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Tail-risk Comprehension and Protection in Real-time Electricity Pricing: Experimental Evidence

Madeline Pretto

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Jeremy Smith (Head of the Department of Economics, University of Warwick) and Michael Ward (Head of the Department of Economics, Monash University)

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Tail-risk comprehension and protection in real-time electricity pricing: Experimental evidence

Madeline Pretto*

Abstract

Do households comprehend the nature of price tail-risks inherent to real-time electricity pricing plans? Through an incentivised online experiment, we find that a probabilistic risk disclosure elicits greater demand for real-time pricing (RTP) products relative to a low-risk fixed-price alternative, without improving comprehension of tail-risk in RTP. Participants also show a tendency to place low value on tail-risk protection. Finally, the experience of a bill shock improves risk comprehension and drives choice away from RTP, suggesting that personal experience plays a greater role in self-imposed risk protection than does a probabilistic risk disclosure. We discuss the implications these findings may have for regulators with a consumer protection mandate.

Keywords: Real-time electricity pricing; Consumer protection; Tail-risk; Retail electricity markets

JEL classification: C91, D18, D81, L94, Q41

*Contact information: mpretto18@gmail.com

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1 Introduction

Real-time pricing (RTP) is a form of dynamic electricity pricing whereby the marginal price paid by consumers changes frequently (sometimes as often as every 5 minutes) in accordance with wholesale (or 'spot') electricity prices (Darby & McKenna, 2012). Contrariwise, flat-rate pricing (FRP) plans entail marginal prices that remain constant despite fluctuating wholesale prices. While the efficiency gains from RTP are widely acknowledged[1] (Allcott, 2011; Ambec & Crampes, 2020; Borenstein, 2005; Borenstein & Bushnell, 2018; Fabra et al., 2021; Wang et al., 2018), RTP is seldom offered in many jurisdictions, and where offered its uptake is extremely low (Matisoff, 2020).

We explore the effect of detailed risk disclosure information about RTP electricity plans (beyond that commonly provided by electricity retailers) on the uptake of these plans, and on consumers' understanding of the risks involved with these plans. We further investigate whether consumers value tail-risk protection in RTP plans that prevents unusually large bill shocks. An online experiment involving 608 household decision-makers provides data on participants' choices between RTP plans and a FRP plan, and on their understanding of the financial risks involved with RTP electricity plans. Although the personal and wider market benefits of RTP primarily stem from changes in consumers' electricity consumption habits, we focus solely on how additional risk disclosure information and tail-risk protection alters consumers' perceptions of, and therefore choice towards or away from, RTP plans, without the influence of their attitudes towards altering their electricity consumption patterns. We hypothesise that if households are well-informed, then their demand for RTP plans will not be impacted by our risk disclosure information. However, uptake of RTP may decline if households are risk averse and the information improves their understanding of the tail-risk inherent to RTP plans.

We find that this detailed risk disclosure information *increases* participants' propensity to choose a RTP plan, without affecting comprehension or perception of the risks involved with RTP. However, the experience of a large bill shock under RTP (as a result of high wholesale prices) not only decreases subjects' propensity to choose a RTP plan, but also significantly improves understanding of RTP tail-risk. Overall, participants show a tendency to not value the protection provided by risk hedging mechanisms in RTP plans. Even the most risk-averse participants, whose first plan preference is a low-risk FRP plan, value a standard unhedged RTP plan over a RTP plan that provides insurance against tail-risk. Importantly, these results show that, despite providing consumers with a more explicit description of

[1] In allowing marginal prices to fluctuate upwards during peak demand periods, RTP increases demand response, consequently increasing grid stability and allowing for greater penetration of renewable energy sources (Nezamoddini & Wang, 2017).

RTP tail-risk, the provision of a probabilistic risk disclosure does not increase consumers' understanding of this risk, and it may in fact increase the likelihood that they will make a risky choice regarding their electricity plan.

Given that uptake of RTP plans is generally low but increasing (Wang et al., 2018), these findings can help inform the suitability of consumer protection measures available to energy market regulators aiming to (a) help households manage tail-risk in RTP, and (b) mitigate moral hazard concerns. The 2021 Texas Power Crisis highlights the importance of questions surrounding the regulation of RTP. During the Winter Storm Uri in February 2021, electricity demand in Texas soared as people sought to heat their homes, while at the same time failures with natural gas providers caused a shock to supply, which together lead the state to introduce rolling blackouts. At the time of the Crisis, electricity retailer *Griddy* provided RTP plans to over 29,000 residential customers throughout Texas. Customers on the *Griddy* plan were exposed to an essentially unbounded tail-risk in their plans, which was realised during the Crisis as the marginal price of their household electricity soared from approximately US$50/MWh to the price ceiling of US$9,000/MWh, where it remained for almost four days (Peachman & Nethercutt, 2021).

This case demonstrates the significant financial hardship that consumers may experience under RTP; 24,000 of Griddy's customers owed a total of US$29.1 million for electricity consumption over the period of one week in February 2021, with the remaining customers having already had their large bill totals auto-debited from their accounts (Texas Attorney General, 2021). Regulators usually have a consumer protection mandate for utility services given their essential nature, and may be particularly concerned in the case of RTP if consumers do not comprehend the risks of their plan. Indeed, following the Crisis, a class action lawsuit against *Griddy* was launched, founded on an accusation of misleading and deceptive conduct, and price gouging. The assertion that *Griddy's* customers were 'unsophisticated' with 'little knowledge of RTP' aligns with Decker's (2020) observation that "consumers... do not fully appreciate or comprehend the potential risks associated with the new contractual arrangements they are signing up to" (p.162)[2].

Further, the case demonstrates the potential for moral hazard, whereby customers or retailers that do not have tail-risk protection in their RTP plans can have debts forgiven but essentially transferred to taxpayers and/or ratepayers. The class action lawsuit against *Griddy* was resolved after the Texas Attorney General directed *Griddy* to offer releases to customers with unpaid bills, and to provide additional relief for those customers whose bills had already been debited. *Griddy* consequently filed for bankruptcy.

[2]This report was prepared for the Australian Energy Market Commission to discuss the current state, and provide insight into the future desirable state, of consumer protection frameworks in the energy sector.

The likelihood for ex-post political or regulatory intervention to such an energy crisis may inefficiently limit the demand for customers and/or retailers to seek a costly hedge against tail-risks. Regulating information provision and product design are two options available to regulators seeking to increase consumer protection for RTP products. However, it is unclear the extent to which household decision makers (a) comprehend tail-risk in RTP plans, and (b) factor this tail-risk into their choice of electricity plan. Our study takes a first step to investigate the impacts that probabilistic information provision and mandated tail-risk protection have on consumer choices and risk comprehension. To do this, we design an online experiment to address three open empirical questions:

1. Does a probabilistic information provision regarding tail-risk for RTP plans decrease the uptake of RTP products for risk averse residential customers, and does it affect consumers' understanding of the tail-risk involved with RTP products?

2. How does the offer of products with tail-risk protection affect consumer demand for RTP relative to FRP electricity products?

3. Can prolonged exposure to wholesale electricity prices through RTP products impact both demand for tail-risk protection and comprehension of tail-risk through an 'experience effect'?

Given the random allocation of participants to treatment, our experimental design allows for a causal examination of the relationships between risk disclosure information and consumer choice, electricity plan options and plan choice, and risk disclosure information and consumers' comprehension of RTP risk. Experiments provide useful complements to observational studies by revealing causal behavioural insights which would be difficult or costly to uncover otherwise. The lack of observational data due to the low prevalence of RTP products in residential electricity markets makes it difficult to consider a field experiment. Thus, our online experiment serves as a steppingstone towards future experimental research in the field. We explore participants' uptake of RTP plans using an electricity plan choice task that is calibrated to a real-world electricity market. Participants in the 'information arm' receive standard RTP risk disclosure information plus the additional RTP risk information, while those in the 'control arm' receive only the standard information. Within each treatment arm are three product offering arms that vary the availability of products with tail-risk protection, thus the experiment includes six treatment groups.

Related literature

This experiment provides novel insights into consumer choice and protection regarding real-time electricity pricing, although RTP has been around for many years, with California's largest commercial and industrial customers placed under a mandatory RTP scheme in 2000 (Borenstein, 2007). Research in the field has predominantly focused on consumers' demand response and the effect of RTP on household electricity bills. Darby and McKenna (2012) define demand response as an action taken by an individual that either shifts or reduces their electricity consumption in response to fluctuating prices. This is a key concept in many papers on RTP (Fabra et al., 2021; Faruqui & Serigici, 2010; Nezamoddini & Wang, 2017; Stromback et al., 2011; Wang et al., 2018), as it is the main driver of the efficiency gains realised when RTP schemes are implemented (Ambec & Crampes, 2020)[3]. The majority of studies exploring RTP's effect on electricity bills conclude that it saves the average residential customer money, with savings increasing as demand elasticity increases (Allcott, 2011; Ambec & Crampes, 2020; Roldan Fernandez et al., 2017; Zethmayr & Kolata, 2018). Furthermore, the literature extends itself beyond the discussion of financial costs/savings in RTP to detail the significant non-monetary costs some consumers face when signed up to these plans (Ambec & Crampes, 2020; Fabra et al., 2021; Salies, 2013). Time, effort, and level of risk-aversion (where higher risk-aversion leads to greater costs) are just a few elements that make-up these non-monetary costs (Ambec & Crampes, 2020). Other studies suggest that the success of RTP programs within the residential sector is highly dependent on households' willingness and ability to change their electricity consumption habits (i.e., their demand response) (Fabra et al., 2021; Salies, 2013; Vesterberg & Krishnamurthy, 2016). The presence of enabling technologies (for example, price and usage alert systems, demand automation technology) within the home has proven to be an important component of increasing household demand response, and thus, in the success of RTP at reducing peak-load demand and, in some cases, overall electricity demand (Allcott, 2011; Dutschke & Paetz, 2013; Fabra et al., 2021; Faruqui & Sergici, 2010). This study complements these areas of the literature by drawing focus away from cost and demand response and taking a first step towards addressing the informational barriers to informed consent for RTP in the residential sector.

Furthermore, and highlighting another potential blocker to the widespread implementation of RTP schemes, is the finding that retailers may be unwilling to offer RTP, as in many instances they will lose revenue, either due to a fall in their customers' electricity consumption (through the demand response mechanism), or because in some

[3]Leslie et al. (2021) examine how household bills would be impacted by RTP assuming no price responsiveness in their investigation into the distributional consequences of RTP.

markets customers are able to consume more electricity but pay less for it (Campillo et al., 2016; Nezamoddini & Wang, 2017; Poletti & Wright, 2020; Roscoe & Ault, 2010). Once again, this study complements this literature by addressing the barriers to RTP for residential electricity customers.

Moreover, there is a general consensus in the literature that the average residential customer has a narrow understanding of electricity pricing, which restricts their ability to make informed decisions and leads to a reluctance to embrace RTP (Allcott, 2011; Dutschke & Paetz, 2013; Niromandfam et al., 2020; Salies, 2013). The broader literature on consumer choice under risk and uncertainty presents mixed results on the impact of simpler and more explicit risk disclosures on the quality of consumers' decisions. Allowing consumers to sample potential outcomes of financial products before they decide how to allocate their funds has been found to improve decisions on fund allocation between safe and risky financial products (Kaufmann et al., 2013), while more salient interest rate disclosures, comparisons, and de-biasing messages in credit card markets show only small-to-moderate positive effects on credit outcomes (Seira et al., 2017). Moreover, Ragin et al. (2019) find that risk disclosures for insurance products that explicitly state the probability of a loss, the expected loss, and the insurer's profit, do not improve consumer choice away from welfare-decreasing high-load insurance. Lastly, in the context of complex products and pricing, simplified product disclosures are effective at improving customers' choices away from high-fee pension plans (Thorp et al., 2020), and consumer literacy training enhances decision quality regarding mobile plans with complex pricing schemes (Friesen & Earl, 2020). Overall, simplified and more explicit information disclosures appear to enhance consumers' decisions when facing risk, uncertainty, and complex products and pricing. This study contributes to this literature by assessing how risk disclosures and product offerings with tail-risk protection impact consumer choice regarding RTP electricity plans.

