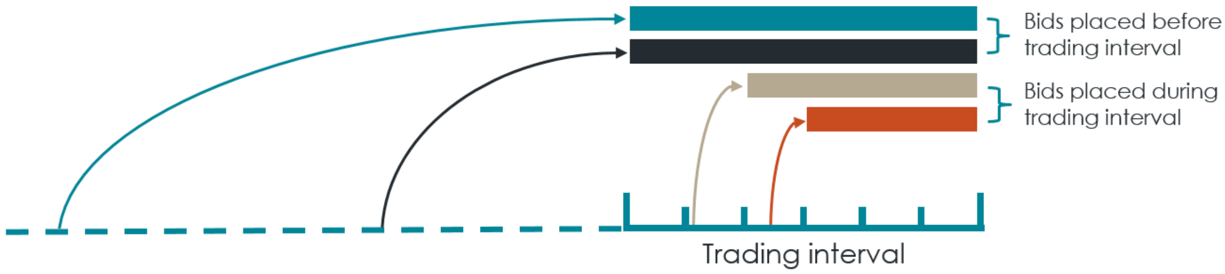
- a bid that shows the price of each of the ten price bands; and
- a bid that shows the capacity offered in each of the price bands.

The former is submitted on a trading day basis and corresponds to each of the trading intervals within that 24-hour block.

The latter is submitted on a trading interval basis and is valid for each of the dispatch intervals within it. This bid type can be resubmitted to alter the DUID's supply curve and DUIDs often rebid their capacity to reflect changes in their operating environment.

A DUID may resubmit a bid for the capacity it has available in each of the capacity bands, which applies to every dispatch interval within that trading interval. A bid can be (re)submitted during the trading interval it applies to and is valid for each of the dispatch intervals that begin after the bid has been submitted. Figure 4.3 provides an illustration of this concept.

Figure 4.3: How bids apply to trading intervals



As well as including bids for energy supply, bids from operators include bids for ancillary services, the maximum capacity available and other technical parameters. This additional information included in a bid creates duplicate bids in the data that must be cleared out in order to create a dataset that is focused solely on the energy bids of generators.

Removing duplicate energy bids

We adopt a two-step process for removing non-energy related bids from the bidding data.

First, for each trading interval, we remove any adjacent bids that do not change the values of the maximum availability or the capacity offered in each band, keeping only the earliest of these duplicates. This removes duplicate bids that represent bids into markets other than the energy market.

Second, we manipulate the capacity offered in each band for the remaining bids so that the total capacity offered across the band is limited to the maximum availability, ie, if there is capacity offered in excess of maximum availability, it is removed from the higher price bands. After this process, we repeat the removal of duplicate adjacent bids. We show a worked example of this process in Appendix A1.

This process removes bids that are for ancillary services that would otherwise be included in the data set so that the remaining bids are representative of the capacity bid into the energy market.

4.1.2 Price setter data

AEMO's NEM dispatch engine identifies the cheapest combination of generators to satisfy demand in the NEM. The spot price for each region is then set by the bid from the most expensive generator in the bidding stack for each region. This most expensive generator can be considered to be the 'price-setter', or marginal, generator. This generator can be identified from the NEMPRICESETTER table for each dispatch interval.

Our analysis is concerned with examining which of the generators is materially influencing regional prices in the NEM. Consequently, some information contained within the NEMPRICESETTER table is superfluous and so we remove some entries from the database prior to undertaking our analysis.

Method of cleaning the marginal generator data

In the price setter table, AEMO includes all plants whose output is predicted to change in response to a 1MW increase in demand in each region. Interconnector and transmission constraints can cause multiple generators to be included in the data for each dispatch interval.

When multiple generating units have the same bid price, these units will all change their output by an equal amount in response to the change in demand and can all be considered marginal. Typically, a 1MW increase will lead to an equal increase in output from a set of units at one plant.

However, owing to interactions between the change in demand, dispatch of generators and constraints, there can also be secondary effects as constraints change in response to the change in demand. These secondary effects are less of a concern for this analysis and so in identifying those generators that are marginal we need to identify those that have a material increase in output due to the change in demand.

To do this we exclude generators that would increase their dispatch by less than 0.05MW in response to a 1MW increase in demand. This will often identify one generator as the marginal unit but, in rare circumstances, this rule will identify multiple generators as being marginal. We show a worked example of this process in Appendix A2.

