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Technical Paper

Lorraine Conway and David Prentice

How much do households respond to electricity prices? Evidence from Australia and abroad

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Abstract

In this paper we review studies to understand how much households change their electricity consumption when there is a price change. We are particularly focussed on finding results from econometric studies that estimate elasticities of demand.

Many studies find residential households demonstrate responsiveness to price, with long term and short run elasticities behaving as economic theory would suggest. For instance, the elasticities are negative which means that as price increases, consumption decreases; long run elasticities are larger than shorter run elasticities which indicates that households can respond over time through investment in more energy efficient appliances; and very short run elasticities exist – while very short run elasticities are small, household responsiveness seems to increase when paired with technology. Long run elasticities range from -0.75 to -0.3 and short run elasticities range from -0.47 to -0.026. The major gaps in research from the empirical economics literature are how low income and vulnerable Australian households could be affected by price changes and how Australians respond to within-day variation in prices.

[1] We would like to thank Kath Rowley and Maria Wilton for detailed feedback. This paper has also benefitted from conversations with colleagues within Infrastructure Victoria.
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1. Introduction

In Australia, the electricity market has undergone significant structural change over the last two decades following competition reforms and the creation of the National Electricity Market. In addition, electricity demand patterns have changed, with a significant impact on the need for infrastructure investment. Although average consumption per head has been declining, demand is becoming more and more peaked (AEMO, 2019). New maximum demand records continue to be set and the diffusion of electric vehicles could further increase maximum demand. New investment in infrastructure is also required due to changes on the supply side such as technological change in generation by renewable sources and storage.

Key economic bodies in Australia, such as the Australian Competition and Consumer Commission and the Productivity Commission, have recommended moving away from flat rate electricity prices to more cost reflective pricing, such as time-of-day pricing, to support more efficient use and investment in electricity infrastructure. There are several reasons why policy makers may have been reluctant to take this step. Concerns that have been raised in a variety of forums include:

1. Effectiveness of differential pricing to manage demand by households — there is public debate around whether households are responsive to substantial price differences.[3]
2. Impacts on vulnerable households — discussion tends to focus on potential negative impacts. For example, charging higher prices when the demand for energy is greatest could place financial burdens on consumers who are least able to change their usage. Alternatively, financial constraints could prompt vulnerable households to cut consumption on particularly

[3] See Ben-David (2018, page 9) and Finkel et al. (2017, pages 146-147). Ben-David states "studies have estimated the long run elasticity of electricity demand lies between -0.08 and -0.15" such that the household has very little opportunity to change its consumption in response to price. However, the studies are not identified. Our review documents studies that household responsiveness is much larger than -0.15. Finkel et al. (2017) provides evidence of the effectiveness of responding to financial incentives, but also notes that overseas evidence suggests the responsiveness of households to price signals is difficult to sustain.

hot days.[4] However, for those low income households who can respond, cost reflective pricing may create opportunities to make savings leaving them better off than under flat rates.[5]

3. A perception that cost reflective pricing will lead to, in general, paying more for electricity.[6]

This paper aims to fill the evidence gap for Australia on the first of these concerns through examining the existing economics literature on the responsiveness of households to changes in electricity prices.[7] We identify and present existing estimates of demand elasticities and complementary evidence on how households respond to prices i.e. empirical evidence of the percentage change in the quantity of electricity demanded in response to a percentage change in the price of electricity (also known as the own-price elasticity of demand). We focus on both the long-run and very short run elasticities of demand. We also consider the influence of new technology on demand responsiveness.

To better understand the second set of concerns, we also examined the literature for how price responsiveness may differ by cohort — especially for lower income and other vulnerable households. We also briefly consider some work that analyse, under no behaviour change, whether different types of households spend more or less under a form of cost reflective pricing.

Our first set of conclusions is that there is strong evidence that Australian households respond to electricity prices in the long run with long run own-price elasticities ranging from -0.75 to -0.3. This means that, in response to a one per cent increase in the price of electricity demand may fall by between 0.3 and 0.75 per cent. The degree of price responsiveness of demand for electricity is comparable, at the upper bound, -0.75, to that of several other products commonly seen as necessities, such as bread and milk. In general, the demand for electricity is more price responsive than the demand for other necessities, like petrol and water.

The second set of conclusions is that international evidence suggests households will respond to incentives to shift consumption within a day. The associated elasticities vary from -0.026 to -0.47.

[4] See Nicolls et al. (2017) which highlights the concerns that a set of vulnerable consumers have about a proposed cost reflective pricing system, as well as evidence around the consequences of financial constraints for electricity consumption.
[5] See Stenner et al. (2015) which assessed consumers' likely uptake of cost reflective pricing.
[6] This sort of concern is raised by the, particularly vulnerable, participants in the study by Nicolls et al. (2017)
[7] Ausgrid (2015) does a brief summary of some Australian and international work.

Demand responsiveness is further increased by complementing price signals with technology, which makes it easier for households to find out about price differences and respond to them.

The third set of conclusions is that there are two significant research gaps. First, there is a shortage of Australian evidence on how households will respond to incentives to shift their consumption within a day. Second, further evidence is needed to better understand how different types of low income and vulnerable households actually respond to cost reflective pricing, and the effectiveness of different policies to mitigate any risks.

These findings have three policy implications. First, as household demand for electricity is responsive to price changes, policies that affect electricity prices will, holding all other variables constant, affect household consumption. Second, any policies that affect electricity prices should, where possible, be combined with technological and regulatory changes that improve consumer information about prices and the ability to respond to them. Finally, future research should prioritise finding out more on how Australian households respond to more dynamic, time-varying electricity pricing with a particular focus on low income and vulnerable households. With its extensive network of smart meters (97% of retail customers), Victoria is particularly well placed to gather more evidence either through examination of existing data or through trials.[8] The lessons would also be relevant for other states.

In the next section, Section 2, we discuss how prices are an essential feature of energy policy. This is followed by a discussion of findings in the literature relating to long run elasticities in Section 3 and short run elasticities in Section 4. Both Section 3 and 4 draw on Australian and international studies of household electricity demand. Section 5 examines literature on the responsiveness of different households, particularly lower income households, followed by a short discussion and concluding comments in Section 6.

[8] Victorian Department of Economic Development, Jobs, Transport and Resources, *Smart meters: End of rollout, fact sheet*, March 2015.

2. Prices as a part of energy policy

Most households in Australia pay for their electricity using relatively flat price schedules with limited on and off-peak differential in prices. However, Infrastructure Victoria and leading economic bodies in Australia have argued for more variable price schedules to improve the efficiency of use of electricity infrastructure and in turn, investment in infrastructure. In this section we review these arguments and the type of pricing structure recommended by these bodies: cost reflective pricing.

2.1 Background on cost reflective pricing

The price of electricity is linked to infrastructure costs as these must ultimately be recovered, albeit subject to regulation, from consumers. As most users are currently unable to store electricity infrastructure must be built to a capacity that can provide electricity when demand peaks on a few hot days each year — otherwise there can be load shedding. The greater the level of peak demand, the greater the cost of infrastructure required to meet it, and the higher the price of electricity must be to recover these costs. Moving away from flat rate electricity pricing could moderate peak demands resulting in better use of the infrastructure and therefore less need to build additional infrastructure. Keeping other variables constant, this will result in lower electricity prices.[9] We now explore the potential role of cost reflective pricing in achieving these outcomes in more detail.