Theoretical research on consumer risk preferences in RTP suggests that risk-averse customers are more willing to adopt RTP plans with built-in risk hedging mechanisms, such as plans with a fixed premium and variable marginal price (based on a customer-chosen deductible) (Niromandfam et al., 2020). Moreover, using data from 1142 large industrial customers, Borenstein (2007) showed empirically that risk hedging in the form of forward purchase contracts significantly reduces electricity bill volatility. It is in these areas of the literature that this paper makes its greatest contribution, firstly by exploring how more explicit risk disclosure information affects consumers' understanding of electricity pricing structures, and secondly by exploring whether or not this improves their decisions in the electricity market. Moreover, the experimental evidence our study provides

on consumers' attitudes towards tail-risk protection in RTP extends upon the theoretical conjecture regarding risk hedging mechanisms for RTP. Other papers exploring tail-risk in RTP primarily focus on how retailers can protect themselves from this risk when offering RTP contracts (Deng et al., 2020; Huang et al., 2015; Uehara et al., 2015), which is useful in the context of encouraging electricity providers to offer RTP plans, but not so in the context of convincing consumers to sign up to these plans.

Accordingly, despite the growing body of RTP research, very little is known about the effect of risk disclosure information on consumers' electricity plan preferences, and on their understanding of the risks involved with RTP, a crucial element of consumer acceptance and protection in RTP. This paper takes a first step towards filling this gap by exploring, via an online experiment, the causal relationship between: (1) risk disclosure information that explicitly communicates the financial risks of RTP electricity plans to the consumer, and (2) residential electricity consumers' demand for RTP plans, and their understanding of the risks involved with these plans. This study contributes to the literature by showing that until consumers actually experience a large bill shock on a RTP plan, they do not value the financial risk involved with these plans, even when provided with probabilistic risk disclosure information that explicitly outlines this risk. A further contribution of this paper is the finding that consumers do not value protection from the tail-risk inherent to wholesale prices when that protection is in the form of a fixed premium payment. Our results are important because they provide evidence for policymakers with a consumer protection mandate that regulation requiring the provision by energy retailers of a probabilistic risk disclosure for RTP plans may impact plan choice without necessarily improving consumers' understanding of the financial risks of these plans. Thus, it may be useful for regulation of RTP products to focus on mandating measures that protect consumers from facing this risk at all, such as requiring that all RTP contracts include a risk hedging mechanisms, placing a mandatory cap on energy charges, or requiring that consumers are granted a trial period for RTP plans.

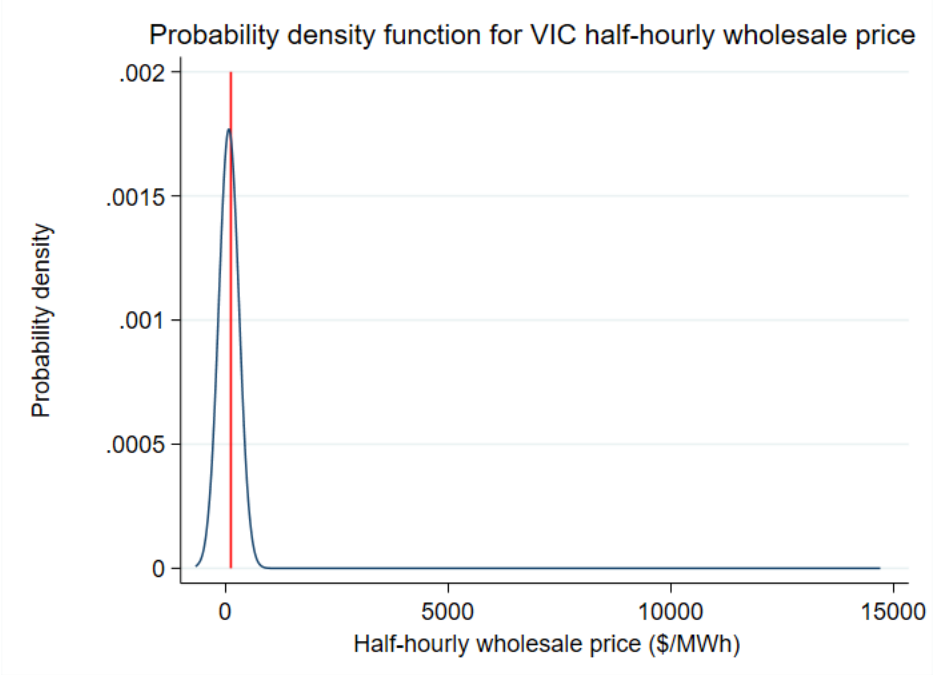
2 Industry background

We calibrate our experiment to the Australian electricity market setting. Like pre-Crisis Texas, Australia has a high market price ceiling and a small but growing RTP retailer. Unlike Texas, the RTP products offered in Australia have tail-risk protection.

The National Electricity Market (NEM) is the Australian wholesale market through which energy retailers and generators trade electricity in Victoria, New South Wales, the Australian Capital Territory, Queensland, South Australia and Tasmania. The market is

highly competitive, and operates around a common pool, where the wholesale (or spot) price reflects physical supply and demand across the market[4]. The Australian Energy Market Commission (AEMC) set the price cap for the NEM, which they increased from \$14,700/MWh in financial year 2019-2020 to \$15,000/MWh in 2020-2021[5]. Figure 1 displays the probability density function for half-hourly Victorian wholesale electricity prices from 1 January 2015 to 1 January 2021. This figure provides a visualisation of the tail-risk inherent in RTP plans without built-in hedging mechanisms, where customers go unprotected from extremely high wholesale prices, which although rare, can pose a serious financial threat to households, as seen in Texas in February 2021.

Figure 1: Probability density function for Victorian half-hourly wholesale electricity prices



Notes: Based on Victorian wholesale price data from 1 January 2015 to 1 January 2021. The half-hourly spot price reached a maximum of \$14,700/MWh twice during this period. The red reference line at \$117.06/MWh represents the 90th percentile of Victorian half-hourly wholesale prices during the period, highlighting the large tail-risk inherent to wholesale electricity prices.

The Australian Government has created the Default Market Offer (DMO), which stipulates the maximum yearly price a retailer is allowed to charge customers on standing offer contracts in Queensland, New South Wales and South Australia, acting as a safety net

[4]Information on the NEM obtained from https://www.energy.gov.au/government-priorities/energy-markets/national-electricity-market-nem

[5]Information on these price caps can be found at https://www.aemc.gov.au/news-centre/media-releases/schedule-reliability-settings-2020-2021

for passive energy customers [6]. The DMO, is also referred to as the 'reference price', as retailers must compare the price of all plans offered to the DMO. Victoria use a similar mechanism called the Victorian Default Offer (VDO)[7]. From September 2020, all households and small businesses within embedded electricity networks cannot be charged more than the VDO [8].

In order to be eligible for any form of dynamic electricity pricing plan, a household must have a smart electricity meter installed at their home, which measures energy consumption in real time and remotely sends this information back to the retailer. While all Victorian households have a smart meter installed[9], just 17.4% of households across the other states and territories in the NEM have a smart meter (AEMC, 2020). This is one factor contributing to the low uptake of dynamic electricity pricing plans across Australia, with 79.2% of customers in the NEM signed up to a FRP plan for their electricity. The remaining 20.8% of customers are reported to be signed up to time of use (TOU) pricing, where consumers are charged higher tariffs for consumption during peak demand periods (AEMC, 2020). TOU tariffs, which reflect long term average expectations of daily peak spot prices, are stable over long time periods (Darby & McKenna, 2012). Very few Australian customers take an active role when it comes to household energy, with most remaining loyal to their electricity retailer, even if they could find a better deal elsewhere (Mountain & Burns, 2020). Thus, only a very small number of Australian households are signed up to a RTP plan. In fact, in October 2020, *Amber Electric,* who operate in each of the NEM states and territories except Tasmania, reported that they provided RTP plans to 2000 residential customers[10]. When accounting for *Powerclub*, the other Australian electricity retailer that offers RTP plans to residential customers, this amounts to an estimated 4000 households that are signed up to a RTP plan, or 0.05% of Australian households (based on population and household data from the Australian Bureau of Statistics[11]).

[6] Information on the DMO found at https://www.aer.gov.au/retail-markets/guidelines-reviews/retail-electricity-prices-review-determination-of-default-market-offer-prices-2020-21#:~:text=The%20DMO%20is%20a%20new,standing%20offer%20customer%20each%20year.

[7] Reference price and VDO information obtained from https://www.canstarblue.com.au/electricity/reference-price/

[8] Additional information on the VDO obtained from https://www.energy.vic.gov.au/victoriandefaultoffer

[9] Information on Victorian smart meters retrieved from https://www.energy.vic.gov.au/electricity/smart-meters

[10] *Amber* customer data sourced from https://www.aer.gov.au/system/files/Amber%20Electric%20Pty%20Ltd%20-%20Application%20for%20electricity%20retailer%20authorisation%20-%20October%202020_0.pdf

[11] Australian state and territory population information is for March 2021 from https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release. Australian household data is for 2016 (projected to 2041) from https://www.abs.gov.au/statistics/people/population/household-and-family-projections-australia/latest-release

3 Research strategy

3.1 Experimental design

3.1.1 Experimental procedure

The experiment comprised three components: an electricity plan choice task to provide insight into the impact of tail-risk information and protection on demand for RTP, a lottery game to reveal participants' risk tolerance, and a questionnaire gathering demographic information and assessing participants' understanding of RTP tail-risk. This section describes each of these components after firstly providing a brief explanation of the procedures followed by the participants prior to the experiment. Appendix C contains a link to screenshots of the instructions and decision screens for all six treatment groups.

Before commencing the online experiment, participants were taken to a screen displaying the consent form, which included a link to the explanatory statement. The statement contained information on the purpose of the research, payment, confidentiality, storage and use of data, and information on where to direct enquiries about the results or complaints. It also explained that, while the decisions made in the experiment had payoff consequences for the participant, the electricity plans described in the experiment are hypothetical, and so these plans and their associated outcomes do not necessarily translate to actual electricity plans and their outcomes.

Electricity plan choice task

After completing the consent form and filling out three questions on demographics (gender, age and location), participants completed task 1 (the electricity plan choice task). During the task, participants received information on FRP and RTP electricity pricing plans before making a choice between one FRP plan, and either a standard RTP plan or a hedged RTP plan, for four consecutive rounds. Some participants were offered a choice between all three plans. There was no cost to switching plans between rounds. The standard RTP plan exposed participants to the full range of wholesale prices, while the hedged RTP plan was set up to mimic the RTP risk-hedging mechanism proposed by Niromandfam et al. (2020) (and that used by *Amber Electric*), where participants paid a premium built into their fixed price to protect themselves from exposure to extremely high wholesale prices. The information provided to participants on FRP and RTP plans included an overview of the main features of both FRP and RTP plans, with a specific focus on RTP plans and how they differ from FRP plans. The characteristics of RTP plans, including information on risk, were described using information that was set up to mimic that provided on the website of *Amber*

Electric. Figures 2 and 3 display the standard risk information on RTP electricity plans that was provided to all treatment groups compared to that provided by *Amber Electric* on their website[12].

Three of the six treatment groups were provided with additional risk disclosure information on the RTP electricity plans, which took the form of a table overviewing the likelihood that the charges on the electricity bills of the RTP plans offered to them will be lower than, the same as, or higher than those of the standard FRP plan offered. This information was integrated into the decision screen of each participant, so that they could see this information before making their decision in each round. Table 1 outlines the treatment groups and their status regarding risk information and electricity plan options. Treatment groups 4, 5, and 6 (i.e., T4, T5 and T6) comprise the information arm, while treatment groups 1, 2, and 3 (i.e., T1, T2 and T3) make-up the control arm. Figure 4 highlights the additional information that was provided to participants in the information arm (examples from T3 and T6 are shown here). This information was chosen as it reflects what might be conceivable under stricter regulation of risk disclosure in electricity industries worldwide, by describing the risk of high charges, and the inherent tail-risk involved with unhedged RTP plans. The difference in the risk information provided between the control arm and the information arm is the primary variable that enables us to answer our main research question, however within the two treatment arms, the variation in electricity plans offered affords us insight into whether or not consumers value tail-risk protection in RTP plans, and how choices towards or away from RTP plans differ based on the other plans offered in the market.