4.2 Gas price data

We utilise short term gas prices from STTM in Sydney, Adelaide and Brisbane and the DWGM in Victoria in the gas price analysis in our analysis.[6] We use the ex-post spot gas price, rather than the ex-ante price, to reflect the actual market outcomes that occurred on each day.

In our econometric analysis, we use a 'spot gas cost' variable as a proxy for variable operating costs of gas generators, which is evaluated for each generator by:

- multiplying gas price by the heat rate;
- adding variable operations and maintenance costs; and
- adjusting by marginal loss factors.

The generator-specific operating and maintenance costs estimates are sourced from AEMO's NTNDP assumptions.[7]

4.3 Contract data

Our analysis of contract market outcomes assesses changes in the contract market that occurred in response to each of the market events. The purpose of the assessment is to identify potential impacts of the market events on contract market liquidity and access for new entrant retailers and so we focus our analysis on trading volumes as they are a measure of the level of activity in the market.

We relied upon information on contract trading through the ASX energy exchange, which we sourced from Bloomberg. We focus our analysis on the products with the highest trading volumes, ie:

- base load quarterly futures; and
- base load quarterly $300 caps.

Our analysis does not consider over-the-counter contracting behaviour.

[6] See AEMO STTM Price and Withdrawals file, available at: http://aemo.com.au/Gas/Short-Term-Trading-Market-STTM/Data

[7] See AEMO, 2016 Planning Studies – Additional Modelling Data and Assumptions Summary, December 2016.

A1. Approach to processing bidding data

To illustrate our method of cleaning the bidding data, we present an example of cleaning the bidding data for the Gladstone 1 unit for the trading interval ending 5am, 1 January 2017. The raw data from the BIDPEROFFER table showed that there were six bids placed for this trading interval. The first was placed three weeks earlier on 10 December 2016 and the latest was placed the day previous.

					Availability in each band (MW)									
DUID	PERIODID	PERIOD_ENDING	OFFERDATE	MAXAVAIL	1	2	3	4	5	6	7	8	9	10
GSTONE1	2	01-01-17 05:00	10-12-16 11:24	280	110	15	0	0	0	0	0	20	0	140
GSTONE1	2	01-01-17 05:00	20-12-16 15:54	280	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	24-12-16 15:54	0	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	25-12-16 13:51	0	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	27-12-16 01:52	0	110	15	0	0	0	30	30	30	0	70
GSTONE1	2	01-01-17 05:00	31-12-16 18:20	0	110	15	0	0	0	30	30	30	0	70

Applying the first step of removing duplicates, we remove two rebids that do not change the maximum availability, nor the energy offers for any of the price bands, highlighted in red below.

					Availability in each band (MW)									
DUID	PERIODID	PERIOD_ENDING	OFFERDATE	MAXAVAIL	1	2	3	4	5	6	7	8	9	10
GSTONE1	2	01-01-17 05:00	10-12-16 11:24	280	110	15	0	0	0	0	0	20	0	140
GSTONE1	2	01-01-17 05:00	20-12-16 15:54	280	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	24-12-16 15:54	0	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	25-12-16 13:51	0	110	15	0	0	0	0	0	30	0	130
GSTONE1	2	01-01-17 05:00	27-12-16 01:52	0	110	15	0	0	0	30	30	30	0	70
GSTONE1	2	01-01-17 05:00	31-12-16 18:20	0	110	15	0	0	0	30	30	30	0	70

For the remaining bids, we cap the sum of the energy offered across the price bands at the level of the maximum availability, so that the sum of the quantity offered across all of the price bands is less than or equal to the maximum availability. We shade the offers we need to modify in red below.

					Availability in each band (MW)									
DUID	PERIODID	PERIOD_ENDING	OFFERDATE	MAXAVAIL	1	2	3	4	5	6	7	8	9	10
GSTONE1	2	01-01-17 05:00	10-12-16 11:24	280	110	15	0	0	0	0	0	20	0	135
GSTONE1	2	01-01-17 05:00	20-12-16 15:54	280	110	15	0	0	0	0	0	30	0	125
GSTONE1	2	01-01-17 05:00	24-12-16 15:54	0	0	0	0	0	0	0	0	0	0	0
GSTONE1	2	01-01-17 05:00	27-12-16 01:52	0	0	0	0	0	0	0	0	0	0	0

This shows that the two most recently placed bids are equivalent, with 0MW in actual capacity offered across each of the price bands, and so the later of the two bids is removed, leaving three unique bids for the trading interval.

