10.07

Price elasticity

Ausgrid

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How do electricity customers respond to price signals?

A study of the price elasticity of demand for electricity

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1. Introduction

This report presents the findings from an econometric study of how the price elasticity of demand for electricity varies between the charging parameters that comprise a number of Ausgrid's key tariffs. The context for this study is the development of Ausgrid's tariff strategy for the five-year period commencing 1 July 2019, which we understand will be informed by our analysis.

Changes to the National Electricity Rules (NER) in 2014 strengthened the requirement on distribution network service providers (DNSPs) to improve the efficiency of their network tariffs. Under this framework, an important decision faced by Ausgrid concerns the extent to which it should depart from strictly efficient network tariffs so as:

- to minimise the distortion to efficient network price signals necessitated by the requirement in the NER that Ausgrid recovers its efficiently incurred costs; and
- to manage any adverse effects on customer's electricity network bills from year to year.

A well-informed understanding of the price elasticity of demand plays an important role in making these decisions and so constitutes a key input to a DNSP's tariff strategy. That said, the role of estimates of the price elasticity of demand in informing network tariff reform in the national electricity market has been somewhat limited to date. This is in part due to limitations in available data and challenges associated with developing and estimating a model that adequately reflects the decision-making framework of electricity customers.

However, advancements in econometric estimation techniques in combination with detailed and desensitised consumption data provided by Ausgrid have enabled us to uncover important insights on how Ausgrid's customers respond to changes in the price of particular charging parameters.

The remainder of our report is structured as follows:

- in section 2, we briefly describe the pricing principles in the NER and the role they establish for estimates of the price elasticity of demand in informing a DNSP's network tariff strategy;
- in section 3, we present an overview of our methodology and summarise our results and findings; and
- In section 4, we conclude on the key implications of our study for Ausgrid's network tariff strategy.

In addition, we include three appendices that present detailed technical information on our methodology and the data we relied upon, along with our full results. In particular:

- Appendix A1 provides a more detailed description of our methodology;
- Appendix A2 explains the consumption and price data relied upon in our study; and
- Appendix A3 expands on section 3 of our report by presenting our full results.

2. The importance of the price elasticity of demand to inform a network tariff strategy

In this section we explain why a well-informed understanding of the price elasticity of demand is an important input to a DNSP's network tariff strategy, ie, we:

- present a brief summary of the distribution network pricing principles in the NER;
- describe the relevance of the price elasticity of demand in developing a network tariff strategy that complies with the requirements of the NER; and
- explain practical considerations for a DNSP in developing its network tariff strategy.

2.1 The distribution network pricing principles

In November 2014, the AEMC made a determination that amended the rules governing distribution network prices. The rule change established a pricing objective and new pricing principles to govern distribution network service providers' (DNSPs') pricing decisions, and also made changes to the network pricing process.

Under the framework set out in the NER a DNSP must develop tariffs that comply with the distribution network pricing principles set out in clause 6.18.5 of the NER in a manner that contributes to the network pricing objective, which is that:[1]

> … the tariffs that a Distribution Network Service Provider charges in respect of its provision of direct control services to a retail customer should reflect the Distribution Network Service Provider's efficient costs of providing those services to the retail customer.

The pricing principles prescribed in the NER:[2]

- establish bounds within which the revenue expected to be derived from each tariff class must fall. The lower and upper bound are, respectively, the avoidable cost and standalone cost of providing the relevant network service;
- mandate that each tariff must be based on the long run marginal cost (LRMC) of providing the relevant service to customers and provide guidance as to the approach to calculating LRMC;
- require the revenue expected to be recovered from each tariff class to reflect the DNSP's total efficient cost of providing the relevant services in a manner that minimises distortions to price signals to promote efficient use of network services;
- require a DNSP to consider the impact on customers of changes in tariffs from year to year and prescribe circumstances in which a DNSP may not be required to comply with particular pricing principles; and
- ensure that tariffs are designed such that they can be understood by customers.

Of particular relevance to the task at hand is the requirement in the NER to set tariffs based on LRMC and to recover the total efficient cost of providing the relevant service in a manner that minimises distortions to price signals to promote efficient use of network services.

[1] NER, clause 6.18.5(a).

[2] NER, clause 6.18.5(e) to (i).

2.1.1 Minimising distortions to price signals based on long run marginal cost

LRMC is a forward-looking concept that measures the cost incurred as a result of an incremental increase in output, evaluated over the long run. As a matter of principle, setting prices equal to LRMC will promote efficient use of the network because:

- it ensures customers face price signals that reflect the resource cost of providing network services, which encourages demand for electricity network services only when the benefit to consumers exceeds the cost of providing those services; and
- it provides signals to DNSPs as to the value customers place on additional capacity, and thereby plays an important role in financing that capacity.

Since LRMC is a forward-looking concept, prices based on LRMC do not reflect unrecovered historical costs related to the provision of services using the existing network. It follows that the level of revenue expected to arise from tariffs that reflect only forward-looking costs – ie, LRMC-based tariffs – will not necessarily permit the recovery of a DNSP's total efficient costs, as required by the NER.

The difference between a DNSP's total efficient costs and the level of revenue recovered by means of LRMC-based tariffs is known as its residual cost. As discussed in section 2.1, the NER require a DNSP to recover its residual costs:[3]

> …in a way that minimises distortions to the price signals for efficient usage of the network.…

This requirement of the NER establishes the principal role for the price elasticity of demand in developing network tariffs. For example, in its final determination on the amended pricing rules the AEMC repeated a statement by its advisors that:[4]

> … the broader goal is to have efficient tariffs based on LRMC, and that departures from LRMC induce inefficiencies. The magnitude of the inefficiencies is minimised if the movement in prices away from LRMC is concentrated on those tariffs or parts of the tariff which have the smallest elasticities.

We explain the price elasticity of demand and its role in minimising distortions to LRMC-based price signals in the section below.

2.2 A customer's own-price elasticity of demand

The price elasticity of demand is a measure of the responsiveness of a customer's consumption to a change in price.

A negative price elasticity of demand – as found for almost all goods and services – signifies an inverse relationship between price and quantity demanded. In other words, customers can generally be expected to respond to a reduction in price by increasing the total quantity of the respective good or service demanded.

The own price elasticity of demand is calculated as follows, ie:

$$\text{Price elasticity of demand} = \frac{\text{per cent change in quantity demanded}}{\text{per cent change in price}}$$

[3] NER, clause 6.18.5(g)(3).

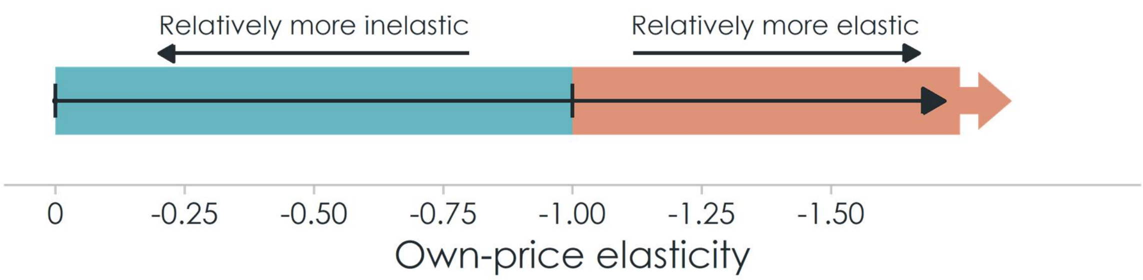
[4] AEMC, Rule Determination – National Electricity Amendment (Distribution Network Pricing Arrangements) Rule 2014, November 2014, p.159.

For example, if a customer has an own price elasticity of demand equal to negative one, then a one per cent increase in price would be expected to give rise to a one per cent decrease in that customer's consumption of the relevant good or service. If a percentage change in price gives rise:

- to a relatively *greater* proportional decrease in consumption, that customer's demand is said to be relatively 'price elastic'; or
- to a relatively *smaller* proportional decrease in consumption, that customer's demand is said to be relatively 'price inelastic'.

We illustrate this concept and nomenclature in Figure 1.

Figure 1: The price elasticity of demand



What role does the price elasticity of demand play in setting tariffs?

It is well-accepted in economic theory that any inefficiencies arising from a deviation from LRMC-based prices necessitated by the recovery of historical costs will be minimised by raising prices above LRMC in inverse proportion to the absolute value of the price elasticity of demand.

Applying this principle in the context of network tariffs, the AEMC explains that:[5]

> The underlying principle that minimises distortions to efficient usage decisions is to assign residual costs to tariff components in inverse proportion to consumers' responsiveness to that tariff component.

It is for this reason that Ausgrid asked us to evaluate the price elasticity of demand at the charging parameter, or component, level, rather than at the total consumption level.

Put simply, economic theory establishes that any distortion to LRMC-based prices will be minimised by allocating:

- relatively more residual costs to charging parameters for which demand is relatively price inelastic; and
- relatively less residual costs to charging parameters for which demand is relatively price elastic.

From a strictly theoretical perspective, this implies that residual costs should be recovered by means of fixed charges, ie, the most price inelastic of the candidate charging parameters. However, there may be adverse impacts on customer's network bills if residual costs are recovered only from fixed charges. In recognition of this, the NER:[6]

- require a DNSP to consider the impact on retail customers of changes in tariffs from the previous regulatory year; and

[5] AEMC, Rule Determination – National Electricity Amendment (Distribution Network Pricing Arrangements) Rule 2014, November 2014, p.159.

[6] NER, clause 6.18.5(h).

- permit a DNSP to vary tariffs from those that comply with the applicable pricing principles, having regard to prescribed criteria.

These requirements act to create a much broader role for the price elasticity of demand in tariff reform, as compared with a purely theoretical role directed at minimising distortions to LRMC-based prices. For example, a well-informed understanding of customer's price elasticity of demand for particular charging parameters can assist in understanding the impacts on particular customers of contemplated tariff changes.

2.3 Practical considerations in network tariff design

To comply with the pricing principles set out in the NER, DNSPs are undergoing a multi-year transition to more closely align tariff structures to the drivers of future network costs, while recovering efficient residual costs without unnecessarily affecting efficient use of the network and managing customer bill impacts. This requires DNSPs to establish a complex balance between managing customer bill impacts (and price expectations) and changing tariff structures and levels to provide improved network price signals.

From a practical perspective, LRMC estimates are likely to vary over time due to:

- improvements in estimation techniques that give rise to more accurate estimates of LRMC; and/or
- the cost of providing additional electricity capacity can be affected by exchange rate deviations and general fluctuations in the cost of constructing electricity infrastructure; and
- rising network demand that brings forward needed capacity expansions.

So as to avoid resultant fluctuations in the level of tariff components which can have unanticipated bill impacts on consumers, it follows that tariff levels can be expected to differ from LRMC estimates at any point in time.

While this means that there might be some risk of inefficient use of the network, network tariffs that unnecessarily distort efficient LRMC-based price signals can also give rise to network cost risks. For example, inefficient price signals may give rise to consumption decisions that require further investment by a DNSP to maintain its security and quality of service obligations, but where customers might not be willing to pay for those further costs.

The risk of inefficient use of the network and network cost risks can be best managed by:

- ensuring that customers are encouraged to shift to tariffs that better reflect the underlying drivers of network costs; and
- recovering a greater proportion of residual costs from those tariff parameters that are least likely to distort consumption decisions by customers.

The first of these two strategies can be achieved by providing customers with a financial incentive to be reassigned to a tariff with a structure that provides better price signals (eg, shifting from a residential block tariff to a time-of-use tariff). If a financial incentive is created by increasing the network charges on the least efficient tariff structure, then the opportunity to shift should be sufficient to satisfy the bill impact consideration set out in the NERs.

The second strategy involves a combination of increasing fixed charges, the revenue from which are unaffected by changes in consumption, and keeping usage based tariff parameters above the estimate of LRMC in circumstances where customers are not likely to be as responsive to changes in price compared to other tariff parameters. How these changes are balanced will necessarily involve the exercise of judgement by the network business, taking into consideration possible bill impacts on affected customers. However, this strategy also ensures that efficient use of the network is promoted, while further minimising cost risks borne by the business.

Understanding how the price elasticity of demand changes by tariff parameter is therefore a critical input to the design of a network's tariff strategy. Historically, estimating the price elasticity of electricity demand at a parameter level has not been practically possible. However, advances in statistical techniques combined with improvements in applying those techniques to large data sets involving individual customer data, means that it is now possible. Indeed, the results of this study demonstrate the insights that can be obtained from such analysis.