Table 1: Treatment group outline

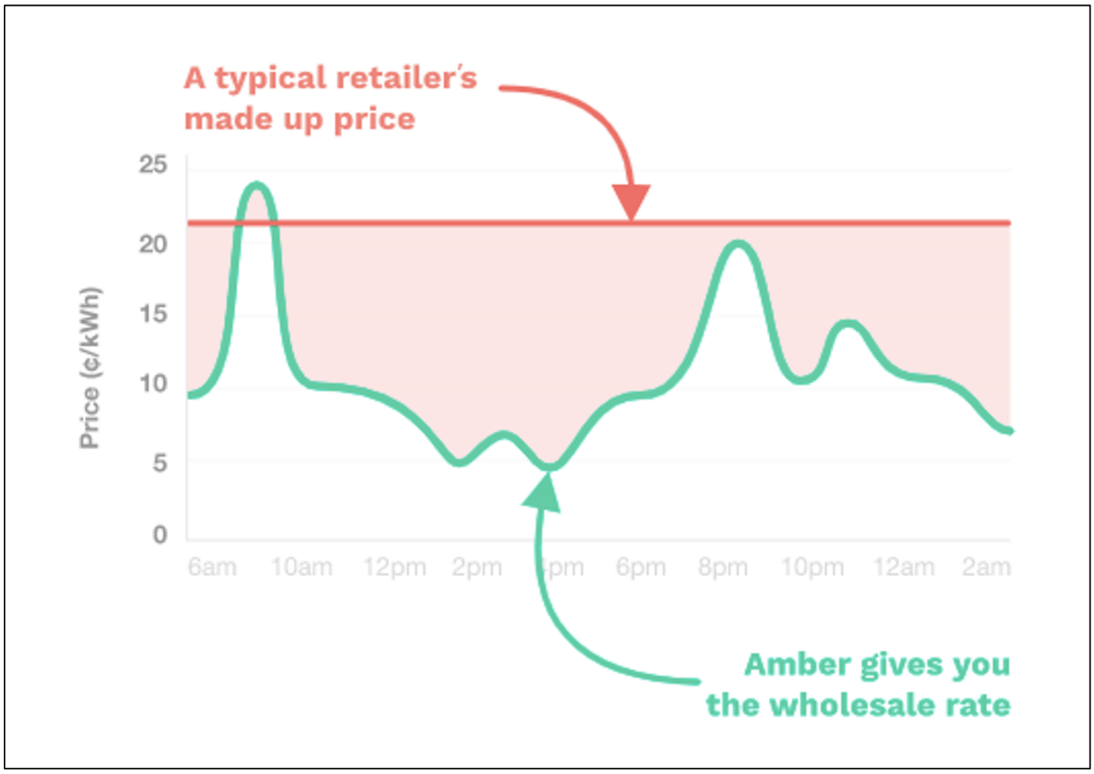
	FRP and standard RTP	***FRP and hedged RTP***	***FRP, standard RTP, and hedged RTP***
Standard RTP risk information	T1	T2	T3
Additional RTP risk information	T4	T5	T6

[12] *Amber Electric* wholesale price graph and table shown in figures 2 and 3 obtained from https://www.amber.com.au/how-it-works

Figure 2: (A) Electricity wholesale price graph provided to all treatment groups. (B) Graph from the website of Amber Electric.

A

B



Notes: Panel A presents the theoretical wholesale price graph and accompanying text that formed part of the RTP risk disclosure information provided to all participants across the information and control arms. This information was designed to mimic that provided by *Amber Electric* on their website (pictured in panel B).

Figure 3: (A) Wholesale price table provided to all treatment groups. (B) Table from the website of Amber Electric.

A

The table below demonstrates the frequency at which the half-hourly wholesale price usually sits within different price bands.

Table: Frequency of wholesale price bands

Price Range (kWh)	Frequency
Below E$0.00	0.1%
E$0.00 – E$0.22	More than 88%
E$0.22 – E$0.35	Less than 9%
E$0.35 – E$3.00	Less than 2.5%
Above E$3.00	0.1%

B

MEL SYD ADE BRI

Price Range (kWh)	Frequency
Below 0¢	0.1%
Between 0¢ - 25¢	89.3%
Between 25¢ - 35¢	8.1%
Between 35¢ - $3	2.4%
Above $3	0.1%

Wholesale prices in table are based on actual prices over the time period 19 June 2018 - 2 April 2020, for the Melbourne postcode 3000.

Notes: Panel A presents the table outlining the frequency of wholesale price bands that formed the second part of the RTP risk disclosure information provided to all participants across the information and control arms. This information was designed to mimic that provided by *Amber Electric* on their website (pictured in panel B).

Figure 4: (A) T3 decision screen. (B) T6 decision screen.

A

Please select one response.

Flat-Rate Pricing Plan

If you choose the flat-rate plan, you will be charged:

1. E$0.22/kWh
2. E$80 fixed price

Real-Time Pricing Plan #1

If you choose the real-time plan, you will be charged:

1. Time-varying wholesale price/kWh (no price cap)
2. E$80 fixed price

Real-Time Pricing Plan #2

If you choose the real-time plan, you will be charged:

1. Time-varying wholesale price/kWh (average price you pay capped at E$0.28)
2. E$90 fixed price

B

Please select one response.

Flat-Rate Pricing Plan

If you choose the flat-rate plan, you will be charged:

1. E$0.22/kWh
2. E$80 fixed price

The expected bill for the average household with 1000kWh consumption is:

1000 x 0.22 + 80 = E$300

The table below shows the chance that the bill for the average household will sit within different bands:

Bill Range	Chance
E$300	100%

Real-Time Pricing Plan #1

If you choose the real-time plan, you will be charged:

1. Time-varying wholesale price/kWh (no price cap)
2. E$80 fixed price

The table below shows the frequency at which the bill for the average household with 1000kWh consumption will sit within different bands:

Bill Range	Chance
E$201 – E$250	42.6%
E$251 – E$300	37.7%
E$301 – E$370	11.5%
E$371 – E$440	6.5%
E$441 or above	1.7%

Real-Time Pricing Plan #2

If you choose the real-time plan, you will be charged:

1. Time-varying wholesale price/kWh (average price you pay capped at E$0.28)
2. E$90 fixed price

The table below shows the frequency at which the bill for the average household with 1000kWh consumption will sit within different bands:

Bill Range	Chance
E$201 – E$250	34.4%
E$251 – E$300	37.7%
E$301 – E$370	27.9%
E$371 – E$440	0%
E$441 or above	0%

Notes: This figure displays the additional RTP risk information provided to participants in the information arm. T3 was a part of the control arm and T6 was part of the information arm. The decision screens of these two groups were chosen to demonstrate what the additional risk information looked like for all three plans offered during the experiment, as T3 and T6 were the only two groups that were given a choice between all three plans.

Participants in T3 and T6, who were given a choice between all three plans, saw the standard and the hedged RTP plans named as 'real-time pricing plan #1' and 'real-time pricing plan #2' respectively. After their choice in each of the four rounds, participants were shown the bill for the plan they chose, and the bill(s) for the plan(s) they did not choose. These bills were set up to approximately mirror the energy consumption and charges that the average Australian household would experience on a quarterly basis, thus total electricity consumption was set to 1000kWh on each bill. Participants did not make choices regarding consumption during the task. The total charges on these bills were displayed in experimental

dollars (E$), and this information could then be used by participants when deciding between plans in the next round.

The FRP plan was set up such that the marginal electricity price was always E$0.22, and the fixed price was E$80 on each bill. Hence, in every round, for all participants, the total charges for the FRP plan were E$300. The marginal electricity price for both the standard RTP plan and the hedged RTP plan varied based on a distribution of 61 prices, from E$0.145 up to E$0.385, with mean E$0.195 and median E$0.18. Supplementing these energy charges are a combination of connection fees (fixed, daily fees) and approximately 10c in volumetric fees. The price distribution can be found in appendix table A.1, and a graphical representation of the distribution is shown in appendix figure A.1. The distribution was created based on data from the Australian Energy Market Operator (AEMO) on the average quarterly load-weighted Victorian electricity spot prices from January 2016 to December 2020 (the distribution of which is also shown in figure A.1). In each round, after a participant had made their choice between plans, the computer randomly generated a marginal price for the RTP plan(s) based on this distribution. This price was applied to all RTP plans offered in a treatment, however, the marginal price for the hedged plan was capped at E$0.28 (no such price cap existed for the standard RTP plan). Thus, both the mean marginal price and the standard deviation of marginal price for the hedged RTP plan, at E$0.19 and E$0.04, respectively, were lower than those of the standard RTP plan, at E$0.195 and E$0.05, respectively. A caveat here is that basing the price distribution on average quarterly prices eliminates some of the volatility of wholesale prices that customers would experience when exposed to the half-hourly spot price. However, the average quarterly price is used as the bills are meant to represent quarterly energy consumption and charges.

Furthermore, the fixed price for the standard RTP plan was set at E$80, to mirror that of the FRP plan, while the hedged plan included a premium of E$10, taking the fixed price to E$90, which is approximately equivalent to the hedging fee charged by *Amber Electric*, although they charge this fee within the marginal price (see appendix figure A.2 for an example of one month's electricity charges for a Victorian household signed up to *Amber Electric* on a RTP electricity plan[13]). Given its higher fixed cost, the mean total bill for the hedged RTP plan was E$280, while that of the standard RTP was E$275. The mean total bill for each of the RTP plans were designed to be lower than the mean bill total for the FRP plan, to reflect that in the NEM, on average, consumers would save money on RTP plans compared to FRP plans. Table 2 sets out (in general terms) the prices and total bills

[13] *Amber's* hedging fee varies over time, but is approximately $7.70 for 1000kWh of energy consumption in 2021/22. Further, while their volumetric fees also vary over time, these are approximately 11c/kWh in 2021/22, while their fixed fees total approximately $70 for a three month period.

for each type of electricity plan offered.

Table 2: Fixed and marginal prices, consumption, and bills of the electricity plans offered during the experiment

Plan	**Consumption (kWh)**	**Fixed price (E$)**	**Marginal price (E$/kWh)**	**Bill total in each round (E$)**
FRP plan	1000	80	0.22	300
Standard RTP plan	1000	80	0.xx	xxx
Hedged RTP plan	1000	90	0.xx	xxx

Notes: The marginal price for both the standard and hedged RTP plans was randomly selected for each participant, in each round, from the price distribution in appendix table A.1. Thus, the total bill for these plans varied from round to round, and from participant to participant.

Lottery choice task

Next, participants completed task 2 – a lottery game designed to measure their risk attitudes. Participants were presented with nine scenarios, each offering a choice between Option A, which paid-out E$5 with certainty, and Option B, which paid-out E$10 with some probability and E$0 with the complementary probability. This game is similar to Brown and Stewart's (1998) risk attitudes experiment, where participants also had to choose between a guaranteed payout and a lottery. In our game, while Option A remained constant, Option B became more risky as participants progressed from scenario 1 to scenario 9, with the chance of a payout of E$10 decreasing from 90% in task 1 to just 10% in task 9. We measure risk preferences by observing the number of risky choices made by a participant. Thus, an extremely risk-averse participant would be expected to choose Option A for task 1 and beyond, whereas an extremely risk-loving participant would choose Option B for all scenarios. Each scenario was presented on a different screen during the experiment, so after participants made their choice for scenario 1, they progressed to scenario 2 on the subsequent screen by pressing the 'next' button, and so on until they had completed all nine scenarios.

Comprehension task

The third and final task of the experiment was a survey consisting of nine questions, four of which were set up to elicit participants' comprehension of the risks involved with RTP electricity plans. The other five gathered information on participants' history with residential electricity plans, their education and occupation. The comprehension questions were included to provide insight into whether the additional risk disclosure information increases participants' understanding of the risks involved with RTP plans, thus providing

data for our secondary research question. All nine questions can be found in the participant instructions in appendix C.

