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Report

Cost Pass-Through (CPT) Tariff: Research Report

This research project investigates the impacts on consumers of implementing a cost pass-through tariff in the retail energy market as a potential alternative to the current default arrangements – SVT tariffs.

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Contents

Executive summary

This research project, delivered by Ofgem's Research Hub,[1] investigates the potential implications for consumers on default arrangements of introducing a "cost pass-through" (CPT) tariff as an alternative to the current default arrangements, which are generally Standard Variable Tariffs (SVTs), which can provide poor value to consumers. The CPT tariff allows for full pass through of upstream costs. For wholesale costs, which are particularly volatile, price changes would be passed through to consumers in close to real time. This is in contrast to the longer term hedging that is often a feature of SVTs.

We have developed a "backcast" model, which covers the period from January 2013 – March 2018, in an attempt to understand if consumers would have paid more or less for their gas and electricity supply on our modelled CPT tariff than the counterfactual SVT. We also investigate the distributional impacts across different socio-demographic groups of consumers. Finally, we explore how consumers might trade-off lower average prices with more volatile monthly bills to understand if consumers would have been better off under a CPT arrangement.

The results of our analysis should be interpreted with caution. They are driven by the assumptions that we make in our modelling and it is possible that a CPT tariff could generate a different set of results if it were actually implemented.

Key findings

Financial savings

- A typical dual fuel consumer would have saved around **£62** (or **5.8%**) per year under a CPT arrangement.
- This saving was driven primarily by lower wholesale costs due to the avoidance of hedging related costs (shaping and reshaping demand, re-hedging, transaction costs etc.). We estimate that wholesale costs would have been around **£33/year** (or 7%) lower under a CPT arrangement.
- The savings figure also reflects an assumed lower level of operating costs, as we have used the default tariff cap bottom-up assessment to inform an efficient operating cost benchmark. We estimate that operating costs would have been around **£16/year** (or 9%) lower under a CPT arrangement. Operating cost savings could be even higher than the stated savings figure, as some costs would be avoided under a CPT arrangement (e.g. employing and managing a trading team), but we have not taken this into account given a lack of explicit information on these costs.
- The savings figure is also influenced by our earnings before interest and tax (EBIT) assumption. We assumed an EBIT of 1.9% in line with the CMA's recommendations in its Energy Market Investigation. Historically, SVT margins have been considerably higher than this and we estimate that EBIT would have been around **£28/year** (or 61%) lower under a CPT arrangement. The savings figure also reflects around **£3/year** (5.8%) lower VAT (Fixed at 5% of the total bill) under the CPT arrangement.
- Our results suggest some costs may have been higher under a CPT arrangement. For example, network costs were **£10/year** (or 3.7%) higher and policy costs were

[1] The Research Hub delivers research projects to ensure we have access to high-quality and robust evidence to inform decision-making. More information on the Hub can be found at https://www.ofgem.gov.uk/system/files/docs/2017/09/research_hub_launch_-_call_for_engagement.pdf

£9/year (or 9.7%) higher in the analysis. For network costs, this could signal some cross subsidisation of costs between SVT and fixed customers. For policy costs, this may reflect the fact that policy costs have historically been lower than when the default tariff cap methodology was designed, which is how this CPT cost component was calculated.

Distributional impact analysis – looking beyond the typical consumer

We investigated how the financial savings that were achieved under the CPT arrangement compared across three broad CACI Acorn classification groups – Affluent, Comfortable and Adversity.[2] We used Low Carbon London actual half-hourly smart meter data (for around 5,000 London households) to create demand profiles that are reflective of each of the three socio-demographic groups (for electricity only). Although all groups experience financial savings, there is a strong link between savings and socio-demographic status. Consumers in the Affluent group tend to save more, as the operating cost savings that they experience are the highest of the three groups and this more than offsets their lower wholesale costs savings under the CPT tariff.

We find that:

- **Adversity** consumers would have saved around **£7/year** on their electricity bill.
- **Comfortable** consumers would have saved around **£10/year** on their electricity bill.
- **Affluent** consumers would have saved around **£18/year** on their electricity bill.

Risk aversion analysis

Although our CPT tariff results in financial savings for consumers, it also induces considerably more price volatility as unpredictable wholesale costs are passed through in close to real time. Energy consumers tend to be relatively averse to such pricing risk.

We use a mean-variance approach to value this additional risk in £ terms in order to capture if consumers value the savings more than the additional risk. This is a standard approach in financial analysis (but a novel application for energy) where a consumer's coefficient of risk aversion R is typically assumed to range from 2 – 3 in the experimental economics literature. While monthly bill amounts are easy to measure, this analysis helps translate consumer disutility from price volatility into a monetised term comparable with the savings in a simple and transparent way. However, as this analysis is experimental, it is illustrative only.

Looking across all the years that were investigated, we find that:

- For electricity profile class 1, a typical consumer (R = 2) would have been broadly indifferent between being on an SVT and the CPT arrangement.
- For gas, a typical consumer (R = 2) would have been better off under the SVT counterfactual. In some years, where gas prices are strongly seasonal and volatile, consumers could have been several hundreds of pounds worse off under the CPT arrangement. However, there are years (where gas prices are low and stable) when these customers would have preferred to be on the CPT arrangement.
- If we assume vulnerable consumers suffer a greater welfare loss from any change in their bill, and that they are at the more extreme end of risk aversion (R = 8), for

[2] See: https://acorn.caci.co.uk/downloads/Acorn-User-guide.pdf

both gas and electricity these customers would have had a strong preference for the SVT arrangement. There are no periods where these customers would have been better off under a CPT arrangement, given their high aversion to price volatility.

- The tipping point (where consumers value the SVT and CPT equally) is around R = 2.1 for electricity, which is characteristic of a typical consumer. For gas, the tipping point is R = 1.4, implying that only customers with a higher tolerance for risk would have been better off under a CPT arrangement.

1. Introduction

Background

The difference between the average annual SVT tariff of the six largest suppliers and the cheapest tariff on the market last year was, on average, £320.[3] Currently, around half of consumers have been on default tariffs for more than three years.

Energy suppliers typically charge their customers on default arrangements more than those on cheaper, low-margin (or loss-leading) fixed-term tariffs. This dynamic is often referred to as the two-tier market. There are concerns that current default arrangements might have adverse impacts on more vulnerable consumers, who are often less able to engage with the market and suffer proportionately more from higher prices.

In January 2019, we implemented a default tariff cap in which we set the maximum rate suppliers are able to charge customers on default tariffs. The default tariff cap is a temporary measure and will be subject to annual reviews into whether the conditions are in place for effective competition for domestic supply contracts from 2020 onwards. If it is deemed that these conditions are still not in place in 2020, the Secretary of State may direct Ofgem to extend the cap post 2020 (with periodic reviews) until the end of 2023 at the latest.

This research project, delivered by Ofgem's Research Hub, investigates the effects of placing disengaged consumers on a tariff that ensures upstream costs are directly passed through to consumers in real time (or close to real time). In this project we consider the consumer implications of implementing such a CPT tariff.

Aims of the project

This research project has three overarching aims:

1. To model the extent of any savings that disengaged consumers could have made under a CPT tariff when compared with the counterfactual SVT.
2. To test whether month-on-month bill volatility would have changed significantly under the CPT tariff when compared with the counterfactual SVT.
3. To investigate whether the above two impacts would have varied for groups of consumers with different levels of income and energy consumption.

[3] Between June 2017 and June 2018. See: https://www.ofgem.gov.uk/system/files/docs/2018/10/state_of_the_energy_market_report_2018.pdf

4. To explore risk aversion and investigate how consumers might trade-off lower average prices with more volatile monthly bills and understand if consumers would have been better off under a CPT arrangement.

The report is structured as follows:

- Section 2 examines the economic literature and empirical evidence on cost pass-through in the energy sector;
- Section 3 outlines the scope and methodology that we have employed in our research on the potential effects of moving default tariff customers onto a CPT tariff;
- Section 4 presents the results of the analysis and attempts to quantify the financial impacts on both electricity and gas customers; and
- Section 5 discusses the implications of our findings and provides some recommendations to inform future policy design for default tariff arrangements.

Acknowledgments

We are grateful for the valuable inputs and feedback provided by Dr Robert Ritz and Prof. Jacopo Torriti, members of Ofgem’s Academic Panel.

2. Cost pass-through in the energy sector: theory and evidence

What can economic theory tell us about cost pass-through?

Cost pass-through (CPT) arises when an organisation changes the prices of the products or services it provides following a change in its input costs.

It can be measured in two ways:

- *Rate of pass-through* – If a £1 unit cost increase causes a £1 price increase, then absolute pass-through = 1
- *Pass-through elasticity* – If a 20% unit cost increase causes a 10% price increase, then pass-through elasticity = 0.5

An absolute pass-through of 1 means that consumers incur the full extent of a change in a producer's input costs, whereas a rate of 0 implies that the producer absorbs all of the cost change.

The degree of CPT will depend on a number of factors, including: market structure and firm characteristics; demand and supply curves; and the elasticity of demand and supply. Below we consider CPT under different market structures.

Cost pass-through in perfectly competitive markets

Assuming perfect competition, i.e. a very large number of similarly sized buyers and sellers in the market, the extent of industry-wide pass-through will depend on the relative elasticities of demand and supply. If demand is relatively elastic, pass-through rates will be low; if it is relatively inelastic, pass-through rates will be high.[4] If demand decreases with increasing prices, and supply increases with increasing prices, the competitive pass-through rate will be between 0 and 100%. Further, close to 100% pass-through will arise when the price elasticity of demand is close to zero and supply is significantly elastic, which are both likely characteristics of the market for electricity. Note that there is no scope for individual firms to pass through firm specific cost changes, so the firm-specific pass-through rate will be zero.

Cost pass-through under monopoly / oligopoly (where firms can strategise)

If firms are relatively few in number, the degree of CPT will depend on the curvature of the demand curve. It is greater with convex inverse demand (the inverse demand curve becomes steeper as output decreases) and lower with concave inverse demand. CPT is lower when marginal cost curves slope upwards (i.e. marginal cost increases as output increases) and greater when marginal cost curves slope downwards (i.e. marginal cost falls as output increases). It can exceed 100% when inverse-demand is convex enough and/or when there are strong increasing returns to scale such that marginal cost curves slope sufficiently downwards (although this is not typically a characteristic of energy markets).

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[4] If the % change in demand is smaller than the percentage change in price, then demand is said to be inelastic. Conversely, if the % change in demand is greater than the percentage change in price it is elastic.

Cost pass through asymmetry

There is evidence of cost pass-through asymmetry across a range of competitive markets, including energy markets. Empirical studies generally conclude that output prices do not react symmetrically to changes in underlying costs. Prices often increase at a quicker rate following an increase in costs than they decrease when costs fall. The analogy of "rockets and feathers" is used to describe the asymmetric nature of cost pass-through – when prices rise like rockets, but fall like feathers.[5] Previous econometric analysis by Ofgem found evidence that customer energy bills respond more rapidly to rising supplier costs than to falling costs.[6]

Peltzman (2000) observes that such asymmetry is apparent in the majority of markets and that it is often both substantial and durable. Many academics postulate that this does not fit with standard economic theory and is likely driven by anti-competitive motives. However, there is research which suggests that such an outcome may be expected if consumer search decisions affect a company's elasticity of demand, i.e. consumers search less when they expect higher production costs compared to when they expect lower production costs (Tappata, 2009).[7]

Features of the retail energy market that influence cost pass-through to consumers

In energy, cost pass-through refers to the extent to which changes in any of the cost components which make up the typical energy bill are passed on to consumers in real (or close to real) time.

Most of the cost components (see Figure 1) which make up a typical domestic energy bill are relatively stable over the short to medium term, with any movements generally occurring over very long timeframes (for example network costs, operating costs and environmental and social obligation costs). The exceptions are wholesale gas and electricity prices, which generally fluctuate considerably over both the very short (i.e. intraday) and longer (annual) timeframes.

