Liquidity Constraints and High Electricity Use Among Low-Income Households

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Abstract

It is a well established fact that electricity use increases with income. What is less well known is that - despite the positive correlation between electricity use and income - a significant portion of low-income households consume very large amounts of electricity.

In this paper, we make a first step towards better understanding this phenomenon. Specifically, we test the hypothesis that the high electricity use is driven by the fact that low-income households find it difficult to purchase heating oil upfront/in bulk and so use electricity to heat their homes.

Using data from the Northern Ireland Continuous Household Survey and Living Cost and Food Survey, we show that an exogenous increase in income by £250 leads to an increase (decrease) in the probability that low-income households use oil (electricity) for heating by approximately 40 (30) percentage points. In addition, we provide evidence which is at odds with a set of alternative explanations for our findings.

1 Introduction

With rising costs of elements in electricity production and distribution and a growing concern regarding the threat of climate change, policy makers are increasingly becoming aware that retail energy prices will have to rise to reflect the full cost of consumption.

At the same time, there is concern that higher energy prices are going to disproportionally impact the poor. The tension between the need for high energy prices on the one hand and the vulnerability of low-income households on the other, has led the Northern Ireland utility regulator (NIAUR) to examine (among other things) different types of 'social tariffs' for the electric utility industry (NIAUR, 2010).

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One type of tariff which is frequently debated in this context is a 'two-part tariff': The idea of this tariff is to provide a subsidized price for low levels of consumption with the subsidy cost recovered in the pricing of larger levels of electricity use. As an illustration, Figure 1 below shows a hypothetical two-part tariff for Northern Ireland. It shows a price below the current flat rate tariff up to 200 KWh per month and a higher price thereafter.[1]

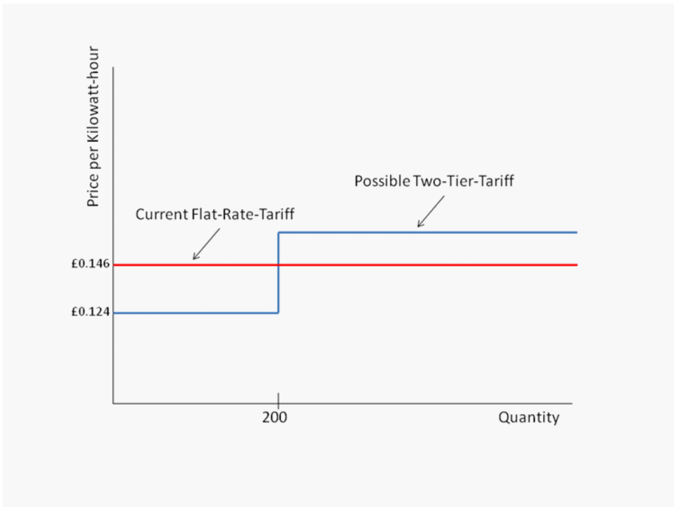

Figure 1: A hypothetical two-part tariff for Northern Ireland.

The central assumption underlying this type of tariff is that low-income households also have low electricity consumption. While this assumption is generally true (i.e. there is a positive correlation between income and electricity use), 17% of households in Northern Ireland with an annual income below the median, have a very high energy use. That is, their energy consumption lies in the top quartile of all households.[2]

In this paper, we make a first step towards better understanding this phenomenon. Specifically, we test the hypothesis that the high electricity use is driven (at least in part) by the fact that a large part of low-income households is not able to purchase heating oil upfront/in bulk and so has to use electricity to heat their homes.

Testing this hypothesis is important: If low income households are forced to use electricity to heat their homes, it is likely that these households will find it difficult to substitute away from electricity use after a change in tariff structure – resulting in higher bills under a two-part tariff. In addition, if we find evidence for our hypothesis, this suggests that there might be other ways to reduce the electricity bills of low-income households – such as by helping them finance the purchase of heating oil.

The paper is divided into seven parts: In the second part, we explore what drives high electricity use among low-income households. In the third part, we motivate our main hypothesis. In the fourth part, we develop an empirical strategy to test our hypothesis.

[1] Please note that the 'two-part tariff' implies an increasing marginal price for electricity. That is, a customer whose consumption level puts him or her on the higher tier (above 200 KWh in the example) would still pay the lower-tier rates for consumption up to the threshold to the higher tier.

[2] Data: Combined dataset of the Expenditure and Food Survey for 2004; 2005; 2006; 2007 and the Living Cost and Food Survey for 2008. The calculation controls for survey month and survey year.

We present the main findings from our analysis and evidence which is at odds with a set of alternative explanations in the fifth and sixth part of the paper. The seventh part concludes, spells out policy implications and outlines next steps.

2 What drives high electricity use among low income households?

In this section, we explore what drives high electricity use among low-income households. We proceed in two steps:

- We first estimate the quantitative relationship between electricity use and a set of household background characteristics
- We then explore to what extent the prevalence of these characteristics varies across different levels of income.

The underlying idea of this approach is that for a variable to explain a significant part of the high electricity use among low income households, we expect it i) to be statistically significantly related to high electricity use and ii) to be more prevalent among low-income households.