Cost reflective pricing refers to a pricing system that more closely ties the price paid for electricity to the cost of supply, including the required infrastructure. Cost reflective pricing includes a wide range of pricing structures, also known as tariff structures. The structures can include time-of-use pricing where blocks of time are charged with different prices, and critical peak pricing where a significantly high price is charged for when system demand is highest (usually reserved for a certain number of days a year). There are also variants on these types of pricing such as peak time rebates, where households are given rebates for electricity that is not consumed, and variable peak pricing,

[9] In its 2017 inquiry, the ACCC recognised that tariff reform has the potential to both reduce the total costs of the network and make charges more equitable. It also stated that 'demand response' programs, such as rebates to short term reductions in usage, are likely to provide a more immediate impact on managing network demand; however, they do not address the issue of equity in the allocation of network cost.

where the price at the time of the peak demand depends on the level of overall electricity demand during the peak.

Demand varies systematically with time and cost reflective pricing structures can reflect the different underlying costs for the network at different times. This can guide more efficient use of electricity and better use of existing infrastructure. It can provide consumers with signals to reduce their consumption in periods of higher peak network use. In addition, it means more of the infrastructure costs are born by those that make use of the peak infrastructure (and those who don't, don't have to bear the costs). Cost reflective prices also provide clearer signals to firms of when there is sufficient demand to justify further investment in the network. Borenstein (2013, page 127) summarises the appeal of cost reflective pricing to energy economists:

> "Economists who study electricity markets are virtually unanimous in arguing that time-varying retail pricing for electricity would improve the efficiency of electricity systems and would lower the overall cost of meeting electricity demand."

2.2 Cost reflective pricing in Australia

In Australia, there are institutions and laws to enable the adoption of cost reflective pricing. For instance, it is an embedded pricing principle for electricity distribution networks, set by national agreement through the Council of Australian Governments (COAG) Energy Council in 2013 and put into effect by the Australian Energy Market Commission through a rule determination in 2014. And, in Victoria, at least, the smart metering technology required to implement cost reflective pricing is also in place.[10]

Nevertheless, there has not been wide spread adoption of cost reflective pricing by households. Electricity companies can offer cost reflective pricing, yet the tariffs for the majority of small customers, such as households, are largely flat tariffs regardless of when that electricity is used (ACCC, 2018). One likely reason for this is that the approach to implementation in Victoria is an opt-in basis. This means customers remain on their existing tariff structure unless they actively choose a new tariff structure. The

[10] Victorian Department of Economic Development, Jobs, Transport and Resources, *Smart meters: End of rollout, fact sheet*, March 2015.

Victorian Government's preference for an opt-in model is to provide households with choice about what pricing arrangements are suitable for their circumstances.[11] However, there are limited incentives for customers to switch to cost reflective pricing, limited incentives for retailers to translate it into value for customers and limited incentives for governments to promote it (ACCC, 2018). Under a flat tariff regime, some households are currently subsidised by others and have little incentive to change to a more cost reflective arrangement.[12] Opt-in generally results in a lower uptake compared with opt-out, which we discuss in more detail in Section 4.

Key economic bodies in Australia have argued for cost reflective pricing based on traditional static efficiency grounds. In 2016, Infrastructure Victoria released *Victoria's 30-year infrastructure strategy* and made recommendations to the state government across all infrastructure sectors including energy. A key energy recommendation was to facilitate a reduction in consumption by *mandating* cost reflective pricing. Infrastructure Victoria argued that a more efficient pricing system would result in better use of existing infrastructure and efficient investment in the future. In 2018, the ACCC also made a recommendation for *mandatory* cost reflective pricing as part of its inquiry into the retail electricity market, accompanied by supporting recommendations to address transitional issues.[13]

2.3 Changing electricity market could be better supported through cost reflective pricing

The case for moving towards cost reflective pricing is strengthened by the current and potential pressures for new investment in generation and the network in general as a result of two sets of shocks.

On the demand side, the uptake of electric vehicles will substantially increase the demand for electricity, possibly further increasing the peak demands on the system. Infrastructure Victoria (2018) argues that a more efficient outcome than just investing to meet this demand would be achieved by

[11] See quote from the Victorian Minister for Energy in the Choice article, *Will Victorians opt in to a new flexible electricity pricing model?*¸2016, accessed 22/11/2018 at www.choice.com.au/shopping/shopping-for-services/utilities/articles/flexible-electricity-pricing-opt-in-victoria. The new Victorian and national default offers are not cost reflective either (See: https://www.esc.vic.gov.au/electricity-and-gas/prices-tariffs-and-benchmarks/victorian-default-offer and https://www.aer.gov.au/retail-markets/retail-guidelines-reviews/retail-electricity-prices-review-determination-of-default-market-offer-prices for the national ones. (accessed 9/9/2019)

[12] Wood and Carter (2014) provide a case of a Victorian consumer who purchases an air conditioner with a capacity rating of five kilowatts. The authors estimate that the air conditioner could add between $1,200 and $1,550 to the cost of the network, but its owner would only pay an extra $53.40 a year in network charges. The rest is recovered from all users.

[13] See Appendix 1 for a summary of recommendations by Infrastructure Victoria and the ACCC on cost reflective pricing for electricity.

adopting mechanisms to shift demand away from the peaks to during the day. Cost reflective pricing is one of these mechanisms.

Similarly, on the supply side, substantial new investment will result from the combination of emission reduction goals, the exit of coal-fired generators, falling costs of renewables and batteries and the geographic dispersion of generation away from the La Trobe Valley. Cost reflective pricing, dampening peak demand, reduces the investment required by encouraging the most efficient use of the new energy infrastructure. Less investment means less costs to be recovered from households through energy bills.

2.4 The empirical question – do households respond to price changes?

The effectiveness of cost reflective pricing in reducing peak demand and delaying additional infrastructure investment depends on the extent to which prices affect household decisions about the quantity and timing of electricity consumption. As mentioned earlier, some commentators have suggested that households do not respond very much to price changes (Ben-David, 2018; Finkel et al., 2017). This is an empirical question. The main way the household responsiveness to prices is measured by economists is by estimating the price elasticity of demand, which returns the general proportional change in consumption to a one per cent change in price. This provides a rate of change at a more micro level which can then be applied in economic modelling.

2.5 Why are elasticities important for policy makers?

In this paper, we focus on finding elasticities. The price elasticity of demand is important in understanding the potential effectiveness of policies that affect the price of electricity and the associated impacts.[14] If the price elasticity of demand for electricity is not zero, then policies affecting prices can affect behaviour and the larger the elasticity the greater the effect. How these elasticities differ between the very short run, the short run and the long run illuminates the time path of impacts following the introduction of such a policy. Finally, if we can see that different household types have a different response to price based upon their specific attributes (i.e. income), this enrichens our

[14] See Appendix 2 for background on demand curves, elasticities and their broad determinants.

understanding of the impacts and the necessity for compensation or adjustment assistance for different cohorts.

Elasticities are also particularly beneficial for better understanding potential transitional impacts of reform and for creating targeted responses. As an example of how knowledge of elasticities can inform policy, Grafton and Ward (2008) demonstrate that households have been found to be responsive to prices for water, and that the welfare costs from volumetric pricing of water to regulate water demand is less than the welfare cost from mandatory water restrictions (Grafton and Ward, 2008).

For electricity, if low income households have inelastic demands, until the savings on infrastructure costs are passed on, their expenditure on electricity could go up. Alternatively, if low income cohorts have relatively elastic demands, cost reflective pricing may result in significant cuts in consumption, particularly on hot days, until prices fall. This could have serious health consequences for, for example, older low income Australians. Targeted responses could include some form of income supplement similar to that which was provided when the carbon price was implemented but this would need to be reviewed to ensure it largely dealt with potential risks. As households adjust their appliances and make other changes, the size of the supplement required may decline. Another approach could be to use regulation.