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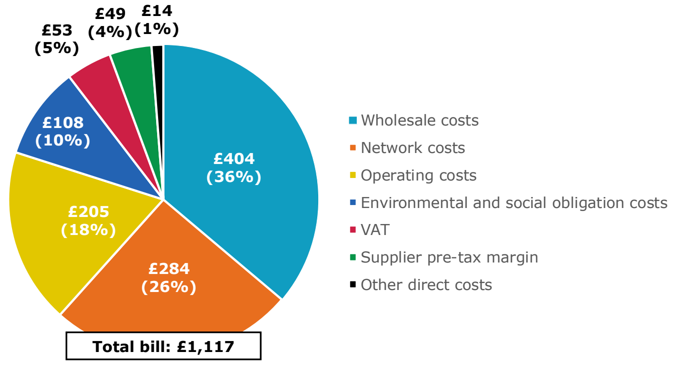
[5] Peltzman, S. (2000), 'Prices Rise Faster than They Fall', *Journal of Political Economy*, Vol. 108, No. 3, pp. 466-502. [Accessed on https://pdfs.semanticscholar.org/0064/a623cf8d56b79dc28b9fe626859ba32e6396.pdf on 20 February 2019].
[6] See: https://www.ofgem.gov.uk/ofgem-publications/39712/priceasymmetry.pdf
[7] Tappata, M. (2009), 'Rockets and Feathers: Understanding Asymmetric Pricing', *The RAND Journal of Economics*, 40(4), 673-687. [Accessed on http://www.jstor.org/stable/25593733 on 3 February 2019].

Figure 1: Costs that made up a typical domestic energy bill in 2017 (dual fuel, based on Consolidated Segmental Statement data for the six largest suppliers)[8]



In a competitive market, one might expect cost increases (or decreases) to be passed through to consumers promptly. However, given that energy is an essential service, there is evidence that consumers tend to dislike the volatile bills which would be a feature of full CPT.[9] To minimise the risks associated with price changes on SVTs, suppliers typically adopt hedging strategies whereby they purchase wholesale products across a range of different timeframes, often years ahead of delivery.

Hedging limits a supplier's exposure to wholesale volatility risk, enabling them to provide relatively stable prices to their consumers who are on default SVTs. However, the discrepancy between wholesale purchasing decisions and actual delivery can make it difficult to determine the extent of cost pass-through.[10] Furthermore, the degree of competitive pressure will influence whether this saving is passed on to consumers in the form of lower energy bills. Hedging also imposes additional costs to suppliers which are, in turn, passed on to consumers such that they might be expected to pay (on average) more for their energy than would otherwise be the case.

Suppliers' pricing strategies

As discussed in the previous section, there is evidence that many suppliers adopt pricing strategies whereby they charge a higher tariff, and therefore earn a greater margin, to consumers on default arrangements. This tactic of "tease and squeeze" acts by incentivising consumers to switch through cheap, lower-margin or loss leading tariffs on the expectation that they will default on to more expensive (and more profitable) SVTs once their fixed rate expires. This pricing strategy (combined with a lack of customer engagement) has prompted a significant price differential between engaged consumers (who are typically on more competitive fixed price deals) and those on default arrangements.

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[8] See: https://www.ofgem.gov.uk/system/files/docs/2018/10/state_of_the_energy_market_report_2018.pdf

[9] See: https://www.ofgem.gov.uk/system/files/docs/2018/07/ofgem_consumer_first_panel_year_9_wave_3_future_of_the_energy_market_0.pdf

[10] Other factors specific to the GB energy sector can make investigating cost pass through problematic. For example, vertically integrated companies may balance profits across the business, rather than in the supply or generation arm separately. Suppliers also face additional policy costs once they reach a threshold number of customer accounts.

3. Scope and methodology

Cost pass-through tariff

Our research models a cost pass-through (CPT) tariff where consumers on default arrangements are moved on to a tariff in which short-run marginal wholesale cost changes are passed through in their entirety (i.e. rate of cost pass-through = 1). This means that SVTs would no longer be a feature of the market, with consumers instead exposed to volatile wholesale costs in close to real time. This mechanism could provide greater price transparency and assurances that default consumers are paying a cost reflective price.

Our hypothesis is that this approach should lead to consumers on default arrangements paying less on average for their energy because of the reduction in costs associated with hedging. We also expect it may help to improve trust in the market by making pricing strategies more transparent, ensuring default consumers can be confident that they are paying a fair price that better reflects the underlying costs of their consumption. Moreover, it could help drive suppliers to become more efficient, by encouraging more competitive pressure on the costs suppliers can control, including operating costs and profit margins. The acceptability (or viability) of such an approach will depend on the trade-off between any cost savings (on average) and consumers' willingness to accept more volatile energy bills.

Scope of the research

The scope of this analysis includes:

1. All domestic customers on SVTs.
2. Customers that pay by direct debit. This simplifying assumption is used so that we can focus on customers that pay on a monthly basis. It also reduces the need to uplift the operating cost allowance to reflect the varying costs of serving customers with distinct payment methods.
3. The period January 2013 – March 2018.
4. The following cost components of a household energy bill – wholesale costs, network charges, policy costs (environmental and social obligations), operating costs (including smart metering), supplier pre-tax margin (or EBIT) and VAT.
5. All 14 Charge Restriction Regions in GB.
6. The segmentation of consumers into three socio-economic groups – Affluent, Comfortable and Adversity – derived from the CACI Acorn classification (2010).

The following are explicitly outside of the scope of this research:

- Non-domestic customers.
- Domestic customers on non-default or fixed tariffs.
- Any forward looking forecasts.
- Any quantitative estimate of demand elasticity, impacts on consumer behaviour or on firm pricing strategies.

Methodology

Below we summarise the methodology used in this research. We have also provided a list of more detailed assumptions in Appendix 2 and further information on the data sources and calculations can be found within the 'Notes' sheet of the CPT model.

Model construction

We have developed a "backcast" model to estimate what consumers on SVTs would have paid for their energy under our modelled CPT tariff. We have used SVT prices from January 2013 to March 2018 to build up a counterfactual estimate of the cost of energy for the typical consumer. These pricing data were acquired through our April 2018 supplier request for information (RFI). We subsequently weighted these tariffs, using the number of customers in each Charge Restriction Region, to produce a GB average SVT for a customer with a typical domestic consumption value (TDCV). We then used information from the Consolidated Segmental Statements (CSS) of the six largest suppliers to disaggregate the SVT into its various cost components (see table 1).

For the CPT model, we have used a bottom up approach (broadly similar to the default tariff cap methodology) to calculate what the individual cost components would have been under a CPT arrangement. We then aggregate these costs across each month to allow us to compare the total cost of the CPT tariff with a monthly SVT bill. We have calculated these monthly bill amounts for TDCV consumption for electricity single rate, electricity multi-register (economy 7) and gas customers.

Electricity demand profiles (class 1 and 2) are based on Elexon's Estimated Regional Average Demands per Customer load profiles.[11] We use the share of demand that falls on each day / settlement period and then adjust it to reflect the TDCV for each metering arrangement, as published by Ofgem, over the annual period.[12] We also account for transmission and distribution losses across each region. Later, in the distributional analysis, we combine load profiles from Lower Carbon London data with the Ofgem TDCV values before applying losses in a similar way.

We derive a daily gas demand profile by combining, for each LDZ, the proportion of annual non-daily metered consumption that falls on each day with the TDCV for gas customers as published by Ofgem. Note that we have not applied losses to the gas analysis due to associated uncertainty – with estimates of the level of unidentified gas ranging from 2% to 8%.[13]

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[11] See: https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/load-profiles/
[12] See: https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values
[13] See: https://www.ofgem.gov.uk/system/files/docs/2018/11/appendix_4_-_wholesale_costs.pdf

Table 1: Cost components in the SVT and CPT tariff

Cost component	SVT (counterfactual)	CPT tariff
Wholesale costs	Calculated using CSS data for the six largest suppliers.	For electricity, two wholesale products have been investigated: the half hourly System Buy Price (SPB) and the half hourly Day Ahead (DA) price. We also include an allowance for capacity market costs.[14] For gas, daily DA prices are used.
Network costs	Calculated using CSS data for the six largest suppliers.	For electricity, we apply the transmission, distribution and balancing charges on a half hourly basis. For gas, we apply transmission and distribution charges on a daily basis.
Operating costs	Calculated using CSS data for the six largest suppliers. This also includes "other direct costs" such as market participation costs, broker / intermediary costs and DCC related costs.	These are based on the efficient operating cost allowances in Ofgem's default tariff cap model. In addition, the allowance is adjusted over time to account for inflation and the changes in efficiency that we observe as based on the most efficient big 6 suppliers. Year-on-year change in operating costs reported in CSS is calculated and then the factors are used to reduce the efficient operating cost assumption for the historical years to reflect the fact the costs have generally risen due to, for example, the introduction of smart meters.
Environmental and social policy costs	Calculated using CSS data for the six largest suppliers.	For electricity, we calculate the policy costs associated with the Renewable Obligation, Contracts for Difference, Feed in Tariff, Energy Company Obligation, Warm Home Discount and Assistance For Areas With High Electricity Distribution Costs schemes. The methodology is consistent with that of Ofgem's default tariff cap. For gas, the policy costs are limited to the Energy Company Obligation and Warm Home Discount schemes.
VAT	Fixed at 5% of the total bill.	Fixed at 5% of the total bill.
EBIT	Calculated using CSS data for the six largest suppliers. These margins vary over time and across the two fuel types.	This is set at a constant rate of 1.9% before interest and tax.[15] This margin reflects the profit calculated by the CMA, in its Energy Market Investigation, for a supplier that does not use a third party to manage its wholesale trading. This also represents the EBIT allowance under the default tariff cap.

Distributional analysis

To capture the distributional impact of the CPT, for electricity only, we consider three Acorn groups (Affluent, Adversity and Comfortable). The demand profiles for these groups were

[14] The European Commission is currently investigating the UK capacity market scheme to determine whether it is in line with EU state aid rules. This follows the EU General Court's annulment of a previous Commission decision approving the scheme in November 2018. See http://europa.eu/rapid/press-release_IP-19-1348_en.htm.

[15] We acknowledge that, in practice, profit margins can fluctuate considerably over time and will differ across suppliers.

constructed using the Low Carbon London data, based on a half hourly demand profile of 5,567 London households covering the period November 2011 – February 2014.[16] We extrapolate this demand profile across the full period of our analysis, and all Charge Restriction regions, to estimate the varying impact that a CPT tariff would have had on each of these groups.

Risk aversion analysis

Intuitively, we might expect customers (especially those in vulnerable circumstances) to dislike the increased volatility that comes with a CPT tariff. To test this hypothesis, we have derived a mean-variance utility function (Ang, 2014),[17] adopting an approach that is commonly used in financial analysis:

*Expected utility cost of bill = average bill + (R/2) * (volatility of electricity bill)*

Where the average bill is the 12-month average estimate; volatility is the month-to-month variation over the course of a 12-month period; and R is the coefficient of risk aversion. The typical range of estimated values for R in the experimental economics literature is from 2 to 3, with a higher R implying a greater degree of risk aversion.

Whilst it is easy to measure the cost of a monthly bill, it is harder to express the disutility that a consumer experiences from volatility in comparable monetary terms. The mean-variance approach is a simple and transparent way of doing this.

Key caveats and limitations associated with methodology

- **Cost components are calculated differently under the counterfactual** - It is not possible to disaggregate the SVT baseline data (electricity and gas) into its various cost components (wholesale costs, network costs etc.) to make them comparable with the CPT tariff cost components. To address this challenge, the CSS data is used to calculate the percentage share of each cost component so that the SVT bill can be disaggregated into its various components. Supplier CSS data undergoes a strict external auditing process, so we are confident that these statements are reflective of historical supplier costs, but note that the same percentage shares in this aggregated data set are used for electricity profile class 1 and 2.[18]
- **CSS data are not limited to SVT customers** – The CSS covers financial and customer information for all suppliers' tariffs, not just SVTs. To the extent that the cost components of an SVT vary, e.g. a higher supplier pre-tax margin than the average supplier tariff, it may be that our estimates of the individual cost components of the SVT do not fully reflect this. However, in aggregate, our results should be robust as we consider each facet of the bill in our analysis.
- **The timing of wholesale purchasing decisions are not captured under the counterfactual** - The wholesale cost component under the SVT counterfactual is based on CSS data for the six largest suppliers and assumes that wholesale costs

[16] See; http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/

[17] Ang, A. (2014). Asset Management: A Systematic Approach to Factor Investing. *Oxford Scholarship Online*. [Accessed on http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199959327.001.0001/acprof-9780199959327-chapter-2 on 22 February 2019].

[18] Elexon define two profile classes for domestic premises. Profile Class 1 – Domestic Unrestricted Customers and Profile Class 2 – Domestic Economy 7 Customers.

are incurred in the year the CSS was published. This means that any wholesale products purchased in the previous reporting year(s) (through hedging) may not be captured in the year in which these costs were incurred.