Finally, given that estimates of LRMC are likely to fluctuate over time, there is merit in considering how best to manage the network bill impacts arising from such fluctuations, while complying with the pricing principles in the NERs to set tariff parameters equal to LRMC. We believe that this might justify deviating from setting tariff parameters equal to LRMC in all circumstances. Given that setting tariffs equal to LRMC for those tariff parameters that are not responsive to changes in price will have an immaterial effect on efficient use of infrastructure, there is likely to be scope to use estimates of the price elasticity of demand to improve the management of bill impacts over time.

3. The price elasticity of electricity demand for customers in Australia

In this section, we summarise the results of our study and highlight the implications for Ausgrid's network tariff strategy. More detailed information on our methodology is set out in Appendix A1, which is followed by a detailed summary of the data we relied upon in Appendix A2 and the presentation of our full results in Appendix A3.

At the outset, we note that the data available to us enabled the estimation of the price elasticity of demand for Ausgrid's:

- residential block tariff (EA010);
- residential time-of-use tariff (EA025);
- small business block tariff (EA050);
- small business time-of-use tariff (EA225); and
- low-voltage (40-160MWh) business time-of-use capacity tariff (EA302).

3.1 How we modelled the consumption decisions of Ausgrid's customers

Evaluating the causal effect of a change in price on the use of Ausgrid's network necessitates a model that reflects the decision-making framework of Ausgrid's customers.

This is a particularly complex task in the context of electricity distribution network services, where customers' consumption decisions are governed by a range of factors, including the applicable price levels, their wealth and climatic conditions.

Further, each of Ausgrid's tariffs comprises a range of price signals that affect customer's decisions, eg, a time-of-use tariff may comprise a peak, shoulder and off-peak charging parameter with different price levels. It follows that a consumption decision related to a particular charging parameter can have important implications on consumption decisions for other charging parameters, eg, a decision to consume less in a peak period may correspond to a simultaneous decision to consume more in the shoulder period.

Indeed, it is clear that electricity consumption decisions are governed by a range of inherently interrelated factors. In our opinion, the inherently interrelated nature of electricity consumption decisions is best captured by a simultaneous equation model.

In economic terms, modelling consumption decisions by means of a system of simultaneous equations reflects circumstances whereby an economic agent is presented with a range of information and, on that basis, simultaneously makes a number of consumption decisions. The contemporaneity of those consumption decisions in a simultaneous equation model ensures that any interrelationships between the factors governing those decisions are adequately reflected in the decision-making framework.

Consistent with this approach, for each variable charging parameter that comprises a tariff we define an equation incorporating the factors that govern a customer's demand for that charging parameter. We then solve the system of equations for each tariff simultaneously.[7] We explain this approach in detail in Appendix A1.

We present an illustrative example of a simultaneous equation model in Box 1.

[7] A more detailed description of the estimation methodology, including the full set of modelled equations, is set out in Appendix A1.

Box 1: An illustrative example of a simultaneous equation model

Equation 1 below presents an illustrative simultaneous equation model for a tariff comprising three variable charging parameters, ie, charging parameters i, j and k.

Since a consumption decision in relation to charging parameter *i* may be affected not only by price of that charging parameter, but also by the relative price of the other charging parameters, we include the price of all charging parameters as explanatory variables. These explanatory variables are highlighted red in the set of equations below.

To reflect the potential for a customer to substitute consumption from one charging parameter to another, we also include the quantity of the other charging parameters in each equation. In other words, the inclusion of these variables is directed at capturing a change in demand for a charging parameter attributable not to a change in its price, but to a change in demand for another charging parameter. These explanatory variables are highlighted blue in the set of equations below.

Finally, we include explanatory variables to capture the effect of climatic conditions and wealth on a customer's consumption decisions. These variables are highlighted grey in the set of equations below.

Equation Set 1: Stylised set of equations for modelling consumption behaviour

$$
\begin{aligned}
q_i &= \beta_{11}p_i + \beta_{12}p_j + \beta_{13}p_k + \beta_{14}q_j + \beta_{15}q_k + \beta_{16}\text{weather} + \beta_{17}\text{income} \\
q_j &= \beta_{21}p_i + \beta_{22}p_j + \beta_{23}p_k + \beta_{24}q_i + \beta_{25}q_k + \beta_{26}\text{weather} + \beta_{27}\text{income} \\
q_k &= \beta_{31}p_i + \beta_{32}p_j + \beta_{33}p_k + \beta_{34}q_i + \beta_{35}q_j + \beta_{36}\text{weather} + \beta_{37}\text{income}
\end{aligned}
$$

We explain in detail our approach to estimating each set of equations, and the data we relied upon in doing so, in Appendix A1 and A2.

We applied three-stage least squares generalised method of moments (3SLS GMM) in our analysis of residential tariffs and spatial 3SLS GMM in our analysis of business tariffs. We used data over the period July 2006 to December 2016 and, in particular:

- for residential customers' electricity consumption data, we used quarterly consumption data, aggregated to the Statistical Area Level 1 (SA1);[8]
- for business customers' electricity consumption data, we used quarterly consumption data, aggregated to the local government area (LGA);[9]
- for price data, we relied on historical regulated and standing offer retail prices for each tariff;
- for weather data, we used a measure of cooling and heating energy demand consistent with that applied by the Australian Energy Market Operator (AEMO) and CSIRO; and
- for income data, we used household weekly mean income in the residential tariff models and measures of gross domestic product (GDP) growth and NSW's state final demand (SFD) growth in the business tariff models.

Again, we direct interested parties to Appendix A1 and A2 for a comprehensive discussion of our methodology and the data used in our analysis.

[8] Adjusted to account for improvements in energy efficiency.

[9] Adjusted to account for improvements in energy efficiency.

Finally, our analysis evaluates the responsiveness of customers' electricity consumption decisions to changes in the retail, rather than network, price of electricity because consumption decisions are ultimately made by reference to retail prices. However, the inferences drawn from our analysis can be appropriately applied in the context of network tariffs.

3.2 The price elasticity of demand for residential electricity customers

In this section, we summarise the results and key inferences arising from our evaluation of the price elasticity of demand for customers on Ausgrid's two main residential tariffs, ie:

- EA010 – a non-time variant tariff comprising three consumption blocks and a fixed charge, where the block charging parameters levy a different marginal price at different levels of consumption; and
- EA025 – a time-of-use tariff comprising fixed, off-peak, shoulder and peak charging parameters, where the latter three charging parameters levy a different price on consumption at different times of the day.

3.2.1 The residential block tariff (EA010)

In this section, we present a summary of our analysis for customers on Ausgrid's residential block tariff (EA010). The full results of this analysis are presented at Appendix A3.

Box 2: Our key findings for the residential block tariff

We find that the demand of residential customers on Ausgrid's block tariff is more responsive to changes in price at higher levels of consumption, ie, their own-price elasticity of demand is more elastic at higher levels of consumption.

Therefore, an inclining block tariff is consistent with the objectives of:

- mitigating network bill impacts for low energy users and vulnerable customers; and
- providing incentives for high energy users to reduce their consumption.

We present a summary of our estimates of the own price elasticity of demand in Table 1 below. We do not allow for any cross-price effects (ie, we do not estimate cross-price elasticities) for block tariffs because of the limited scope for interaction between the blocks, eg, customers cannot readily substitute consumption between blocks.

Table 1: The price elasticity of demand of customers on the residential block tariff (EA010)

	Block one consumption	Block two consumption	Block three consumption
First block retail charge	-0.0518 ***	---	---
Second block retail charge	---	0.0871 ***	---
Third block retail charge	---	---	-0.2068 ***

It is relevant first to highlight the nonsensical, positive estimate of the own-price elasticity for block two consumption. Further analyses confirmed there exists an effect on block two electricity consumption that is not adequately captured by our model. Nevertheless, alternative specifications confirmed that our key finding is not sensitive to this unobserved effect, as discussed in Appendix A3.

Our analysis shows that the own-price elasticity of demand in block one and three is relatively inelastic and statistically significant at the one per cent level. Specifically, our analysis indicates that a ten per cent increase in the price level of the charging parameter:

- for block one would be expected to give rise to a 0.5 per cent reduction in the level of electricity consumption in block one; and

- for block three would be expected to give rise to a four times greater reduction of 2.1 per cent in the level of electricity consumption in block three.

In other words, customers are approximately four times more responsive to changes in the price of the block three charging parameter, as compared with block one. We illustrate our findings in Figure 2 below.

Figure 2 The own-price elasticity of demand for the residential block tariff (EA010)

Our finding that customers are more responsive to changes in price at higher levels of consumption is consistent with economic theory, which suggests that the marginal benefit derived from each unit of a particular good or service consumed decreases as consumption increases. Therefore, we would expect demand to be relatively more responsive to changes in price at higher levels of consumption.

If the economic efficiency of this tariff was considered in isolation and from a purely theoretical perspective, our findings suggest that relatively more residual costs should be allocated to earlier blocks of consumption. However, it is important to consider our findings in the context of Ausgrid's particular tariff strategy and its transition to more efficient tariffs, as well as customer feedback on potential structures for block tariffs, consistent with the requirements of the NER.

We understand from Ausgrid that central components of its tariff strategy include:

- preventing unacceptable increases in electricity network bills from year-to-year, particularly for low energy users and vulnerable customers; and
- providing incentives for large customers to reduce their use of the network.

Of particular relevance to these objectives, our results show that customers with marginal consumption:

- in the first block – low energy users – are very unresponsive to changes in price and so are least able to reduce their consumption in response to a price increase, as compared with other customers; and
- in the third block – high energy users – are most responsive to changes in price and so an increase in the price of block three consumption would be expected to elicit the greatest marginal decrease in consumption per customer, as compared with the other blocks.

We understand that Ausgrid is proposing to apply an inclining block structure to EA010 in the forthcoming regulatory control period, which involves the application of a marginal price that is lowest for block one, relatively higher for block two and highest for block three. Our results show that this is consistent with the objectives of Ausgrid's tariff strategy because it will be effective at:

- mitigating network bill impacts for low energy users and vulnerable customers, ie, because relatively less residual costs are recovered from these customers; and
- providing incentives for high energy users to reduce their consumption, ie, because these customers are most responsive to changes in price and will face the highest marginal price.

3.2.2 The residential time of use tariff (EA025)

In this section, we present a summary of our analysis for customers on Ausgrid's residential time of use tariff (EA025). The full results of this analysis are presented at Appendix A3.

Box 3: Our key findings for the EA025 tariff

We find that the demand of residential customers on Ausgrid's time of use tariff is extremely inelastic during the peak and off-peak periods, and relatively more elastic in the shoulder period. It follows that the recovery of residual costs during the peak period would better promote economic efficiency, as compared with the shoulder period.

Although demand in the shoulder period is most elastic and so least suited to the recovery of residual costs from the perspective of economic efficiency, the high level of volume in the shoulder period likely means that it will still have a role to play in the recovery of residual costs.

A summary of our estimates of the own price elasticity of demand (shaded cells) and the cross-price elasticity of demand for Ausgrid's residential time of use tariff are presented in Table 2 below.

Table 2: The price elasticity of demand of customers on the residential time of use tariff (EA025)

	Off-peak consumption	Shoulder consumption	Peak consumption
Off-peak retail charge	-0.0725 *	0.2697 ***	-0.3024 ***
Shoulder retail charge	0.0481	-0.3062 ***	0.3658 ***
Peak retail charge	0.1969 ***	-0.5767	-0.0740 ***

Our analysis shows that residential time of use customers are generally unresponsive to changes in price (ie, they're relatively price inelastic) and that their consumption is extremely inelastic in the peak and off-peak periods. Further, consumption is most elastic in the shoulder period (although still relatively inelastic). We illustrated these observations in Figure 3 below.

Figure 3: The own-price elasticity of demand for the residential time of use tariff (EA025)

Recovering some level of residual costs during the peak period

A particularly interesting finding is that consumption is extremely inelastic in the peak period, which is when use of the network drives Ausgrid's forward-looking costs and Ausgrid sends a LRMC-based price signal to customers. In economic terms, our analysis suggests that any allocative inefficiency arising from the recovery of residual costs during the peak period, ie, setting a peak price above the LRMC-based level, would be relatively low, as compared with recovering those costs from the shoulder period.

We understand that Ausgrid's current estimate of LRMC is below that implied by its existing peak price and that Ausgrid is planning to transition the peak price down to the LRMC-based level over time, rather than by means of a step-change. In other words, Ausgrid is proposing to recover some degree of residual costs from the peak price during its transition down to the LRMC-based level. Our results show that this proposal is not contrary to the promotion of economic efficiency, ie, in light of peak period consumption being highly unresponsive to changes in price.

Finally, we note that the observed very inelastic demand in the peak period lends weight to a proposition that a relatively sharp increase in the peak price would be required to elicit a material reduction in network use during times of peak demand. For example, our results indicate that a fifty per cent increase in the peak price would elicit only a 3.7 per cent decrease in the use of the network during the peak period.