There are two limitations of the literature we are about to review. First, because of the very limited diffusion of cost reflective pricing across Australia, the elasticities we will review are, unless noted otherwise, for households facing flat rate prices. Second, the quantity data typically refers not to demand at a point in time but consumption over a period of time. Cost reflective prices would be expected to provide stronger incentives to moderate demand than consumption but the two are correlated. And the elasticities are still informative as to whether, even when households are not facing pointed price incentives, households will respond to price changes. Hence, in the next two sections we review the evidence on the long run and short run price elasticities of demand for electricity, followed by Section 5 which considers the very limited empirical evidence on differences in elasticities by cohort.

3. Long run price elasticities of demand for residential electricity

Long run price elasticities of demand capture the responsiveness of households after they have had as long as possible to respond to price changes. For example, they can also change their electrical appliances, household insulation or make other substantial changes in response to a price change. They are typically estimated over a substantial period and can produce an annual elasticity or even multi-year elasticities. A set of estimates of long run elasticities of largely residential demand is presented in Table 1.

3.1 Long run elasticities of demand for electricity in Australia

The empirical evidence demonstrates that in the long run the demand for electricity will fall as the price of electricity rises. The literature summarised in Table 1 suggests the long run elasticity for electricity demand is somewhere between -0.75 to -0.3. Although the demand for electricity is inelastic it is substantially different from zero so consumers will respond substantially to changes in prices.

Specifically, a recent analysis of Australia-wide residential demand for over 40 years (1970 to 2011) (Rai et al., 2014) finds a long-run price elasticity of -0.748 and a short run elasticity of -0.447. Using a shorter, slightly older, time series (1969 to 2000), Narayan and Smyth (2005) find more conservative annual estimates of -0.541 in the long run and -0.263 in the short run. Using a structural break test, Rai et al. (2014) found that the price elasticity fell from -0.5 during 1970 to 1982 to -0.3 during 1982 to 2011. This suggests that there is some evidence that the long run elasticity has changed over time and people have become less responsive in the long run in more recent decades.

There is more limited work at the state level in Australia which typically analyses total (not just residential) consumption — though it is not clear which way this biases the results. Fan and Hyndman (2011) used half hourly data for South Australia from 1997 to 2008 to develop annual own price elasticities of total demand (excluding demand associated with mining) for South Australia and found values of between -0.428 to -0.363. Similar values are found nationally by Doojav and Kalirajan (2019). We note a survey paper by the National Institute of Economic and Industry Research reports elasticities of between -0.53 and -0.23 for Victoria and a long run own price elasticity of demand between -0.5 to -

0.2 for the National Electricity Market[15] (NIEIR, 2006). However, the methodology used by the NIEIR is not specifically described so our preferred estimates do not reflect this work.

Those studies which also estimate short run elasticities of demand find these are smaller than the long run elasticities. This is consistent with economic theory and possibly results from capital adaptation or learning.

The long run elasticities for electricity are comparable to those, for Australia, for other products seen by some consumers as necessities, as summarised in Table 2. The demand for all of these products is inelastic— demand responds less than proportionally to price changes — but is still responsive to prices. The long run demand for electricity is a lot more elastic than the demand for petrol or water. The long run elasticity of demand for electricity is most comparable to that for cigarettes. The upper bound estimates for electricity own-price elasticities are comparable to those for milk and bread.

In addition, the results for long run elasticities in Australia for electricity are more elastic than those internationally as estimated in a meta-analysis (Labandeira et al., 2017).

[15] Created in 1998, the National Electricity Market combines the wholesale electricity markets of Victoria, New South Wales, Queensland, Australian Capital Territory, South Australia and Tasmania.

Table 1: Summary of long run price elasticities of demand for residential electricity

Authors	Method	Time period/market	Results
Rai et al. (2014)	Error-correction model	Australia-wide and Australian states, 1970 to 2011.	**Long run model** Australia -0.748 Australian structural break tests Fallen from -0.5 to -0.3 over time **Short run model** Australia Own price: -0.447
Narayan and Smyth (2005)	Time series using bounds testing approach	Australia, 1969 to 2000	Own price Long run: -0.541 Short run: -0.263
National Institute of Economic and Industry Research (2007)	Review of own work and review of overseas and Australian literature	Australia-wide and Australian states, 1980 to 1995.	Australia Residential: -0.25 Commercial: -0.35 Industrial: -0.38 National Electricity Market -0.50 to -0.20 (mean -0.35) Victoria -0.53 to -0.23 (mean -0.38)
Deryugina et al. (forthcoming)	Natural experiment, flexible difference-in-differences matching approach	Illinois (US), 2007 to 2014.	Own price: -0.09 in first six months, up to -0.27 after two years
Combined residential and industry			
Doojav and Kalirajan (2019)	Autoregressive-distributed lag model	Australia-wide and Australian States, 1999 to 2013.	Australia Long run: -0.38 Short run: -0.30 Victoria Long run: -0.19 Short run: -0.12 (statistically significant at the at 10% level)
Fan and Hyndman (2011)	Linear demand model	Annual, South Australia, 1997 to 2008	Ranges from -0.428 to-0.363

Table 2: Other estimates of demand elasticities for electricity, gas and other necessities

Paper	Product	Elasticity
Australia		
Breunig and Gisz (2009)	Petrol	Short run: -0.13 Long run: -0.20
Grafton and Ward (2008)	Water	-0.17
Pham and Prentice (2013)	Cigarettes	-0.4 (Sydney) to -0.26 (Brisbane)
Hasan and Sinning (2018)	Various foods	Milk: -0.732 Bread: -0.781 Baby food: -0.136
International		
Labandeira et al. (2017)		Electricity (Short run): -0.126 Electricity (Long run): -0.365 Natural Gas (Short run): -0.180 Natural Gas (Long run): -0.684

3.2 Long run elasticities of demand for households?

The Australian long run elasticities of demand use data on households aggregated to the state or national level. Unfortunately we did not find long run elasticity estimates for Australia using data reported at the household level. While this informs us about households as a group respond it doesn't necessarily inform about the typical individual household response.

Looking overseas, Deryugina et al. (forthcoming) provides results that are closest to estimates of elasticities for households. They examined the Illinois Municipal Aggregation program, which was a program that allowed communities in Illinois to aggregate their demand for the municipality to negotiate for a deal with an electricity supplier. The authors found that demand increased when there was an expectation that price would decrease. In the first six months following a community decision to aggregate, price elasticity of demand was estimated at -0.09, which increased up to -0.27 after two years.

The way the program was implemented created a de facto natural experiment, which means that Deryugina et al. are confident these represent causal effects. The estimates are broadly similar to the long run estimates using annual data, albeit lower.

3.3 What this means

We conclude, based on empirical evidence for Australia, that in the long run the household demand for electricity does fall in a material way as price increases. This implies that, in the long run, reforms that increased the price of electricity would reduce the household demand for electricity.

The work of Deryugina et al. (forthcoming) suggests a promising direction for further research to be undertaken for Australia. Following households or even small communities and observing their demand by month (rather than by year) over several years offers the promise of learning more about the responsiveness of demand as households adjust to the new price policy over time. Working with higher frequency data enables the analysis to be confined to a period where there is a stable relationship between variables. In addition, it also offers greater surety that we are estimating a causal impact rather than mere correlation.

In the next section we analyse the evidence on the short run elasticity of demand for electricity in Australia.

4 Short run price elasticities of demand for residential electricity

Short run elasticities of demand for electricity focus on how responsive households are within much shorter time frames. In the short run, determinants of electricity demand like insulation and the costly appliances in the house remain unchanged so the main way the consumer can respond is by altering how they use these appliances and electricity in general. Hence these results are more relevant for assessing the potential impact of cost reflective pricing. The available estimates are reviewed in Table 3.

The first set of studies focus on household responses to the price schedules in the monthly bills with different incentives to moderate consumption. The elasticities from these studies are much lower than the long run elasticities — in one case completely inelastic. We explore the reasons for these results below.