- **Electricity demand profiles are based on the GB average** – Elexon was only able to provide us with the actual demand profiles for GB as a whole and these have then been applied across each Charge Restriction Region. Consequently, there is a risk that we may under- or over-state the change in cost under the CPT tariff if some regions experience daily and seasonal peaks in consumption that differ considerably from the GB average.
- **The counterfactual refers to the average SVT price** – There are a large number of default tariffs and, in order to calculate the average saving across the market, we have taken the average of all supplier SVTs. The actual savings (or otherwise) of a CPT arrangement will depend on the specific SVT that a customer is on. For volatility estimates, this also means that the average will create a "smoothing effect", where the volatility experienced by any individual SVT customer will be marginally higher.
- **Distributional analysis is undertaken for electricity only** – There is insufficient data to create demand profiles for different gas customer archetypes that are based on demographics. Distributional analysis for electricity is based on a London sample (~5,000 customers) so it may not be representative on a regional scale.
- **Socio-demographic demand data based on 2011-2014 consumption data** – The 2013-2014 Acorn groups (Affluent, Adversity and Comfortable) demand profiles are used for the year 2014-2015 and onwards as the Acorn groups demand profiles are based on LCL data which only covers the period November 2011 – February 2014.
- **Risk aversion analysis is offered as illustrative only** – We have developed a novel application of risk aversion analysis, adapting a theoretical risk valuation model that is commonly used in the financial services academic literature. We have developed this thinking with Dr Robert Ritz. We offer this analysis as illustrative, aiming to account for energy consumer preferences to avoid price instability risk. However, we recognise that this analytical tool, although useful, would benefit from more research and development in collaboration with the academic community.
- **Electricity wholesale prices converted from hourly to half hourly for comparability** – The electricity Day Ahead (DA) price is available on an hourly basis and is formatted / treated half hourly in the CPT model to match the half hourly electricity demand profiles. This caveat applies to both electricity profiles (1 and 2).
- **Incomplete gas price data** – The DA gas price for the weekends, public holidays and a few days in each year is not available. In these instances, the most recently available gas DA price is used.
- **We assume no behaviour change by either consumers or firms** – Consumers do not adjust their consumption in response to time-varying prices, and nor do firms adjust their costs.

4. Results

In this section we set out the results of our analysis.

Dual fuel default customers could save under cost pass-through

From January 2013 to March 2018, under the system buy price (SBP) wholesale prices for electricity and day ahead (DA) wholesale prices for gas, a customer with typical domestic consumption values (TDCV) would have seen a reduction of **5.8%** in their dual fuel bill if they had been switched to the CPT tariff. Equivalently, they would have saved, on average, around **£62/year**.

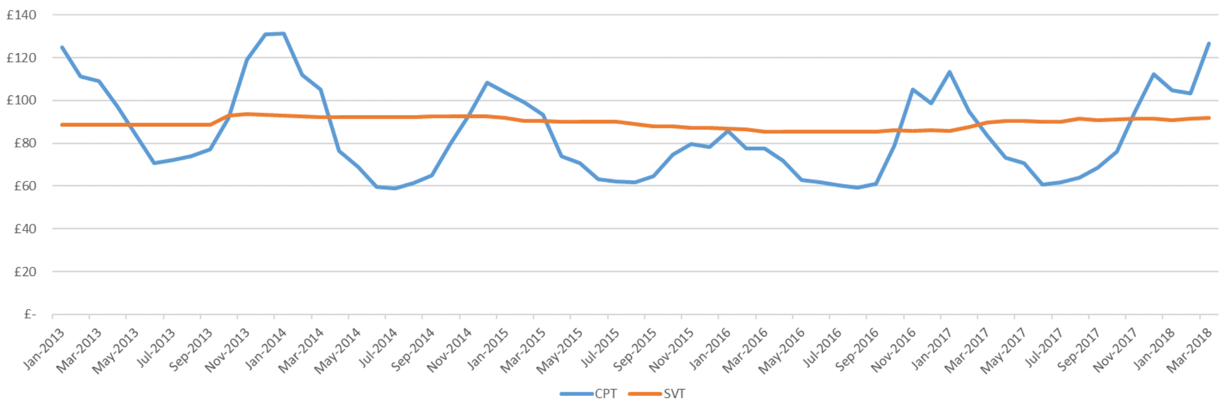
However, the below table reveals that, in addition to changes in the wholesale cost, this saving is being driven by lower operating costs and supplier pre-tax margin.

Table 2: Cost pass-through savings under electricity SBP and gas DA wholesale prices (dual fuel)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£175.12	7.4%	£33.36	7.4%	£4.67	£17.94
Network costs	(£50.91)	(3.7%)	(£9.70)	(3.7%)	£1.30	£2.16
Operating costs	£84.19	9.1%	£16.04	9.1%	£2.20	£1.04
Environmental and social obligation costs	(£45.74)	(9.7%)	(£8.71)	(9.7%)	£0.81	£1.35
VAT	£15.61	5.8%	£2.97	5.8%	£0.12	£0.99
Supplier pre-tax margin	£149.45	60.8%	£28.47	60.8%	£0.27	£0.38
Total	**£327.71**	**5.8%**	**£62.42**	**5.8%**	**£2.54**	**£20.75**

But their bills would have been more volatile
It can be seen from the below chart that this saving would have come at the cost of increased bill volatility. The CPT tariff exhibits a strongly seasonal trend with higher costs in the winter months when consumption and prices tend to peak. Indeed, the standard deviation around the mean is £20.75 for the CPT tariff compared with just £2.54 for the SVT.

Figure 2: Dual fuel monthly TDCV bill under SVT and CPT (with electricity SBP and gas DA prices)



Electricity analysis

Profile Class 1 – cost savings

Using the SBP wholesale prices under the CPT arrangement, on an annual basis, a typical Profile Class 1 consumer would have saved (on average) **4.1%** on their electricity bill.[19] In nominal terms, this reflects savings of **£21/year** (see Appendix 3 for the DA analysis).

Table 3: Cost pass-through savings under electricity SBP price (profile class 1)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£101.32	9.8%	£19.30	9.8%	£0.94	£4.27
Network costs	(£19.35)	(2.8%)	(£3.69)	(2.8%)	£0.81	£1.58
Operating costs	£35.81	8.3%	£6.82	8.3%	£1.16	£0.50
Environmental and social obligation costs	(£3.32)	(0.9%)	(£0.63)	(0.9%)	£1.15	£1.44
VAT	£5.32	4.1%	£1.01	4.1%	£0.10	£0.27
Supplier pre-tax margin	(£8.17)	(21.1%)	(£1.56)	(21.1%)	£0.76	£0.10
Total	**£111.62**	**4.1%**	**£21.26**	**4.1%**	**£2.13**	**£5.73**

Profile Class 2 – cost savings

Over the same period, a typical Profile Class 2 consumer would have saved (on average) **6.9%** on their electricity bill under CPT using SBP wholesale prices. In nominal terms, this reflects savings of **£44/year** (see Appendix 3 for the DA analysis).

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[19] Elexon defines two profile classes for domestic premises. Profile Class 1 – Domestic Unrestricted Customers and Profile Class 2 – Domestic Economy 7 Customers.

Table 4: Cost pass-through savings under electricity SBP price (profile class 2)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	(£10.12)	(0.8%)	(£1.93)	(0.8%)	£1.11	£7.64
Network costs	£161.35	19.2%	£30.73	19.2%	£1.05	£2.29
Operating costs	£133.37	25.1%	£25.40	25.1%	£1.45	£0.50
Environmental and social obligation costs	(£57.10)	(12.0%)	(£10.88)	(12.0%)	£1.42	£1.72
VAT	£10.95	6.9%	£2.09	6.9%	£0.13	£0.47
Supplier pre-tax margin	(£8.54)	(18.0%)	(£1.63)	(18.0%)	£0.94	£0.18
Total	**£229.91**	**6.9%**	**£43.79**	**6.9%**	**£2.72**	**£9.94**

Gas analysis

Over the period January 2013 to March 2018, a typical gas consumer would have saved (on average) **7.3%** on their bill under the DA wholesale price. In nominal terms, this reflects savings of **£41/year**.

Of note, the volatility of the gas CPT bill is more than three times higher than the electricity CPT bill under the DA price. This volatility, which is predominantly driven by the seasonal nature of gas consumption, feeds through into the high standard deviation that is observed in the dual fuel CPT tariff.

Table 5: Cost pass-through savings under gas DA price

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£73.79	5.5%	£14.06	5.5%	£3.77	£14.12
Network costs	(£31.57)	(4.7%)	(£6.01)	(4.7%)	£0.65	£1.10
Operating costs	£48.38	9.8%	£9.22	9.8%	£1.07	£0.55
Environmental and social obligation costs	(£42.42)	(49.0%)	(£8.08)	(49.0%)	£0.81	£0.52
VAT	£10.29	7.3%	£1.96	7.3%	£0.13	£0.76
Supplier pre-tax margin	£157.61	76.1%	£30.02	76.1%	£0.96	£0.29
Total	**£216.09**	**7.3%**	**£41.16**	**7.3%**	**£2.70**	**£15.93**

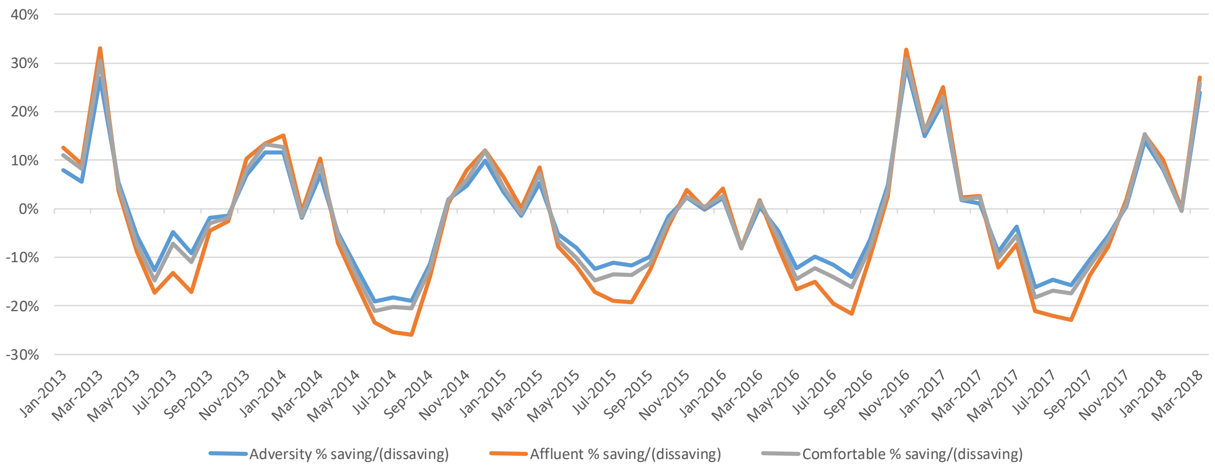
How might a cost pass-through tariff affect different consumer groups?

Overview

The below chart provides an overview of the impact that moving from the SVT to the CPT would have had on the electricity bills of the three Acorn groups.[20] It can be seen that the pattern in the % increase or decrease in the cost of the bill is very similar for each of the three groups. The groups that we consider do have demand profiles that follow a similar seasonal pattern and this explains why wholesale cost savings are comparable (see figure 13 in Appendix 3). However, the *total* cost savings appear to increase in line with the overall consumption level, in part due to the largely fixed nature of the operating cost assumption in the CPT tariff.

Specifically, the analysis suggests that the Adversity, Comfortable and Affluent groups would have saved £7.06, £9.86 and £18.08 per year respectively under the electricity SBP price CPT tariff. Interestingly, in percentage terms, the wholesale cost savings are highest for the Adversity group. However, the operating cost saving increases with consumption (as it is largely fixed on a per customer basis) and this explains why the Affluent group benefits the most under the CPT arrangement.

Figure 3: Electricity single rate tariff difference to SVT under CPT for Acorn groups (with electricity SBP price)



Adversity group

Over the period January 2013 – March 2018, consumers in the Adversity group would have saved (on average) **1.4%** on their electricity bill (using SBP electricity wholesale prices) under the CPT arrangement. In nominal terms, under the SBP price, this reflects savings of **£7/year** (see Appendix 3 for analysis of the DA price).

[20] Note that the demand profiles for the three Acorn groups were only available for electricity, so we have not considered gas customers in this analysis.