The role of the off-peak and shoulder periods

We also find that consumption is extremely inelastic in the off-peak period, which suggests economic efficiency would be promoted by the recovery of residual costs during the off-peak period. However, from a practical perspective the relatively low volume in the off-peak period means that its role in the recovery of residual costs is somewhat diminished.

Conversely, consumption in the shoulder period is the most elastic of the three periods (although still very inelastic) and so, from a theoretical perspective, the shoulder period is least suited to the recovery of residual costs. However, approximately 50 per cent of all volume occurs in the shoulder period and so, from a practical perspective, the shoulder period may still play a material role in the recovery of residual costs.

We understand that Ausgrid is proposing to transition down the price of consumption in the shoulder period to a level commensurate with the price in the off-peak period. Our results show that the implicit reduction in the proportion of residual costs recovered from the shoulder period is consistent with the promotion of economic efficiency.

Observations of the cross-price elasticity of demand

A positive cross-price elasticity of demand indicates that consumption in one period is a substitute for that in another, as can be observed in Table 2 for all but two of our estimates of the cross-price elasticity of demand. For example, our results indicate that a ten per cent decrease in the price of the shoulder period would be expected to elicit a 1.2 per cent reduction in consumption in the peak period, ie, as customers substitute consumption from the peak period to the shoulder period following the change in relative prices.

It is interesting to observe the negative cross price elasticity of demand between the off-peak and peak periods, which suggests that, at least to a certain extent, consumption in those periods can act as complements to each other, rather than substitutes. A potential explanation for this peculiarity arises from the assignment of customers with solar photovoltaic (PV) installations to the small business time of use tariff.

These customers with solar PV installations would be expected to have a lower ratio of peak to off-peak consumption, as compared with other customers on this tariff. Against a backdrop of generally increasing price levels, any such change in relative consumption over time may be attributed by our model to a perceived cross-price relationship, rather than the addition of new customers with particular consumption profiles.

Given that the incidence of solar PV amongst these customers is likely to be higher than for business customers, this would explain the higher perceived response of peak consumption to changes in off-peak prices for the residential time-of-use tariff (-0.30), as compared with that for the small business time-of-use tariff (-0.14) discussed in section 3.3.2.

3.3 The price elasticity of low-voltage business electricity demand

In this section, we summarise our analysis of the price elasticity of demand for business customers assigned to Ausgrid's:

- small business block tariff (EA050);
- small business time-of-use tariff (EA225); and
- low-voltage (40-160MWh) business time-of-use capacity tariff (EA302).

3.3.1 The small business block tariff (EA050)

Ausgrid's small business block tariff comprises two consumption blocks and a fixed charge. It differs from the residential block tariff in that it has only two blocks and those blocks are defined by reference to higher consumption thresholds.

Box 4: Our key findings for the small business block tariff

We find that the consumption of customers on Ausgrid's small business block tariff is more responsive to changes in price at higher levels of consumption, ie, their own-price elasticity of demand is more elastic at higher levels of consumption.

Therefore, an inclining block tariff is consistent with the objectives of:

- mitigating network bill impacts for low energy users (very small businesses); and
- providing incentives for high energy businesses users to reduce their consumption.

We present a summary of our estimates of the own price elasticity of demand (shaded cells) in Table 3 below.[10] We present our full results at Appendix A3.

Table 3: The price elasticity of demand of customers on the business block tariff (EA050)

	Block one consumption	Block two consumption
First Block retail charge	-0.1374 ***	---
Second block retail charge	---	-0.2892 ***

We find that our estimates of the own-price elasticity of demand are statistically significant at the one per cent level and that consumption in both block one and two is very price inelastic. In particular, our results show that a ten per cent increase in the price level:

- for block one would be expected to give rise to a 1.4 per cent decrease block one consumption; whereas
- for block two would be expected to give rise to a 2.9 per cent decrease in block two consumption.

Consistent with our results for the residential block tariff, we find that consumption for Ausgrid's small business block tariff is more responsive to changes in price at higher levels of consumption, ie, because the own price elasticity for block two is more elastic than that for block one. We illustrate this observation in Figure 4.

10 For the same reasons highlighted in relation to the residential block tariff in section 3.2.1, our model specification for the business block tariff does not allow for the existence of cross-price effects.

Figure 4: The own-price elasticity of demand for the EA050 tariff

The very inelastic own price elasticity for small business customers in both block one and two is consistent with a view that electricity consumed by a business is a necessary input to its operation and so likely to be unaffected by changes in price, unless it starts to impact on the competitiveness or profitability of the business.

For the same reasons we discuss in section 3.2.1 in relation to the residential block tariff, our results show that an inclining block tariff for small business customers is consistent with the objectives of:

- mitigating network bill impacts for low energy users (very small businesses); and
- providing incentives for high energy businesses users to reduce their consumption.

We note that our estimates of the own price-elasticity of demand for the small business block tariff (above) are slightly more elastic, as compared with our estimates for the residential block tariff. This was unexpected and may arise from the potential unobserved effect on the residential block tariff that our model does not capture, as discussed in section 3.2.1. It is also relevant to note that the consumption of small business customers is generally higher than that of residential customers and we observe that price responsiveness generally increases with consumption. Therefore, even if it is the case that small business consumption is, on average, more responsive to changes in price, as compared to residential consumption, business consumption may still be more inelastic on a like-for-like basis, ie, when compared over the same level of consumption.

3.3.2 The small business time-of-use tariff (EA225)

In this section, we present a summary of our analysis for customers assigned to Ausgrid's small business time of use tariff (EA225). The full results of this analysis are presented at Appendix A3.

Box 5: Our key findings for the EA225 tariff

We find that the demand of customers on Ausgrid's small business time of use tariff is extremely inelastic during the peak period, relatively more elastic in the shoulder period and most elastic in the off-peak period.

Therefore, the recovery of residual costs during the peak period would better promote economic efficiency, as compared with the off-peak and shoulder periods.

A summary of our estimates of the own price elasticity of demand (shaded cells) and the cross-price elasticity of demand for Ausgrid's small business time of use tariff are presented in Table 4 below and the full results are presented at Appendix A3.

Table 4: The price elasticity of demand of customers on the business time of use tariff (EA225)

	Off-peak consumption	Shoulder consumption	Peak consumption
Off-peak retail tariff	-0.3962 ***	0.2008 ***	-0.1365 ***
Shoulder retail tariff	0.6461 ***	-0.2345 ***	0.1207 ***
Peak retail tariff	-0.6013 ***	0.1724 ***	-0.0841 ***

We find that all of our estimates of the own-price elasticity of demand are statistically significant at the one per cent level and that demand for Ausgrid's small business time of use tariff is relatively price inelastic.

Our analysis shows that customers are most responsive to changes in price during the off-peak period and least responsive during the peak period, as illustrated in Figure 5 below.

Figure 5: The own-price elasticity of demand for the small business time of use tariff (EA225)

Recovering residual costs during the peak period

Consistent with our results for the residential time of use tariff, we find that demand in the peak period is extremely inelastic. For the same reasons discussed in section 3.2.2, this suggests that economic efficiency would be better promoted by the recovery of residual costs during the peak period, as compared with the shoulder and off-peak periods.

We understand that Ausgrid's current estimate of LRMC is below that implied by its existing peak price and that Ausgrid is planning to transition the peak price down to the LRMC-based level over time, rather than by means of a step-change. In other words, Ausgrid is proposing to recover some degree of residual costs from the peak price during its transition down to the LRMC-based level. Our results show that this proposal is consistent with the promotion of economic efficiency.

3.3.3 The low-voltage business (40-160MWh) time-of-use capacity tariff (EA302)

In this section, we present a summary of our analysis for customers on Ausgrid's small business time of use capacity tariff (EA302), which applies to business consuming between 40 and 160 megawatt hours of electricity per annum and comprises a fixed, peak, shoulder, off-peak and capacity charging parameter. The capacity charging parameter levies a charge on a customer's highest monthly demand over the preceding 12 months. We present the full results of our analysis at Appendix A3.

Box 6: Our key findings for the EA302 tariff

We find that the demand of customers on Ausgrid's small business time of use and capacity tariff is extremely inelastic during the peak period and relatively more elastic in the shoulder period and so the recovery of residual costs during the peak period would better promote economic efficiency, as compared with the shoulder period.

More generally, our review of the capacity charge and our endeavours to robustly model the corresponding demand suggests that it is better suited to the recovery of fixed costs, rather than signalling to customers the forward-looking costs of their consumption decisions.

We present in Table 5 below a summary of our estimates of the own-price elasticity of demand (shaded cells) and the cross-price elasticity of demand. The full results of this analysis are presented at Appendix A3.

It is relevant first to note that identifying an appropriate model specification for this tariff was challenging due to the definition of Ausgrid's capacity charging parameter and the absence of a strong nexus between monthly demand and the charge for that particular month. We present below the results of our preferred model specification, but note that it does not well capture how customers respond to the capacity charge, which accounts for approximately 50 per cent of the average customer's network bill. This likely contributes to our nonsensical, positive estimate of the price elasticity of demand during the off-peak period.

Table 5: The price elasticity of demand of customers on the business time-of-use and capacity tariff (EA302)

	Off-peak consumption	Shoulder consumption	Peak consumption
Off-peak retail charge	0.0515 **	0.3859 **	-0.0454 ***
Shoulder retail charge	0.0338	-0.3198 ***	0.3242 ***
Peak retail charge	-0.1575 ***	0.2000 ***	-0.1605 ***
Capacity retail charge	0.0249 ***	0.7762 ***	-0.0845

Our estimates of the own-price elasticity of demand for the shoulder and peak periods are statistically significant at the one per cent level and show that demand in these periods is relatively price inelastic. Despite the challenges associated with modelling this tariff, and consistent with our results for other time of use tariffs, we find that demand in the peak period is extremely price inelastic and relatively more inelastic than demand in the shoulder period. We illustrate this observation in Figure 6 below.

Figure 6: The own-price elasticity of demand for the small business (40-160MWh) time of use tariff

Implications for recovering residual costs from the peak and shoulder periods

Consistent with our results for all time of use tariffs the subject of our analysis (both residential and business), we find that demand in the peak period is extremely inelastic. For the same reasons discussed in section 3.3.2, this suggests that economic efficiency would be better promoted by the recovery of residual costs during the peak period, as compared with the shoulder period.

The capacity charge may be better suited to the recovery of residual costs

The definition of Ausgrid's capacity charging parameter contributes to a weak nexus between the price of the capacity charge and a customer's observed monthly demand. This weak nexus between price and observed demand presents a significant challenge for modelling the causal relationship between changes in price and demand.

Box 7 How does the capacity charge work?

Ausgrid's capacity charge is levied on a customer's maximum monthly demand over the preceding 12 months and, therefore, ratchets up and down over time.

By way of example, consider circumstances where a customer has a particularly high demand month that is the basis for the capacity charge component of their next quarterly network bill. If this customer responds to the increase in their network bill by permanently reducing their monthly demand in the following month, there would be no corresponding change in the capacity component of their next quarterly bill. Then, if the price of the capacity charge changed in the following quarter, there would be a change in the customer's network bill that is unrelated to their monthly demand over that quarter.

This hypothetical example illustrates the relatively weak nexus between the price signal and a customer's observed monthly demand.

It is for this reason that we were unable to identify a model specification that robustly captures how customers respond to the capacity charge component of this tariff, which accounts for approximately 50 per cent of the average customers network bill.

However, our focus on the nature of Ausgrid's capacity charge highlighted that it may not be well suited to the provision of LRMC-based price signals, as compared with the time of use energy charge. Instead, the relatively more stable, or less variable, nature of the capacity charging mechanism may leave it better suited to the recovery of residual costs, ie, because it is less distortionary.

While recovering residual costs from the fixed charge would minimise the distortion to LRMC-based prices necessitated by the need to recover residual costs, Ausgrid's capacity charging mechanism may better assist in managing customer bill impacts because it is relatively more avoidable, as compared with a fixed charge.