3.1.2 Incentives

Incentive payments were used to motivate participants to take part in the experiment, and to encourage them to make judicious choices during tasks 1 and 2. All participants were awarded a base payment of AU$3 for completing the experiment, and all had the chance to earn a bonus reward of between AU$0 - AU$10, determined based on both chance and their choices during either task 1 or task 2. Total payments were calculated at the end of the survey, at which point the computer randomly selected task 1 or 2 for the bonus payment. Participants were shown the amount of their bonus, how it was calculated, and their total payment (including the AU$3 base payment). If task 1 was chosen, participants received payment based on the following equation: $Reward = [1700 - X] * 0.01$, where X equals the sum of all charges across the four rounds. This equation was set up such that if a participant chose the FRP plan in each of the four rounds of task 1, they would receive a guaranteed bonus payment of AU$5[14]. If task 2 was chosen, then the computer completed a second randomisation to choose one of the 9 scenarios from round 2 for payment. A participant's outcome in experimental dollars on this scenario was then converted directly into AUD for the bonus payment. Thus, if the participant chose Option A for the randomly selected scenario, their bonus reward would total AU$5. However, if they chose Option B, then the computer randomly generated a number between 0 and 100, and if that number was less than or equal to that scenario's probability of a E$10 payout, the participant received a bonus reward payment of AU$10, and they received AU$0 otherwise. On average, participants completed the experiment in approximately 20 minutes and the average total payment was AU$8.81 (equating to an average hourly rate of AU$26.43), with standard deviation AU$2.15.

3.2 Sample characteristics

The online experiment was completed by 608 participants, all of whom were recruited via *Pureprofile*, an online panel of over 350,000 Australians. Participants were recruited via a post on their personal *Pureprofile* 'news feed' before being directed to a screen displaying the consent form. All participants were aged 18+ and were either the primary decision-maker

[14] All task 1 bonus payments were rounded up to the next whole dollar (for example, an earned bonus reward of AU$4.24 was rounded up to an actual bonus reward of AU$5), as PureProfile's system only allowed for payment in whole dollars.

for their household, or shared this responsibility[15]. Participants were randomly assigned to treatment, with 101 participants allocated to each of T2, T3, T5, and T6, and 102 participants in both T1 and T4. The sample included 314 females, 293 males, and 1 non-binary participant, and the composition of the sample was designed to match the Australian state and age bracket population shares[16]. After reading the instructions for task 1, but before commencing the task, participants were asked two comprehension questions regarding the instructions (refer to appendix C for these questions). If a participant failed to answer both questions correctly on their second attempt, they were screened out of the survey. Additionally, for quality control, *Pureprofile* assigns ratings to all their members based on the quality of answers provided across surveys, and if a member's rating drops below a certain threshold, they are suspended from the platform. *Pureprofile* also conduct multiple tests and checks to avoid fraud and maintain data quality[17].

All demographic characteristics except age and education were balanced across treatment groups, with those in the information arm slightly younger and more educated on average than those in the control arm. However, these slight differences did not affect the overall balance between treatment groups across observable variables. Summary data on demographics can be found in appendix table B.1, while data on balance is shown in appendix table B.2.

4 Data

We present two distinct analyses in the results section, the first being an analysis of plan choice, for which a dummy that equals 1 if FRP was chosen, and 0 otherwise, is regressed on treatment group. Wald tests are subsequently performed on these OLS estimates, which allows inference of both the effect of the additional risk information on plan choice, as well as the effect of product offerings on plan choice. Rounds 2-4 are considered separately to round 1 in this specification, as the RTP marginal price from the previous round is expected to create a feedback effect that influences participants' decision between plans in rounds 2, 3

[15]Between 60-70% of all *Pureprofile* members are either a primary or shared household decision maker. Six participants from the sample used in this experiment did not indicate whether they were a primary or shared decision maker in their household. Participants were screened out of the survey if they indicated that they were less than 18 years old, or if they indicated that they were not the primary or shared decision maker in their household.

[16]All Australian states and territories were represented in the sample, and the age brackets included: 18-25, 26-30, 31-40, 41-50, 51-60, 61-70, and 71-99.

[17]These checks include digital fingerprinting, unique survey IDs, cookies checks, and GeoIP on all surveys to ensure no participant completes a survey twice. CAPTCHA is used to verify that no robots answer their surveys, and the raw survey data is sent to the coding team to check for bad responses, 'straight lining', and a final check for fraud or a participant who has completed the survey twice.

and 4. Thus, a control is included for *previous round RTP per-unit price* in the regression for rounds 2-4. Additionally, considering rounds 2-4 collectively changes the dataset to closely resemble panel data (with each round acting as a time period), with $N = 1824$. Hence, standard errors are clustered at the participant level to account for each participant making multiple decisions. Two dummies, one for round 3 and one for round 4, are also included in this specification.

A second regression for both round 1 and rounds 2-4 is conducted with informative controls, where *lottery task risk metric* represents participants' risk aversion level - the greater the number of times a participant chose Option B (the risky option) during the lottery game, the higher their lottery task risk metric will be. Moreover, *heard of RTP before* and *has signed up to RTP* indicate whether a participant had heard of real-time pricing electricity plans prior to the experiment, and whether they had previously, or were at the time of the experiment, signed up to an RTP plan for their home electricity. Lastly, *has solar panels* indicates that a participant had solar panels installed at their home (this is included as a measure of participants' interest and investment in their home energy). We also include demographic controls in these regressions, which include age, gender, level of education, and place of residence (metropolitan or a regional area). Table 3 provides descriptive statistics for the informative controls, while descriptive statistics for the demographic controls can be found in appendix table B.1.

Table 3: Descriptive statistics for informative controls (by treatment group)

Variable	**T1**	**T2**	**T3**	**Control arm**	**T4**	**T5**	**T6**	**Information arm**
RTP per-unit price R1	0.20	0.19	0.19	0.19	0.21	0.18	0.20	0.19
RTP per-unit price R2	0.20	0.20	0.20	0.20	0.19	0.19	0.20	0.19
RTP per-unit price R3	0.20	0.20	0.19	0.20	0.18	0.19	0.19	0.19
Lottery task risk metric	3.40	3.11	2.82	3.11	3.10	3.48	2.95	3.17
Heard of RTP before	0.28	0.27	0.26	0.27	0.29	0.36	0.31	0.32
Has signed up to RTP	0.17	0.15	0.09	0.13	0.20	0.19	0.14	0.17
Has solar panels	0.31	0.37	0.33	0.34	0.27	0.31	0.30	0.29
Σ RTP per-unit prices	0.79	0.77	0.78	0.78	0.78	0.76	0.79	0.77

Notes: Variable means are reported for each treatment group and each treatment arm. T1, T2, and T3 comprise the control arm, and T4, T5, and T6 comprise the information arm.

In a secondary analysis, we use OLS regressions to provide insight into the effect of the additional risk information on participants' comprehension and perception of the financial risks of RTP plans. Firstly, five binary dependent variables representing participants' ratings of RTP risk (from very low to very high) are regressed on treatment arm, with informative and demographic controls. This component of the analysis provides insight

into participants' perception of the risks of RTP plans. Secondly, we perform a regression of binary variables of participants' responses to the three survey questions measuring risk comprehension (= 1 if question answered correctly) on treatment arm, with informative and demographic controls (see appendix C for these questions). This component of the analysis includes four dependent variables, one for each of the three questions and a composite variable that equals 1 if a participant correctly answered all three risk comprehension questions. Table 4 provides a description of each of these four comprehension variables, where 'yes' indicates that the participant answered that particular question (or all three, in the case of the composite) correctly, and 'no' indicates an incorrect answer. Throughout all analyses on risk comprehension and perception, Σ *RTP per-unit prices* replaces *previous round RTP per-unit price* as an informative control, representing the sum of the marginal price received by a participant across each of the four rounds. Descriptive statistics for this variable are presented in the last row of table 3.

Table 4: Description of risk comprehension variables

Variable label	**Comprehension component tested**	**Value**
Risk Q1	Do participants understand that RTP plans do not always lead to lower bills?	Y = 1 N = 0
Risk Q2	Do participants understand that the risk of bill shocks is greater on RTP plans than FRP plans?	Y = 1 N = 0
Risk Q3	Do participants understand the magnitude of financial risk that can accompany RTP plans?	Y = 1 N = 0
Risk composite	Do participants understand all three of the above comprehension components?	Y = 1 N = 0

Notes: Three questions testing participants' comprehension of the risks involved with RTP plans were included in task 3 of the experiment. These questions can be seen in appendix C. *Risk Q1* aligns with question 3 of task 3, *Risk Q2* aligns with question 5 of task 3, and *Risk Q3* aligns with question 6 of task 3. The table describes which component of comprehension was tested by each question.

5 Results

Here, we first examine the impact of our probabilistic information provision on the uptake of RTP plans and on participants' understanding of the financial risks involved with RTP in section 5.1, before exploring the effect of the product offerings on choice of electricity plan in section 5.2. Lastly, in section 5.3, we exploit the multi-round nature of the experiment to describe the role that experience plays in both participants' electricity plan choice and their comprehension of the risks of RTP.

5.1 Impact of information provision on plan choice and risk comprehension

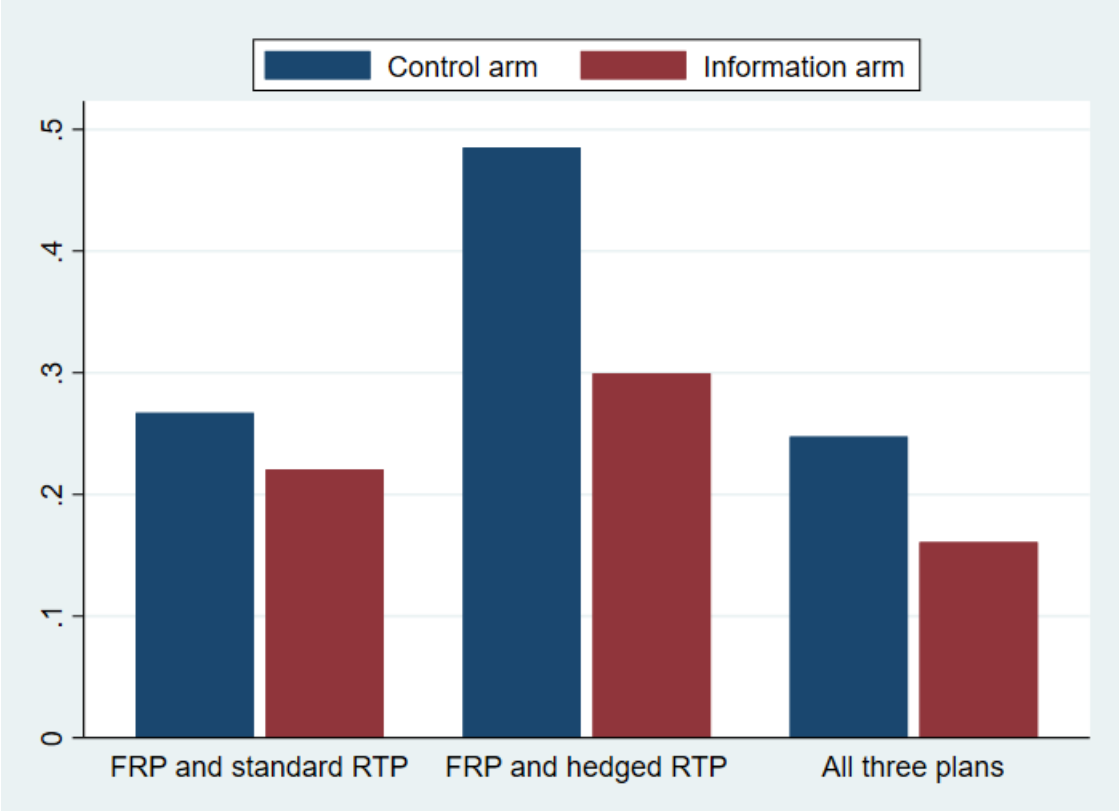
Overall, we find that the propensity of participants to choose a RTP plan is greater than the propensity to choose the FRP plan. Figure 5 highlights this, showing that the proportion of choices towards FRP is less than 0.5 for all treatment groups across the four rounds. The information presented in table 5 complements this figure. The graph also highlights that participants in the information arm were more inclined to choose a RTP plan over the FRP plan than those in the control arm, indicating that the additional risk disclosure information made the RTP plans seem more favourable. This result would not be unusual with high shares of risk-neutral households, as the table outlining the chance of the bill sitting within different price bands indicates that the probability of a bill falling below E$300 is 72.1% for the hedged RTP plan, and 80.3% for the standard RTP plan. However, table 3 demonstrates that the majority of participants in our experiment are risk-averse, as the average participant chose only 3 risky choices during the lottery game in task 2 across both the information and control arms. Thus, this result contradicts our hypothesis, which is predicated on risk-aversion, that uptake of the RTP plans would be lower in the information arm, as it was expected that these tables would highlight the financial risk associated with RTP and turn participants away from choosing these plans. This effect was hypothesised to be particularly strong for the standard RTP plan, where the additional risk information alerts participants that the chance of receiving a bill totalling over E$370 is 8.2%.