Table 6: Cost pass-through savings under electricity SBP price (Adversity group)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£84.19	8.6%	£16.04	8.6%	£0.92	£3.82
Network costs	(£39.61)	(6.1%)	(£7.54)	(6.1%)	£0.75	£1.31
Operating costs	£14.21	3.5%	£2.71	3.5%	£1.09	£0.50
Environmental and social obligation costs	(£14.55)	(4.0%)	(£2.77)	(4.0%)	£1.08	£1.47
VAT	£1.77	1.4%	£0.34	1.4%	£0.09	£0.24
Supplier pre-tax margin	(£8.93)	(24.3%)	(£1.70)	(24.3%)	£0.72	£0.09
Total	**£37.08**	**1.4%**	**£7.06**	**1.4%**	**£1.97**	**£5.01**

Comfortable group

Over the period January 2013 – March 2018, consumers in the Comfortable group would have saved **1.8%** on their electricity bill (using SBP electricity wholesale prices) under the CPT arrangement. In nominal terms, under the SBP price, this reflects savings of **£10/year** (see Appendix 3 for analysis of the DA price).

Table 7: Cost pass-through savings under electricity SBP price (Comfortable group)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£66.26	6.0%	£12.62	6.0%	£1.03	£4.67
Network costs	(£49.78)	(6.9%)	(£9.48)	(6.9%)	£0.85	£1.69
Operating costs	£62.75	13.6%	£11.95	13.6%	£1.23	£0.50
Environmental and social obligation costs	(£20.09)	(4.9%)	(£3.83)	(4.9%)	£1.22	£1.68
VAT	£2.46	1.8%	£0.47	1.8%	£0.11	£0.30
Supplier pre-tax margin	(£9.85)	(23.9%)	(£1.88)	(23.9%)	£0.81	£0.11
Total	**£51.76**	**1.8%**	**£9.86**	**1.8%**	**£2.24**	**£6.23**

Affluent group

Over the period January 2013 – March 2018, consumers classified as Affluent would have saved (on average) **2.9%** on their electricity bill (using SBP electricity wholesale prices) under the CPT arrangement. In nominal terms, under the SBP price, this reflects savings of **£18/year** (see Appendix 3 for details on the DA price).

Table 8: Cost pass-through savings under electricity SBP price (Affluent group)

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£50.70	4.0%	£9.66	4.0%	£1.18	£5.93
Network costs	(£52.50)	(6.3%)	(£10.00)	(6.3%)	£0.99	£2.32
Operating costs	£130.26	24.6%	£24.81	24.6%	£1.42	£0.50
Environmental and social obligation costs	(£27.33)	(5.8%)	(£5.21)	(5.8%)	£1.41	£1.97
VAT	£4.52	2.9%	£0.86	2.9%	£0.12	£0.39
Supplier pre-tax margin	(£10.72)	(22.6%)	(£2.04)	(22.6%)	£0.93	£0.15
Total	**£94.93**	**2.9%**	**£18.08**	**2.9%**	**£2.62**	**£8.17**

Price volatility and risk of price shock

The introduction of real time (or close to real time) prices means consumers pay a price that reflects the wholesale market prices at the time of consumption. More precisely, the wholesale costs are calculated on the basis of half-hourly prices for electricity and daily prices for gas. Directly linking retail prices to wholesale costs can deliver benefits in terms of reducing peak demand, if consumers are able to respond to these price signals.[21]

However, dynamic prices may expose consumers to risk from fluctuations in their energy costs. If consumers are less able to respond to these price signals, for example if they have personal circumstances that mean they cannot adjust their consumption and therefore reduce it when prices are high, this may lead to “surge pricing”.

In this section we analyse the effects of a CPT tariff using the mean-variance utility framework that we set out in section 3. The graphs below illustrate how, under the CPT arrangement, fluctuations in wholesale costs lead to oscillatory periods of lower prices (generally in summer) followed by periods of higher prices (generally in winter). In the majority of cases, the monthly bill paid by a default consumer would have been lower under the CPT arrangement compared with the counterfactual SVT. For some months, however, monthly bills under a CPT arrangement would have been considerably higher (up to around 33% more).

[21] On the topic, see: Borenstein (2006). “Customer risk from real-time retail electricity pricing: Bill volatility and hedgability”. Available at https://www.nber.org/papers/w12524.

Figure 4: Price peak analysis: relationship between wholesale costs and retail prices (electricity profile class 1)

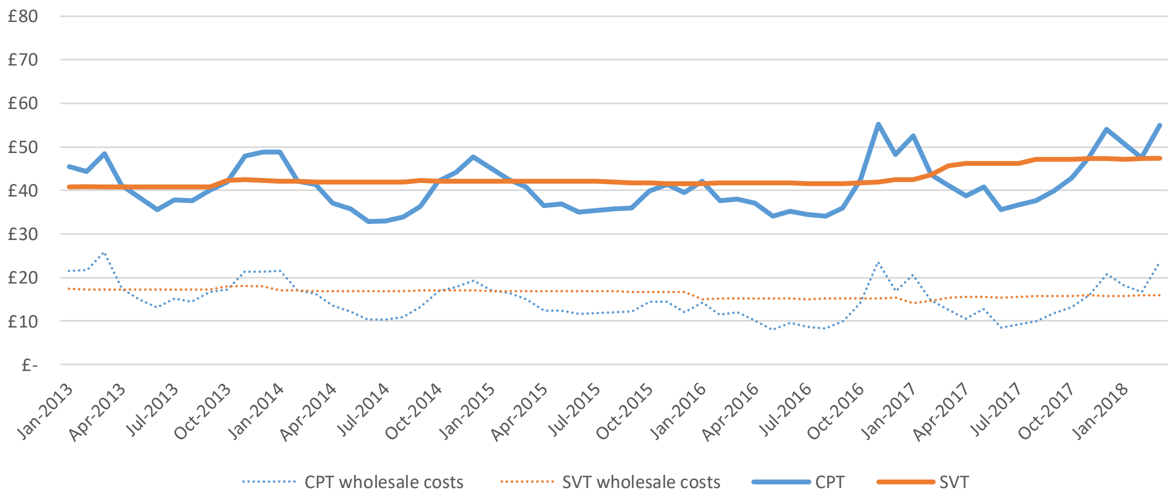
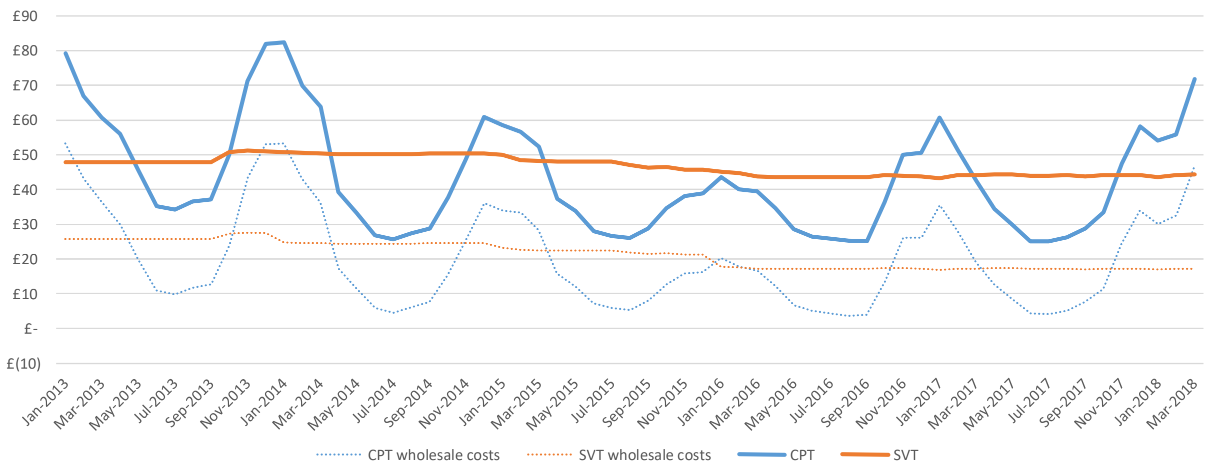


Figure 5: Price peak analysis: relationship between wholesale costs and retail prices (gas)



Quantifying risk aversion – is the volatility worth the savings?

In this section, we analyse the consumer impact associated with increased monthly bill volatility, using an approach that seeks to capture this increased price risk in a monetised way. This is an important factor in understanding if consumers, overall, might be better off under a CPT arrangement for a given level of risk aversion. Since consumers will invariably have different subjective views on price risk, in line with their personal preferences, the magnitude of this volatility impact varies according to consumers' willingness to accept risk.

Using the formula set out in our methodology, we calculate a risk-based cost in £ terms associated with price volatility risk.[22] We calculate this for a typical consumer, where R = 2, and for a more risk averse (potentially vulnerable) consumer, where R = 8. We also

[22] It is important to note that we aim to define the risk profile of consumers without controlling for consumption. The results are based on the means.

calculate the “tipping point” where we calculate how risk averse a consumer would need to be if they were to be indifferent between the SVT and CPT tariff.

As consumers are likely to base their judgements on past observations, we use a rolling 12-month volatility metric to estimate the disutility that they would have realised in any given month. This means we have only conducted this analysis where we have 12 months of historical data, i.e. from January 2014 onwards.

Impacts for a typical consumer (R = 2)

- *Electricity:* Our results suggest that, for electricity profile class 1, a typical consumer would be broadly indifferent between the SVT and CPT tariff. This means that the financial savings observed under a CPT arrangement are offset by the additional price risk that is imposed. These consumers would be marginally worse off under a CPT arrangement, but only to the tune of £4.10 per year.
- *Gas:* Our results suggest that typical gas consumers would have experienced higher detriment when compared with electricity. In periods where gas price volatility is particularly high (e.g. 2014 – 2015), consumers would have been several hundred pounds worse off, taking into account their risk aversion. There was, however, a period observed (for approximately one year) where gas customers would have been better off under a CPT arrangement.

Figure 6: comparison of SVT and CPT prices adjusted for the risk coefficient R = 2 (electricity profile class 1)

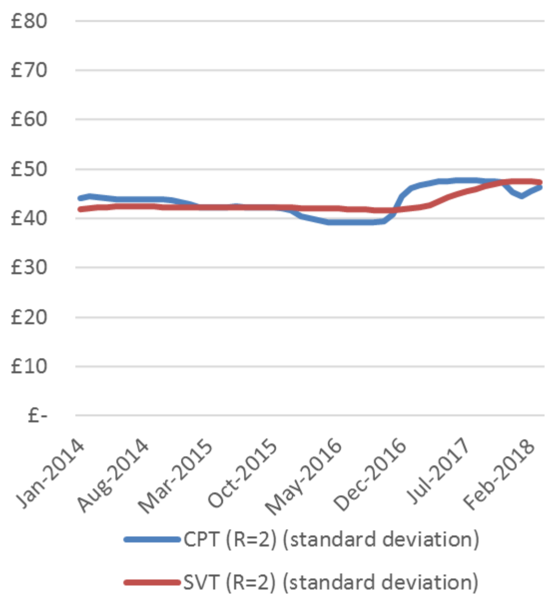
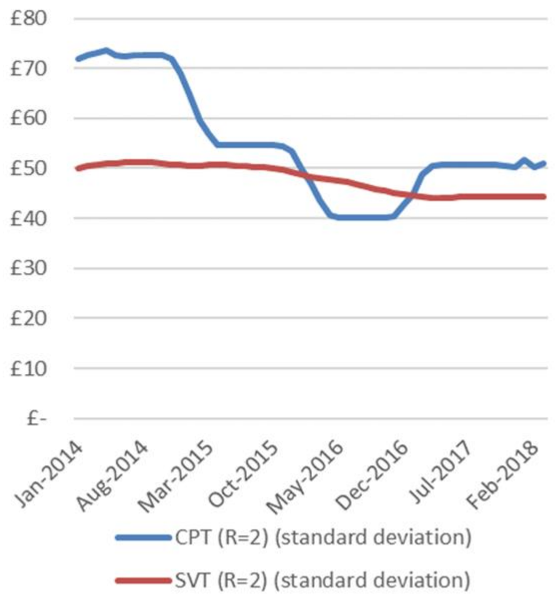


Figure 7: comparison of SVT and CPT prices adjusted for the risk coefficient R = 2 (gas)



Impacts for a risk averse / vulnerable consumer (R = 8)

- *Electricity:* Our results suggest that, for electricity profile class 1, a risk averse / vulnerable consumer would have had a strong preference for the SVT counterfactual. Given their strong aversion to price fluctuations, we estimate they would have incurred detriment of £140.53 per year under a CPT arrangement. There are no periods with sufficient price stability that would have led these consumers, even for shorter periods, to have a preference for a CPT arrangement.
- *Gas:* Similar to electricity, a risk averse / vulnerable consumer would have had a strong preference for the SVT counterfactual – and the impact is even more

pronounced. These consumers could have experienced several hundreds of pounds of detriment per year as a result of the more severe price fluctuations and their stronger aversion to risk. Again, there are no periods with sufficient price stability that would have led these consumers, even for shorter periods, to have a preference for a CPT arrangement.