2.1 What drives high electricity use?

We start our analysis with a simple empirical exercise: we regress electricity use on a set of household characteristics – such as household demographics, household size, housing type and income level.

In order not to impose a particular functional form on the relationship between electricity use and income, we use a semi-parametric specification of our model – of the following form:

$$e_i = g(x_i) + z_i\beta + \varepsilon_i \quad (1)$$

where e_i stands for electricity use of household i; x_i is household income; z_i are household characteristics (which are added in a linear way) and ε_i is an iid mean-zero error term such that Var$[e|x,z]$=σ_ε^2. We estimate our model using the 'differencing' method discussed by Yatchev (1998, 2003).[3]

Our data comes from the 2008/2009 Northern Ireland Continuous Household Survey (CHS). The CHS is a voluntary sample survey of private household. The basic unit of the survey is the household. Each individual aged 16 or over in the household is interviewed. The survey covers questions on population, housing, employment, education and health.

Around 4,500 households are selected each year for the CHS. 2,632 households co-operated fully in 2008/2009 – giving a response rate of 58 per cent. Table 2 provides summary statistics of our sample. It shows the number of observations in our sample and mean values of the key variables. (Variables marked with a * take on a value of either 0 or 1 for each household).[4]

[3] See also Alan et al (2002, 2003) and Mesnard and Ravallion (2001)

[4] To deal with problems of non-response, we exclude households with zero income. To ensure the robustness of our estimates we exclude households with an income >50,000.

	Summary Statistics
Number of Observations	1,773
Electr. Consumption (quarterly)	747.7
	(545.5)
Age (HRP)	50.9
	(18.3)
Household Income	22,104
	(23,912)
Labour Market Status*	0.38
(Inactive=1)	(0.49)
Housing Type* (Detached=1)	0.38
	(0.49)
Electric Heating* (EH=1)	0.24
	(0.43)
Number of Rooms	5.73
	(1.82)
Ownership* (Rent=1)	0.31
	(0.46)
Number of Adults	1.99
	(0.96)
Number of Children	0.55
	(0.98)
Env. Attitude* (No Concern=1)	0.19
	(0.39)

Table 2: Background Characteristics

Table 3 below gives the estimates of our background characteristics on household electricity use (i.e. the estimates of β in equation 1). It shows that electricity use tends to be higher in larger houses; houses which are detached; houses occupied by more people and by older people. The table also shows that – on average – using electricity for heating is associated with a significantly higher electricity use (by ca 210 KWh per quarter).

	Coefficient
Age HRP	23.56***
	(9.03)
Age HRP^2	-0.23***
	(0.09)
LM Status* (Inactive=1)	4.08
	(42.48)
Housing Type* (Det=1)	86.76**
	(36.53)
Electric Heating* (EH=1)	213.63***
	(33.81)
Number of Rooms	23.90**
	(11.51)
Ownership* (Rent=1)	-41.34
	(37.71)
Number of Adults	106.30***
	(20.00)
Number of Children	113.32***
	(18.26)
Env. Attitude* (No Concern=1)	12.42
	(36.96)
Significance HH Income	V=1.336 P>|V|=0.09

Table 3: Semi-parametric Euler estimation

In Figure 2, we plot the estimated relationship between electricity use and household income.

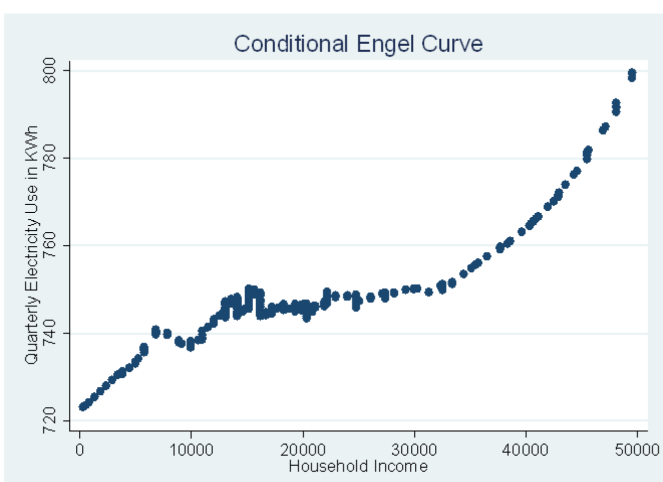

Figure 2: Conditional Engel Curve

The figure shows a positive relationship between electricity use and income – conditional on the variables in Table 3. That is, the figure shows that, all else equal, higher levels of income are typically associated with higher levels of electricity use.

2.2 Low Income Households

One reason why – despite the positive relationship between income and electricity use – electricity use may be very high for some low-income households is that one or more background characteristics which are positively associated with electricity use are relatively prevalent among households with low levels of income.

The idea is that if, say, having a child increases electricity use, but it is mostly low-income households which have children, then having a child is a likely driver for the high electricity use among low income households (relative to that of all households). In Figure 3, we plot the prevalence of our background characteristics by income – using local linear regressions to smooth the data.

To save space, we only show figures for characteristics which were significant in Table 3. (Plots for all other variables can be found in Appendix A).