Table 5: Plan choices across the four rounds (by treatment group)

Plan choice	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Flat-rate plan (%)	26.7	48.5	24.8	22.1	30.0	16.1
Hedged real-time plan (%)	-	51.5	13.9	-	70.1	21.5
Standard real-time plan (%)	73.3	-	61.4	77.9	-	62.4

Notes: The numbers reported signify the percentage of all participants' choices towards a particular electricity plan, within a particular treatment group, across all four rounds of task 1. T1 and T4 were offered only the FRP plan and the standard RTP plan. T2 and T5 were offered only the FRP plan and the hedged RTP plan. T3 and T6 were offered all three plans. T1-T3 comprise the control arm, where participants received only standard risk disclosure information on RTP plans, and T4-T6 comprise the treatment arm, where participants received the additional piece of risk disclosure information.

Figure 5: Proportion of choices towards the FRP plan over rounds 1-4 (by treatment group)



Notes: T1, T2, and T3 comprise the control arm. T4, T5, and T6 comprise the information arm. T1 and T4 were both offered the FRP and standard RTP plans, T2 and T5 were both offered the FRP and hedged RTP plans, and T3 and T6 were offered the FRP plan and both RTP plans.

We quantitatively analyse the effect of the information provision on demand for electricity plans using the specifications outlined in section 4. Table 6 displays the OLS estimates for choice towards the FRP plan in round 1 and in rounds 2-4. The rounds 2-4 regression with no controls in column 3 is used solely as a reference point for columns 4 and 5, which provide richer information on participants' choices across these rounds. A comparison (within product offering arms) of the coefficients for the groups in the control arm and the information arm further highlights how the probabilistic risk disclosure boosted demand for RTP plans.

Table 6: OLS estimates for choice towards FRP plan

Variables	*Selected the FRP plan in round...*				
	1	**1**	**2-4**	**2-4**	**2-4**
	(1)	(2)	(3)	(4)	(5)
T1	0.32***	0.43***	0.25***	-0.28***	-0.15*
	(0.05)	(0.11)	(0.03)	(0.05)	(0.08)
T2	0.59***	0.71***	0.45***	-0.07	0.07
	(0.05)	(0.11)	(0.04)	(0.06)	(0.09)
T3	0.36***	0.47***	0.21***	-0.31***	-0.17**
	(0.05)	(0.11)	(0.03)	(0.05)	(0.08)
T4	0.24***	0.35***	0.21***	-0.30***	-0.17**
	(0.04)	(0.11)	(0.03)	(0.05)	(0.08)
T5	0.35***	0.48***	0.28***	-0.21***	-0.07
	(0.05)	(0.11)	(0.03)	(0.05)	(0.08)
T6	0.22***	0.34***	0.14***	-0.37***	-0.24***
	(0.04)	(0.11)	(0.03)	(0.04)	(0.08)
Previous round RTP per-unit price				2.64***	2.61***
				(0.21)	(0.21)
Round 3 dummy			0.00	-0.01	-0.01
			(0.02)	(0.02)	(0.02)
Round 4 dummy			0.01	0.01	0.01
			(0.02)	(0.02)	(0.02)
Lottery task risk metric		-0.01			-0.01*
		(0.01)			(0.01)
Heard of RTP before		-0.07			-0.03
		(0.04)			(0.03)
Has signed up to RTP		0.09*			0.03
		(0.05)			(0.04)
Has solar panels		0.01			0.04*
		(0.04)			(0.03)
Demographic controls	No	Yes	No	No	Yes
R^2	0.39	0.41	0.29	0.36	0.38
Observations	608	608	1824	1824	1824

Notes: * significant at 10%. ** significant at 5%. *** significant at 1%. Standard errors in parentheses, robust for specifications 1 and 2, and clustered at the level of randomisation for specifications 3, 4, and 5. The data used for the regressions in columns 3-5 represents panel data, to account for the feedback effect of the bills and RTP marginal prices experienced in the previous round. Thus, 1824 observations are recorded for these specifications. Demographic controls include age bracket, gender, area of residence (metro/regional), primary/joint household decision maker, and education level. *Previous round RTP per-unit price* is, for rounds 2-4, the marginal price drawn for the RTP plan(s) faced by a participant the preceding round of task 1. *Lottery task risk metric* is the number of times a participant chose the lottery option (option B) during task 2 of the experiment. *Heard of RTP before* and *has signed up to RTP* indicate, respectively, whether a participant has heard of RTP electricity plans before, and whether they have ever signed up to a RTP plan for their home energy.

The results of the Wald tests for the effect of the additional risk information on plan choice are presented in table 7. We conducted these tests on the estimates from both the controlled (table 6, columns 2 and 5) and uncontrolled regressions (table 6, columns 1 and 4), and the results were not systematically different across the two specifications. Thus, the tests of the uncontrolled regressions are reported here. These tests consolidate the finding that the additional risk information decreased participants' propensity to choose the FRP plan, evidenced by the significance of tests 4 and 5. Moreover, the statistical insignificance of test 1, and the significance of tests 2 and 3, reveal that this result is driven solely by the differences between groups T2/T5 and T3/T6, both in round 1 and in rounds 2-4. This indicates that when the standard RTP plan was presented next to only the FRP plan, the additional risk information had no effect on plan choice. That is to say, the appeal of the standard RTP plan to participants was just as strong without the enhanced risk disclosure information as it was with this information.

Table 7: Wald tests for risk information impact

Test	**Comparison samples**	**Null hypothesis**	***p*-value**	
			Round 1	Rounds 2-4
1	T1, T4	$\beta_{T1} = \beta_{T4}$	0.161	0.677
2	T2, T5	$\beta_{T2} = \beta_{T5}$	0.000	0.002
3	T3, T6	$\beta_{T3} = \beta_{T6}$	0.029	0.043
4	T1, T2, T3, T4, T5, T6	$\beta_{T1} + \beta_{T2} + \beta_{T3} = \beta_{T4} + \beta_{T5} + \beta_{T6}$	0.000	0.001
5	T1, T2, T3, T4, T5, T6	$(\beta_{T1} = \beta_{T4}), (\beta_{T2} = \beta_{T5}), (\beta_{T3} = \beta_{T6})$	0.000	0.003

Notes: Wald tests for round 1 are conducted on coefficients from specification 1 in table 6. Tests for rounds 2-4 are conducted on coefficients from specification 4 in table 6. Reported p-values are for the F-statistic produced by the Wald test.

In our secondary analysis on risk comprehension and perception, we find that the additional risk information increases participants' perception of risk related to RTP plans. Table 8 reports the OLS estimates for perceived financial risk. This regression is based on question 4 in task 3 of the experiment: *what are the chances of a customer on a real-time pricing plan receiving an unusually expensive bill as a result of high wholesale prices?* The results reveal that the information treatment had no effect on risk perception. Although information arm participants were 3 percentage points more likely to rate the risk of a bill shock as very high, this result shows statistical significance only at $\alpha = 0.10$.

Table 8: OLS estimates for perceived RTP financial risk

Variables	**Very low (< 5%)**	**Low (5-10%)**	**Moderate (10-30%)**	**High (30-50%)**	**Very high (> 50%)**
	(1)	(2)	(3)	(4)	(5)
Information arm	-0.03	-0.04	0.05	-0.01	0.03*
	(0.02)	(0.04)	(0.04)	(0.03)	(0.01)
Σ RTP per-unit prices	-0.11	-0.70***	0.32	0.50***	-0.01
	(0.11)	(0.16)	(0.20)	(0.16)	(0.07)
Lottery task risk metric	0.00	0.00	-0.01	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Heard of RTP before	0.06*	-0.11***	0.06	-0.02	0.01
	(0.03)	(0.04)	(0.05)	(0.03)	(0.02)
Has signed up to RTP	-0.07**	-0.03	0.00	0.06	0.03
	(0.03)	(0.05)	(0.06)	(0.04)	(0.03)
Has solar panels	0.03	-0.03	-0.01	0.04	-0.02*
	(0.03)	(0.04)	(0.04)	(0.03)	(0.01)
Constant	0.19*	0.74***	0.27	-0.26*	0.06
	(0.10)	(0.16)	(0.19)	(0.15)	(0.06)
Demographic controls	Yes	Yes	Yes	Yes	Yes
R^2	0.05	0.06	0.03	0.07	0.03
Observations	608	608	608	608	608

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses. Demographic controls include age bracket, gender, area of residence (metro/regional), primary/joint household decision maker, and education level. Σ*RTP per-unit prices* is the sum, across rounds 1-4, of all marginal prices drawn for the RTP plan(s) faced by a participant in task 1 of the experiment. *Lottery task risk metric* is the number of times a participant chose the lottery option (option B) during task 2 of the experiment. *Heard of RTP before* and *has signed up to RTP* indicate, respectively, whether a participant has heard of RTP electricity plans before, and whether they have ever signed up to a RTP plan for their home energy.

Participants who had heard of RTP before taking part in the experiment were significantly less likely to rate the risk of receiving an unusually high bill as low ($p < 0.01$), but more likely to rate the chance as very low ($p < 0.10$). Conversely, those who had actually signed up to a RTP plan for their home electricity where significantly less likely to rate this risk as very low ($p < 0.05$). This may be attributable to the positive advertising surrounding RTP electricity plans offered in Australia, including sentiments such as 'you could save hundreds of dollars' and 'with RTP you can take control of your bill'[18]. Prior exposure to such messaging may have seen participants who were familiar with RTP perceiving a lower risk, as compared to those who have actually experienced RTP plans in real life, and may be more aware of the

[18]Statements like these can be found on the websites of *Amber Electric* (https://www.amber.com.au/how-it-works) and *Powerclub* (https://powerclub.com.au/powerbank)

financial risks involved. However, it is likely that these two characteristics were overstated by participants, as the number of participants that indicated they had signed up to RTP plans far exceeds the population average for Australian residential households[19]. This may reflect a level of confusion among some participants regarding what RTP is and how it works. Thus, any inferences made regarding the effects of these characteristics on plan choice and risk perception/comprehension must be taken lightly.

Table 9 displays the OLS estimates for risk comprehension, which, as described in section 4, are based on the three risk comprehension questions from task 3 (refer to appendix C). Surprisingly, the additional risk information had no effect on risk comprehension, which was low across all participants, with less than a third answering all risk comprehension questions correctly. This result is unexpected, given that the additional risk information was presented in a table that explicitly described that there was a 27.9% chance that a bill for the hedged RTP plan would exceed that for the FRP plan, and a 19.7% chance the standard RTP bill would exceed the FRP bill.

Having heard of RTP before, having signed up to RTP before and having installed solar panels all made a participant significantly more likely (by 9, 7, and 7 percentage points, respectively) to answer all comprehension questions correctly. This indicates that consumers who are more invested in thinking about and acting upon their home energy arrangements are more likely to have a better understanding of the financial risks involved with RTP plans, which complements the common conclusion in the literature that passive customers (who comprise the majority of residential consumers) possess limited understanding of electricity pricing (Allcott, 2011; Dutschke & Paetz, 2013; Niromandfam et al., 2020; Salies, 2013).

[19] 15.4% of participants indicated that they had previously (or are currently) signed up to an RTP plan for their home electricity, and a further 20.6% stated that they had heard of RTP electricity plans before taking part in the experiment.