Figure 8: comparison of SVT and CPT prices adjusted for the risk coefficient R = 8 (electricity profile class 1)

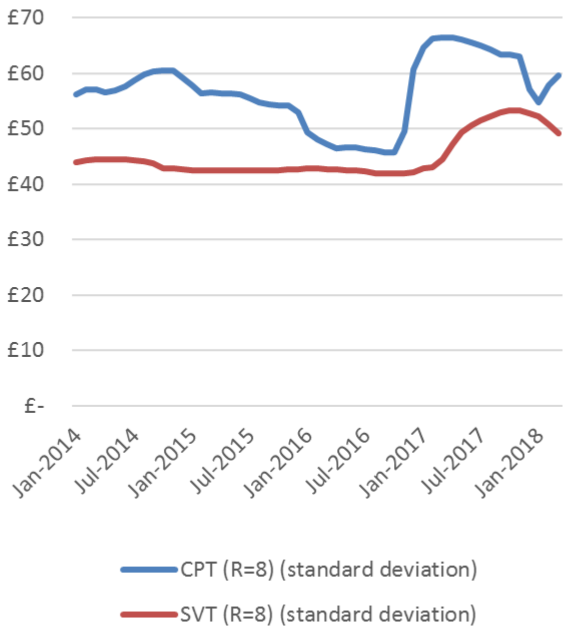
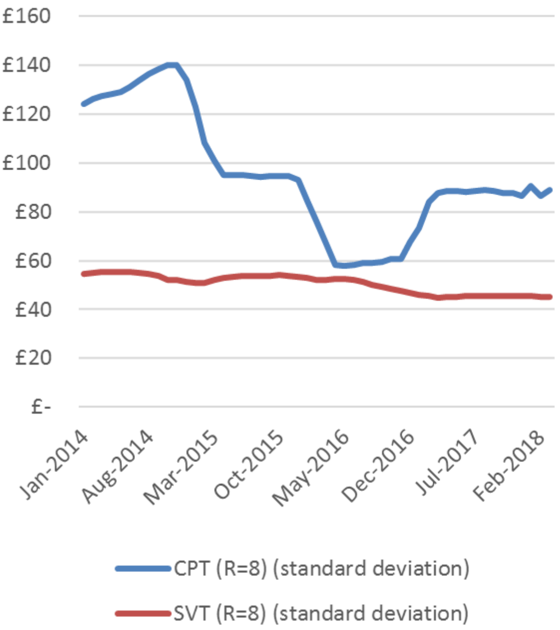


Figure 9: comparison of SVT and CPT prices adjusted for the risk coefficient R = 8 (gas)



Tipping point analysis – how risk averse does a consumer need to be for the savings to outweigh the risk?

For the tipping point analysis, we identify the critical values of risk aversion (R*) for both electricity and gas which equate consumer utility for the SVT and CPT tariff in the period from January 2014 onwards. Keeping the volatility estimates and the monthly averages fixed,[23] we let the R values for the CPT tariff vary in order to meet the corresponding monthly SVT bill amounts before taking an average of these values across the entire time interval we analyse.

The graphs below show how the R values for the CPT tariff vary from month to month (the dashed lines) if we keep the CPT bill amount fixed at the SVT utility levels, whereas the solid lines represent the average critical values that would equate the two tariffs across the period. A consumer would have been indifferent between the arrangements if they had the following risk aversion characteristics: $R^* = 2.13$ for electricity and $R^* = 1.38$ for gas. This means that an electricity consumer would need to have a risk aversion with $R^* < 2.13$ to be better off under a CPT arrangement. A gas consumer would need to have a higher tolerance for risk, $R^* < 1.38$, in order to be better off.

[23] Note that both expectations and volatility have been calculated on the basis of CPT prices.

Figure 10: Monthly fluctuations of the risk aversion coefficient in CPT to meet SVT price levels under R = 2 and critical value R*CPT across the period (electricity profile class 1)

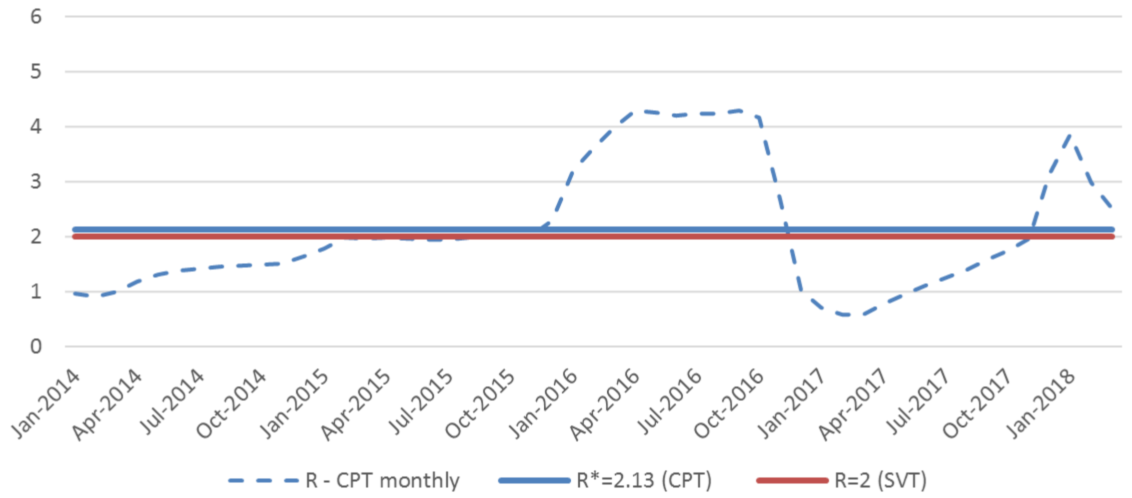
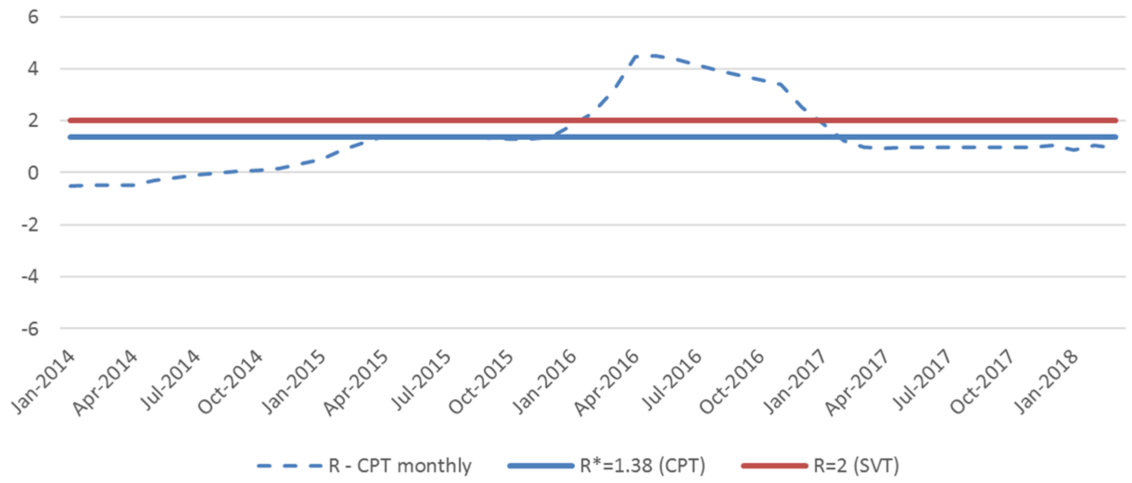


Figure 11: Monthly fluctuations of the risk aversion coefficient in CPT to meet SVT price levels under R = 2 and critical value R* CPT across the period (gas)



5. Discussion

Factors driving higher / lower costs under a cost pass-through arrangement

Wholesale costs

Under the CPT arrangement, on average, the wholesale cost of electricity, gas and dual fuel for a profile class 1 customer is cheaper than the SVT. For instance, for a typical dual fuel consumer, wholesale costs are around 7.4% cheaper (£33.36/year) under a CPT arrangement with DA gas prices and the electricity SBP. Likewise, on average, wholesale costs are 9.8% (£19.30/year) lower under a CPT arrangement for profile class 1 consumers (electricity only) than consumers on SVT tariffs.[24] This is primarily due to the removal of costs that are associated with hedging. Under the SVT counterfactual, suppliers incur costs associated with shaping (and reshaping) demand in line with hedging strategies, additional transaction costs and additional risk. When setting allowances under the default tariff cap, we have estimated that these hedging related costs account for approximately 6 – 8% of total wholesale related costs (see Appendix 1).[25] This is in line with the wholesale cost savings observed under the CPT arrangement.

Whilst wholesale costs in the CPT tariff are cheaper, on average, than the SVT for profile class 1 consumers (electricity, gas and dual fuel), consumers would be exposed to considerably more variation in the cost of their energy bills. In particular, gas consumption (and to a lesser extent prices) is strongly seasonal and, as such, bills in the colder winter months would be considerably higher under a CPT arrangement. We have also put forward analysis that suggests that the risk associated with wholesale price fluctuations could be detrimental to vulnerable / risk averse consumers, outweighing cost savings.

Network costs

We would not expect the CPT tariff to produce higher or lower network costs than the SVT as these charges are already time varying in line with demand profiles. However, our modelling does suggest slightly higher network costs under the electricity (2.8%) and gas (4.7%) CPT tariffs. We use CSS data to estimate the network cost component of an SVT and, if these costs are not borne equally across all tariff types, it may reduce the precision of our estimates. Alternatively, this could reflect some of the limitations of our modelling approach but, to the extent that it reduces the overall saving under the CPT tariff, it does help us to arrive at a more conservative savings estimate.

Operating costs

We have set an operating cost allowance below large suppliers' historical costs, in line with Ofgem's default tariff cap. Whilst it seems reasonable that, under the CPT tariff, a supplier would likely incur lower operating costs with respect to, for example, wholesale energy trading and sales & marketing, the reality is that this allowance implies considerable

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[24] Depending on different wholesale products the magnitude of saving varies. On average wholesale costs are 9.8% (£19.3) cheaper under CPT arrangement for profile class 1 consumers (using SPB prices – electricity only) whereas using DA prices wholesale costs are 19.8% (£38.6) lower than SVT for profile class 1 consumers (electricity only) per annum. In the same way, on average wholesale costs are 7.4% (£33.4/year) cheaper (using DA prices for gas and SBP for electricity) under CPT arrangement for dual fuel profile class 1 consumers while wholesale costs are 11.5% (£53.4/year) lower (using DA prices for gas and electricity) than SVT for dual fuel profile class 1 consumers.
[25] Note that this allowance does not include any operating costs associated with hedging.

improvements in efficiency. Since the default tariff cap, a number of suppliers have announced cost reduction plans in response to what they consider to be the challenges of the default tariff cap.[26] Consequently, under the CPT tariff with DA wholesale prices, operating costs would be lower for both single rate electricity (8.3%) and gas (9.8%) customers.

Environmental and policy costs

Similar to network costs, there is no reason that the costs associated with environmental and social obligations should vary under the CPT tariff with DA wholesale prices. However, our modelling suggests that these policy costs would be marginally higher for electricity (0.9%) but considerably higher for gas (49.0%) customers. However, in absolute terms, the difference in the gas policy costs estimates is quite small at only £8.08/year. We can only speculate that this reflects different assumptions on how the cost of the ECO and WHD schemes are apportioned between electricity and gas customers by the large six suppliers in the CSS data. An alternative explanation may be that there is cross-subsidisation of policy costs across default and fixed customers that is not picked up in our analysis.