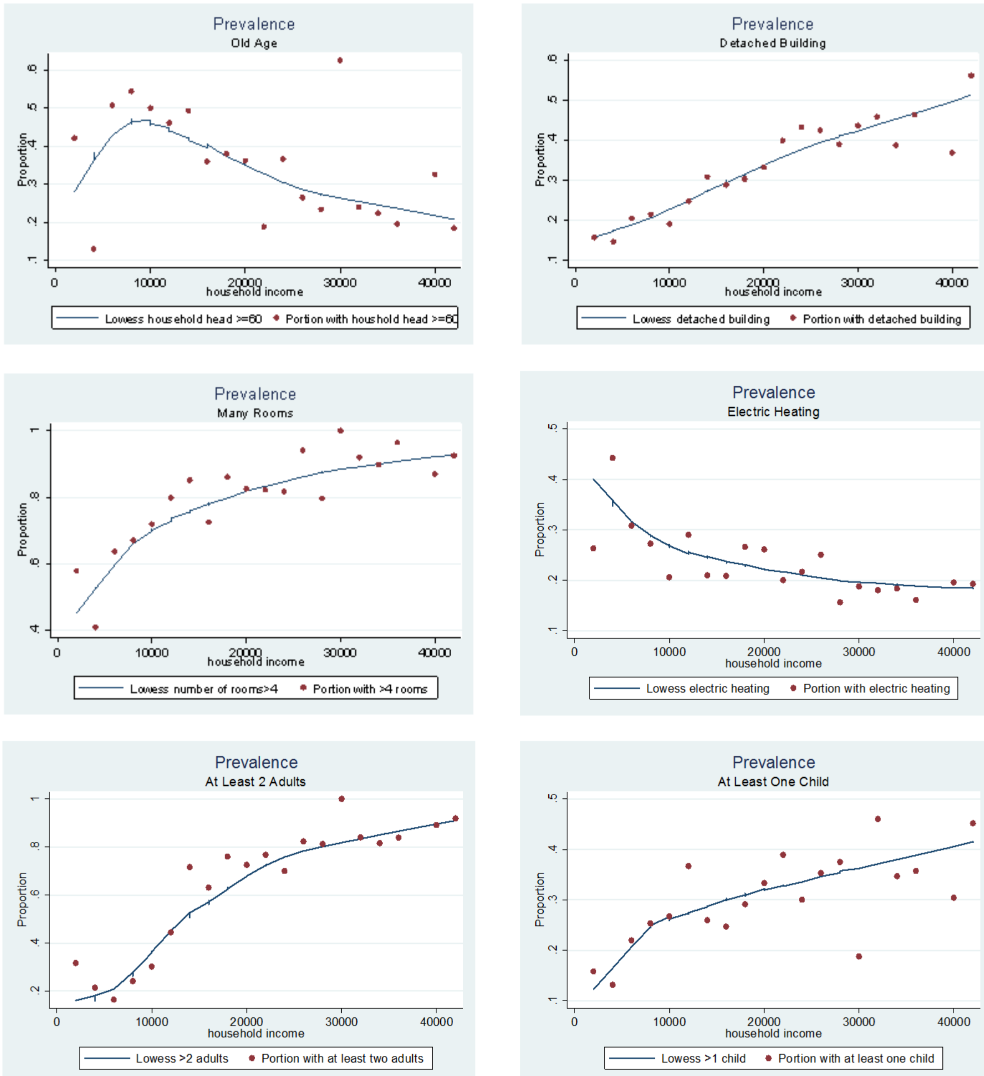

Figure 3: Distribution of background characteristics over household income

The figures show that – among the main background variables in our model – only being above 60 and using electricity for heating are significantly more prevalent among low levels of income. This – together with the finding that both variables are associated with a significantly higher electricity use – suggests that they are important drivers of the high electricity use among low income households.[5]

In the following we focus on the second background characteristic – which is use of electric heating.

[5]We have (implicitly) assumed that the effects of our background variables on electricity consumption are the same across different levels of income. This need not be the case. To explore (possible) differences in our impact estimates, we plot the (conditional) relationship between household income and electricity use as before – but now separately for different values of our background characteristics. (See Appendix A for details). Our plots are consistent with the main conclusion in this section.

3 Why so much Electric Heating?

In the last section, we presented evidence that the widespread use of electric heating plays an important role for the high electricity use among low-income households. This poses the question: why is heating by means of electricity so popular among low-income households?

There are several possible explanations. These include that low-income households:

- Tend to live in houses with electric central heating.
- Have no working central heating – and so have to use electric fan heaters etc.
- Have a working central heating system but cannot afford purchasing heating oil upfront/in bulk.
- Find it more efficient to heat (parts of the house) with an electric heater compared to using a central heating system.

In the following, we focus on the third possible explanation – which is that electric heating is widely used among low-income households because these households find it difficult to purchase heating oil upfront/in bulk.