4. Implications for Ausgrid's network tariff strategy

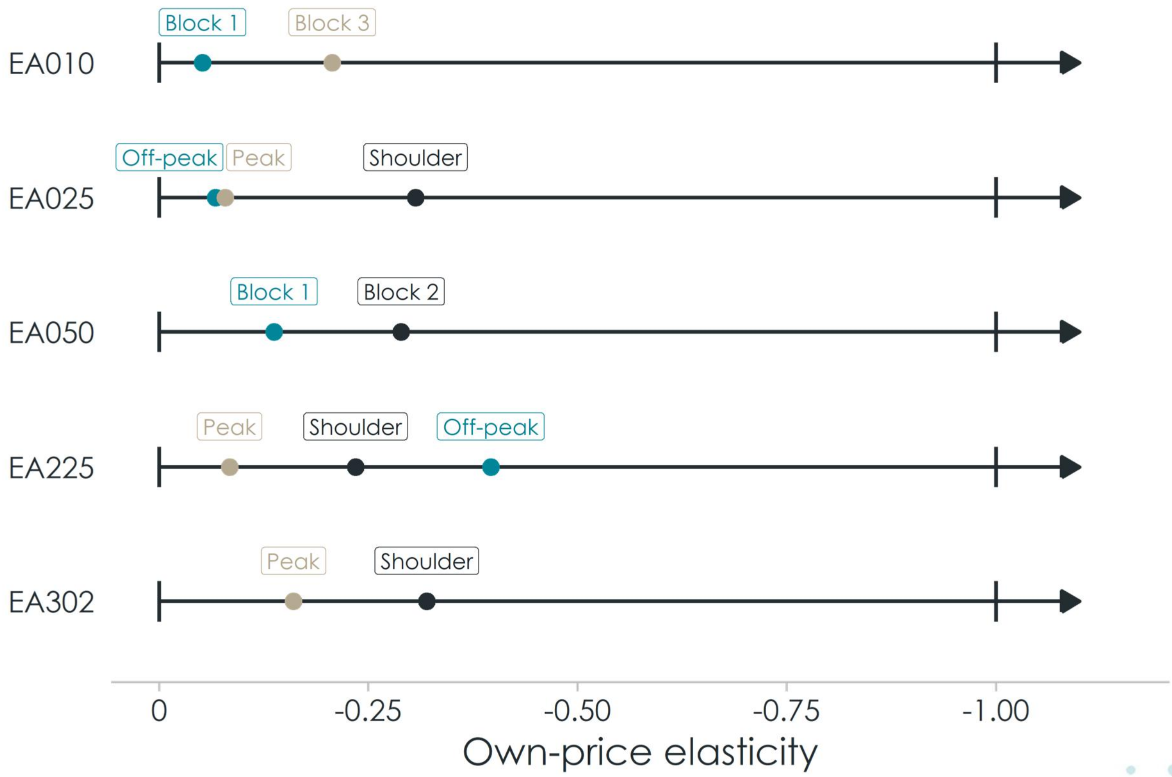
In this section, we conclude on the insights to be gained from our empirical estimates of the price elasticity of demand and the corresponding implications for Ausgrid's network tariff strategy.

Before we summarise our results, it is important again to emphasise that it is well-established and accepted in economics that economic efficiency is promoted by the recovery of 'residual costs' from charges that do not distort the efficient use of a good or service. In the context of electricity network services, this would most likely involve recovering residual costs from the fixed charge component of network tariffs.

However, to the extent consideration of the impact on retail customers of tariff reform necessitates the recovery of some degree of residual costs from variable, rather than fixed charges, it is relevant to consider the responsiveness of customer's consumption to changes in the price of those variable charges. To this end, our empirical estimates of the price elasticity of demand enable us to rank variable charging parameters in order of least to most responsive to changes in price.

We illustrate our estimates of the own-price elasticity of demand in Figure 7 below.

Figure 7 Summary of our estimates of the own price elasticity of demand



Consistent with empirical literature and economic intuition, we find that the consumption of Ausgrid's customers is relatively price inelastic, ie, the price elasticity of demand ranges from approximately -0.01 and -0.40 depending on the charging parameter. In other words, Ausgrid's customers are relatively unresponsive to changes in price.

4.1 Implications for Ausgrid's residential and small business block tariffs

A key finding of our study is that customers assigned to Ausgrid's block tariffs are more responsive to changes in price at higher levels of consumption. This finding is consistently observed across both Ausgrid's residential block tariff (EA010) and small business block tariff (EA050).

From a purely economic perspective, this suggests relatively more residual costs should be allocated to earlier blocks of consumption. However, it is important to consider our findings in the context of Ausgrid's particular tariff strategy, its transition to more efficient tariffs and customer feedback on potential structures for block tariffs, consistent with the requirements of the NER. In this context, we understand from Ausgrid that central components of its tariff strategy for its block tariffs include:

- preventing unacceptable increases in electricity network bills from year-to-year, particularly for low energy users and vulnerable customers; and
- providing incentives for high energy users customers to reduce their use of the network.

Preventing unacceptable network bill impacts

The NER prescribes that, in complying with the requirement to consider customer impacts, Ausgrid may vary tariffs from those that comply with the economic criteria established by particular pricing principles having regard to:[11]

> …the extent to which retail customers are able to mitigate the impact of changes in tariffs through their usage decisions.

Our results show that consumption is most unresponsive to price at low levels of consumption, and so it follows that low energy users are least able to reduce their consumption in response to changes in price, as compared with other customers. Therefore, allocating relatively less residual costs to earlier consumption blocks would be consistent with preventing unacceptable network bill impacts for low energy users.

Providing incentives for unacceptable network bill impacts

Our results show that consumption is most responsive to changes in price at higher levels of consumption. Therefore, for every dollar of residual cost to be recovered from customers on Ausgrid's block tariffs, a relatively greater reduction in consumption will arise from recovering that dollar from a later consumption block. Put differently, the greatest marginal decrease in consumption per customer will arise from:

- increasing the price of block three for the residential block tariff, as comparted with blocks one and two; and
- increasing the price of block two for the small business block tariff, as compared with block one.

Indeed, the marginal consumption of high energy users on Ausgrid's block tariff is in the last consumption block. Therefore, allocating relatively more residual costs to later consumption blocks is consistent with the provision of incentives to encourage high energy users to reduce their use of the network.

Ausgrid's proposed inclining block tariffs

We understand that Ausgrid is proposing to apply an inclining block structure for its residential and small business block tariffs, which involves:

- allocating relatively less residual costs to earlier consumption blocks; and
- allocating relatively more residual costs to later consumption blocks.

[11] NER, clause 6.18.5(h)(3).

Our results show that this is consistent with the objectives of Ausgrid's tariff strategy because it will be effective at:

- mitigating network bill impacts for low energy users and vulnerable customers; and
- providing incentives for high energy users to reduce their use of the network.

4.2 Implications for Ausgrid's time of use tariffs

The key finding from our study of the price elasticity of demand for Ausgrid's time of use tariffs is that consumption in the peak period is less responsive to changes, as compared with the shoulder period, and larger business customers' consumption is *least* responsive in the peak period. This was consistently observed across the relevant time of use tariffs we evaluated.

Implications for the peak period

In economic terms, our key finding for the time of use tariffs suggests that any allocative inefficiency arising from the recovery of residual costs during the peak period, ie, setting a peak price above the LRMC-based level, would be relatively low, as compared with recovering those costs from the shoulder period.

Relevantly, we understand that Ausgrid's current estimate of LRMC is below that implied by its existing peak price and that it proposes to transition its peak prices down to the LRMC-based level over time, rather than by means of a step-change. In other words, Ausgrid is proposing to recover some degree of residual costs from the peak price during its transition down to the LRMC-based level.

Our results show that this proposal is not contrary to the promotion of economic efficiency, ie, in light of peak period consumption being highly unresponsive to changes in price.

Implications for the shoulder and off-peak periods

In principle, those charging parameters that generally do not provide a signal to promote efficient use of the network at times of peak demand, ie, the shoulder and off-peak charging parameters, and in which consumption is also more price elastic, should be considered as a higher priority for a price reduction as part of a tariff strategy to promote efficient use of the network.

We find that consumption in the shoulder period is towards the more price-responsive end of the range of estimated price elasticities, which suggests that, from a theoretical perspective, it is generally less suited to the recovery of residual costs. That said, from a practical perspective there exists a large level of volume in the shoulder period, particularly for the residential time of use tariffs (EA025), and so it will likely still play a role in the recovery of residual costs.

For Ausgrid's residential time of use tariff in particular, consumption in the shoulder period and off-peak period is, respectively, the most elastic and most inelastic of the parameters. We understand that Ausgrid is transitioning down the price of the shoulder period to a level commensurate with the off-peak period. Our results show that the implicit reduction in the proportion of residual costs recovered from the shoulder period is consistent with the promotion of economic efficiency.

Our finding that residential customer's consumption is most unresponsive to changes in price in the shoulder period contrasts with our finding that small business customers on a time of use tariff are most price responsive in the off peak period. However, the role of the off-peak period in the recovery of residual costs is somewhat diminished by the low level of volume in the off-peak period and the low price applied in that period.

More general observations

Finally, we note that the observed very inelastic demand in the peak period lends weight to a proposition that a relatively sharp increase in the peak price would be required to elicit a material reduction in network use during times of peak demand. For example, our results indicate that a fifty per cent increase in the peak price for residential customers would elicit only a 3.7 per cent decrease in the use of the network during the peak period.

One consequence of this observation is that a narrowing of the peak period, and the resulting increase in the peak price, may not give rise to a material reduction in peak demand.

4.3 Further areas of interest for the industry

In our view, the success of this study paves the way for the industry to better understand how customers respond to price signals. Potential future applications of our methodology could be directed at informing an understanding of:

- how customers with particular characteristics, say those with solar photovoltaic and or battery installations, respond to particular price signals;
- how to provide incentives for customers to elect to be voluntarily reassigned to a more efficient tariff;
- the effects on the use of electricity from any rebalancing of relative price levels by electricity retailers;
- whether the price responsiveness of customers varies by geographic location;
- how to maximise use of the network in locations or at times where there is excess capacity; and
- incorporating a demand-response in the evaluating the impacts on customers of tariff changes, as required by the NER.

Finally, we are grateful to the Australian Energy Regulator for the feedback it provided in the presentation of our findings in October 2017.

A1. Our methodology for estimating the price elasticity of demand

The price elasticity of demand is a measure of the responsiveness of a customer's consumption to a change in price. The own price elasticity of demand is calculated as follows, ie:

$$\text{Price elasticity of demand} = \frac{\text{per cent change in quantity demanded}}{\text{per cent change in price}}$$

Estimating the price elasticity of demand for a good or service necessitates the specification of a functional form for the demand function, ie, a mathematical expression explaining the relationship between price and quantity demanded. A commonly applied functional form is the constant price elasticity demand function, which can be expressed as follows, ie:

$$q = p^{\epsilon}$$

Where

q is the quantity of consumption;

p is the price paid for consumption; and

ε is the price elasticity of demand.

In this functional form, the price elasticity of consumption is constant across the range of observed consumption. By taking a logarithmic transformation of this equation, we translate the equation into its linear form:

$$\log q = \epsilon \log p$$

The key advantage of this linear form is that it allows the elasticity of demand to be directly estimated using linear regression methods, where the coefficient estimate can be directly interpreted as the price elasticity of demand. Further, additional variables can be added to this equation to assist in better explaining a customer's consumption decisions.

We explain our simultaneous equation model approach to modelling the consumption decisions of Ausgrid's customers in section 3.1 of our report.

We describe below our approach to accounting for interactions between charging parameters that comprise a tariff and the effect of weather and income on electricity consumption.

A1.1 Accounting for the effect of weather on electricity consumption

Temperature is the principal driver of peak demand on Ausgrid's network and so it is important that we account for its effect on the use of Ausgrid's network.

To this end, we include in our equations two weather variables, ie, cooling degree days (CDD) and heating degree days (HDD). Similarly, the Australian Energy Market Operator (AEMO) also incorporates these variables in its methodology for forecasting electricity demand in Australia.[12]

CDD reflects the number of degrees by which the ambient temperature, $\overline{T_a}$ exceeds a pre-defined threshold temperature of discomfort, T_u, during a quarter. We calculate CDD for each quarter by:

[12] AEMO, *Forecasting methodology information paper,* July 2016, p 14.

- measuring the number of degrees by which the temperature exceeded the threshold in each half hour period;
- calculating the average number of degrees of exceedance for each day; and
- summing the number of degrees for each quarter.

HDD is defined analogously, except it reflects a measure of how many degrees below a threshold of discomfort, T_l, the ambient temperature is for each half hour period. We express these calculations in the equation below.