Table 9: OLS estimates for RTP risk comprehension outcomes

Variables	**Risk composite**	**Risk composite**	**Risk Q1**	**Risk Q1**	**Risk Q2**	**Risk Q2**	**Risk Q3**	**Risk Q3**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Information arm	-0.02	-0.04	0.02	0.01	-0.04	-0.07*	0.00	-0.01
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Σ RTP per-unit prices		0.76***		0.81***		0.45**		0.45**
		(0.20)		(0.17)		(0.20)		(0.18)
Lottery task risk metric		-0.02		-		-0.01		0.00
		(0.01)		0.02**		(0.01)		(0.01)
				(0.01)				
Heard of RTP before		0.10**		0.04		0.08*		0.03
		(0.05)		(0.04)		(0.05)		(0.04)
Has signed up to RTP		0.10		0.11**		0.16***		0.06
		(0.06)		(0.05)		(0.06)		(0.05)
Has solar panels		0.06		0.01		0.01		-0.02
		(0.04)		(0.04)		(0.04)		(0.04)
Constant	0.32***	-0.45**	0.66***	0.00	0.45***	-0.01	0.73***	0.47***
	(0.03)	(0.18)	(0.03)	(0.18)	(0.03)	(0.19)	(0.03)	(0.17)
Demographic controls	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.00	0.11	0.00	0.09	0.00	0.08	0.00	0.05
Observations	559	559	608	608	608	608	559	559

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses. Demographic controls include age bracket, gender, area of residence (metro/regional), primary/joint household decision maker, and education level. Σ*RTP per-unit prices* is the sum, across rounds 1-4, of all marginal prices drawn for the RTP plan(s) faced by a participant in task 1 of the experiment. *Lottery task risk metric* is the number of times a participant chose the lottery option (option B) during task 2 of the experiment. *Heard of RTP before* and *has signed up to RTP* indicate, respectively, whether a participant has heard of RTP electricity plans before, and whether they have ever signed up to a RTP plan for their home energy.

5.2 Impact of product offerings on plan choice

From table 6, we can see that in round 1, the proportion of participants that selected the FRP plan is less than 0.5 for all treatment groups except T2. Additionally, in rounds 2-4, participants in T2 show the highest incidence of choosing the FRP plan, with subjects choosing this plan 45% of the time. When controls are added in column 5, the incidence of choosing FRP for T2 is only significantly affected by the previous round's RTP marginal price, and not assignment to treatment. This is also observed for T5, the only other group that was offered the FRP and the hedged RTP plans only. This indicates that the hedged RTP plan looked less attractive to participants than the standard RTP plan.

This result can also seen for groups 3 and 6 in table 5, where the hedged RTP plan was chosen just 14% and 22% of the time, respectively, compared to 61% and 62% for the standard RTP plan. This shows that most participants valued the E$10 saving on their fixed price in the standard RTP plan (and, in some cases, the FRP plan) more than they valued the tail-risk protection provided by the hedged RTP plan. In other words, most participants did not see the value in paying a premium in order to protect themselves from large bill shocks. Although this refutes the hypothesis that participants would value the tail-risk protection provided by the hedging mechanism, it is possible that in choosing the standard RTP plan, participants were self-insuring against this risk. Hirst (2002) contends that customers on RTP plans self-insure in two ways: firstly, by avoiding payment of financial insurance through FRP (and hedged RTP) plans, and secondly, by shifting their energy consumption away from times of high prices. Although the latter does not factor into this experiment, it is possible that participants self-insured when selecting the standard RTP plan, given the reward payment structure faced by participants, where the reward for task 1 was based on the sum of all four of a participants' bills across the task. Thus, in anticipation that they would generally receive a bill lower than that of both the FRP plan and the hedged RTP plan, participants may have been willing to risk receiving an unusually high bill in one round under standard RTP, given the savings they expected to accrue on their bills in the other three rounds of task 1.

Furthermore, in rounds 2-4, participants with a higher lottery task risk metric in task 2 (the lottery game) were significantly less likely to select the FRP plan ($p < 0.05$). An extremely risk-loving participant is estimated to be 8 percentage points less likely to select FRP than an extremely risk-averse participant. Interestingly, we find that participants who had heard of RTP before the experiment (but never actually signed up to it for their home electricity) demonstrated a propensity towards choosing the RTP plans across all rounds, although this is not statistically significant. This is potentially a result of prior exposure to RTP advertising (as described in section 5.1). It is not necessarily a result of having actually experienced financial benefits from RTP, as subjects who indicated that they had signed up to a RTP plan for their home electricity prior to the experiment were 9% more likely to select the FRP plan in round 1 ($p < 0.10$), and during rounds 2-4 showed no significant preference towards or away from the FRP plans. Finally, participants who had installed solar panels at their homes were more likely by 4 percentage points to choose the FRP plan over rounds 2-4 ($p < 0.05$).

In addition to the tests above, table 10 displays the Wald test results highlighting the effect of the electricity plan options on participants' plan choice. These tests reveal an interesting dynamic for T2 and T5, where the OLS estimates for these groups in round 1

and rounds 2-4 are significantly larger than the estimates of the other two groups within their respective treatment arms, shown by tests 6 and 8 for T2, and tests 9 and 11 for T5. This supports the finding that the FRP plan looked more appealing when offered next to only the hedged RTP plan. Again, this likely stems from the E$10 premium included in the fixed price of the hedged RTP plan, which seems to have made the plan look uneconomical to participants. In order to analyse this more deeply, participants' preference orderings of the three plans offered during the experiment can be considered. There are six possible preference orderings between the plans, and these orderings are named and listed in table 11. When considering the results in table 10 in conjunction with the statistics in table 5, inferences relating to participants' preference ordering of the three plans can be made. The incidence of selecting the standard RTP plan in T1 is approximately 22 percentage points greater than that of choosing the hedged RTP plan in T2. When comparing T1 and T3, a small shift (approximately 13 percentage points) away from standard RTP and into the hedged RTP is observed. This conclusion can be made given the insignificant difference in propensity to choose the FRP plan. This indicates that the switch out of FRP from T2 to T3 consists only of people switching into the standard RTP plan.

Table 10: Wald tests for product-offering impact

Test	**Comparison samples**	**Null hypothesis**	***p*-value**	
			Round 1	Rounds 2-4
6	T1, T2	$\beta_{T1} = \beta_{T2}$	0.000	0.000
7	T1, T3	$\beta_{T1} = \beta_{T3}$	0.622	0.535
8	T2, T3	$\beta_{T2} = \beta_{T3}$	0.000	0.000
9	T4, T5	$\beta_{T4} = \beta_{T5}$	0.081	0.047
10	T4, T6	$\beta_{T4} = \beta_{T6}$	0.767	0.024
11	T5, T6	$\beta_{T5} = \beta_{T6}$	0.042	0.000

Notes: Wald tests for round 1 are conducted on coefficients from specification 1 in table 6. Tests for rounds 2-4 are conducted on coefficients from specification 4 in table 6. Reported p-values are for the F-statistic produced by the Wald test.

Moreover, between T2 and T3, the incidence of choosing the FRP plan halves (an approximate 24 percentage point drop), and that of the hedged RTP plan decreases by approximately 37 percentage points, while the incidence of choosing the standard RTP plan in T3 is 61%. This further consolidates that participants switching out of the FRP plan from T2 to T3 switched up to the standard RTP plan, not the hedged plan. Furthermore, this indicates that, when given the choice between all three plan options, compared to solely the FRP and hedged RTP plans, participants that switch out of the hedged RTP plan switch only into the standard RTP plan. All of this together suggests

that in the control arm, where participants did not receive the additional risk information, we cannot reject the null hypothesis that no participants have the δ_4 or δ_6 plan preference orderings; that is, that no participant had a plan preference ordering in which the standard real-time plan was preferred last.

Table 11: Electricity plan preference orderings

Name of preference order	**Order of plans**
δ_1	Standard RTP > hedged RTP > FRP
δ_2	Standard RTP > FRP > hedged RTP
δ_3	Hedged RTP > standard RTP > FRP
δ_4	Hedged RTP > FRP > standard RTP
δ_5	FRP > standard RTP > hedged RTP
δ_6	FRP > hedged RTP > standard RTP

Notes: The table reports all possible preference orderings that may be held by a participant for the three electricity plans offered during the experiment.

This same phenomenon is observed for the information arm as well, but only for round 1, where tests 9 and 11 show once again that the FRP plan looked more appealing when offered next to only the hedged RTP plan. Additionally, in rounds 2-4, the same important switching ratios between T5 and T6 are observed as between T2 and T3, which suggest that we cannot reject the null hypothesis that no participants have the δ_4 plan preference ordering. However, in rounds 2-4 the propensity to choose the FRP plan in T6 is significantly lower (by 7 percentage points) than in T4 ($p < 0.05$). This suggests that the additional risk information made the hedged RTP plan seem more attractive to those participants who value certainty in their bill. In the control arm, without that additional information demonstrating that the tail-risk of RTP is eliminated in the hedged plan, these participants opted for the FRP plan, and thus we cannot reject the null hypothesis that no participants had the preference ordering δ_6. Without the additional risk information, the focus of participants is likely on that E$10 higher fixed price in the hedged RTP plan, and not on the potential to receive a lower bill by being exposed to the wholesale price without the tail-risk. However, when participants do see this information, those who value bill certainty but also value taking some risk for a potentially higher payout (i.e., lower bills), see the hedged RTP plan as a better choice. Thus, the information treatment appears to cause some participants to take up the δ_6 preference ordering, as they switch out of the FRP plan and into the hedged RTP plan from T4 to T6. This is also demonstrated when using table 5 to compare T3 with T6, where we see an approximate 8 percentage point decrease in choice towards the FRP plan, and a corresponding 8 percentage point increase in choice towards the hedged RTP plan when moving from T3 to T6.

5.3 Impact of RTP experience on plan choice and risk comprehension

The *previous round RTP per-unit price* variable reported in table 6 demonstrates that participants exposed to higher marginal prices under the RTP plans during a particular round were significantly more likely to select the FRP plan in the next round ($p < 0.01$), and this remains unchanged when controls are added. From table 3, we can see that the marginal price for RTP plans averaged approximately E$0.19 across the four rounds for each treatment group. Recall that the maximum was set at E$0.385. If a participant were to receive this maximum marginal price in any given round, they are estimated to be 51 percentage points more likely to select the FRP plan in the next round than a participant who received the average per-unit price of E$0.19. This illustrates that actually experiencing a high marginal price on their bill deterred participants from choosing RTP plans, whereas just receiving the additional risk information that solely warned of this possibility did not have the same effect. Although it works in the opposite direction, this result aligns with that of Kaufmann et al. (2013), who find that allowing consumers to experience a sample of outcomes for financial products desirably increases their allocation of funds towards a risky product.

We test this finding further using two regressions of a binary variable which equals 1 if (a) a participant is in the information arm and chose the FRP plan in round 1, and (b) if a participant is in the control arm and selected the FRP plan in round 4, on treatment arm. Table 12 shows the output of these regressions. The first regression includes observations from all participants, while the second includes only those participants who experienced RTP marginal prices that averaged over E$0.22 per round over rounds 1 to 3 (in other words, participants who experience bill shocks (large or small) above E$300, which is the total bill for the FRP plan).

On average, participants' uptake of FRP plans is the same in round 1 for the information arm as it is in round 4 for the control arm. This suggests some equivalence between the pure effect of the probabilistic risk disclosure and the pure experience effect. However, the nature of that experience can impact plan uptake, as participants that saw poor RTP billing outcomes ex-post tended to reactively select into the FRP plan. Participants in the control arm who received marginal prices summing to over E$0.66 across the first three rounds were 27 percentage points more likely to select the FRP plan in round 4 than participants in the information arm were in round 1. Interestingly, these results align with the results of a similar laboratory experiment for the mobile phone plan market, where consumers with low phone plan literacy showed improvement in their plan choices only after they gained

substantial experience in the market (Friesen & Earl, 2020).

Table 12: OLS estimates for choice towards the FRP plan - comparison of pure information effect and pure experience effect

Variables	*Selected the FRP plan in (a) round 1 if in the information arm, or (b) round 4 if in the control arm*	
	All participants	**Participants who experience RTP bill shocks**
	(1)	(2)
Control arm	0.04	0.27***
	(0.04)	(0.04)
Constant	0.27***	0.22***
	(0.03)	(0.03)
R^2	0.29	0.07
Observations	608	118

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses. A binary dependent variable is used in both specifications. This variable equals 1 if (a) a participant is in the control arm and they chose the FRP plan in round 4 (pure experience effect), and (b) a participant is in the treatment arm and they chose the FRP plan in round 1 (pure information effect). *Participants who experience RTP bill shocks* includes all participants who experienced RTP marginal prices averaging over E$0.22 across rounds 1-3 of task 1 (i.e., the RTP marginal prices experienced over rounds 1-3 sum to over E$0.66).