The background to this is that ca 75% of dwellings in Northern Ireland (89% in rural areas) have an oil central heating – and oil typically has to be purchased upfront and in bulk.[6]

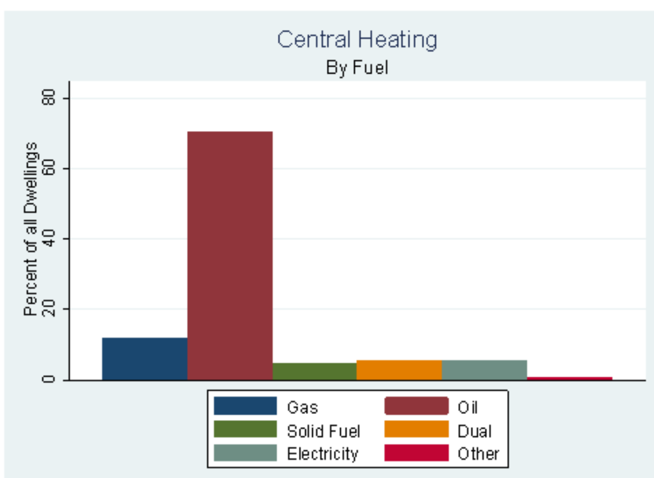

Figure 5: Distribution of Dwellings over Central Heating Systems

We focus on this explanation, because it seems more plausible than explanations one and two: Figure 4 gives the distribution of dwellings across different types of central heating. It shows that only ca 5% of dwellings in Northern Ireland have an electricity central heating.[7]

[6] Data: NI House Condition Survey 2006. See Frey et al (2007).
[7] This number is marginally larger for low-income households.

Similarly, in case of explanation two, ca 98% of dwellings in Northern Ireland have (some form of) central heating. In addition, only 1.3% of central heatings are defective – 88% of which are in non-occupied dwellings. This makes it unlikely that the widespread use of electricity for heating is due primarily to the absence of a working central heating system.

Explanation four is more plausible. We will return to it in sections 5.4.

3.1 A simple Theoretical Model

In this section, we spell out our (liquidity constraint) argument in more detail by means of a simple model. Our model is based on Fisher's theory of inter-temporal consumption.[8]

Take a representative individual. Suppose her decision horizon spans one year – a realistic assumption for most low-income households[9] – which we divide into two periods: period 1 (summer and autumn) and period 2 (winter and spring). Further assume all our individual is interested in is to heat her home in period 2. She can do so using either oil or electricity. We take capital stock as given.[10]

If our individual uses oil to heat her home she has to purchase whatever amount she needs upfront (i.e. in period 1). If she uses electricity, she can pay as she goes (i.e. in period 2). Suppose our consumer earns after-tax income Y_1 in period 1 and Y_2 in period 2. Further assume (for the moment) that our individual has the opportunity to borrow and save. From these assumptions we can derive a standard inter-temporal budget constraint:

$$S_1 + \frac{S_2}{1+r} = Y_1 + \frac{Y_2}{1+r} \quad (2)$$

If the real interest rate (r) is zero, all the budget constraint says is that total spending on oil and electricity (S_1 and S_2) in the two periods is equal to total income in the two periods. In the usual case in which the interest rate is greater than zero, electricity expenditure and future income are discounted by a factor of $1 + r$.

The second part of our model concerns the preferences of our consumer. We assume that her objective function is her utility over the two heating fuels – i.e.

$$U(C_1) + \beta U(C_2) \quad (3)$$

Where C_1 is consumption of heating oil; C_2 consumption of electricity and u(.) is the instantaneous utility function. β is the discount factor.

We assume that $C_1 = S_1$ and $C_2 = S_2$. That is, our consumer uses all the fuel she purchases. Because we assume that consumption of both fuels takes place in period 2, we can set $\beta = 1$.

Optimisation of our consumer's objective function subject to her inter-temporal budget constraint gives an optimal combination of oil and electricity expenditure. The optimum is characterised by the following condition:

$$\frac{U'(C_1)}{U'(C_2)} = (1 + r) \quad (4)$$

[8] Fisher (1930); Creedy (1994)

[9] See e.g. Harvey et al (2007) p.41

[10] We will come back to this assumption in section 5.3.

It says that at the optimum, the Marginal Rate of Substitution is equal to the Marginal Rate of Transformation – or the slope of our consumer's optimal indifference curve is the same as that of her (inter-temporal) budget constraint. The idea is illustrated in Figure 5a below – where point O marks the best combination of oil and electricity.[11]

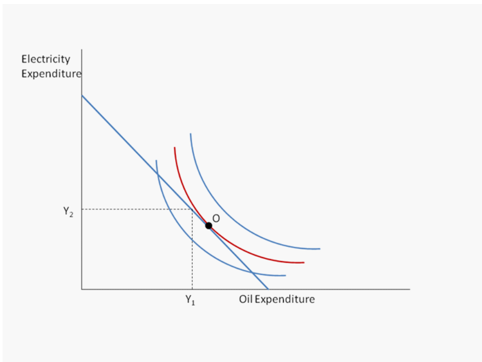

Figure 5a: Optimal spending on Oil/Electricity

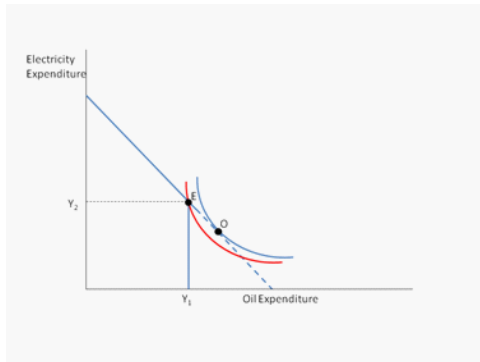

Figure 5b: Optimal spending given liquidity constraints.