Equation 1: Equations to evaluate CDD and HDD

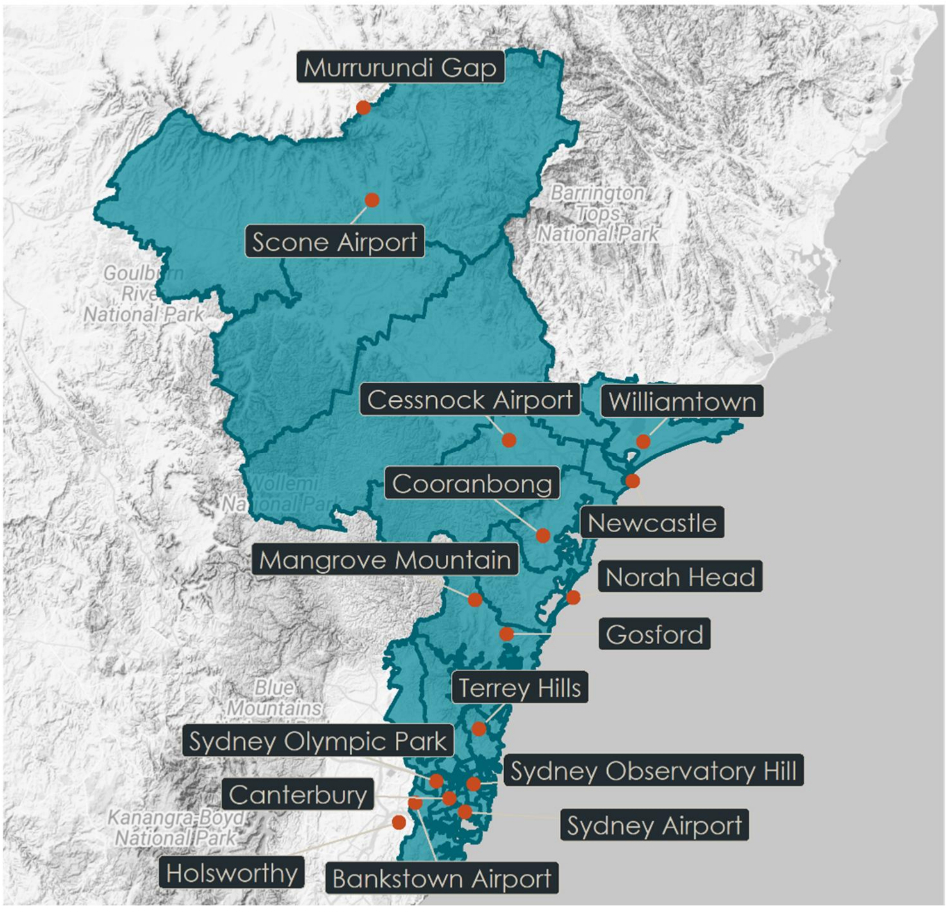
$$\mathrm{CDD} = \sum \frac{\max\left(\overline{T}_a - T_u, 0\right) \times \Delta t}{24} \quad \text{where} \begin{cases} T_u = 25^\circ \text{ between 6am and 10pm} \\ T_u = 23^\circ \text{ between 10pm and 6am} \end{cases}$$

$$\mathrm{HDD} = \sum \frac{\max\left(T_l - \overline{T}_a, 0\right) \times \Delta t}{24} \quad \text{where} \begin{cases} T_l = 18^\circ \text{ between 6am and 10pm} \\ T_l = 15^\circ \text{ between 10pm and 6am} \end{cases}$$

Source: CSIRO, Residential air-conditioner use behaviour & building performance analysis, June 2017, p 9.

Each customer in the sample is assigned a weather station, determined by the closest weather station to the customer's electricity network zone substation. To evaluate the CDD and HDD for each of the weather stations we use half hourly dry bulb weather data obtained from the Bureau of Meteorology (BOM), as illustrated in Figure 8.

Figure 8: Location of weather stations in Ausgrid's service area



Source: Google, maps.google.com, accessed 15 August 2017; Statistical Geography, ABS, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1259.0.30.0022006, accessed 15 August 2017; BOM, Weather station details, accessed 13 July 2017.

A1.2 Accounting for the effect of wealth on electricity consumption

For residential customers, we relied upon household income data from the Australian Bureau of Statistics' census as a proxy for customer wealth. This data is aggregated by statistical area one (SA1) and presents the number of households in each SA1 with a weekly income level between defined bands, ie, the number of households with a weekly income between $0 and $1,000, between $1,000 and $2,000 and so on.

We present descriptive statistics for these data in Table 6 below.

Table 6: Descriptive statistics of household mean weekly income

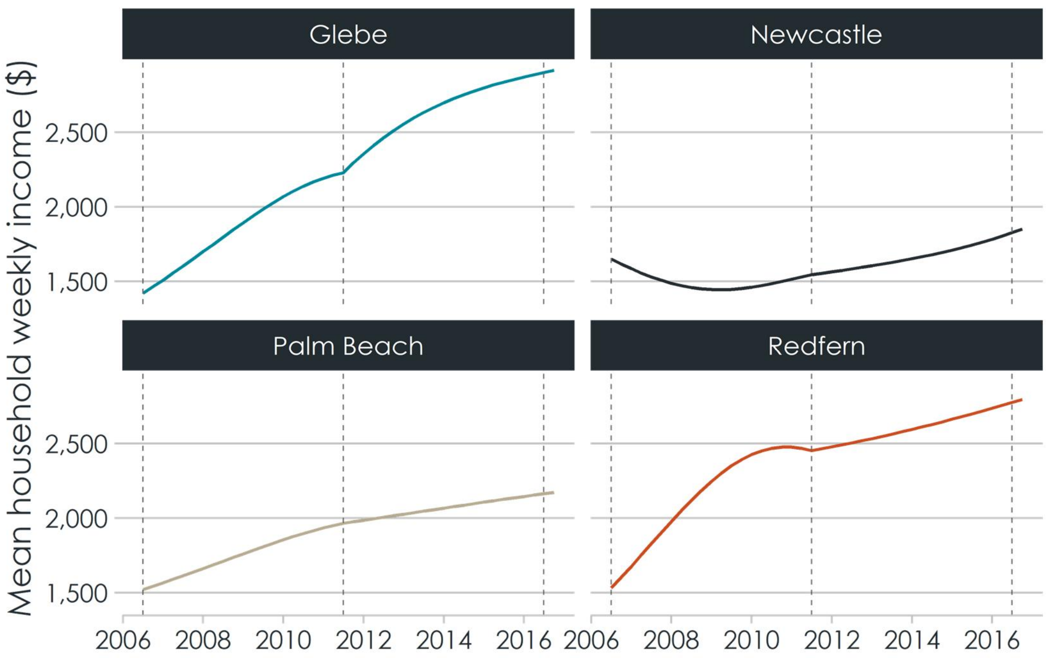
Descriptive statistic	Value	Observation SA1
Minimum household weekly income	$552.20	Redfern, Sydney
Median household weekly income	$1,801.70	
Mean household weekly income	$1.842.00	
Maximum household weekly income	$4,061.10	Mosman, Sydney

These data are reported every five years and so we interpolate the results for the intervening years. In particular, we interpolate the number of households in each tranche for each quarter by applying an assumed geometric growth rate between the census dates.

We then take the midpoint of each income tranche and calculate the weighted average household income for each SA1, where the weights are determined by reference to the number of households in each tranche in each SA1.

In Figure 9, we present a selection of the evaluated mean income for four SA1s that shows that the interpolated data fits the three census observation points well.

Figure 9: Mean household weekly income



Source: HoustonKemp analysis of Australian Bureau of Statistics data; Australian Bureau of Statistics, Census tablebuilder, https://guest.censusdata.abs.gov.au/webapi/jsf/dataCatalogueExplorer.xhtml, accessed 13 July 2017. Note: The dotted vertical lines indicate the date of the actual observations from the ABS census data.

For Ausgrid's business customers, we were not able to identify any appropriate measure of business income by location. Instead, we applied the growth rate of gross domestic product (GDP) and NSW's state final demand (SFD) as a proxy for wealth in each year, consistent with demand modelling undertaken by AEMO.[13] These variables are supplied by the ABS as quarterly measures.

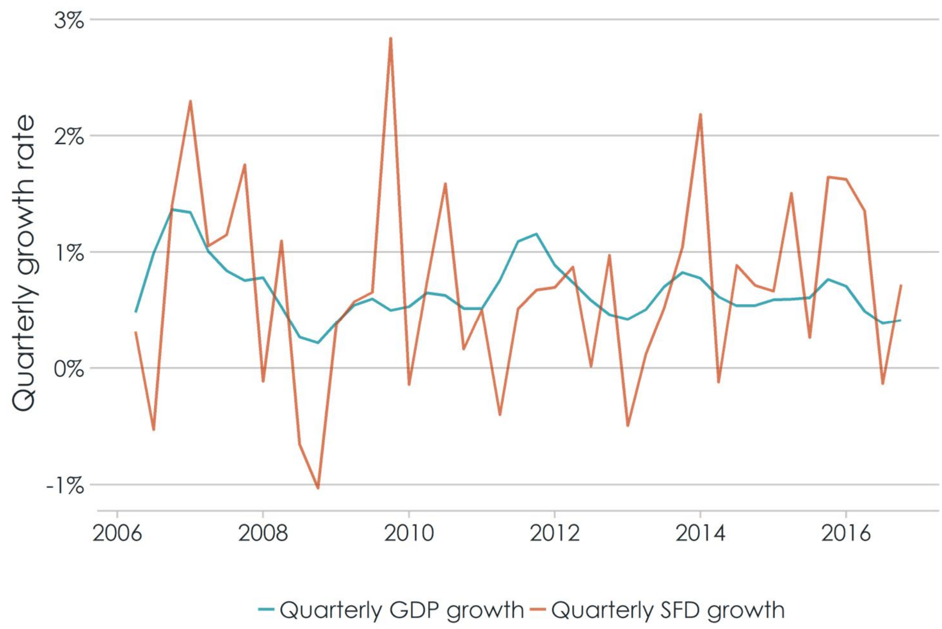
We find that GDP growth is the better of the two candidate explanatory variables but, since our data indicates GDP growth and SFD growth are not highly correlated,[14] it may be appropriate to use both explanatory variables.

We present quarterly GDP growth and SFD growth over our evaluation period in Figure 10.

[13] AEMO, *Forecasting methodology information paper,* July 2016, p 16.

[14] We computed a linear correlation coefficient of 0.37.

Figure 10: Gross domestic product and state final demand quarterly growth rate



Source: HoustonKemp analysis of Australian Bureau of Statistics GDP and SFD data; Australian Bureau of Statistics, Australian national accounts, http://www.abs.gov.au/ausstats/abs@.nsf/mf/5206.0, accessed 25 July 2017.

A1.3 Accounting for improvements in energy efficiency

We account for the effect of changes in energy efficiency on the use of Ausgrid's network by adjusting the consumption data provided by Ausgrid. In particular, we adjust upwards the consumption data by reference to estimates provided by Ausgrid of the change in consumption over the evaluation period arising from:

- improvements in appliance and equipment efficiency;
- the NSW Energy Savings Scheme and the Greenhouse Gas Reduction Scheme; and
- improvements to building thermal efficiency.

A1.4 Estimation procedure and techniques

In this section, we briefly outline the estimation procedure we used to evaluate the coefficients for each of the model specifications – presented in appendix A.3 – and outline the various statistical tests we applied to check the validity of our results.

It is instructive to note that previous studies of the price elasticity of demand for electricity in Australia, of which we are aware, rely upon highly aggregated annual consumption data, which limits the scope to distill the effect on electricity consumption of changes in price, as distinct from the range of other factors affecting electricity consumption.[15]

In contrast, the quarterly, desensitized customer-level consumption data provided by Ausgrid enables us to specify an estimation technique that better captures customer behavior. That said, these data violate the statistical assumptions underpinning the regression techniques generally applied in the literature to date.

[15] See: Akmal, M and Stern, D, *The structure of Australian residential energy demand,* ANU working papers in ecological economics, March 2001; and Rai, A, et al, *Price and income elasticities of residential electricity demand: the Australian evidence,* Australian Conference of Economists 2014, July 2014.

Therefore, we apply an advanced estimation technique that is more robust than common regression methods since it does not rely on the same statistical assumptions, eg:

- independent explanatory variables;
- homoskedastic model residuals; and
- independent model residuals between geographic areas.

Spatial three-stage least squared generalised method of moments

We applied the three-stage least squares generalised method of moments (3SLS GMM) and spatial-3SLS GMM estimation techniques to evaluate the equations that describe the consumption decisions of residential and business customers, respectively. We implement both techniques using the R statistical programming language.[16]

These methods allow us to estimate a system of simultaneous equations for each tariff class, where each individual equation explains a different charging parameter. This allows us to examine price elasticities separately for each of the tariff classes, rather than on an aggregated level, and further allows us to elicit the underlying relationships between charging parameters and geographic areas.

The business consumption data is aggregated at the local government area (LGA) level, which introduces spatial dependence to our estimation procedure, ie, the model residuals are not independent between geographic areas. The spatial 3SLS GMM approach corrects for residual dependence between these different geographic areas and can increase the precision of the elasticity estimates.