In order to account for the possibility that participants' decisions about electricity plans in task 1 were not myopic, we include an additional specification for rounds 2-4 in appendix table D.1, which controls for the total sum of RTP marginal prices experienced by a participant in all prior rounds. Though the results do not differ substantially from those reported earlier in table 6, the smaller magnitude of the coefficient of the summed RTP marginal price variable compared to that of the *previous round RTP per-unit price* variable indicates that participants placed a greater weight on the marginal price experienced in the previous round than they did on the cumulative sum of marginal prices experienced throughout task 1.

We return to table 8 that reports estimates of the determinants for participants' perceived financial risk from RTP. Of particular interest here is the significance of the estimates for Σ *RTP per-unit prices*, which show that a participant who received the highest occurring sum of RTP marginal prices during the experiment of E$1.24 ($N = 4$) was approximately 45 percentage points less likely to rate the chance of a bill shock as low, compared to a participant who received the lowest occurring sum of E$0.60 ($N = 4$). Moreover, subjects who received the highest occurring sum were 32 percentage points more likely to rate the chance of a bill shock as high compared to those who received the lowest sum. This suggests that the actual exposure to wholesale prices on RTP has a greater effect on participants' perception of risk than does the receipt of a probabilistic risk disclosure. In other words, it is only those participants who were 'burned' by high wholesale prices who learned the true

nature of RTP tail-risk.

Moreover, and in contrast to the effect that the additional risk information has on risk comprehension (see table 8), exposure to higher RTP per-unit prices significantly increased the likelihood of participants correctly answering the risk comprehension questions. A participant who received the highest occurring sum of RTP per-unit prices (E$1.24) was 48 percentage points more likely to correctly answer all three risk comprehension questions than a participant who received the lowest occurring sum (E$0.60). This provides further evidence that experiencing high wholesale prices on a RTP plan is a better tool for increasing consumers' awareness (comprehension and perception) of the risks of RTP than the risk disclosure information provided in this experiment.

6 Discussion

In this experiment, we explore the effect of risk disclosure information and tail-risk protection on consumers' demand for RTP electricity plans, and on their understanding of the risks involved with these plans. The results reveal that additional probabilistic risk disclosure information, beyond what is usually provided by electricity retailers, made both the standard and the hedged RTP plans look more attractive to participants than the FRP plan. This is likely because the focus was on the bulk of the probability distributions for the RTP plans, which showed that the probability of receiving a bill totalling less than the total FRP bill of E$300 was 80.3% for the standard RTP and 72.1% for the hedged RTP (due to the E$10 premium built into the fixed price of this plan). Similarly, Ragin et al. (2020) find that a probabilistic risk disclosure does not improve consumers' choices away from high-load insurance plans in a modest-stakes risk environment, despite welfare losses. The difference in this experiment is that the risk disclosure was intended to push consumers' choice away from a risky option, whereas Ragin et al. (2020) designed their disclosure to push choices towards a riskier, but still welfare-improving, option.

Furthermore, in both the information and control arms of our experiment, participants preferred the standard RTP plan to the hedged plan, demonstrating that they were unwilling to pay a premium to protect themselves from the tail-risk associated with the standard RTP plan. This result arose despite the average participant revealing an aversion to risk during the lottery game in task 2. This contradicts the conclusion of Niromandfam et al. (2020), who theorised that risk-averse customers value RTP plans with hedging mechanisms built in to protect themselves from financial risk. This suggests that, in reality, a lack of understanding of the potential consequences of this tail-risk prevents consumers from protecting themselves from this risk, which aligns with Decker's (2020) assertion that customers are often unaware

of the risks involved with the new energy products that they sign up to. The intention of the additional risk information was to focus participants' attention on this tail-risk, where they faced an 8.2% chance of receiving a bill of over E$370 for the standard RTP plan, however in T6 we observe a similar propensity to choose this plan as what we do in T3. Moreover, the information and control arms show no economically significant difference in perception or comprehension of financial risk regarding RTP plans, confirming that the additional risk information failed to alert participants to the greater risk of a bill shock under RTP, instead highlighting the potential for a lower electricity bill.

Conversely, experiencing a high marginal price for the RTP plans both decreased the propensity of participants to choose a RTP plan and increased participants' comprehension and perception of the financial risks of RTP plans. This highlights that the actual experience of a bill shock as a result of high wholesale prices has a much greater impact on understanding of risk, and thus willingness to expose oneself to that risk, than does a probabilistic risk disclosure about the risk of a bill shock.

These findings pose implications for policymakers seeking to increase consumer protection for RTP energy products. The majority of participants did not fully comprehend the risks involved with the standard RTP plan and did not act to protect themselves from this risk by selecting into either the hedged RTP plan or the FRP plan. Thus, regulation around RTP plans should focus on protecting consumers from the tail-risk associated with RTP plans. This may come in the form of mandatory hedging mechanisms built into all RTP contracts, such as the more simple premium payment and tail protection method described in this experiment and in Niromandfam et al. (2020), or more complex mechanisms, like the forward purchase contracts described by Borenstein (2007). Such regulation could allow for retailers to offer differentiated risk hedging contracts for customers across a range of risk tolerances. However, it has been claimed that incumbent retailers have little incentive for offering dynamic pricing plans, which would likely lose them revenue (Campillo et al., 2016; Nezamoddini & Wang, 2017; Roscoe & Ault, 2010), thus regulators may also consider mandating large retailers make RTP plans available to their customers.

Furthermore, given that the experience of high bills and bill shocks under RTP caused participants to select out of the RTP plans and into the low-risk FRP plan, policymakers might consider enforcing a mandatory trial period for RTP plans, so that customers can experience the volatility of wholesale prices before committing to the plan. Currently, all

customers across the NEM in Australia who engage in market retail electricity contracts[20] are provided with a cooling off period of ten days under the National Energy Consumer Framework (NECF)[21]. However, such a policy tailored to RTP plans would need a much longer cooling off period, potentially up to two-three months, in order to provide customers with sufficient experience of wholesale price volatility to make an informed decision. Such a policy may also stipulate a bill guarantee, as suggested by Parrish et al. (2020), to ensure that customers do not face any significant financial risk during their trial period. Although such a guarantee would reduce bill volatility, and thus risk, it is unlikely to detract from the learning experience provided by exposure to wholesale prices, as demonstrated in this experiment, where although participants' finances were not at risk, they still selected away from the RTP plans after observing a high RTP marginal price. Another way to provide customers with this experience is to prohibit electricity retailers from offering lock-in contracts to households, which would allow free switching between plans within an energy provider, as suggested by Friesen and Earl (2020) for phone plan providers.

A final option for consumer protection in RTP is one that is observed in some Australian markets, where regulators may enforce a restriction on the total average yearly price that can be charged to a household for its energy consumption. This would be similar to the DMO (or the reference price) used in Queensland, New South Wales and South Australia, and the VDO used in Victoria, which place a cap on the yearly electricity charges for customers on standing offer contracts, based on usage and supply charges which differ by geographical region[22]. *Amber Electric* already provide this kind of safety net for their customers, where they guarantee that the yearly charges for their RTP plans will not exceed the VDO (or the DMO, where applicable)[23]. The introduction of such regulatory measures for RTP electricity products would help to increase both consumer protection surrounding RTP products and the provision of RTP plans. This in turn could improve demand response, grid stability and efficiency in electricity markets, while at the same time providing protection for consumers who may not fully understand the risk they take on when entering into an unhedged RTP

[20] Australian energy retailers offer small customers two types of contracts: standard and market retail contracts. A standard retail contract includes set terms and conditions that cannot be changed with no expiration date, and prices are set at a standing offer rate. Market retail contracts include terms and conditions that can vary from contract to contract, are generally more competitive than standard contracts, and often include fixed term durations with exit fees for early termination. https://www.aer.gov.au/consumers/choosing-an-energy-retailer/energy-contracts

[21] Information on this cooling off period can be found in section 10.5 of the AEMC 2020 Retail Energy Competition Review at https://www.aemc.gov.au/sites/default/files/documents/2020_retail_energy_competition_review_-_final_report.pdf

[22] Information on the Australian reference price and the VDO obtained from https://www.canstarblue.com.au/electricity/reference-price/

[23] *Amber Electric* pricing information can be found at https://www.amber.com.au/pricing

contract.

Study limitations

It is acknowledged that conducting this study as an online laboratory experiment imposes certain limitations, including the fact that, if confused, participants had no way of asking for help or clarifying their understanding of questions in the survey, which may have negatively impacted comprehension of the actual survey questions. As Ragin et al. (2020) recognise, laboratory experiments are often abstract and confusing, requiring the full attention and careful thought of participants. So, the fact that the experiment was fully online with no option for participants to seek help constitutes a considerable limitation of the experiment. Moreover, the low stakes environment of the experiment may have caused participants to make riskier decisions than they would in their real lives, skewing plan choice towards the riskiest RTP plan.

Furthermore, throughout the experiment we hold electricity consumption constant, which is an obvious disparity from the real world. This potentially further skewed the decisions of participants towards the RTP plans, where in reality these participants might not actually be willing to take that more active role in their household energy, as is required when signing up to a RTP plan. This may also work the other way, however, where participants' choices may have been skewed away from the RTP plan, as consumers who are able to control their consumption may be more willing to adopt a RTP plan in the real world, as they can save more money by increasing their demand response. Therefore, keeping consumption constant mitigates each of these aspects that can confound the decision on electricity plan choice, allowing participants' to make decisions based solely on risk information and perception. This study acts as a steppingstone towards future research in the field, which can address these limitations by observing consumers' actions in the real world. Moreover, our findings motivate future research focusing on the 'experience effect' of RTP bills and bill shocks to provide insight into how this experience can be used to shape consumer protection policy for RTP products.

7 Conclusion

We explore how a probabilistic risk disclosure that explicitly states the risk of receiving a large electricity bill when signed up to a real-time pricing (RTP) plan affects consumers' demand for these plans, and their understanding of the risk of a large bill shock when signed up to RTP. We also investigate consumer attitudes towards tail-risk protection for RTP plans. Overall, the additional risk disclosure did not increase consumers'

comprehension or perception of the risks involved with RTP plans, and it actually *increased* the propensity of participants to choose a RTP over the flat-rate pricing (FRP) plan. This indicates a tendency of customers to overlook the tail-risk associated with exposure to wholesale prices through RTP plans. Furthermore, participants did not place great value on the tail-risk protection provided by the RTP plan with a built-in risk hedging mechanism, and in some circumstances, even risk averse participants who held the FRP plan as their first preference still preferred the standard RTP plan over the plan with tail-risk protection, further highlighting consumers' tendency to place little value on tail-risk protection. However, the experience of a large bill shock as a result of high wholesale prices was found to significantly increase participants' understanding of the financial risks of RTP plans, making them more likely to select the FRP plan. This suggests that many consumers learn primarily from the first hand experience of a negative outcome for their electricity bill (i.e., a high bill), and not from a warning that this outcome is possible.

These findings have significant policy implications, where regulators seeking to increase consumer protection for RTP products should consider that a probabilistic risk disclosure alone might impact electricity plan choice without necessarily increasing consumers' understanding of the risk involved with RTP plans. Thus, a regulator seeking to protect consumers from tail-risk in RTP may instead need to mandate product design instead of information disclosure. This may be achieved by mandating that RTP plans are offered with built-in risk hedging mechanisms, rather than relying on the consumer to self-select into this type of plan. Moreover, the enforcement of yearly price ceilings, prohibiting retailers from providing lock-in contracts, or the mandatory provision of a trial period for all RTP customers, may also work to protect customers from exposure to high wholesale prices. Future research in the field is required to validate these recommendations, which are based on experimental findings. This study also motivates further research into the measures that can be taken to increase consumers' understanding of RTP risks before they are made aware of these risks through the first-hand experience of a large bill shock.