So far, we have assumed that our consumer can borrow (as well as save). The ability to borrow allowed her to spend more on oil than her period 1 income. Yet, for many people such borrowing is not possible (or only at substantially higher rates).[12]

Formally, this situation translates into a further constraint in our optimisation problem – which is:

$$S_1 - Y_1 \leq 0 \ (5)$$

It can be shown relatively easily that this additional constraint (when binding) leads to higher spending on electricity.[13]

The idea is illustrated in Figure 5b above: The liquidity constraint translates into a kinked budget constraint. As a result (of this change in the shape of the budget constraint), our consumer can no longer choose point 'O' – but has to settle for point E (where E lies above and to the left of point O).

3.2 Minimum Purchase Requrirement

Let us add one more complication to the model. Suppose there is a minimum purchase amount for oil. In Northern Ireland, this lies at around £200. This complication leads to four possible situations. Our consumer can be:

- Not liquidity constrained and not constrained by the minimum purchase amount for oil
- Not liquidity constrained but constrained by the minimum purchase amount for oil
- Liquidity constrained but not constrained by the minimum purchase amount for oil or

[11] Note that, under non-satiating preferences, the solution must lie on the inter-temporal budget constraint.
[12] For simplicity, we subsume both cases under the term 'liquidity constrained'
[13] This leads to the following optimisation problem: $L = u(C_1) + u(C_2) + \lambda_1(Y_1 + Y_2/(1+r) - C_1 + C_2/(1+r)) + \lambda_2(Y_1 - C_1)$

- Liquidity constrained and constrained by the minimum purchase amount for oil.

We discuss the four situations in turn: As we have seen earlier already, in the simplest case, when our consumer is not liquidity constrained and not constrained by a minimum purchase amount for oil, she chooses electricity and oil at point 'O'. This is illustrated in Figure 6a below (again).

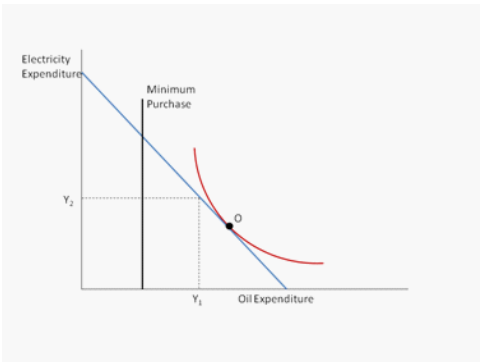

Figure 6a: Optimal spending given no liqu. const. & no min. purch. amt.

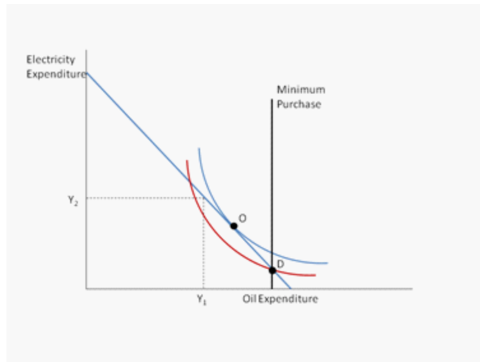

Figure 6b: Optimal spending given binding minimum purchase amount

In the second situation – where the minimum purchase amount for oil is higher than her desired spending on oil – our consumer ends up spending more on oil and less on electricity than she would otherwise. This is illustrated in Figure 6b. It shows that the best our consumer can do – given a binding minimum purchase amount – is to consume at point D (where point D lies below and to the right of point O).

The opposite happens (to electricity and oil spending), if our consumer is liquidity constrained but not constrained by a minimum purchase amount for oil: In this case, our consumer ends up spending less on oil and more on electricity than she would want ideally. Given her liquidity constraint the best she can do is to consume at point E in Figure 7a – where E is above and to the left of point O.

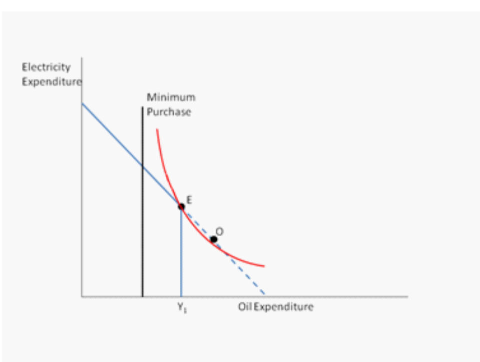

Figure 7a: Optimal spending given binding liquidity constraint

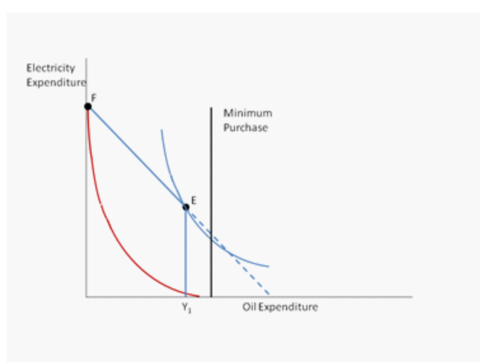

Figure 7b: Optimal spending given liquidity const. & min purchase amt.