EBIT (supplier pre-tax margin)

For the purposes of the CPT tariff, we have set a profit margin of 1.9% before interest and tax in line with the CMA's recommendation on normal profit in its Energy Market Investigation. It is therefore unsurprising that our dual fuel CPT tariff generates a considerably lower margin that that which prevails under the SVT. Curiously, under the DA price, the gas tariff produces a saving (76.1%) whereas the electricity tariff under the SBP increases costs by 21.1%. This notable contrast between gas and electricity arises from the low (often negative) electricity profit margins that are reported in the CSS data. This may, in turn, reflect how suppliers' pricing strategies are based on their dual fuel offerings.

Comparison with current market arrangements

Introducing a CPT arrangement would be a considerable deviation from the SVT based default arrangements:

- *Lower (but more volatile) prices* – SVT prices are generally stable, although SVT customers can experience significant step changes. In the last decade, the largest price change for an SVT was a ~10% increase which was observed across a number of suppliers in 2017 (dual fuel, direct debit). Although price changes are common, they are usually on a smaller scale. The CPT tariff represents an annual saving to consumers, but this will be at the expense of their monthly bills being significantly more volatile with the potential for monthly tariff increases in excess of 70% over a two-month period.[27]
- *Transparency* – If cost-reflectivity and transparency are to be advocated as core principles of a future energy framework, the CPT does have inherent benefits compared with the opaque pricing and hedging strategies typically adopted by suppliers for their SVT customers. However, this would require energy consumers to have access to wholesale market prices and their consumption data to see how costs

[26] See, for example, the recent announcement from npower: https://www.theguardian.com/business/2019/jan/31/npower-to-cut-900-jobs-predicts-financial-losses-2019-big-six-energy

[27] For example, our model suggests a typical dual fuel consumer on a CPT arrangement would have paid around £61 for their energy in September 2016, compared with around £105 for their energy in November 2016.

flow through to their bills. It also has the potential to ease concerns over 'profiteering'.

- *Similarity to default tariff cap* – By mandating that the rate of cost pass-through = 1, this methodology sets an enduring framework which includes an explicit cost allowance for the specific cost components that make up a typical domestic energy bill. This is similar to elements of the design of the default tariff cap, which sets upper thresholds for each cost component of a customer's bill.
- *Price signals for default customers* – This arrangement also creates high-frequency price signals, meaning that the price of energy for default consumers will change at least on a daily basis (but potentially half-hourly for electricity once key industry settlement arrangements are in place). This also represents a significant deviation from SVT prices, where (excluding a small number of economy 7/10 default tariffs) a single p/kwh unit rate is set regardless of what time of the day, week, year that unit is consumed.

Areas for further research

Our research has improved our understanding of the distributional impact of CPT, and has highlighted additional avenues of research that could be explored in more detail:

- We have been able to use Low Carbon London data to estimate the impact on three Acorn groups, but a more detailed quantitative assessment of distributional impacts by consumer segment could help inform any change to the current default tariff arrangements. This would require access to more disaggregated data sets and knowledge of the different consumption habits of groups of consumers, e.g. use of electric vehicles.
- Consideration of the impacts for consumers on fixed term tariffs, who may experience a price increase if a CPT default arrangement is introduced, could also be explored in future sensitivity analysis.
- Consumers may adjust their consumption in response to prices. It would be interesting to consider how changes to pricing signals associated with the CPT arrangement could affect domestic demand elasticity, by assessing the impacts associated with any increase in demand elasticity, e.g. system level benefits, demand side response product uptake etc. Such research could also inform other areas of change in the energy market, such as the growth of half-hourly settlement for domestic consumers.
- Modelling of variations in the design of the CPT tariff to smooth out or constrain price volatility, for instance the introduction of a "cap and floor" to minimise price shocks. Results suggests that a successful real time pricing mechanism entails careful analysis of consumer behaviour in response to price signals.[28] The nature of consumers is quite heterogeneous and their preferences, needs, and valuation for electricity may vary over time.
- Investigation of influences on customer behaviour beyond simple risk aversion.[29] For instance, in making their decisions, consumers may value differently very high or

[28] On the topic, see: M. Roozbehani, M. A. Daleh, S. K. Kitter (2012). "Volatility of power grids under real-time pricing" (available here: https://arxiv.org/pdf/1106.1401.pdf) and E. Hobman, E. R. Frederiks, K. Stenner (2016). "Uptake and usage of cost-reflective electricity pricing: Insights from psychology and behavioural economics", (available here: https://www.sciencedirect.com/science/article/pii/S1364032115015270)
[29] On the topic, see: Cardella and Kitchens (2016). "Price volatility and residential electricity decisions:

very low possible prices, or they may overestimate or underestimate their future energy consumption. This could influence consumer reaction to increased price volatility of bills and could warrant further investigation.

Experimental evidence on the convergence of energy generating source"
(available here: https://www.sciencedirect.com/science/article/pii/S0140988316301840)

Appendix 1 – Default tariff cap hedging assumptions

The assumed uplifts for reshaping, forecast error and imbalance, transaction costs and (for gas) unidentified gas in the wholesale cost allowance methodology of the default tariff cap model are outlined below.[30] This provides an indication of the level of hedging costs that are assumed to feature in a typical energy tariff.

Table 9: Electricity Allowances

	Single rate	Multi-register
Seasonal to monthly shaping	0.20%	0.20%
Monthly peak/baseload to hourly shaping	4.20%	4.20%
Rehedging day ahead	0.20%	0.20%
Imbalance	1.30%	1.30%
Transaction costs	0.40%	0.40%
Additional risk allowance	1.00%	1.00%
Total	**7.30%**	**7.30%**

Table 10: Gas Allowances

	Gas
Quarterly to monthly shaping	0.79%
Rehedging day ahead	3.39%
Imbalance	0.12%
Transaction costs	0.32%
Additional risk allowance	1.00%
Unidentified gas	0.96%
Total	**6.60%**

30 https://www.ofgem.gov.uk/system/files/docs/2018/11/annex_2_-_wholesale_cost_allowance_methodology_v1.2.xlsx

Appendix 2 – Full list of assumptions in CPT model

Electricity – TDCV Customer

Table 11: Electricity wholesale costs (TDCV customers) - Key Assumptions

Variable	Description
Electricity demand profile	The electricity demand profile (Class 1 and 2) are based on Elexon Estimated Regional Average Demands per Customer (ERADPC) data. The ERADPC data is scaled up based on Typical Domestic Consumption Values (TDCVs). Ofgem Publishes the TDCVs figures every two years.
	On 31 March 2013 and 2014, Data for settlement period 00:00 and 23:30 is not available, and hence is treated as zero.
	On 30 March 2015, Data for settlement period 00:00 and 23:30 is not available, and hence is treated as zero.
	On 27 March 2016, Data for settlement period 00:00 and 23:30 is not available, and hence is treated as zero.
	On 26 March 2017, Data for settlement period 00:00 and 23:30 is not available, and hence is treated as zero.
	On 27 March 2018, Data for settlement period 00:00 and 23:30 is not available, and hence is treated as zero.
Wholesale prices	All prices (SBP and DA) are nominal. Prices are obtained from Ofgem Wholesale markets team
Wholesale prices (SBP)	SBP Price on 31 March 2013 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Prices for the period 01/04/2012 - 31/12/2012 is missing, dummy prices for the year 2013 is used for these period (i.e. 01/04/2013-31/12/2013 data is used).
	SBP Price on 31 March 2014 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 29 March 2015 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 27 March 2016 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 26 March 2017 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 25 March 2017 for the settlement period 47 and 48 is not available, and hence is treated as zero.
Wholesale prices (DA)	DA price is available by hour which is formatted/treated as half hourly.
	DA Price on 1 Jan 2014 for the settlement period 45 and 46 is not available, and hence is treated as zero.
	DA Price on 30 March 2014 for the settlement period 3,4, 43 and 44 is not available, and hence is treated as zero.
SVT tariff	SVT baseline data cannot be disaggregated by various cost component. The CSS data is used to calculate the % share of each cost component and used to disaggregate the SVT into various components (Wholesale cost, Network cost etc.). Same % shares are used for profile class 1 and 2.

Table 12: Electricity network costs (TDCV customers) - Key Assumptions:

Variable	Description
Demand profile	Note that the same Elexon GB demand profile is applied to each Charge Restriction Region. In addition, we use the 2017/18 data for 2018/19 as these data were not available at the time of publication.
Transmission Network Use of System (TNUoS) charges	We apply the TNUoS charges for non-half-hourly customers, as published by National Grid, on a half hourly basis. Only distribution losses are applied to the demand profile.

Variable	Description
Distribution Use of System (DUoS) charges	We apply the DUoS charges, as published by the distribution network companies in their charging statements, on a half hourly basis. These are the final charges. We also use Ofgem's standard assumption on peak / off peak split for Economy 7 in the given period.
Balancing Services Use of System (BSUoS) charges	We apply the BSUoS charges, as published by National Grid, on a half hourly basis. Charges are as per the "SF" settlement run. Both distribution and transmission losses are applied to the demand profile.

Table 13: Electricity policy costs (TDCV customers) - Key Assumptions

Variable	Description
Demand profile	We use the typical domestic consumption values as published by Ofgem. Note that the same Elexon GB demand profile is applied to each Charge Restriction Region. Seasonal weights are applied to policies on this basis. In addition, we use the 2017/18 data for 2018/19 as these data were not available at the time of publication.
Renewable Obligation	We estimate the cost to a supplier of meeting its obligation under the renewable obligation scheme by combining the buyout price (as published by Ofgem) and obligation level (as published by BEIS).
Contracts for Difference (CfD)	We estimate the costs of CfDs by combining forecasts of the interim levy rate (as published by the LCCC) with assumptions about the proportion of demand which takes place in each quarter (based on the Elexon demand profile). An adjustment is made for green excluded electricity (based on the capped level of excluded energy). Finally, the operational cost levy (as published by the LCCC) is added. We also apply distribution and transmission losses here.
Feed in Tariff (FiT)	We estimate the cost to a supplier of meeting its obligation under the FiT scheme combining the latest OBR forecast of environmental levies for the scheme year, the BEIS Central projections of electricity which will be supplied by licensed suppliers and Ofgem's published exempt supply cap (MWh) in each scheme year.
Energy Company Obligation (ECO)	We estimate the cost to a "fully" obligated supplier of meeting its obligation under the ECO scheme. Forecasts of annual total scheme costs are based on those published by BEIS in its impact assessment. These are combined with Ofgem estimates of the share of total eligible supply volumes accounted for by "fully" obligated suppliers - and the total number of customers of those suppliers.
Warm Home Discount (WHD)	We calculate the cost to an obligated supplier of the WHD scheme. Target spending for the year is split out between Ofgem's expectation of core and non-core spending. The cost per customer is then calculated using our estimates of the number of customers of obligated suppliers. We also exclude that part of core spending captured by voluntary suppliers.
Assistance For Areas With High Electricity Distribution Costs	We apply the costs of charges associated with assistance for areas with high electricity distribution costs, as published by National Grid. We also apply distribution loss multipliers here.

Table 14: Electricity losses (TDCV customers) - Key Assumptions

Variable	Description
Demand profile	We use the typical domestic consumption values as published by Ofgem. Note that the same Elexon GB demand profile is applied to each Charge Restriction Region. In addition, we use the 2017/18 data for 2018/19 as these data were not available at the time of publication.
Distribution Line Loss Factors (LLF)	We apply the LLFs as published by the Distribution Network Operators in their charging statements (Schedule of Charges and other tables, Annex 5).
Estimated Transmission	We apply the ETLMO as published by Elexon.

Variable	Description
Loss Multiplier (ETLMO)	
Regional Transmission Loss Factor (TLF)	We apply the adjusted seasonal zonal transmission loss factors, as published by Elexon, to each region.

Table 15: Electricity capacity market (TDCV customers) – Key Assumptions:

Variable	Description
Capacity Market	The capacity market cost is calculated using the information on obligated capacity and clearing prices from previous capacity auctions held by National Grid, which are combined with the demand and losses to derive a cost per domestic electricity customer. **Electricity demand profile**: The electricity demand profile (Class 1 and 2) are based on Elexon Estimated Regional Average Demands per Customer (ERADPC) data. The ERADPC data is scaled up based on Typical Domestic Consumption Values (TDCVs). Ofgem publishes the TDCVs figures every two years. **Losses**: Loss multipliers for the specific winter peak period are applied to the estimated cost of the scheme in £/MWh. **Obligated Capacity:** Obligated capacity is taken from the capacity market registers as published by National Grid. **Administrative Costs:** Administrative cost is based on the total budget of Electricity Settlements Company published by BEIS. **Clearing Prices:** Clearing prices are based on the National Grid figures published.