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Appendices

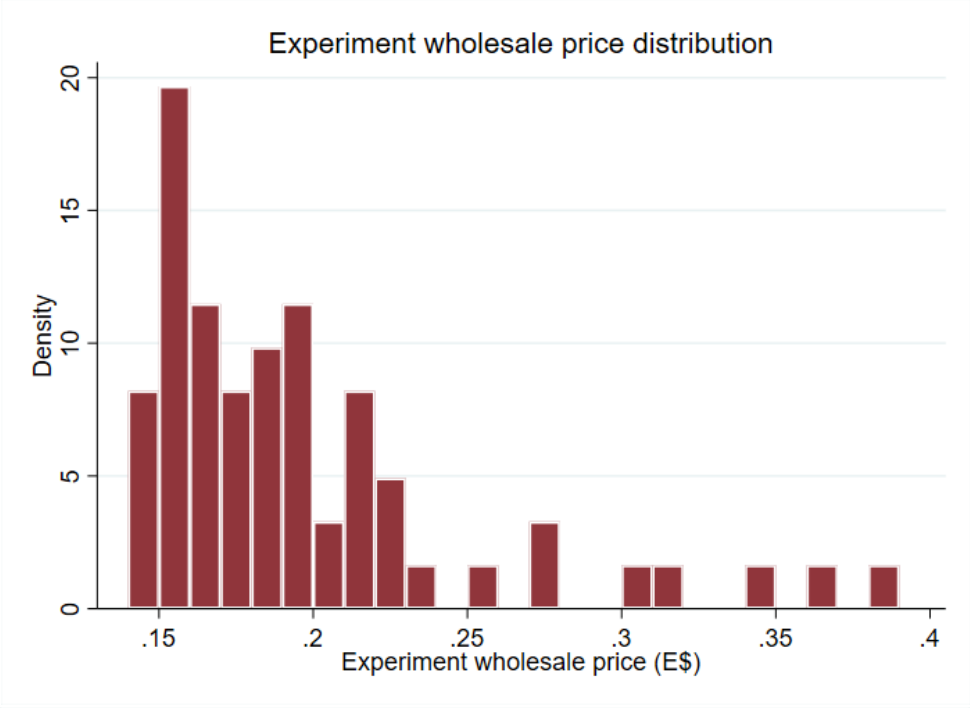
A Materials relating to experimental design

Table A.1: Experiment RTP marginal price distribution

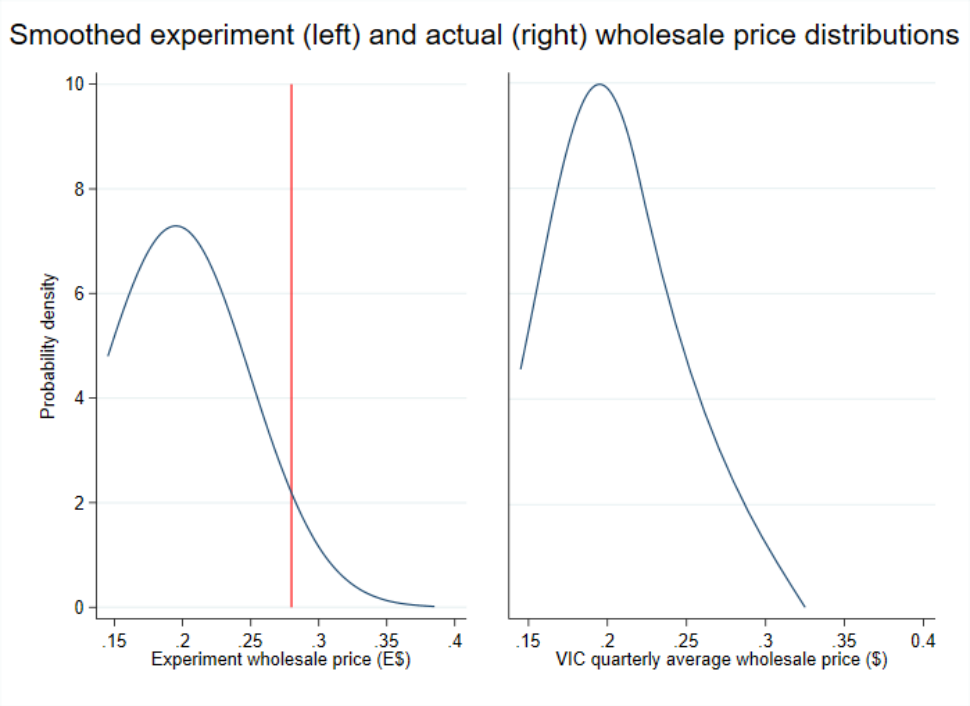
Price (E$)						
0.145	0.15	0.16	0.175	0.19	0.215	0.27
0.145	0.15	0.16	0.175	0.19	0.215	0.27
0.145	0.15	0.16	0.18	0.195	0.215	0.3
0.145	0.15	0.165	0.18	0.195	0.215	0.32
0.145	0.155	0.165	0.18	0.195	0.225	0.34
0.15	0.155	0.165	0.185	0.195	0.225	0.36
0.15	0.155	0.17	0.185	0.205	0.225	0.385
0.15	0.155	0.17	0.185	0.205	0.24	-
0.15	0.16	0.175	0.19	0.215	0.26	-

Notes: This table lists the numbers in the distribution of marginal prices for the standard and the hedged RTP plans in task 1 of the experiment. A marginal price for the RTP plans was randomly drawn from this distribution for each participant, in each round of task 1. Given the tail-risk protection provided in the hedged RTP plan, if the price drawn exceeded E$0.28, the bill for the hedged RTP plan included a marginal price of E$0.28.

Figure A.1: (A) Histogram for the experiment RTP marginal price distribution. (B) Smoothed experiment RTP marginal price distribution and Victoria wholesale price distribution.



A



B

Notes: Panel A shows the histogram of the price distribution used to randomly allocate marginal prices to the RTP plans throughout task 1. Panel B displays the smoothed experimental wholesale price distribution (left) and the distribution of real Victorian average quarterly load-weighted wholesale prices from 2016-2020 (right), which the experimental price distribution was based on. The red reference line at E$0.28 in panel B shows the marginal price ceiling of the experiment's hedged RTP plan. The figure highlights the tail-risk participants faced on the experiment's standard RTP plan.

Figure A.2: Extract from a real Victorian household's RTP bill

Electricity Usage Charges - Breakdown

Description	Charge Period	Quantity	Rate (incl. Gst)	Total (incl. Gst)
Carbon Neutral Offset	26 Mar - 25 Apr	322.14 kWh	0.1100 c/kWh	$0.35
Environmental Certificate Cost	26 Mar - 25 Apr	322.14 kWh	2.6191 c/kWh	$8.44
Market Charges	26 Mar - 25 Apr	322.14 kWh	0.2486 c/kWh	$0.80
Metering Charge	26 Mar - 25 Apr	31.00 day	21.4665 c/Day	$6.65
General Usage Wholesale (Av. Price)	26 Mar - 25 Apr	322.14 kWh	5.6615 c/kWh	$18.24
Amber - $10 per month	26 Mar - 25 Apr	31.00 day	32.8734 c/Day	$10.19
Price Protection Hedging	26 Mar - 25 Apr	322.14 kWh	0.7700 c/kWh	$2.47
Network - Fixed	26 Mar - 25 Apr	31.00 days	75.9330 $/pa	$6.45
Network - All Time	26 Mar - 25 Apr	322.14 kWh	8.1554 c/kWh	$26.27
			Total incl. GST	**$79.86**
			GST (10%)	$7.26
			Total	**$79.86**

Notes: This figure presents the breakdown of one month's electricity charges (in 2021) presented on the bill of a Victorian household signed up to a RTP plan with Amber Electric.

B Demographic summary statistics and balance table

Table B.1: Summary statistics for demographics

Variable	**Full sample**	**Control arm**	**Information arm**
Median age bracket	41-50	41-50	41-50
Female (%)	51.64	51.97	51.32
Lives in metropolitan area (%)	73.19	71.71	74.67
Primary decision maker (%)	63.79	64.33	63.25
Highest level of education			
Some high school, no diploma (%)	10.20	12.50	7.89
High school graduate (%)	20.89	20.72	21.05
Some university credit, no degree (%)	7.40	7.24	7.57
Completed trade/vocational/technical training (%)	18.75	21.05	16.45
Completed Bachelor's/Master's/Doctorate degree (%)	42.76	38.49	47.04

Notes: T1-T3 comprise the control arm, and T4-T6 comprise the treatment arm.

Table B.2: Balance across treatment groups

	Full sample		*T1 and T4*		*T2 and T5*		*T3 and T6*	
Variable	**Control mean**	**T-C**	**Control mean**	**T-C**	**Control mean**	**T-C**	**Control mean**	**T-C**
Gender	1.52	0.00	1.51	0.03	1.52	0.04	1.54	-0.07
Age group	5.24	-0.31**	5.26	-0.45*	5.27	-0.26	5.19	-0.23
Region	1.28	-0.03	1.31	-0.07	1.24	0.05	1.30	-0.07
Type of decision maker	1.36	0.01	1.37	0.04	1.43	-0.07	1.27	0.07
Level of education	3.52	0.21*	3.41	0.17	3.62	0.32	3.54	0.16
Has solar panels	0.35	0.05	0.31	0.04	0.39	0.08	0.33	0.03
Lottery task risk metric	3.11	0.06	3.40	-0.30	3.11	0.37	2.82	0.13
Heard of RTP before	0.27	0.05	0.28	0.01	0.27	0.09	0.26	0.05
Has signed up to RTP	0.14	0.04	0.17	0.03	0.15	0.04	0.09	0.05
Joint test (p-value)	0.362		0.808		0.238		0.802	

Notes: This table reports the results of the tests for balance between the information and control arms in the full sample, and between treatment groups with the same electricity plan offerings. T1 and T4 were both offered the FRP plan and the standard RTP plan, T2 and T5 were both offered the FRP plan and the hedged RTP plan, and T3 and T6 were offered the FRP plan, and both the standard and the hedged RTP plans. *Region* refers to whether a participant lives in a metropolitan or regional area. *Type of deicion maker* refers to whether a participant was the primary or a shared decision maker in their household. *Lottery task risk metric* is the number of times a participant chose the lottery option (option B) during task 2 of the experiment. *Heard of RTP before* and *has signed up to RTP* indicate, respectively, whether a participant has heard of RTP electricity plans before, and whether they have ever signed up to a RTP plan for their home energy.

C Participant instructions

Please click the following link to view the experiment instructions by treatment group: https://drive.google.com/drive/folders/1yGcHJAbY8OmPQ19dwho9zxmi5a-BS9V3?usp=sharing

D Other specifications

Table D.1: OLS estimates for choice towards FRP plan - long-sighted decision making

Variables	*Chose the FRP plan in any one of rounds...*	
	2-4	**2-4**
	(1)	(2)
T1	-0.15***	-0.02
	(0.04)	(0.08)
T2	0.07	0.20**
	(0.05)	(0.08)
T3	-0.18***	-0.45
	(0.04)	(0.08)
T4	-0.18***	-0.47
	(0.04)	(0.08)
T5	-0.07*	0.08
	(0.04)	(0.08)
T6	-0.25***	-0.11
	(0.04)	(0.08)
Cumulative sum of RTP per-unit prices	1.98***	1.94***
	(0.17)	(0.17)
Round 3 dummy	-0.39***	-0.38***
	(0.04)	(0.04)
Round 4 dummy	-0.76***	-0.75***
	(0.07)	(0.07)
Lottery task risk metric		-0.01
		(0.01)
Heard of RTP before		-0.03
		(0.03)
Has signed up to RTP		0.03
		(0.04)
Has solar panels		0.04
		(0.03)
Demographic controls	No	Yes
R^2	0.37	0.38
Observations	1824	1824

Notes: * significant at 10%. ** significant at 5%. *** significant at 1%. Standard errors clustered at the level of randomisation in parentheses. The data used for the regressions in columns 1 and 2 represents panel data, to account for the feedback effect of the bills and RTP marginal prices experienced in the previous round. Thus, 1824 observations are recorded for these specifications. Demographic controls include age bracket, gender, area of residence (metro/regional), primary/joint household decision maker, and education level. *Cumulative sum of RTP per-unit prices* is, for any of rounds 2-4, the sum of marginal prices drawn for the RTP plan(s) faced by a participant in all preceding rounds of task 1. *Lottery task risk metric* is the number of times a participant chose the lottery option (option B) during task 2 of the experiment. *Heard of RTP before* and *has signed up to RTP* indicate, respectively, whether a participant has heard of RTP electricity plans before, and whether they have ever signed up to a RTP plan for their home energy.