We get the most extreme distribution of spending on oil and electricity in the fourth situation – which is when our consumer is liquidity constrained and constrained by a minimum purchase amount for oil. As shown in Figure 7b, the best our consumer can do in this situation is to consume at point F, where F implies zero oil expenditure and a maximum expenditure on electricity.

What this suggests is that (also) a combination of liquidity constraints and a binding minimum purchase amount for oil can explain the high use of electric heating among low income households. The intuition is that low-income households facing liquidity constraints and a minimum purchase amount may find it difficult to purchase heating oil upfront and in bulk – and so end up substituting electricity for oil when it comes to heating their homes.

In the following, we derive a series of implications from this model and test whether they stand up to the data.

4 Testing for Liquidity Constraints

One way of testing the role of liquidity constraints or a combination of liquidity constraints and a binding minimum purchase requirement for the widespread use of electric heating among low-income households, is to look at what happens if we give a random set of households enough money to purchase heating oil (compared to a set of households which does not receive this money).

The underlying idea is that our model suggests a different response to such a cash transfer in terms of oil expenditure and electricity expenditure on heating – depending on whether a household is liquidity constrained; faces a binding minimum purchase amount; both; or neither. To see this, we go through the different situations in turn.

To determine the response to a cash transfer, we have to make an assumption about whether we consider electricity and oil heating 'normal goods' or 'inferior goods'. A 'normal good' is one where an increase in income typically leads to an increase in consumption – while an 'inferior good' is one where the opposite is true.

While 'oil heating' is a 'normal good', the literature is not clear whether electric heating is (See Wills, 1981 and Halvorsen, 2001). In the following, we assume that electric heating (too) is a 'normal good'. We will discuss the possibility that it is an 'inferior good' later – together with the corresponding consequences for our empirical strategy (see section 5.4).[14]

Given this assumption: What is the implication of an (exogenous) increase in income when our consumer is not liquidity constrained and not constrained by a minimum purchase amount?

[14] Please note that the upward sloping Engel Curve from section 2.1 does not help us decide whether electric heating is a normal or inferior good. The estimation used total electricity expenditure (rather than expenditure on electric heating only) – and so does not allow any conclusions about the nature of the relationship between electric heating and income.

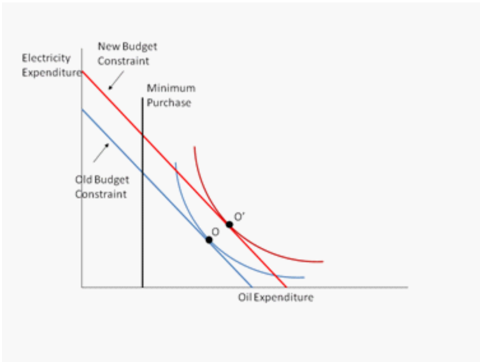

Figure 8a: Optimal response to income shock - no constraint

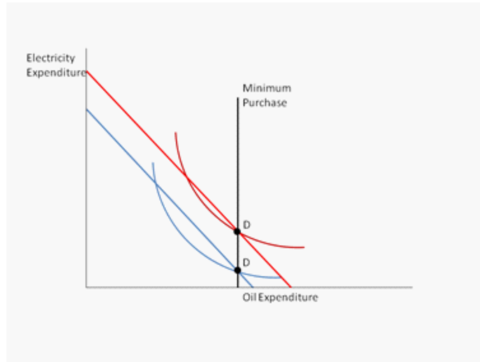

Figure 8b: Optimal response given binding minimum purchase amount

The answer is: our consumer will increase spending on both oil and electricity. This is illustrated in Figure 8a above. First note that an increase in either Y_1 or Y_2 shifts the budget constraint outward. This shift leads to a shift in optimal spending from point O to point O' (above and to the right of point O).

What happens if our consumer is not liquidity constrained, but the minimum purchase amount is binding? In this case, our consumer leaves her oil expenditure unchanged, while increasing her expenditure on electricity. Figure 8b above shows how the shift in the budget constraint leads to a shift in optimal spending from point D to D' – where D' lies exactly above point D.

The effect of an (exogenous) increase in income, if our consumer is liquidity constrained but not constrained by a minimum purchase amount, is illustrated in Figure 9a below. It shows that, in this situation, our consumer responds to the change in income by increasing her spending on oil while leaving electricity spending unchanged. Her optimal point moves from point E to point E'.

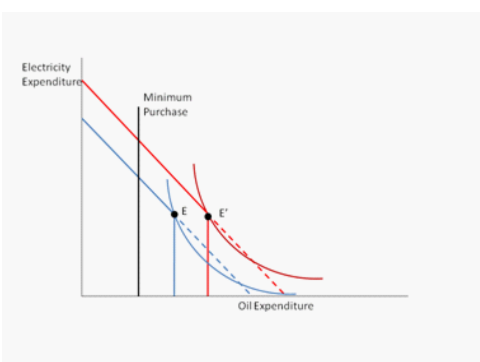

Figure 9a: Optimal response given binding liquidity constraint

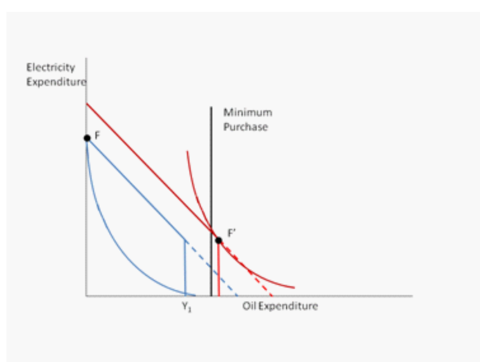

Figure 9b: Optimal response given liquidity const. & min purchase amt.