In contrast, studies that focus on daily or within daily responses by households to prices tend to find that households reduce consumption when the price is higher. Like in the long run, demand varies less than proportionally with price changes i.e. it is inelastic. Furthermore, several studies suggest that the responsiveness of households is greater when price reform is accompanied by new technology that makes it easier for households to observe and respond to price changes. Furthermore, some of the studies reviews suggest that more households will take up cost reflective pricing packages if they are made to be opt-out rather than opt-in.

After briefly reviewing the studies which focus on monthly consumption, we then concentrate on those studies that estimate the responsiveness of household demand to price changes that attempt to shift consumption within a day, on days with peak demands or are provided with short notice. These studies typically find stronger results than those using monthly data. However, as nearly all these studies have been done overseas, we highlight a major research gap in that there are almost no studies of this type for Victoria or Australia.

4.1 Studies using monthly electricity consumption

There are two studies that considered the effect of different types of prices on household monthly consumption. Ito (2014) finds monthly consumption does respond to average price changes with a statistically significant elasticity of -0.054. However, the same study does not find evidence of households responding when per-unit prices increase as monthly consumption exceeds a threshold. In addition, the average elasticity of demand with respect to average price increased to -0.082 when a monthly lag was considered, which could reflect some adaptive learning. Ito suggests two reasons for the lack of response to marginal incentives. First, households may find the more complex pricing systems too hard to respond to so they just respond to the average prices which they can estimate. Secondly, households do not observe their consumption during the month and so cannot alter their behaviour around thresholds. Hence, they respond to average prices instead.

Table 3: Summary of short run price elasticities of demand for residential electricity

Authors	Method	Time period/market	Results
Monthly and six monthly elasticities			
Byrne et al. (2019)	Experiment	Victoria (Australia), October to November 2015.	Monthly own price: -0.003 (statistically insignificant)
Ito (2014)	Natural experiment, panel data with fixed effects	Orange County, California (US), 1999 to 2007	Monthly response to average price: -0.054 (-0.082 with a lag) Monthly response to marginal price: 0.0002 (statistically insignificant) (0.006 with a lag)
Deryugina et al. (forthcoming)	Natural experiment, flexible difference-in-differences matching approach	Illinois (US), 2007 to 2014.	Own price: -0.09 in first six months, up to -0.27 after two years
Combined household and business			
Kim et al. (2015)	Natural experiment	Ontario (Canada), May 2006 to October 2014	On-peak: -0.10 (not statistically significant) Mid-peak: -0.25 (statistically significant) Off-peak: -0.06 (statistically significant p<0.10)
Daily or within-day elasticities			
Allcott (2011)	Field experiment, randomised control	Chicago (US), 2003 to 2006	Day-ahead notice of hourly prices, overall reduced form demand elasticity: -0.1
Gillan (2018)	Natural field experiment, utility model	California (US), 2017	Bounds of own price: -0.050 to -0.470
Faruqui et al. (2017)	Meta-analysis of dynamic pricing trials using linear regression to estimate effects of peak/off-peak ratio	Global	A 10% increase in the price ratio would result in a 6.5% decrease in peak usage. With technology, this decrease was 11.1%.
Faruqui et al. (2014)	Analysis of experiment results on daily and within-day consumption.	Connecticut (US), 2009	Daily own price: -0.026 Time substitution response to price: -0.081 to -0.047price only; -0.128 to -0.047 price and technology

In Australia, there was an experiment with residential customers in Victoria undertaken over two months in 2015 analysed in the unpublished study of Byrne et al. (2019). Customers were provided temporary discounts on their per unit consumption and on the fixed infrastructure component of the bill. The study found that residential electricity demand is largely unresponsive to large reductions in both marginal and average prices, with an own price elasticity of demand estimate of -0.003 (statistically insignificant) (Byrne et al., 2019). The authors note that this could reflect that the pricing did not provide the sharp incentives to reallocate consumption like that done by time-of-use or critical peak pricing. In addition, the discounts were not long enough to encourage substantial behaviour change or the replacement of appliances. This may be one of the reasons for the different effects to the Ito (2014) study which was not a trial but based on the ongoing prices charged by utilities.

A third, unpublished, study analysed changes in average aggregate (households, small business, commercial and industrial) monthly consumption due to changes in average monthly price under time-of-use pricing in Ontario (Kim et al., 2015). The study found on-peak demand had an elasticity of -0.10 (not statistically significant); mid-peak demand had a statistically significant elasticity of -0.25; and off-peak had an elasticity of -0.06 (significant at the 10 per cent significance level). A potential problem with this study is that industrial and commercial consumption included in the dependant variable is not subject to time-of-use pricing.

There is a tension between the results of Byrne et al. (2019) and Ito (2014) and those from the studies we review next in the next sections which cover studies of responsiveness by day or within a day. These studies tend to find that consumers do respond to price incentives. We discuss in section 4.5 how to reconcile the different outcomes using monthly and daily and within-daily data.

4.2 Daily or within-day elasticities

There is no published research reporting elasticities for how Australian households respond to prices by day or within a day. When consumers face prices that vary within a day or across days these are more immediate price signals that households can respond to. The response to within day price variation is of most interest to understand responsiveness to pricing for a peak demand event. Hence the lack of studies for Australia is a significant research gap. However, there has been considerable international research which we will now review.

An example of this type of research is Faruqui et al. (2014) which analysed a 2009 pilot in Connecticut, USA, of 2,200 residential and small commercial and industrial customers and assessed the difference of responses in hourly consumption to time-of-use pricing, critical peak pricing and peak time rebates. Households were found to shift their consumption from peak to off-peak periods when there is a change in the ratio of peak to off-peak prices with elasticities ranging from -0.047 for time-of-use pricing, to -0.052 for the peak time rebate, to -0.081 for those on critical peak pricing (i.e. households were almost twice as responsive to critical peak pricing) (Faruqui et al., 2014).[16] When critical peak pricing was combined with technology that automatically adjusts the air conditioning unit or thermostat, the elasticity increased a further 50 per cent to -0.128. When analysing the effects on daily consumption, the authors found that time-of-use pricing had no statistically significant effect, but that critical peak pricing and peak time rebate both reduced daily consumption (daily elasticities of -0.026 with price, and with price and technology).[17]

The effect of combining very short run price signals (rather than those through the monthly or quarterly bill) with technology to make it easier for households to learn and respond to the signals has been of considerable interest in this literature. Technology could increase household price elasticity of demand by allowing households to more easily observe prices and consumption, and adjust appliances in the more immediate term (Allcott, 2011).

In general, the studies of how households respond to prices in the very short run find that consumers respond to near time prices, and respond substantially more so when paired with enabling technology that can automate household appliances, or otherwise assist households, to respond to near time prices. Analysis of a database which contains evidence from various dynamic pricing pilots found that consumers do respond to very short term price incentives (Faruqui et al., 2017). In addition, the

[16] That is, a one per cent increase in the peak to off-peak price ratio implies that the usage ratio decreased by 4.7 per cent for those on time-of-use pricing and 8.1 per cent for those on critical peak pricing.
[17] That is, a one per cent increase in price implies a decrease in overall consumption of 2.6 per cent.