The simultaneous nature of our model specifications can result in a mathematical problem where there is not a single unique value for the coefficient estimates. To establish a functional form that is unique (also known as an 'identified' model) we restrict the coefficients on selected explanatory variables such that they are constant across the different equations. For each model specification, we require as many restrictions in each equation as there are cross-quantity variables, which will in turn ensure that the estimation procedure obtains identified values.

Statistical tests of model validity

For each of the model specifications we evaluate, we test for non-stationarity in the data by implementing a panel-generalised augmented Dickey-Fuller test to evaluate the presence of a unit root. The presence of a unit root indicates that without statistical correction, the results we would obtain from our models would be misleading. The data is not shown to have a significant unit root and so we undertake no further data transformations.

After each model specification is evaluated, we test for the presence of serial correlation in the model residuals using a panel-generalised Durbin Watson test. The presence of serial correlation falsely reduces standard errors and may give rise to an inference that some coefficients are statistically significant when they are actually not statistically significant.

We find evidence of serial correlation in the model residuals. Therefore, we correct the coefficient standard errors and associated p-values for serial correlation by estimating Newey-West heteroskedasticity and autocorrelation consistent (HAC) standard errors, which are robust to serial correlation and will ensure we are not incorrectly reporting statistical significance.

We further test the robustness of own-price elasticity estimates by running an iterative re-estimation procedure where the equations are estimated while incrementally decreasing the number of time periods included in the data. This robustness test can help identify whether there exist outlier data that may

[16] R Core Team, *R: A language and environment for statistical computing,* R Foundation for Statistical Computing, 2017.

overleverage the coefficient estimates and lead to incorrect inferences as to the price elasticity of demand. This iterative re-estimation indicates that our estimated coefficient values are robust.

A1.5 Modelling the fixed charge causes econometric problems

We exclude from our model specification fixed charges because of the corresponding econometric problem of collinearity. Collinearity occurs in statistical modelling when two variables are highly correlated with each other, reducing the explanatory power of each of the affected variables when they are both included in a model. The reduction in explanatory power diminishes the precision of the coefficient estimates, making inference from any of the singular variables problematic.

For each of the tariffs we model, we find that the fixed charge has a high correlation coefficient with each of the variable charges. Indeed, the inclusion of the fixed charge in some circumstances gives rise to estimates of price elasticities with a wide confidence interval and that are often not statistically significant at any reasonable level. Therefore, and since our study is not focused on the responsiveness of demand to changes in fixed charges, we exclude fixed charges from our model specifications.

A2. Price and consumption data relied upon in our study

This section provides a more detailed description of the price and consumption data we relied upon

Ausgrid provided us with a sample of desensitised monthly consumption data between July 2006 and December 2016 for approximately two million customers assigned to five of its tariffs, which comprised over 202 million total monthly observations.

Since customers receive their electricity bill each quarter, we aggregated this monthly consumption data to reflect the same quarterly basis on which customers evaluate their consumption decisions. This quarterly aggregation gives rise to 42 time periods in our sample.

We further aggregate residential consumption data to the SA1 level and business consumption data to the LGA level by calculating the average household or business consumption in each quarter. Our sample covers 8,161 SA1 areas and 42 LGA areas. We present the average quarterly electricity consumption and summary statistics by tariff in Figure 11 and Table 7 below, respectively.

Figure 11: Average quarterly electricity consumption by tariff, 2006 to 2016

Source: HoustonKemp analysis of Ausgrid billing data.

Table 7: Summary statistics by network tariff

	EA010	EA025	EA050	EA225	EA302
Number of unique customers	1,450,025	389,012	151,629	91,751	47,928
Number of monthly consumption observations	150,550,632	31,933,539	11,076,939	5,475,877	3,096,104

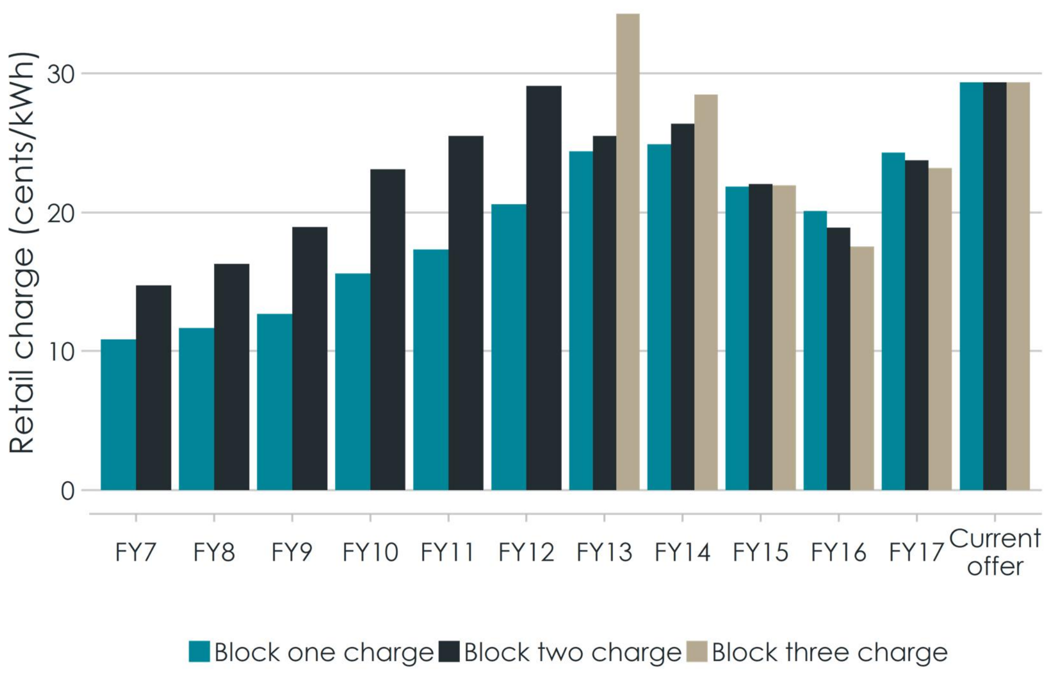
Source: HoustonKemp analysis of Ausgrid data.

A2.1 Residential block tariff (EA010)

Ausgrid's residential block tariff comprises a fixed charge and three variable charging parameters, or blocks, that apply different marginal prices as consumption increases. However, prior to the 2012/13 year this tariff had only two variable charging parameters.

Figure 12 below presents the structure and retail price levels for the variable charges that comprise the residential block tariff from FY07 onwards. Figure 12 also illustrates the change from an inclining block to declining block structure over our sample period.

Figure 12: The price and structure of the residential block tariff



Source: HoustonKemp analysis of retail price data sourced from: IPART, Frequently asked questions, https://www.ipart.nsw.gov.au/Home/About-IPART/FAQs/Energy, accessed 17 May 2017; Ausgrid internal data; and Energy Australia, Energy price fact sheets, https://secure.energyaustralia.com.au/EnergyPriceFactSheets/PricingFactSheets.aspx, accessed 17 May 2017.

When this tariff comprised only two blocks the threshold for block two was set at quarterly consumption equal to 1,750 kWh, ie, the block two price was levied on marginal consumption above 1,750 kWh. However, when a third block was introduced the definition of the blocks changed such that:

- the block one price was levied on quarterly consumption up to 1,000 kWh;
- the block two price was levied on quarterly consumption between 1,000 kWh and up to 2,000kW; and
- the block three price was levied on quarterly consumption above 2,000 kWh.

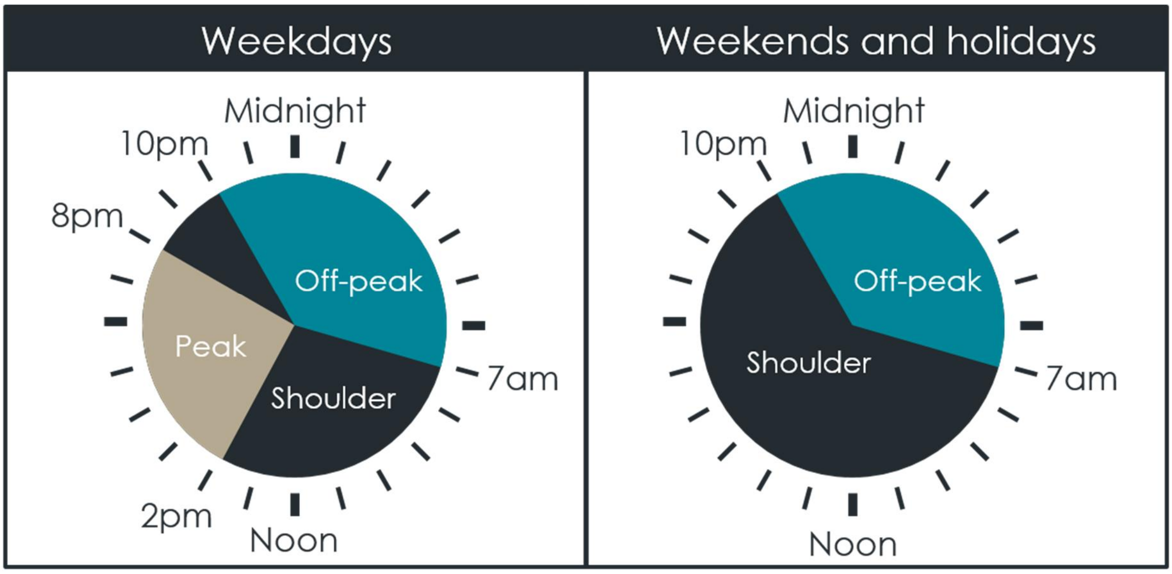
So as to ensure consistency over our sample period we adopt consistent block thresholds of 1,000 kWh for block two and 1,750 kWh for block three. In other words, over the period where there were only two blocks we split block one into a notional two block structure and applied the same price level to both blocks.

One consequence of this approach is that the block three threshold is set 250 kWh below its actual level in the second half of our sample period. However, the majority of customers on Ausgrid's residential block tariff consume less than 1,750 kWh per quarter (the average customer consumes approximately 1,250 kWh) and so this did not materially affect our results.

A2.2 Residential time-of-use tariff (EA025)

The residential time of use tariff comprises a fixed charge and three variable charging parameters that levy a difference price on consumption at different times of the day. Figure 13 illustrates the applicable time-of-use periods over our sample period.

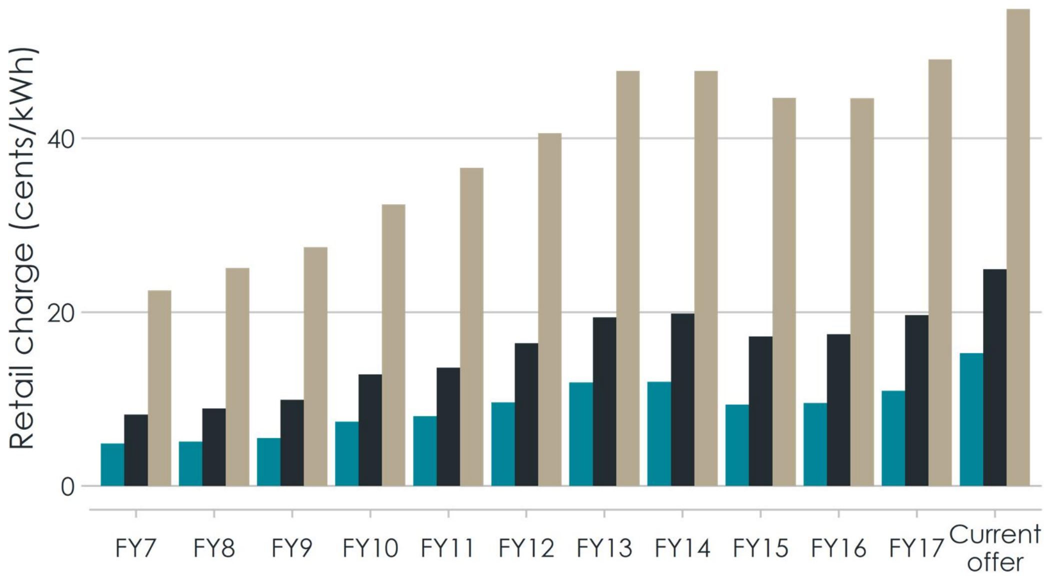
Figure 13: The definition of Ausgrid's residential charging windows over our sample period



Source: Ausgrid, Time of use pricing, http://www.ausgrid.com.au/Common/Customer-Services/Homes/Meters/How-meters-are-read/Time-of-use-pricing.aspx#.Wa0By8gjGUI, accessed 4 September 2017.

Figure 14 shows the prices applicable in each of these periods since FY07.