Finally, when our consumer is both liquidity constrained and constrained by a minimum purchase amount, an increase in income (which is large enough for a minimum purchase of oil) leads to a reduction in spending on electricity and an increase in spending on oil. The intuition is that our consumer can now afford to purchase oil and so to cut electricity. The situation is shown in Figure 9b. The optimal point moves from F to point F'.

Table 4 summarises the different implications of an (exogenous) increase in income for the spending behaviour of our consumer. It shows that depending on whether we assume our consumer to be liquidity constrained; constrained by a minimum purchase amount; both; or neither, our model yields different implications in terms of oil and electricity expenditure for heating.

Model	Oil Expenditure	Elec. Expenditure
No Liquidity Constraint/ No Minimum Purch. Am.	+	+
No Liquidity Constraint/ Minimum Purch. Am.	No Change	+
Liquidity Constraint/ No Minimum Purch. Am.	+	No Change
Liquidity Constraint/ Minimum Purch. Am.	+	-

Table 4: Summary Testable Hypotheses

What this suggests is that: assuming that our consumer is representative for all (low-income) households in Northern Ireland, we can test for liquidity constraints/a combination of liquidity constraints and a binding minimum purchase amount simply by looking at how households respond to an (exogenous) increase in income.

In the next section, we discuss how we go about doing so.

4.1 Regression Discontinuity

To test how an (exogenous) increase in income actually changes oil and electricity spending for heating, ideally, we would randomly allocate individuals into a treatment group and a control group.

Individuals in the treatment group would receive £250 (which is slightly more than the average minimum purchase amount for oil) while individuals in the control group would receive nothing. Because of the random allocation into treatment and control, we could be sure that whatever happens to oil and electricity expenditure would be due to this payment.

Luckily, we do not have to implement such an experiment: it turns out that the payment of 'Winter Fuel Payment' by the government provides a 'natural experiment'. Winter Fuel Payment is a one-time lump sum cash transfer of £250 which is not taxable nor means tested. It is paid to all households with at least one household member aged 60 or over. Take up is near 100%.

To see how a 'treatment effect' of receiving £250 can be identified from this payment, notice that within a small interval around the cut-off age the allocation of Winter Fuel Payment is very similar to a randomized experiment. That is, because it is unlikely that there is something systematically different between people age 59 and 60, we can interpret individuals just above 60 as treatment group, while individuals just below the cut-off age as control group.[15]

A practical problem with this approach is that, in a given sample, we typically have only a few observations near the cut-off point. This makes it hard to get robust estimates. One way of dealing with this problem is by increasing the interval around the cut-off point (comparing e.g. individuals age 55-59 with individuals age 60-64). Yet, this is likely to produce a bias in the effect estimate (since individuals age 55 are most certainly different from individuals age 64).

A better approach is to make an assumption about the functional form of the relationship between age and oil/electricity expenditure on either side of the cut-off point. This double extrapolation combined with the exploitation of the 'randomised experiment' around the cut-off point forms the basis of a 'regression discontinuity' design – which is our approach to test the role of liquidity constraints/a combination of liquidity constraints and a minimum purchase amount with regard to the use of electric heating among low-income households.[16]

4.2 A Note on the Data

For our estimation, we use data from the Continuous Household Survey (CHS) for 2008/2009. It is the largest dataset which includes information on spending on oil and electricity for Northern Ireland. A shortcoming of the CHS data is that it does not distinguish between oil/electricity expenditure for heating and oil/electricity expenditure for other uses.

One way of dealing with this problem is to use aggregate expenditure on oil and electricity – which includes both heating and other uses. The problem is that this may not allow us to detect our hypothesised effect: To the extent that spending on heating makes up only a (small) part of aggregate expenditure on oil/electricity, the change in spending on heating (as a result of receiving Winter Fuel Payment) may not be large enough to be detectable using aggregate data.[17]

In addition, even if the change in heating expenditure is large enough to be detectable, using aggregate data, we will not be able to exclude the possibility that the changes we observe are driven (at least in part) by uses of oil/electricity other than heating. As an example, we will not be able to exclude that a decrease in aggregate electricity expenditure is driven by the fact that households use their Winter Fuel Payment to buy a more efficient fridge/freezer.[18]

An alternative way of dealing with the lack of data on heating expenditure is by exploiting the information on whether households use oil/electricity for heating (or not). The CHS provides this information.[19] It is a good alternative to using aggregate expenditure data in

[15] Beatty et al (forthcoming) use a similar approach to estimate the effect of Winter Fuel Payment on the trade off between 'heat and eat'.