Figure 1: Summary of North American pricing pilots

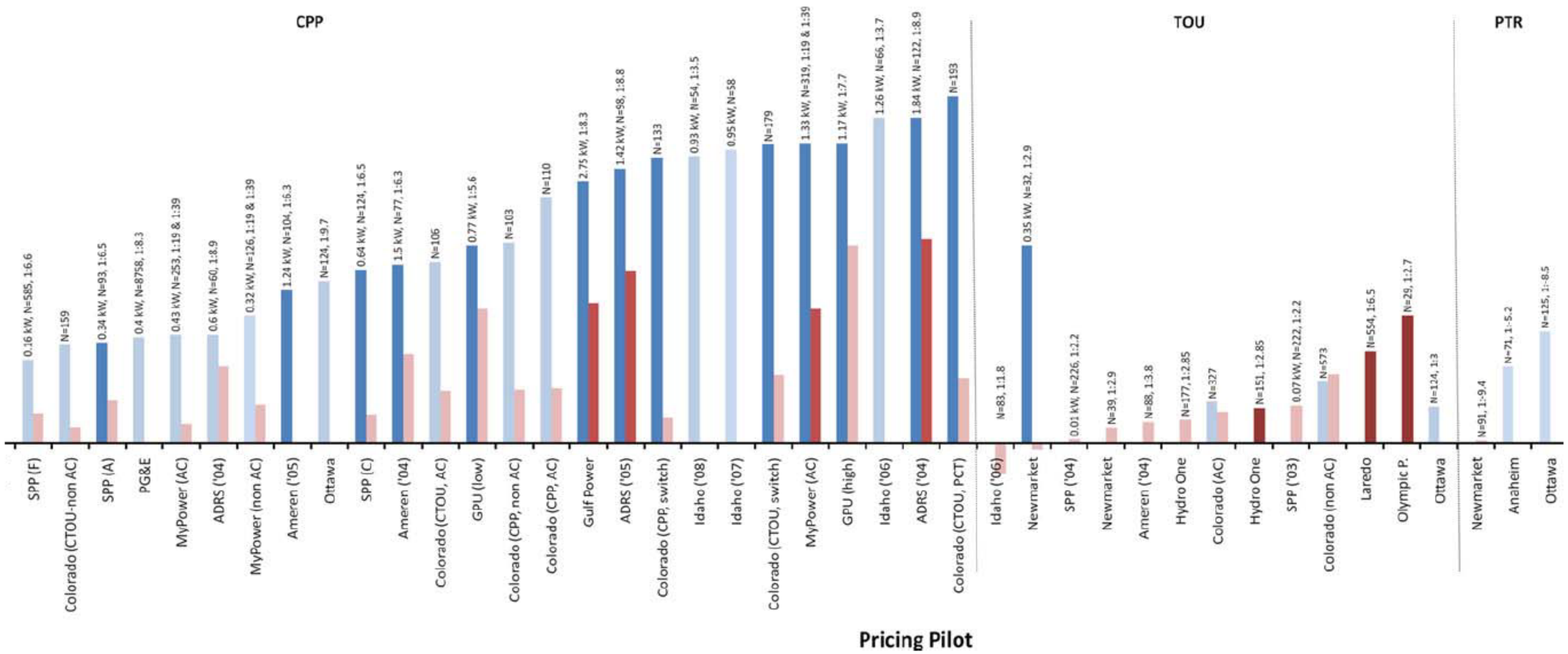

Fig. 1. The reported average reduction in peak load for the reviewed time-varying pricing studies. Different treatment groups in each study (where applicable) are shown separately, and the effects are rank ordered according to the size of the percentage peak load reduction, and grouped according to the dynamic price option used. The blue-shaded bars indicate reductions during peak hours (variously defined) on critical event days, and the red-shaded bars indicate savings during those same hours, but on non-event days. The bars carry a label indicating the size of the average reduction in terms of kW per house, the number of houses involved in the study, and the ratio of lowest to highest price in effect. The darker-shaded bars indicate that an enabling technology was in use. Most studies involved a mix of customers with and without air-conditioning, but where studies presented results for these two groups separately, this is indicated by "AC" and "non AC" in the study label. The Colorado study involved both programmable communicating thermostats and AC switches as enabling technology, the results for these two groups are presented separately, as indicated by "PCT" and "switch" in the study label. The SPP study involved groups with different rate structures or drawn from different samples, the results for these groups are presented separately, as indicated by "F", "A", and "C" in the study label. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Source: Newsham and Bowker (2010)

average effect on the peak across the different types of cost reflective pricing with enabling technology was found to be greater than then average effect on the peak than those without enabling technology.

An earlier review of North American studies also found that technology to automate responses to price signals appears to increase responsiveness (Newsham and Bowker, 2010). Figure 1 on the previous page presents these results with darker shaded bars representing the demand response to pricing with technology. Critical peak pricing, in particular, was found to be generally very effective at reducing peak loads in the earlier review of North American pilots (Newsham and Bowker, 2010).

4.3 Other studies of how consumers respond to within-day price variation

There are also several other studies that do not estimate elasticities but provide estimates of the impacts of types of within day pricing as well as having other interesting features.

First, the different effects of dynamic peak pricing and peak rebates were analysed, using the Smart Grid Smart City dataset from Sydney and surrounds in 2013. Households who signed up for network dynamic peak pricing or a peak rebate changed their behaviour after subscribing to the products. While an elasticity was not reported, the study found that the response was greater under the dynamic peak rebate (usage reduction of 12.04%) than the dynamic peak pricing (usage reduction of 8.71%) (Motagh et al., 2015).

Secondly, Allcott (2011) evaluated a program that exposed residential customers to hourly prices based on a day-ahead wholesale prices— this is a version of real time pricing but with notice of the price for each hour provided one day ahead. Key findings from the evaluation included that:

- program households are responsive — if average price was higher by one cent/kWh, the demand reduction is around 17.4 watts in summer and 21.8 watts in non-summer.

- energy management and information technology, such as the Pricelight[18], can significantly increase a household's responsiveness.
- program households reported that they responded to real time pricing through conserving energy, rather than shifting load from high to low price times.[19]

Allcott (2011) also examined the original treatment group after one year on the program and found that they consumed six to eight watts less on average when the price was higher by one per cent – so the treatment group increased their responsiveness further by about 30%.

Thirdly, in a recent study based on a field experiment in California, Gillan (2018) found households with automation technology were more responsive than those without, but also found that households with notification of a pricing event still exhibited some responsiveness to price. In this experiment, households were provided with less than an hour notice of a pricing event and received an offer to reduce consumption for a financial incentive. Some households received notifications, some received notice along with an environmental message (moral suasion) and some received notifications paired with an incentive to purchase technology that could automate responses to price events. The author found households which received a pricing notice, with and without automation technology, responded to a price increase by reducing consumption, but had limited response to the price level itself (i.e. consumption change is the same, regardless of the size of the price increase) — which indicated that people use heuristics[20] to make decisions. Households that were notified of a pricing event reduced consumption by 12.4% on average. Households with the automation technology reduced their consumption more than households without the

[18] Pricelight is a device that changes colour when there is a change in price, providing a visual prompt for a household to respond to. Farqui et al. (2014) reports mixed results for a similar technology, the Energy Orb.

[19] This was found through a small survey of households in the program. When asked about what changes participants thought they made after entering the program, respondents largely reported energy efficiency measures rather than substitution. However, the author notes that within day substitution (i.e. using more in the off-peak times compared to the peak, such as pre-cooling before the peak) could not be measured in the evaluation.

[20] Heuristics are mental shortcuts that ease the cognitive load of making a decision. For instance, using rules of thumb or an educated guess are heuristic methods. In this particular study, it was theorised that households could be using expected price change instead of the actual price change, such that demand is insensitive to the magnitude of the price change (Gillan, 2018)

automation technology. Comparing consumption during the price event to consumption two hours earlier for non-automated households, non-automated households had reduced their consumption by 7.9% whereas the automated households had reduced their consumption by 23.4%. In addition, the author found the response was precise as participants returned to normal consumption levels post event.