Table 16: Electricity SVT (TDCV customers) – Key Assumptions:

Variable	Description
Annual tariff data	We source annual tariff data for single electricity customers across a range of suppliers and Charge Restriction regions from Energy Helpline. These tariffs are based on the annual bill of a Typical Domestic Consumption Values (TDCV) customer. Note that only tariffs classed as SVTs were included.
Market Shares	We use Ofgem data on the domestic (profile class 1 and 2) regional market shares. We use this data to weight the average SVT tariff in each Charge Restriction Region in line with supplier market shares. Implicitly, we are assuming that the distribution of SVT customers across regions is the same as the distribution of all customers (including those on fixed tariffs) across the regions.
Regional Weights	We use data from electricity Distribution Network Operator areas on household numbers (from DNOs' CDCM15 models, 2015-16) to weight each Charge Restriction Region in the GB average. Again, we assume that the distribution of SVT customers across regions is the same as the distribution of all customers.

Table 17: Electricity operating costs (TDCV customers) – Key Assumptions:

Variable	Description
Baseline value of operating costs allowance	We use the Baseline Value of the Operating Cost Allowance for each Benchmark Metering Arrangement as published in the default tariff cap notice. These are used as the values for April - September 2017.
Smart metering net cost change	We use the value of the Smart Metering Net Cost Change for electricity customers as published in the default tariff cap notice. These are used as the values for April - September 2017.
Payment method adjustment	We use the Payment Method Adjustment Additional Cost and Payment Method Adjustment Percentage for a non-standard credit customer on each Benchmark Metering Arrangement with the Benchmark Annual Consumption Level. These are used as the values for April - September 2017.

Variable	Description
Inflation adjustment	We adjust the operating cost and the Payment Method Adjustment Additional Cost baseline to account for inflation. We index relative to CPIH in December 2016.
Efficiency adjustment	We adjust the operating cost and the Payment Method Adjustment Additional Cost baseline to reflect the general increase in operating costs over time due to, for example, the introduction of smart meters. This adjustment reflects the trend in operating costs as reported in the Consolidated Segmental Statements.

Electricity – Distributional Analysis - Acorn group customers

Table 18: Electricity wholesale costs (Acorn group) – Key Assumptions:

Variable	Description
Electricity demand profile	We have used Low Carbon London (LCL) data to construct the demand profile for three Acorn groups. The LCL data covers the period Nov 2011 – Feb 2014 and is based on 5,567 London households.
	28 Feb 2013-31 March 2013 data is used for the period 28 Feb 2014 - 31 March 2014 as the LCL data covers the period Nov 2011-27 Feb 2014. This applies to all three Acorn groups (Affluent, Adversity and Comfortable).
	The 2013-2014 Acorn group (Affluent, Adversity and Comfortable) demand profile is used for the years 2014-2015, 2015-2016, 2016-2017, 2017-2018 and 2018-2019.
Wholesale prices	All prices (SBP and DA) are nominal. Prices are obtained from Ofgem Wholesale markets team.
Wholesale prices (SBP)	SBP Price on 31 March 2013 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Prices for the period 01/04/2012 - 31/12/2012 is missing, dummy prices for the year 2013 is used for these period (i.e. 01/04/2013-31/12/2013 data is used).
	SBP Price on 31 March 2014 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 29 March 2015 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 27 March 2016 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 26 March 2017 for the settlement period 47 and 48 is not available, and hence is treated as zero.
	SBP Price on 25 March 2017 for the settlement period 47 and 48 is not available, and hence is treated as zero.
Wholesale prices (DA)	DA Price is available by hourly which is formatted/treated half hourly.
	DA Price on 1 Jan 2014 for the settlement period 45 and 46 is not available, and hence is treated as zero.
	DA Price on 30 March 2014 for the settlement period 3,4, 43 and 44 is not available, and hence is treated as zero.
SVT tariff	SVT baseline data cannot be disaggregated by various cost component. The CSS data is used to calculate the % share of each cost component and used to disaggregate the SVT into various components (Wholesale cost, Network cost etc.). Same % shares are used for all three Acorn groups.

Table 19: Electricity network costs (Acorn group) – Key Assumptions:

Variable	Description
Demand profile	Note that the same LCL demand profile for the three Acorn Groups is applied across each Charge Restriction Region. In addition, we use the 2013/14 data for the years 2014/15 to 2018/19 as these years were not covered in the trial.
Transmission Network Use of System (TNUoS) charges	As per electricity TDCV customer

Distribution Use of System (DUoS) charges	As per electricity TDCV customer
Balancing Services Use of System (BSUoS) charges	As per electricity TDCV customer

Table 20: Electricity policy costs (Acorn group) – Key Assumptions:

Variable	Description
Demand profile	We use the LCP demand profiles and consumption values for the three Acorn groups. Note that the same demand profile is applied to each Charge Restriction Region. Seasonal weights are applied to policies on this basis. In addition, we use the 2013/14 data for the years 2014/15 to 2018/19 as these years were not covered in the trial.
Renewable Obligation	As per electricity TDCV customer – except we adjust the figure to reflect MWh supplied
Contracts for Difference (CfD)	As per electricity TDCV customer – except we adjust the figure to reflect MWh supplied
Feed in Tariff (FiT)	As per electricity TDCV customer – except we adjust the figure to reflect MWh supplied
Energy Company Obligation (ECO)	As per electricity TDCV customer – except we adjust the figure to reflect MWh supplied
Warm Home Discount (WHD)	As per electricity TDCV customer
Assistance For Areas With High Electricity Distribution Costs	As per electricity TDCV customer – except we adjust the figure to reflect MWh supplied

Table 21: Electricity losses (Acorn group) – Key Assumptions:

Variable	Description
Demand profile	We use the LCP demand profiles and consumption values for the three Acorn groups. Note that the same demand profile is applied to each Charge Restriction Region. Seasonal weights are applied to policies on this basis. In addition, we use the 2013/14 data for the years 2014/15 to 2018/19 as these years were not covered in the trial.
Distribution Line Loss Factors (LLF)	As per electricity TDCV customer
Estimated Transmission Loss Multiplier (ETLMO)	As per electricity TDCV customer
Regional Transmission Loss Factor (TLF)	As per electricity TDCV customer

Table 22: Electricity capacity market (Acorn group) – Key Assumptions:

Variable	Description
Capacity Market	The capacity market cost is calculated using the information on obligated capacity and clearing prices from previous capacity auctions held by

Variable	Description
	National Grid, which are combined with the demand and losses to derive a cost per domestic electricity customer. **Electricity demand profile**: We have used the Low Carbon London (LCL) data to construct the demand profiles for Acorn groups (Affluent, Adversity and Comfortable). The LCL data is based on half hourly demand profile of +5 thousand London households covering periods Nov 2011 - Feb 2014. We have applied the same demand profile of the three groups (i.e. demand profile constructed based on LCL data) to all Charge Restriction Region. We have also adjusted the demand profiles to Typical Domestic Consumption Values (TDCV) published by Ofgem. **Losses**: Loss multipliers for the specific winter peak period are applied to the estimated cost of the scheme in £/MWh. **Obligated Capacity:** Obligated capacity is taken from the capacity market registers as published by National Grid. **Administrative Costs:** Administrative cost is based on the total budget of Electricity Settlements Company published by BEIS. **Clearing Prices:** Clearing prices are based on the National Grid figures published.

Table 23: Electricity SVT (Acorn group) – Key Assumptions:

Variable	Description
Annual tariff data	We adjust the annual tariff data that was sourced from Energy Helpline to reflect the varying consumption levels of the three different Acorn groups. We isolate the variable charge and then increase/decrease it to reflect the Acorn group's consumption level. We then add back in the standing charge.
Market Shares	As per electricity TDCV customer
Regional Weights	As per electricity TDCV customer

Table 24: Electricity operating costs (Acorn group) – Key Assumptions:

Variable	Description
Baseline value of operating costs allowance	As per electricity TDCV customer
Smart metering net cost change	As per electricity TDCV customer
Payment method adjustment	As per electricity TDCV customer – note we were unable to adjust this methodology to account for the varying consumption levels of the different Acorn Groups
Inflation adjustment	As per electricity TDCV customer
Efficiency adjustment	As per electricity TDCV customer

Gas – TDCV customers

Table 25: Gas wholesale costs (TDCV customer) – Key Assumptions:

Variable	Description
Gas Demand Profile	We have used National Grid gas daily demand profiles by combining daily LDZ demands, and calculating what proportion of annual demand is allocated to each day and then adjusted/scaled up to gas Typical Domestic Consumption Values (TDCV) published by Ofgem.
	Demand Data for the period 01/01/2013 - 17/11/2013 is not available and hence 2014 data is used for this period.
	Demand profile data is adjusted for the Typical Domestic Values (TDCV) published by Ofgem.

Variable	Description
Wholesale Price (DA)	All prices are nominal and are obtained from Ofgem Wholesale market team.
	DA gas data for the weekends and public holidays are not available and hence the most recent available price data is used for the weekends and bank holidays
	Most recent available DA price data is used for the missing price data.
	Data for the month Jan 2013 - 31 March 2013 is not available, 2014 data for this period is used.
Mapping	13 LDZs are mapped with 14 electricity regions based on CMA weighted figures which is also used in price cap.

Table 26: Gas network costs (TDCV customer) – Key Assumptions:

Variable	Description
Demand profile	We use Ofgem's standardised typical domestic consumption values. A daily demand profile was constructed from National Grid data on actual non-daily metered consumption by LDZ.
Load factors	We use the annual load factors for the meters that we use to estimate peak daily demand in each region, as published by Xoserve.
NTS capacity by exit zone	We use the target volume of capacity by exit zone to weight the exit zones when calculating the ECN charges by LDZ. These are taken from the Gas transporter licence, special conditions, Chapter 1, Appendix 2 (p40).
Exit Capacity NTS (ECN) charges	We use the NTS exit capacity charges (in pence per peak day kWh per day) for each charging year, taken from the gas distribution companies charging statements. Weighted average charges for LDZs are calculated by weighting exit zones according to target flat capacity.
SO and TO exit charges	We apply the SO and TO exit commodity charges (in pence per kWh), as published by National Grid. These are weighted averages of the relevant periods when the charges were in effect.
Gas distribution charges	We apply the gas distribution commodity (in pence per kWh) and capacity (in pence per peak day kWh per day) charges, as published by the gas distribution network companies.
Mapping LDZ charges to Charge Restriction Regions	We match gas transmission and distribution charges by LDZ to the Charge Restriction Regions. Weighted averages are calculated, according to overlap between LDZ and the electricity regions, with the relevant weightings used being those that were published by the CMA.

Table 27: Gas policy costs (TDCV customer) – Key Assumptions:

Variable	Description
Demand profile	We use the typical domestic consumption values as published by Ofgem.
Energy Company Obligation (ECO)	We estimate the cost to a "fully" obligated supplier of meeting its obligation under the ECO scheme. Forecasts of annual total scheme costs are based on those published by BEIS in its impact assessment. These are combined with Ofgem estimates of the share of total eligible supply volumes accounted for by "fully" obligated suppliers - and the total number of customers of those suppliers.
Warm Home Discount (WHD)	We calculate the cost to an obligated supplier of the WHD scheme. Target spending for the year is split out between Ofgem's expectation of core and non-core spending. The cost per customer is then calculated using our estimates of the number of customers of obligated suppliers. We also exclude that part of core spending captured by voluntary suppliers.

Table 28: Gas SVT (TDCV customer) – Key Assumptions:

Variable	Description
Annual tariff data	We source annual tariff data for single gas customers across a range of suppliers and Charge Restriction regions from Energy Helpline. These tariffs that are based on the annual bill of a Typical Domestic Consumption Values (TDCV) customer. Note that only tariffs classed as SVTs were included.

Variable	Description
Market Shares	We use Ofgem data on the domestic (gas) regional market shares. We use this data to weight the average SVT tariff in each Charge Restriction Region in line with supplier's market shares. Implicitly, we are assuming that the distribution of SVT customers across regions is the same as the distribution of all customers (including those on fixed tariffs) across the regions.
Regional Weights	We use Gas Distribution Network areas data on customer numbers with consumption < 73,200 kWh/y (GDN supplied information, 2014) to weight each LDZ in the GB average. Again, we assume that the distribution of SVT customers across regions is the same as the distribution of all customers. Finally, the LDZ weights are converted to Charge Restriction Region weights using the aforementioned CMA mappings.