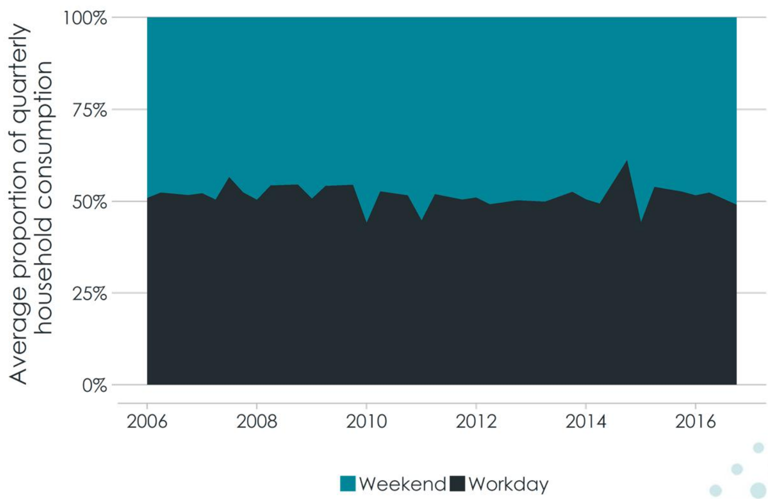
Figure 14: EA025 time-of-use retail tariff structure



Source: HoustonKemp analysis of retail price data sourced from: IPART, Frequently asked questions, https://www.ipart.nsw.gov.au/Home/About-IPART/FAQs/Energy, accessed 17 May 2017; Ausgrid internal data; and Energy Australia, Energy price fact sheets, https://secure.energyaustralia.com.au/EnergyPriceFactSheets/PricingFactSheets.aspx, accessed 17 May 2017.

Our analysis shows that approximately 60 per cent of the average customer's consumption occurs in the shoulder period, where there is an approximate 50/50 split between shoulder consumption on weekdays versus weekends and holidays, as shown in Figure 15.

Figure 15: Proportion of weekend and weekday shoulder consumption

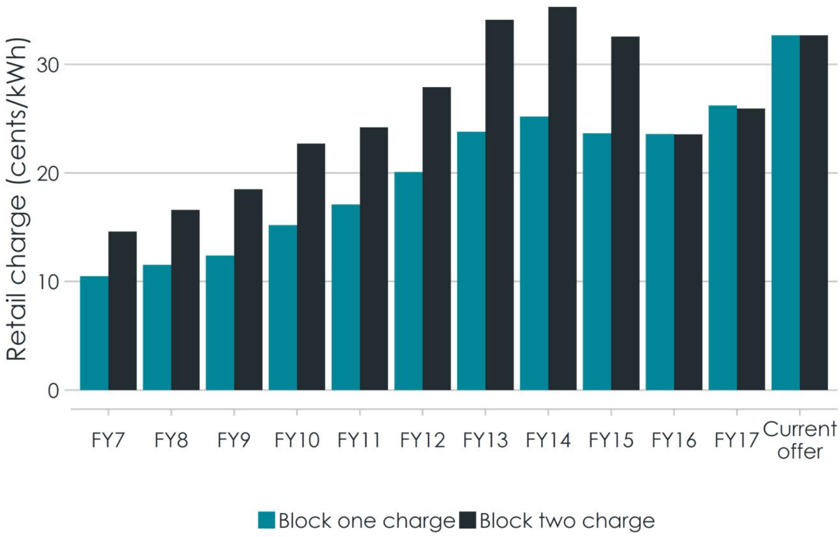


Source: HoustonKemp analysis of Ausgrid billing data.

A2.3 Small business block tariff (EA050)

Ausgrid's small business block tariff comprises a fixed charge and two block consumption parameters, where the threshold between the blocks is set at 2,500 kWh. Figure 16 presents the retail prices from FY07 onwards.

Figure 16: Retail prices for small business block tariff

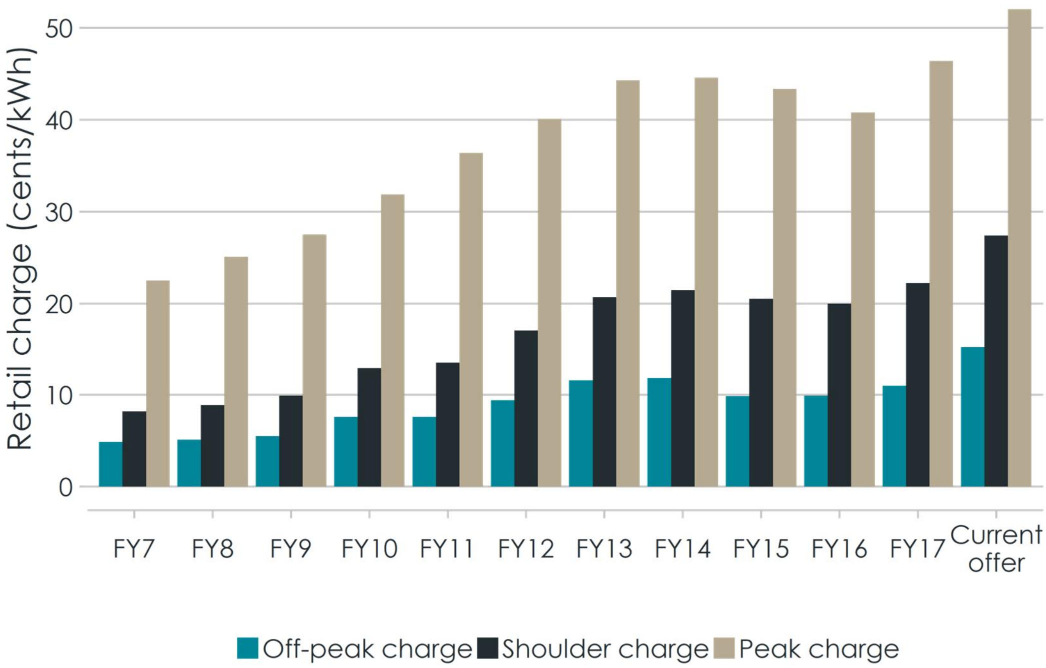


Source: HoustonKemp analysis of retail price data sourced from: IPART, Frequently asked questions, https://www.ipart.nsw.gov.au/Home/About-IPART/FAQs/Energy, accessed 17 May 2017; Ausgrid internal data; and Energy Australia, Energy price fact sheets, https://secure.energyaustralia.com.au/EnergyPriceFactSheets/PricingFactSheets.aspx, accessed 17 May 2017.

A2.4 Small business time-of-use tariff (EA225)

The small business time of use tariff comprises the same structure as the residential time of use tariff, ie, a fixed charge and three time-variant variable charges. Figure 17 below illustrates the retail prices from FY07 onwards.

Figure 17: Structure of EA225 time-of-use demand tariff



Source: HoustonKemp analysis of retail price data sourced from: IPART, Frequently asked questions, https://www.ipart.nsw.gov.au/Home/About-IPART/FAQs/Energy, accessed 17 May 2017; Ausgrid internal data; and Energy Australia, Energy price fact sheets, https://secure.energyaustralia.com.au/EnergyPriceFactSheets/PricingFactSheets.aspx, accessed 17 May 2017.

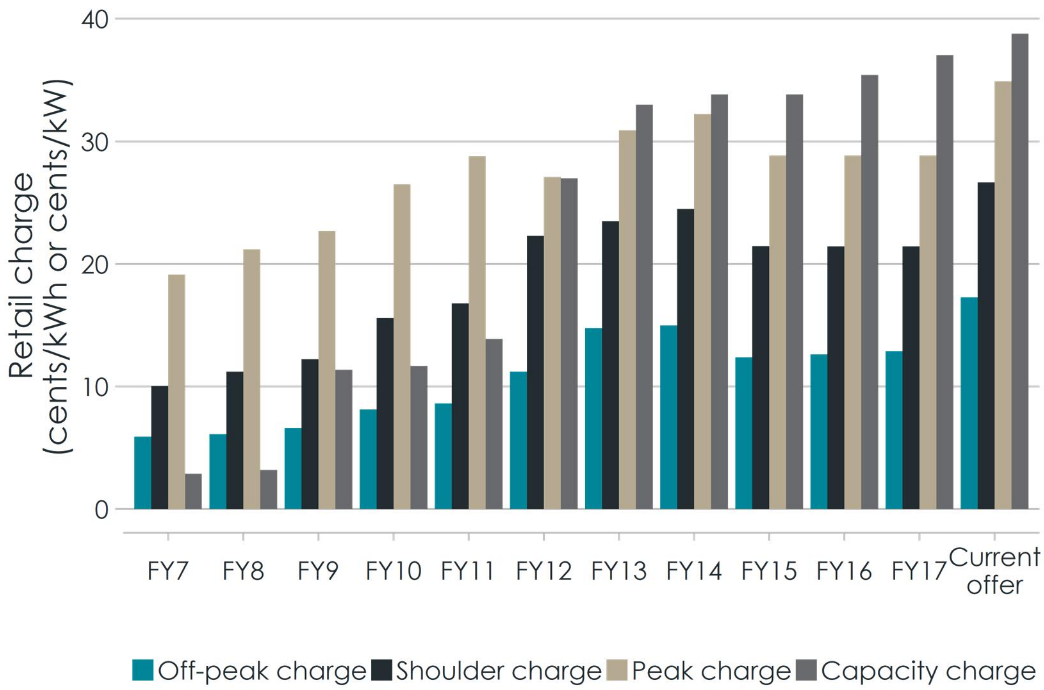
A2.5 40-160MWh business time-of-use capacity tariff (EA302)

This tariff applies to business customers consuming between 40MWh and 160MWh per annum and comprises a fixed charge, three time-variant time of use energy charges and a capacity charge. The charging windows for this tariff are consistent with that for the small business time of use tariff, except that all consumption on weekends and holidays is off-peak.

During the first four quarters of our sample period (July 2006 to June 2007) customers consuming between 160MWh and 750MWh were also assigned to this tariff, although they were reassigned to Ausgrid's EA305 tariff from July 2008. This contributed to average customer consumption in these initial four quarters that was more than double that in the remainder of the sample. We therefore disregarded the first four quarters of our sample period for this tariff so as to ensure our results are not influenced by these unrepresentative customers.

Figure 18 presents the retail prices for this tariff from FY07 onwards.

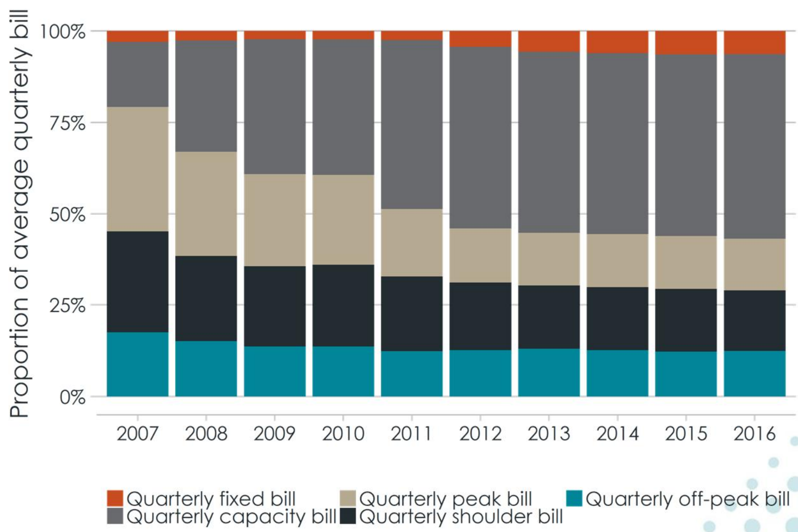
Figure 18: Structure of EA302 time-of-use capacity demand tariff



Source: HoustonKemp analysis of retail price data sourced from: IPART, Frequently asked questions, https://www.ipart.nsw.gov.au/Home/About-IPART/FAQs/Energy, accessed 17 May 2017; Ausgrid internal data; and Energy Australia, Energy price fact sheets, https://secure.energyaustralia.com.au/EnergyPriceFactSheets/PricingFactSheets.aspx, accessed 17 May 2017.

We draw attention to the marked increase in the price of the capacity charge over our sample period, which contributed to a substantial increase in the capacity charge component of the average customer's retail bill, as illustrated in Figure 19 below.

Figure 19: Average billing proportions for customers on the EA302 tariff



Source: HoustonKemp analysis of Ausgrid billing data.

A3. Our full results

In this section we present the simultaneous model specifications and full results for each network tariff. These results are discussed in section 3 of our report.

In presenting our results, we highlight in red the variables that are restricted to have equal coefficient values across the functional forms. We also place a green border around the coefficients that are the estimates of the own-price and cross-price elasticities of demand, where the former are highlighted in beige.