Finally, in Victoria, Australia, the electricity distribution company, Jemena, in partnership with the Department of Environment, Land, Water and Planning, Victorian Government, ran a pilot over the summer of 2017/18 to test two forms of peak time rebates, made available at six, roughly peak, trial times during the trial period. Households were given 48 hours notice of when the trials were to be held and those that met a pre-set electricity target reduction received rebates either for themselves or a local school or community organisation (Jemena, 2019). Households chose whether to participate in the trial as a whole and whether to participate in each trial. On the two hottest days average consumption reductions, compared with a control group, were between 26 and 35 per cent of individual base peak consumption. Average participation rates in each trial were between 43 and 53 per cent. There were greater average participation rates but lower percentage reductions for the group receiving the personal rewards compared with the group for whom the school/community organisation received the rewards.

4.4 Opt-in, opt-out regimes

Another area examined in the literature is the different effects of using opt-in, opt-out or mandatory assignment for cost reflective tariff structures. Generally, opt-out and mandatory assignment are more effective than opt-in because more people take up the cost reflective pricing.

From a review of studies across six countries, Nicholson et al. (2018) found that with opt-out arrangements, between 57% and 100% of customers remained on cost reflective pricing, whereas opt-in models have a take up of cost reflective pricing arrangement of between 1% and 43% of customers. Providing upfront financial incentives for signing up to time of use pricing was found to have a strong statistically positive effect on uptake, but uptake is not suggested to be related to the presence of automation technology.[21]

On whether the type of regime has an impact on peak consumption, Faruqui et al. (2017) found that requiring consumers to opt-out rather than opt-in to having time varying electricity prices led to a further 3.9% reduction in consumption in the peak demand period.

4.5 What this means

International studies of short run responsiveness to price changes confirms the result of the review of the long run responsiveness – that is, contrary to concerns, households are responsive to substantial price differences. Technology assists in generating a greater response to price incentives, particularly if responses are automated, but is not necessarily required for prices to have an effect. The limited evidence suggests that the simple change of making participation in cost reflective pricing opt-out rather than opt-in will considerably increase its uptake.

The results from the studies of Ito (2014), Byrne et al. (2019) and Deryugina et al. (forthcoming), in combination with those for shorter time periods, are suggestive of the conditions under which households are most likely to substantially respond to the incentives provided by cost reflective pricing. The conditions under which moderating consumption will result in a financial payoff need to be clear to the household. Reducing consumption on specified days or for specified hours is easier than to avoid breaching a threshold that is not observed. The changes need to be permanent and greater changes will be observed over time as it takes time and possibly further investments to alter electricity consumption. A reduction in demand during short periods of time, rather than over a whole month, may not be quantitatively large but could still be economically important in reducing the need for costly infrastructure. An analysis of demand data for Victoria from the 1/11/2016 to 31/10/2017 found the peak demand was over 8400MWs. But demand only exceeded 7000MWs on eighteen days. If demand could be moderated on these days back towards

[21] Automation was not found to have any effect on uptake of real time pricing or dynamic tariffs.

7000MWs considerably less capacity would be required. Lower capacity means less costs to be recovered which ultimately means lower prices.

The limitation of all this work is that it doesn't inform on the second major concern around the equity impacts of cost reflective pricing. We review the limited evidence on this in the next section.

5 Price responsiveness by different types of households

The second of the concerns for cost reflective pricing is the potential impact it could have on lower income households. If low income households are less price responsive[22], their bills could go up and if they are more price-responsive, they may be exposing themselves to a greater risk of, for example, health problems due to heat. There is, however, little systematic evidence on the effect of cost reflective pricing for lower income households, with inconsistent findings across the limited research. Researchers have attempted to generate evidence by directly measuring effects in surveys, analysing how consumers report about different pricing plans and how the bills of consumers with different incomes would change under different pricing plans.

5.1 Responsiveness by household income

The literature on responsiveness by household income level is somewhat mixed. In 2012, Frontier Economics and Sustainability First undertook a literature review of 30 residential customer demand side response trials for the UK Department of Energy and Climate Change. The authors found vulnerable and low-income consumer responsiveness to demand side response initiatives varies across studies, with some finding that these groups respond less than the average response. There was little evidence on the impact of demand side response incentives on low-income and

[22] An implicit assumption underlying this concern is that lower income households could be less price responsive than other household and would wear any price increase at a cost to other items in an already stretched budget. Some reasons for being less price-responsive could be that lower income households are:

- already mindful of their energy consumption and are limited in making further changes
- generally in less energy efficient homes
- have older and less energy efficient appliances
- are renting and cannot make physical changes to the property;
- have more health needs which require better thermal comfort such as those with children or the elderly.

vulnerable consumers in the UK in particular. In the US, Deryugina et al. (forthcoming) found little evidence that elasticities depended on economic characteristics, such as income and education, but did find some variation across age and race.

Faruqui et al. (2010) found mixed results from reviewing five programs for differences in price responsiveness between low and high income households. Elasticities were referred to but not reported in the paper, but two of the programs found low income customers were equally responsive to average customers, while the other three studies found that they were less responsive (but responsive nonetheless).

5.2 Examination of bills for impacts of cost reflective pricing

An alternative way to analyse household impact is to analyse existing bills to see how much lower income households could be impacted by a move to cost reflective pricing. The limitation is that current consumption by a household does not reflect any behaviour change in response to a different price structure.

Simshauser and Downer (2016) undertook an analysis of smart meter bills from Victoria merged with information from AGL Energy's household survey to analyse what types of customers might gain from a shift from flat rate to a cost reflective type tariff (time of use plus critical peak pricing). They consider six types, two of which include groups that are typically characterised as low income and/or vulnerable: "Households in Hardship" and "Concession and Pensioner". When no allowance for behaviour change was made, the "Households in Hardship" group had the greatest share of households that gained (65%) because their daily consumption profile was such that they gained from off-peak discounts without losing too much in the peak. Only 45% of the "Concession and Pensioner" group gained though. Once some demand responsiveness was included in the calculations the majority of these groups (79% and 62%) gained – indeed 64% of all consumers gained related to a flat rate system. This assumes overall revenue doesn't change. If cost reflective pricing reduces peak demand, costs and revenue will fall and more households will gain.[23]

5.3 Low income households in Australia

In Australia, there is no direct evidence on the impact of cost reflective pricing on low income households similar to the studies above, but there are studies which examine household sentiment and potential behaviour if there were cost reflective pricing. One study asked consumers how they felt about different pricing plans with analysis based on income group (Stenner et al., 2015). The authors found that critical peak pricing had the greatest, albeit small, appeal to lower income consumers which could reflect the desire for cheaper electricity for most of the year and avoidance of usage at critical times. In addition, flat rates were increasingly preferred over critical peak pricing as household income rises. On the other hand, Nicolls et al. (2015) asked vulnerable households about cost reflective pricing and found considerable concern about it.

5.4 Potential relationship between income and types of appliances

To the extent electricity consumption is driven by appliances, the use of energy consuming appliances might be expected to increase with income. However, it is also possible that higher income households can afford more efficient appliances.

In Sydney and regions, Fan et al. (2015) examined a range of factors and found that a pool pump drives the most consumption, with increased daily consumption by about 50 per cent on an average annual basis when compared to those who did not have a pool pump. The next feature that drove consumption was air conditioning. Gas hot water was found to decrease daily electricity consumption by 18% on an average annual basis[24]. Owning a pool pump and the extent of air conditioning is likely to be positively correlated with income which suggests that households that

[23] These results assume a certain pricing pattern and consumer demand profiles. Horowitz and Lave (2014) do a similar exercise (without demand response) for households in northern Illinois and Chicago and find only 25 per cent of customers would be better off and only 19 per cent of low income customers.

[24] This data includes half hourly demand for 12 months from households in the Sydney region, as well as a range of other variables.

consume more electricity are more likely to save the most money, if the findings of Horowitz and Lave (2014) applied in Australia.