Table 29: Gas operating costs (TDCV customer) – Key Assumptions:

Variable	Description
Baseline value of operating costs allowance	We use the Baseline Value of the Operating Cost Allowance for gas customers as published in the default tariff cap notice. These are used as the values for April - September 2017.
Smart metering net cost change	We use the value of the Smart Metering Net Cost Change for gas as published in the default tariff cap notice. These are used as the values for April - September 2017.
Payment method adjustment	We use the Payment Method Adjustment Additional Cost and Payment Method Adjustment Percentage for a non-standard credit gas customer with the Benchmark Annual Consumption Level. These are used as the values for April - September 2017.
Inflation adjustment	As per electricity TDCV customer
Efficiency adjustment	As per electricity TDCV customer

Appendix 3 – Further analysis of CPT tariffs

Figure 12: Dual fuel monthly TDCV bill under SVT and CPT (with electricity and gas with DA prices)

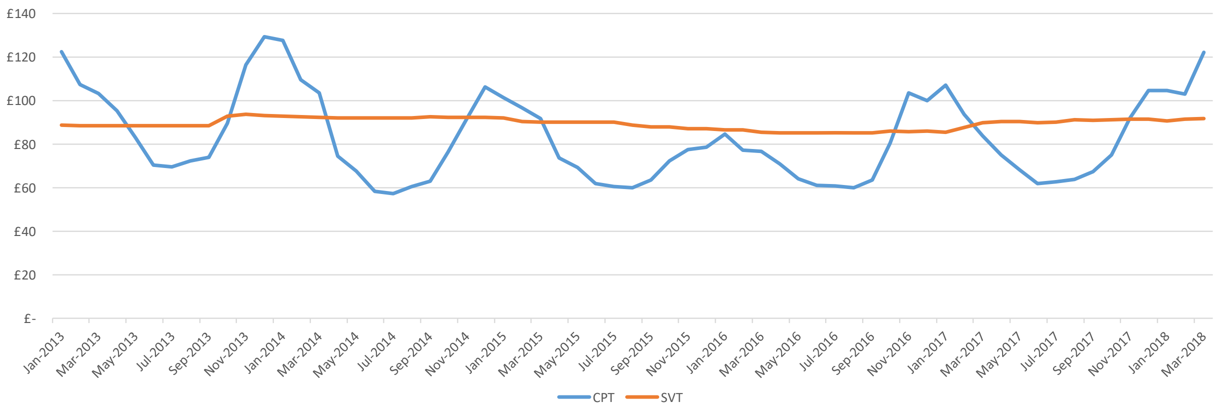


Table 11: Cost pass-through savings under DA wholesale price for electricity and gas – dual fuel

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£261.62	11.0%	£49.83	11.0%	£4.67	£16.96
Network costs	(£50.91)	(3.7%)	(£9.70)	(3.7%)	£1.30	£2.16
Operating costs	£84.19	9.1%	£16.04	9.1%	£2.20	£1.04
Environmental and social obligation costs	(£45.74)	(9.7%)	(£8.71)	(9.7%)	£0.81	£1.35
VAT	£15.61	5.8%	£2.97	5.8%	£0.12	£0.99
Supplier pre-tax margin	£149.45	60.8%	£28.47	60.8%	£0.27	£0.38
Total	**£414.21**	**7.3%**	**£78.90**	**7.3%**	**£2.54**	**£19.82**

Table 12: Cost pass-through savings under electricity DA price – profile class 1

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£187.83	18.2%	£35.78	18.2%	£0.94	£3.25
Network costs	(£19.35)	(2.8%)	(£3.69)	(2.8%)	£0.81	£1.58
Operating costs	£35.81	8.3%	£6.82	8.3%	£1.16	£0.50
Environmental and social obligation costs	(£3.32)	(0.9%)	(£0.63)	(0.9%)	£1.15	£1.44
VAT	£5.32	4.1%	£1.01	4.1%	£0.10	£0.27
Supplier pre-tax margin	(£8.17)	(21.1%)	(£1.56)	(21.1%)	£0.76	£0.10
Total	**£198.12**	**7.3%**	**£37.74**	**7.3%**	**£2.13**	**£4.97**

Table 13: Cost pass-through savings under electricity DA price – profile class 2

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£124.68	9.8%	£23.75	9.8%	£1.11	£6.00
Network costs	£161.35	19.2%	£30.73	19.2%	£1.05	£2.29
Operating costs	£133.37	25.1%	£25.40	25.1%	£1.45	£0.50
Environmental and social obligation costs	(£57.10)	(12.0%)	(£10.88)	(12.0%)	£1.42	£1.72
VAT	£10.95	6.9%	£2.09	6.9%	£0.13	£0.47
Supplier pre-tax margin	(£8.54)	(18.0%)	(£1.63)	(18.0%)	£0.94	£0.18
Total	**£364.71**	**11.0%**	**£69.47**	**11.0%**	**£2.72**	**£8.48**

Table 14: Cost pass-through savings under electricity DA price – Adversity group

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£222.90	22.8%	£42.46	22.8%	£0.92	£3.70
Network costs	(£39.61)	(6.1%)	(£7.54)	(6.1%)	£0.75	£1.31
Operating costs	£14.21	3.5%	£2.71	3.5%	£1.09	£0.50
Environmental and social obligation costs	(£14.55)	(4.0%)	(£2.77)	(4.0%)	£1.08	£1.47
VAT	£1.77	1.4%	£0.34	1.4%	£0.09	£0.24
Supplier pre-tax margin	(£8.93)	(24.3%)	(£1.70)	(24.3%)	£0.72	£0.09
Total	**£175.79**	**6.9%**	**£33.48**	**6.9%**	**£1.97**	**£5.57**

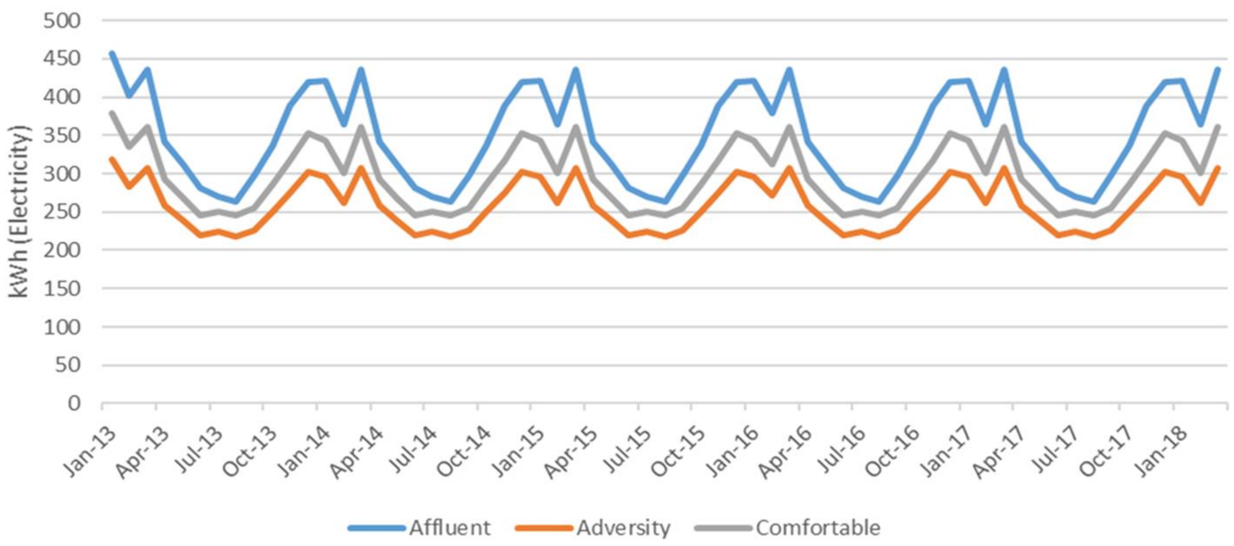
Table 15: Cost pass-through savings under electricity DA price – Comfortable group

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£228.29	20.8%	£43.48	20.8%	£1.03	£4.39
Network costs	(£49.78)	(6.9%)	(£9.48)	(6.9%)	£0.85	£1.69
Operating costs	£62.75	13.6%	£11.95	13.6%	£1.23	£0.50
Environmental and social obligation costs	(£20.09)	(4.9%)	(£3.83)	(4.9%)	£1.22	£1.68
VAT	£2.46	1.8%	£0.47	1.8%	£0.11	£0.30
Supplier pre-tax margin	(£9.85)	(23.9%)	(£1.88)	(23.9%)	£0.81	£0.11
Total	**£213.79**	**7.4%**	**£40.72**	**7.4%**	**£2.24**	**£6.61**

Table 16: Cost pass-through savings under electricity DA price – Affluent group

Cost component	Jan-2013 to Mar-2018		Annual equivalent		Standard deviation	
	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	CPT (dis)saving vs. SVT	% (dis)saving vs. SVT	SVT	CPT
Wholesale costs	£244.51	19.4%	£46.57	19.4%	£1.18	£5.45
Network costs	(£52.50)	(6.3%)	(£10.00)	(6.3%)	£0.99	£2.32
Operating costs	£130.26	24.6%	£24.81	24.6%	£1.42	£0.50
Environmental and social obligation costs	(£27.33)	(5.8%)	(£5.21)	(5.8%)	£1.41	£1.97
VAT	£4.52	2.9%	£0.86	2.9%	£0.12	£0.39
Supplier pre-tax margin	(£10.72)	(22.6%)	(£2.04)	(22.6%)	£0.93	£0.15
Total	**£288.74**	**8.7%**	**£55.00**	**8.7%**	**£2.62**	**£8.29**

Figure 13: Average monthly demand profile (Acorn group)



Appendix 4 – Risk aversion analysis

Methodology approach and further considerations

Consumers, especially those in vulnerable circumstances, tend to dislike the increased volatility that comes with CPT and this can increase their overall disutility. We considered that consumers' disutility depends on their past consumption (habit) and their estimates of price shocks. However, having no direct information about these shocks, they care about their monthly energy bills.[31]

In particular, following some insights from the mean-variance utility literature,[32] we assumed that consumers looked at where their bills are centred (the mean) and how dispersed they are (the variance), supposing a trade-off between these two that is captured by the risk aversion coefficient. If we increase the risk (higher standard deviation) the agent needs to be compensated more and, therefore, will expect higher savings (or lower expected bills) to account for this increase in risk. Therefore, we defined the "total monthly disutility" for the consumers as the sum of the monthly average bills and the monthly volatility measured on the correspondent period and adjusted for a given coefficient of risk aversion R, whose values range from 1 to 10. The higher the level of R, the greater the degree of risk aversion. The benchmark level associated with a typical consumer is set at R=2.

We estimated the "variability" of energy bills, expressed in terms of standard variation,[33] and therefore tried to monetise the associated risk of price shocks under the assumptions of a 12-month rolling timeframe and a forward looking approach so that the value at time t is based on the 12 earlier periods (t-12; t-1). To maintain time consistency, the average bill is the simple average of the monthly bill payments referring to the same previous 12 months.

Our results on volatility are based on two different risk averse scenarios. In particular, we looked at the typical consumer (R=2) who tends to equally weight savings and volatility, and highly risk averse consumers (R=8), more vulnerable, who care more about price variations. In all our exercises (either comparing the risk profiles or the price strategies) it is important to note that we did not allow for potential behavioural responses to time-varying prices. Such responses could strengthen the case for a cost pass-through tariff, because of the individual and system benefits of consuming less when demand (and prices) are high.[34]

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[31] "Real-time pricing under information asymmetry induces additional uncertainties due to the uncertainty in consumer behaviour, preferences, private valuation for electricity, and consequently, unpredictable reactions to real-time prices", M. Roozbehani, M. A. Daleh, S. K. Kitter (2011).
[32] Ang, A. (2014). Asset Management: A Systematic Approach to Factor Investing. Oxford Scholarship Online. [Accessed on http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199959327.001.0001/acprof-9780199959327-chapter-2 on 22 February 2019].
[33] Notably, the standard deviation (σ) is a dispersion measure of the mean deviations of the values from their average. It is largely adopted in the literature, however, in the context of this research, we are aware of potential limitations. Among these: 1) "smoothing effect" as it does not take into account the intensity and so the different magnitude of the observations; 2) "spurious effect" as it assigns the same weights to the observations.
[34] William W. Hogan (2014). Time of-use rates and real time prices. [Accessed on https://sites.hks.harvard.edu/fs/whogan/Hogan_TOU_RTP_Newark_082314.pdf].