					Availability in each band (MW)									
DUID	PERIODID	PERIOD_ENDING	OFFERDATE	MAXAVAIL	1	2	3	4	5	6	7	8	9	10
GSTONE1	2	01-01-17 05:00	10-12-16 11:24	280	110	15	0	0	0	0	0	20	0	135
GSTONE1	2	01-01-17 05:00	20-12-16 15:54	280	110	15	0	0	0	0	0	30	0	125
GSTONE1	2	01-01-17 05:00	24-12-16 15:54	0	0	0	0	0	0	0	0	0	0	0

A2. Approach to processing price setter data

The first example below shows a sample from the price setter table for price setting in QLD during a dispatch interval. In this example, the Gladstone generator units are setting the price in Queensland. In response to a 1MW increase in demand each of the units increase by the same amount, ie, 0.2, because they all have the same bid price. The sum of these INCREASE values equals one. In this case, each of the Gladstone generator units increase their dispatch by more than a 0.05MW in response to a 1MW increase in demand and each are identified as marginal.

PERIOD DATETIME	REGIONID	PRICE	UNIT	RRN BAND PRICE	MARKET	DISPATCHED MARKET	BANDCOST	BANDNO	INCREASE
1/01/2014 11:15	QLD1	49.53001	GSTONE1	49.53	Energy	ENOF	9.906	4	0.2
1/01/2014 11:15	QLD1	49.53001	GSTONE2	49.53	Energy	ENOF	9.906	4	0.2
1/01/2014 11:15	QLD1	49.53001	GSTONE3	49.53	Energy	ENOF	9.906	4	0.2
1/01/2014 11:15	QLD1	49.53001	GSTONE4	49.53	Energy	ENOF	9.906	4	0.2
1/01/2014 11:15	QLD1	49.53001	GSTONE5	49.53	Energy	ENOF	9.906	4	0.2

The identification of a marginal generator is not as clear when constraints are having a material impact on interconnector flows and generator dispatch. The example below shows a case where, in response to a 1MW increase in demand in SA, dispatch outcomes need to change to curtail wind generation in South Australia to allow increased imports over the interconnector from Victoria. This curtailment is most likely to satisfy system security considerations, and the resultant interactions between constraints through NSW means that output from Gladstone must decrease slightly.

The sum of the INCREASE values for all of SA does not equal 1 owing to interconnector losses. In this circumstance, Loy Yang A (located in VIC) is the ‘true’ price setter in South Australia as they increase dispatch by more the 0.05MW in response to a 1MW increase in demand, and the changes in output from Lake Bonney and Gladstone, are secondary effects.

PERIOD DATETIME	REGIONID	PRICE	UNIT	RRN BAND PRICE	MARKET	DISPATCHED MARKET	BANDCOST	BANDNO	INCREASE
1/01/2014 11:15	SA1	49.85166	GSTONE1	49.53	Energy	ENOF	-0.10326	4	-0.00208
1/01/2014 11:15	SA1	49.85166	GSTONE2	49.53	Energy	ENOF	-0.10326	4	-0.00208
1/01/2014 11:15	SA1	49.85166	GSTONE3	49.53	Energy	ENOF	-0.10326	4	-0.00208
1/01/2014 11:15	SA1	49.85166	GSTONE4	49.53	Energy	ENOF	-0.10326	4	-0.00208
1/01/2014 11:15	SA1	49.85166	GSTONE5	49.53	Energy	ENOF	-0.10326	4	-0.00208
1/01/2014 11:15	SA1	49.85166	LKBONNY2	28.64	Energy	ENOF	-33.8502	6	-1.18192
1/01/2014 11:15	SA1	49.85166	LYA1	38.2	Energy	ENOF	21.05455	2	0.55117
1/01/2014 11:15	SA1	49.85166	LYA2	38.2	Energy	ENOF	21.05455	2	0.55117
1/01/2014 11:15	SA1	49.85166	LYA3	38.2	Energy	ENOF	21.05455	2	0.55117
1/01/2014 11:15	SA1	49.85166	LYA4	38.2	Energy	ENOF	21.05455	2	0.55117

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