5.5 What this means

The limited mixed evidence of low income and vulnerable households' responsiveness is consistent with cost reflective pricing not automatically having a uniform impact. The surveys undertaken in Australia on the perceptions of low income households indicate that some households are apprehensive about the potential impact, while other households perceive they may be able take advantage of cost reflective pricing to make savings. An analysis of bills would be a useful starting point to better understand potential impacts. Concessional cost reflective pricing could also be considered. For instance, a cost reflective pricing scheme could feature discounts for concession holders. So although concession householders would pay a differential price for peak and off-peak times, both the peak and off-peak prices could be well below the prices paid by non-concession holders.

6 Discussion and conclusion

With technological change reducing the costs of renewable and distributed generation, and with the prospect of a substantial shift in demand due to the uptake of electric vehicles, considerable investment in new infrastructure is likely. Hence it is even more important to have a pricing structure that encourages efficient use and investment of electricity infrastructure, which will be better than the prevailing flat rate structure. Governments have been reluctant to proceed too far with pricing reform though for two reasons. First, there is an active public debate around whether prices can have a significant influence on consumer choices. Second, there is a concern that moving away from flat rates for electricity could exacerbate energy affordability issues for the lowest income households.

The empirical literature on the importance of each of these conditions provides substantial international and local evidence that households, in the long run, respond to electricity prices. While the demand for electricity is found to be inelastic, households do respond in a material way to an increase in price. And this responsiveness is greater than what is estimated for some other necessities, like petrol and water. The responsiveness of the demand for electricity is comparable to that for cigarettes and the greatest estimates for electricity are similar to those for milk and bread.

There is also a substantial body of international evidence from pilots and trials that consumers respond to price signals that encourage moderating consumption during peak periods. While these very short run price elasticities are smaller than the long run estimates, this is consistent with economic theory that people can adapt over longer time frames by making more efficient investment decisions. Furthermore, the very short run responsiveness is increased if pricing reform is accompanied by technology that improves the information to households and eases their ability to respond to price changes. Pricing reform is also found to be more likely to work if households must opt-out, rather than opt-in, to cost reflective pricing.

There are caveats on applying elasticities compiled from pilots and experiments to an entire population as pilots and experiments can involve self-selection and incentives to participate which may not hold in other circumstances. However, the weight of evidence would support that households are responsive to price changes through adjusting demand. Further pricing reform is likely to be effective and at the very least, further local research on the impacts of pricing reform should be undertaken.

There is insufficient evidence to determine whether low income and vulnerable households respond less to electricity prices compared to other households. There is no Australian quantitative evidence and the international evidence is ambiguous on the direction and size of any effects. The qualitative evidence seeking to understand whether low income and vulnerable households are more likely to be adversely affected by electricity price reforms is mixed. Future Australian research could improve focus on more precisely understanding the impact of cost reflective electricity prices on households by including a sample of a sufficient size of low income and vulnerable Australians. This would support reform efforts. Estimating the responsiveness of demand changes over time based on a panel of households or communities for a substantial period of time is a recommended area for this research. If, for example, it turns out that cost reflective pricing benefits many low income earners (through providing savings most of the year that offset higher prices in the peak periods) then this would bolster the cases for making cost reflective pricing opt-out rather than opt-in and for making the default offer a cost reflective rather than flat rate.

In addition, there could be complementary policies to support a change to cost reflective pricing for low income and vulnerable households, such as including discounts for concession holders, providing additional information to concession households to support their decision-making to opt-in or not to the new pricing system, once-off discounts for new appliances or a targeted program of energy efficiency retrofits for homes e.g. for social housing tenants. The likely effectiveness of relevant policies that would complement the change to cost reflective pricing would need to be examined further. Access to data for researchers appears to be a key limitation. Most short run pricing studies appear to partner with energy companies to access customer data. In addition, similar to other research areas, details about income can sometimes be difficult to access as disclosure through surveys is limited. In Victoria, smart meters are in place which means household usage data exists and is held by electricity companies. Access to this data requires working with electricity companies with permission from households. The literature for Australia, and indeed Victoria, is limited and further studies would assist in better understanding the dynamics of household electricity use.

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Appendix 1

Infrastructure Victoria recommendations

Mandate cost reflective pricing for all energy customers within 0-5 years to fully realise the benefits of smart meters, increase customer engagement on energy consumption patterns and influence customer choices to reduce peak and potentially total energy demand. The first step to achieving this would be to provide leadership in working with industry to increase customer awareness on the benefits of cost reflective tariffs, benefits that include fairer pricing and lower costs pricing.

ACCC recommendations

The ACCC considers that steps should be taken to accelerate the take up of cost reflective network pricing.

Governments should agree to mandatory assignment of cost reflective pricing on retailers, ending existing opt-in and opt-out arrangements.

Mandatory assignment of the network tariff should apply for all customers of a retailer that have metering capable of supporting cost reflective tariffs (that is, a smart of interval meter).

Retailers should not be obligated to reflect the cost reflective network tariff structure in their customers' retail tariffs, but should be free to innovate in the packaging of the network tariff as part of their retail offer.

Given the potential for negative bill shock outcomes from any transition to cost reflective network tariffs should retailers pass these network tariffs through to customers, governments should legislate to ensure transitional assistance is provided for residential and small business customers. This assistance should focus on maximising the benefits, and reducing the transitional risks, of the move to cost reflective pricing structures. This includes:

- A compulsory 'data sampling period' for consumers following installation of a smart meter
- A requirement for retailers to provide a retail offer using a flat rate structure

- Additional targeted assistance for vulnerable consumers.

Demand tariffs, which charge retailers based on their customers' maximum demand during pre-determined typical system peak times, represent an appropriate structure for the initial mandatorily assigned network tariffs. This tariff structure provides a balance of the objectives of cost reflectivity, simplicity and price certainty.

We note that the extent to which cost reflective tariffs can be introduced is limited to the extent that a retailer's customers have smart (or interval) meters. We therefore note the importance of the ACCC's recommendation 15, on supporting to uptake of smart meters, in achieving outcomes in this area.

Governments should appropriately fund communication campaigns around the benefits of cost reflective pricing and smart meters to build community acceptance and awareness of individual and community wide benefits, as well as customer awareness of their rights.

Appendix 2 - Elasticities, electricity and equity

Elasticities are an important concept in economics. They tell us about how responsive people are to price through quantitatively summarising how much people change their consumption in response to a change in price.[25] After reviewing the economics of elasticities, we analyse the determinants of the elasticity of demand for electricity, followed by a discussion of how elasticities can provide useful information for dealing with negative equity consequences.

Demand curves

In general, people will consume more of a good if the price is low. If the price is higher, then people will consume less. This is the law of demand and is represented by a downward sloping demand curve (see Figure 1). There are also factors which can shift a demand curve (also see Figure 1). These are known as exogenous factors, such as weather or a change in income. For instance, a household could choose to consume more electricity at the same price due to a hot day, or use more appliances because their household income has increased. The demand curve could also shift due to the purchase of new appliances, such as an air conditioner or pool pump. This shift could also be a decrease in demand from the grid though the purchase of solar panels or the adoption of more energy efficient energy appliances.