A3.1 The residential block tariff (EA010)

The specification of simultaneous equations we use to estimate the price elasticity of demand for the EA010 tariff is shown in Equation 2.

Equation 2: Set of equations estimated for the residential block tariff (EA010)

$$\begin{aligned}
\log q_1 &= \beta_{11}\log p_1 + \beta_{12}\log q_2 + \beta_{13}\log q_3 + \beta_4\mathrm{CDD} + \beta_5\mathrm{HDD} + \beta_{16}\mathrm{income}\\
\log q_2 &= \beta_{21}\log p_2 + \beta_{22}\log q_1 + \beta_{23}\log q_3 + \beta_4\mathrm{CDD} + \beta_5\mathrm{HDD} + \beta_{26}\mathrm{income}\\
\log q_3 &= \beta_{31}\log p_3 + \beta_{32}\log q_1 + \beta_{33}\log q_2 + \beta_4\mathrm{CDD} + \beta_5\mathrm{HDD} + \beta_{36}\mathrm{income}
\end{aligned}$$

The coefficient estimates from evaluating this set of simultaneous equations with the 3SLS GMM procedure are shown in Table 8. Each of the coefficient estimates except for the restricted weather variables are significant at the one per cent level. We find that the household weekly income has a significant, yet negligible effect on electricity consumption for each of the three charging parameters. The coefficient restrictions on the CDD and HDD weather variables reflects the equivalent effect of the weather on consumption for each charging parameter.

Table 8: EA010 residential block tariff estimates

Variable	Log block one consumption	Log block two consumption	Log block three consumption
Log block one retail charge	-0.0518 ***	---	---
Log block two retail charge	---	0.0871 ***	---
Log block three retail charge	---	---	-0.2068 ***
Log block one consumption	---	1.3348 ***	-2.5202 ***
Log block two consumption	0.1771 ***	---	2.1966 ***
Log block three consumption	-0.0553 ***	0.4219 ***	---
Quarterly CDD		0.0001	
Quarterly HDD		0.0001	
Mean household weekly income	-0.0000 ***	0.0001 ***	-0.0002 ***

* indicates the significance of the estimate where: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

We note the nonsensical, positive estimate of own-price elasticity of demand for the block two charging parameter. A potential alternative, albeit less robust, model specification we considered with a fixed charge explanatory variable produced a statistically significant estimate for block two and a three, but a positive estimate for block one. Notwithstanding, we observe that the elasticity of the two statistically significant estimates in both these specifications showed that demand is more elastic at higher levels of consumption.

We explain the shortcomings arising from including a fixed charge explanatory variable in appendix A1.5.

A3.2 The residential time of use tariff (EA025)

We include in our specification for the EA025 tariff both own and cross-price elasticities of demand. The inclusion of cross-price effects reflects the ability of customers to substitute consumption between charging parameters, eg, from peak to shoulder times. Since temperature is the principal driver of peak demand on Ausgrid's network, we also include a measure of peak-period specific CDD and HDD.

We present the equations for the EA025 tariff in Equation 3.

Equation 3: Set of equations estimated for the residential time-of-use tariff (EA025)

$$
\begin{aligned}
\log q_{pk} &= \beta_{11}\log p_{pk} + \beta_{12}\log p_{sh} + \beta_{13}\log p_{op} + \beta_{14}\log q_{sh} + \beta_{15}\log q_{op} + \beta_6\text{CDD} \\
&\quad + \beta_7\text{HDD} + \beta_{18}\text{income} + \beta_{19}\text{Peak CDD} + \beta_{110}\text{Peak HDD} \\
\log q_{sh} &= \beta_{21}\log p_{pk} + \beta_{22}\log p_{sh} + \beta_{23}\log p_{op} + \beta_{24}\log q_{pk} + \beta_{25}\log q_{op} + \beta_6\text{CDD} \\
&\quad + \beta_7\text{HDD} + \beta_{28}\text{income} \\
\log q_{op} &= \beta_{31}\log p_{pk} + \beta_{32}\log p_{sh} + \beta_{33}\log p_{op} + \beta_{34}\log q_{pk} + \beta_{35}\log q_{sh} + \beta_6\text{CDD} \\
&\quad + \beta_7\text{HDD} + \beta_{38}\text{income}
\end{aligned}
$$

The results presented at Table 9 show that our estimates of the own-price elasticity of demand are significant at the one per cent level of significance. The level of household income does not have a statistically significant effect on the consumption in off-peak or shoulder periods and has a significant, yet negligible, effect on consumption in the peak period.

Table 9: EA025 residential time-of-use tariff estimates

Variable	Log off-peak consumption	Log shoulder consumption	Log peak consumption
Log off-peak retail charge	-0.0725 *	0.2697 ***	-0.3024 ***
Log shoulder retail charge	0.0481	-0.3062 ***	0.3658 ***
Log peak retail charge	0.1969 ***	-0.5767	-0.0740 ***
Log off-peak consumption	---	0.2237 ***	0.0802
Log shoulder consumption	0.7507 ***	---	0.9535 ***
Log peak consumption	0.2192	0.7553 ***	---
Peak quarterly CDD	---	---	0.0002
Peak quarterly HDD	---	---	0.0003 ***
Quarterly CDD		-0.0000	
Quarterly HDD		-0.0000 **	
Mean household weekly income	-0.0000	0.0000	-0.0000 ***
* indicates the significance of the estimate where: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.			

A3.3 The small business block tariff (EA050)

The specification for the simultaneous equations for consumption on the EA010 tariff are shown in Equation 4.

Equation 4: Set of equations estimated for the business block tariff (EA050)

$$\log q_1 = \beta_{11} \log p_1 + \beta_{12} \log q_2 + \beta_{13}\text{CDD} + \beta_{14}\text{HDD} + \beta_5\text{GDP growth}$$
$$\log q_2 = \beta_{21} \log p_2 + \beta_{22} \log q_1 + \beta_{23}\text{CDD} + \beta_{24}\text{HDD} + \beta_5\text{GDP growth}$$

The coefficient results from the estimation of this system of equations are shown in Table 10. Each of the coefficient estimates are significant at the one per cent level of significance except for GDP growth, which is significant at the ten per cent level.

Table 10: EA050 business block tariff estimates

Variable	Log block one consumption	Log block two consumption
Log block one retail charge	-0.1374 ***	---
Log block two retail charge	---	-0.2892 ***
Log block one consumption	---	1.7033 ***
Log block two consumption	0.0992 ***	---
Quarterly CDD	0.0004 ***	0.0008 **
Quarterly HDD	0.0001 ***	-0.0002 ***
Quarterly GDP growth	2.9018 *	

* indicates the significance of the estimate where: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

For the EA050 tariff, we place a restriction on the coefficient of the GDP growth variable to be equal between the two simultaneous equations. This restriction reflects the equivalent effect of GDP growth on consumption for each charging parameter.

A3.4 The small business time of use tariff (EA225)

The specification for the system of equations that model electricity consumption on the EA225 tariff is shown in Equation 5.

Equation 5: Set of equations estimated for the business time-of-use tariffs (EA225)

$$\begin{aligned}
\log q_{pk} = {} & \beta_{11} \log p_{pk} + \beta_{12} \log p_{sh} + \beta_{13} \log p_{op} + \beta_{14} \log q_{sh} + \beta_{15} \log q_{op} + \beta_6\text{CDD} \\
& + \beta_7\text{HDD} + \beta_{18}\text{GDP growth} + \beta_{19}\text{Peak CDD} + \beta_{110}\text{Peak HDD} \\
\log q_{sh} = {} & \beta_{21} \log p_{pk} + \beta_{22} \log p_{sh} + \beta_{23} \log p_{op} + \beta_{24} \log q_{pk} + \beta_{25} \log q_{op} + \beta_6\text{CDD} \\
& + \beta_7\text{HDD} + \beta_{28}\text{GDP growth} \\
\log q_{op} = {} & \beta_{31} \log p_{pk} + \beta_{32} \log p_{sh} + \beta_{33} \log p_{op} + \beta_{34} \log q_{pk} + \beta_{35} \log q_{sh} + \beta_6\text{CDD} \\
& + \beta_7\text{HDD} + \beta_{38}\text{GDP growth}
\end{aligned}$$

We present the coefficient estimates from the above model specification in Table 11, where each of the own and cross price elasticities are significant at the one per cent level of significance. None of the four coefficient estimates for measures of CDD and HDD are significant at any reasonable level of significance.

Table 11: EA225 business time-of-use tariff estimates

Variable	Log off-peak consumption	Log shoulder consumption	Log peak consumption
Log off-peak retail charge	-0.3962 ***	0.2008 ***	-0.1365 ***
Log shoulder retail charge	0.6461 ***	-0.2345 ***	0.1207 ***
Log peak retail charge	-0.6013 ***	0.1724 ***	-0.0841 ***
Log off-peak consumption	---	0.2183 ***	-0.0428 ***
Log shoulder consumption	0.9673 ***	---	1.0314 ***
Log peak consumption	0.0486	0.7582 ***	---
Peak quarterly CDD	---	---	0.0002
Peak quarterly HDD	---	---	-0.0000
Quarterly CDD		-0.0000	
Quarterly HDD		0.0000	
Quarterly GDP growth	4.0957 ***	-1.6636 ***	1.09007 ***

* indicates the significance of the estimate where: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

A3.5 The 40-160MWh business time of use capacity tariff (EA302)

Our approach in determining the form of the system of equations for the EA302 tariff initially incorporated the capacity charging parameter as its own equation. However, as discussed in section 3.3.3 the capacity charging parameter is challenging to model due to the weak nexus between the retail price and observed demand.

Ultimately, we were unable to identify an appropriate specification that included a separate equation for the capacity charge, which would have enabled us to derive a corresponding estimate of the price elasticity of demand. The most appropriate specification we identified includes the capacity retail charge as an explanatory variable in each of the consumption equations to capture the effect of changing this charge on the other charging parameters. Our specification for the EA302 tariff is presented in Equation 6.

Equation 6: Set of equations estimated for both business time-of-use and maximum capacity charge (EA302)

$$
\begin{aligned}
\log q_{pk} = {} & \beta_{11} \log p_{pk} + \beta_{12} \log p_{sh} + \beta_{13} \log p_{op} + \beta_{14} \log p_{cap} + \beta_{15} \log q_{sh} + \beta_{16} \log q_{op} \\
& + \beta_7 \text{CDD} + \beta_8 \text{HDD} + \beta_{19} \text{GDP growth} + \beta_{110} \text{SFD growth} \\
& + \beta_{111} \text{Peak CDD} + \beta_{112} \text{Peak HDD} \\
\log q_{sh} = {} & \beta_{21} \log p_{pk} + \beta_{22} \log p_{sh} + \beta_{23} \log p_{op} + \beta_{24} \log p_{cap} + \beta_{25} \log q_{pk} + \beta_{26} \log q_{op} \\
& + \beta_7 \text{CDD} + \beta_8 \text{HDD} + \beta_{29} \text{GDP growth} + \beta_{210} \text{SFD growth} \\
\log q_{op} = {} & \beta_{31} \log p_{pk} + \beta_{32} \log p_{sh} + \beta_{33} \log p_{op} + \beta_{34} \log p_{cap} + \beta_{35} \log q_{pk} + \beta_{36} \log q_{sh} \\
& + \beta_7 \text{CDD} + \beta_8 \text{HDD} + \beta_{39} \text{GDP growth} + \beta_{310} \text{SFD growth}
\end{aligned}
$$

We find that for this tariff, the inclusion of quarterly state final demand (SFD) growth provides additional explanatory power and so we include it in addition to GDP growth. We present the coefficient estimates for the above model specification in Table 12 below.

Table 12: EA302 business time-of-use estimates

Variable	Log off-peak consumption	Log shoulder consumption	Log peak consumption
Log off-peak retail charge	0.0515 **	0.3859 **	-0.0454 ***
Log shoulder retail charge	0.0338	-0.3198 ***	0.3242 ***
Log peak retail charge	-0.1575 ***	0.2000 ***	-0.1605 ***
Log capacity retail charge	0.0249 ***	0.7762 ***	-0.0845
Log off-peak consumption	---	0.0131	0.0896 ***
Log shoulder consumption	-0.3534 ***	---	0.8676 ***
Log peak consumption	1.3391 ***	0.9766 ***	---
Peak quarterly CDD	---	---	0.0046 ***
Peak quarterly HDD	---	---	0.0000
Quarterly CDD		-0.0007 ***	
Quarterly HDD		0.0000	
Quarterly SFD growth	0.5702 ***	0.1798 *	-0.2136 **
Quarterly GDP growth	-2.5325 **	6.7907 ***	-7.1198 ***

* indicates the significance of the estimate where: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.

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