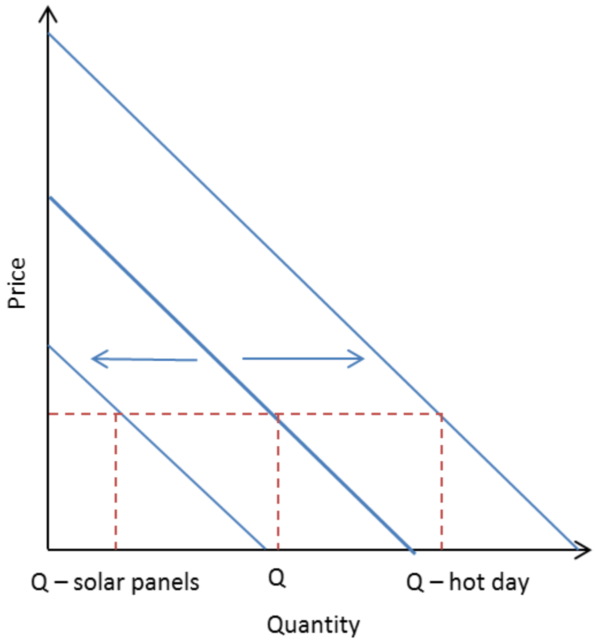
Elasticities and the shape of demand curves

Elasticity is a measure of how much buyers and sellers respond to change in market conditions and allows more precise analysis of supply and demand (Gans et al., 1999)[26]. The price elasticity of demand is the percentage change in quantity demanded in response to a one percent change in price. For instance, an elasticity of -0.2 means that the quantity demanded falls by 0.2 per cent in response to a one per cent increase in price. This elasticity can differ along the demand

[25] This paper concentrates on how the demand for electricity responds to a change in the price of electricity. Electricity consumption will also respond to the price of other goods, income and the weather. It is straightforward to define and possible to estimate elasticities of demand with respect to these products, interpretable in the same way (see Gans et al. (1999) for more details).
[26] This is a contemporary introductory microeconomics text book.

curve.[27] One of the main advantages of an elasticity is that as it is a proportional change, it is unit-free which enables comparison of the results of different studies considering different changes in prices.

Figure 1: Demand curve and shifts



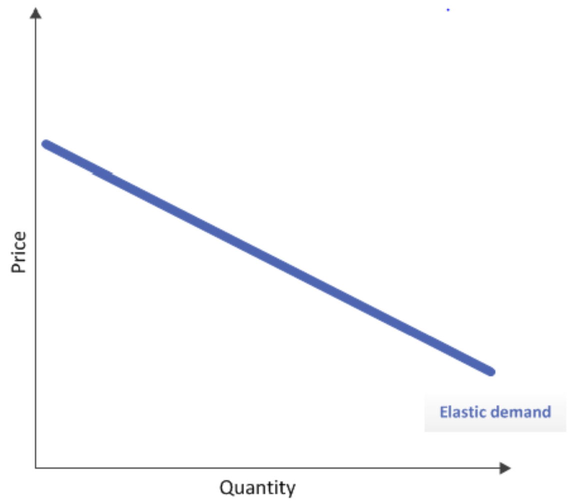
The slope of the demand curve can represent how responsive buyers are to a change in price. A demand curve that is steep is said to be 'inelastic' which means that for a given price change, the quantity demanded changes less than proportionally. A demand curve that has a less steep gradient is said to be 'elastic' which means that for a given change in price, the quantity demanded will change by a greater proportion. Buyers are more sensitive, or responsive, to price changes than when the demand curve is more inelastic. It is only when demand for a good is perfectly inelastic that buyers are unresponsive to price[28]. Figure 2 represents these shapes for demand curves.

[27] There is also a link between the elasticity of demand and household expenditure. Household expenditure is price times the quantity. If demand is relatively inelastic, then changes in price cause total expenditure to move in the same direction – that is, with inelastic demand if the price goes up, then the household expenditure on that good will also go up. This may be of concern to households with relatively low incomes.

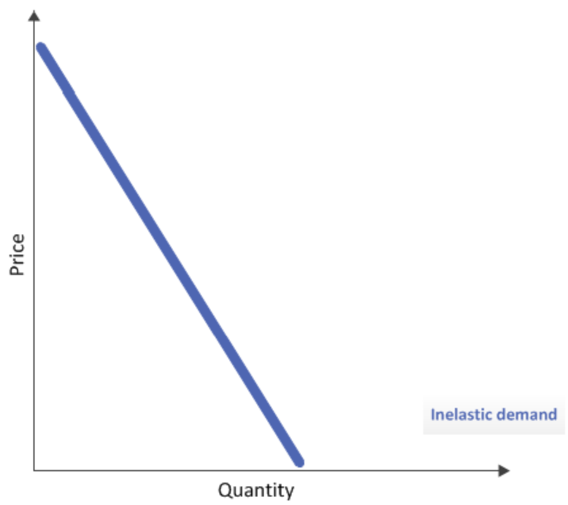
[28] A demand curve can also be perfectly elastic – any increase in the price of the good will cause demand to drop to zero.

Figure 2: Shape of demand curves and responsiveness to price

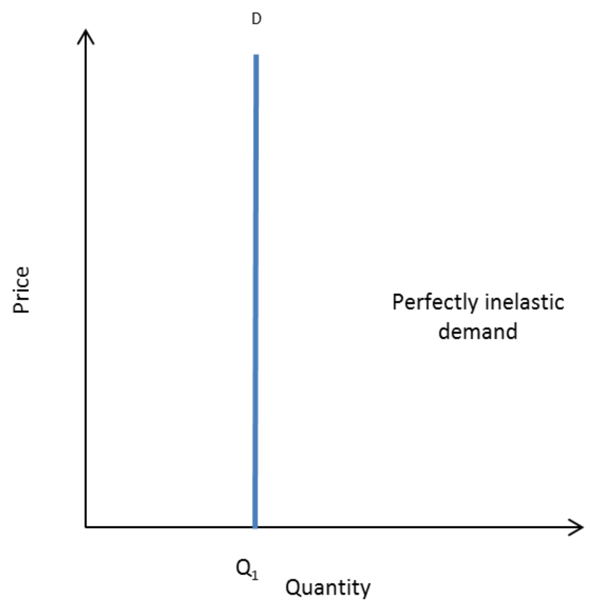
Elastic demand (E>1): Q changes proportionally more than P



Inelastic demand (E<1): Q changes proportionally less than P



Perfectly inelastic (E=0): P changes, but Q remains the same



<u>Broad determinants of demand elasticities</u>

There are some broad determinants of how elastic demand may be. This include whether a good is a necessity, the time horizon under consideration and the type of the consumer.

If a good is a necessity, then the quantity demanded by a buyer tends to not change by much if there is a price change. This means that demand for necessity goods tends to be relatively more inelastic compared to goods which are discretionary purchases. For electricity, we would expect demand to be relatively inelastic as it is something we use every day.

The time horizon for a good can influence the nature of the elasticity. This issue is particularly acute for electricity as it is almost exclusively consumed upon purchase. Consumers are able to adjust to a different extent over different time periods. Adjustment at a point in time may involve substituting consumption over time, such as doing the laundry or charging an electric car in an off-peak period. Long run elasticities tend to be more elastic than short run elasticities. For instance, a person may not be able to change their electricity consumption today by much (as, for example, they need their car for the next day), but over time they can buy more energy efficient appliances which can result in lower energy consumption over a longer time period. Electricity is a complementary good to several significant products like air-conditioning, pool pumps, ovens and fridges. A rise in the electricity price will also affect the demand for these goods. Indeed, it is likely that the long run effects of a change in the price of electricity would result in consumers adjusting their set of appliances over time (for instance, replacing air conditioners or adjusting processes to reduce the electricity bill). Forming habits and learning about consumption patterns can also increase price responsiveness over a longer time period.

Price elasticities are also likely to be greater if a price increase is permanent rather than temporary. If a price increase is known to be temporary a household is less likely to make changes to its behaviour, let alone to appliances or insulation, than if a price change is known to be permanent.

Lastly, there can be differences in elasticities depending on the type of consumer. For instance, some industrial consumers may have more substitutes for electricity available, such as gas, or substituting times when they can consume electricity, such as choosing to run components of their plants during off-peak pricing times. By comparison, a household may have less choice of when it uses electricity. This suggests that industrial consumers tend to be more price elastic than households. The same could be said for cohorts within households - lower income households could respond differently to higher income households. It could be that higher income households over time can invest in energy efficient appliances compared to lower income households.