[16] RD designs have been implemented in a wide range of contexts. See e.g. Card, Shore-Sheppard (2004); Carpenter, Dobkin (2009); Chen, Shapiro. (2004); Malamud, Pop-Eleches (2010)

[17] This problem is particularly severe in the CHS. The CHS is sampled over the course of a year. As a result, heating is likely to play a minor role for the reported (weekly/monthly) expenditure of a large part of the sample.

[18] This is particularly problematic, because we may get very different predictions for the directions of an effect for uses other than heating.

[19] The CHS asks people about their primary, secondary; and tertiary heating fuel. It also asks about fuel number six, seven, eight, nine and ten. However the number of responses are negligible after: fuel number three.

particular if we focus on the hypothesis that the widespread use of electric heating is due to a combination of liquidity constraints and a binding minimum purchase amount (rather than just liquidity constraints).

The idea is that our model with liquidity constraints and a minimum purchase amount is the only one which suggests a significant increase in the probability that a household uses oil as a heating fuel (and is compatible with a significant decrease in the probability that a household uses electricity as a heating fuel):

The (direct) implication of our model is that our consumer starts using oil for heating (and decreases her spending on electricity). This suggests that, if we find a significant increase in the probability that households use oil (and, depending on the optimal amount of electricity use, a decrease in the probability that households use electricity) this provides evidence for the existence of liquidity constraints and a binding minimum purchase amount.

Heating Mode	# of obs: oil	# of obs: electricity
Primary, Secondary, or Tertiary Use	1,711	497

Table 5: Sampel Size by Heating type[20]

A second potential problem for our analysis is that one of our key identification assumptions may not hold. The assumption is that payment of Winter Fuel Payment is the only discrete change at age 60. One reason why this may not be the case is that 60 is the official pension age for women in Northern Ireland (while the pension age for men is 65). In order not to confound our estimates with the effect of retirement on fuel expenditure:

- We define a 'reference age' as the age of the older one of the household reference person and his/her spouse;[21] and
- Drop households from our sample for which the 'reference age' is between 60 and 62 and the older one of the household reference person and his/her spouse is retired.

We show in section 6.3 that reducing our sample in this way effectively deals with the problem of retirement at age 60. To limit our sample (as much as possible) to households with an oil central heating, we also exclude households with a gas central heating from our sample.[22] In addition, we exclude households with an electricity consumption of <1 KWh/day.[23]

A final problem we have to address is the fact that our data tells us the age of a household member in years in the sampling month only (i.e. when he/she was interviewed). This means that we do not know if someone who was sampled in, say, December just turned 60

[20] The sample can be further broken down as follows: 3 rooms: 102 observations; 4 rooms: 316 observations; pre-payment customers: 520 observations; households with no environmental concern: 368 observations; households renting from the Housing Executive: 216 observations; households with a female household head: 705 observations; households living in a detached/ semi-detached building: 833

[21] The number of households with an additional 'old' family member – with a household head age 60/65 are negligible.

[22] We do not know the type of central heating. Instead, we drop households which report using gas a primary, secondary or tertiary heating fuel.

[23] Gas is typically paid ex post – so gas customers do not fit our model. We exclude households with electricity use < 1 KWh/day, because a refrigerator typically uses 1-2 KWh/day- which makes it implausible that an occupied primary residence would fall below 1 KWh/day.

or whether he/she was 60 at the date of the qualifying week for Winter Fuel Payment (in late September) already.

We deal with this problem by estimating our treatment effect with and without households for which we are not sure whether they have actually received Winter Fuel Payment.

4.3 Empirical Framework

In this section, we define our empirical strategy more formally. Consider the regression model:

$$Y_i = \beta X_i + \delta TREAT_i + f(age) + \varepsilon_i \ (6)$$

where Y_i is our outcome variable – i.e. whether or not a household uses oil/electricity for heating. X_i represents a set of control variables which we include to increase precision of our estimates.[24] $TREAT_i$ is a treatment dummy that captures the effect of Winter Fuel Payment at age 60. $TREAT_i$ is defined as:

$$TREAT_i = \begin{cases} 0 \ if \ a \ < \ 60 \\ 1 \ if \ a \ \geq \ 60 \end{cases}$$

Finally, f(age) is a smooth function of age. A critical question for implementing our strategy is how to model f(age). To ensure the robustness of our findings we consider both parametric and non-parametric functions of age.

For our parametric specifications, we focus on linear and (conditional) cubic models – using splines. For our non-parametric specifications, we follow Hahn et al (2001) and Porter (2003) by using local linear regressions to estimate the treatment effect. We estimate this in one step using a simple rectangular kernel.[25]

Given the absence of a widely agreed upon method for selecting an optimal bandwidth, we follow Ludwig and Miller (2007) and present results for a range of candidate bandwidth. Our preferred estimates are based on a bandwidth of 5 – which we calculate using the Imbens-Kalyanaram optimal procedure.[26] However, we also consider bandwidths that are twice and half the size of our preferred bandwidth.[27]

5 Main Results

In this section, we provide the main results from our regression discontinuity. We report our results for two different groups: a Low Income Group with household income below the

[24] They have little effect on our estimates of the discontinuity.

[25] Although a triangular kernel has been shown to be boundary optimal (by putting more weight on observations closer to the cut-off point), Lee and Lemieux (2009) argue that a more transparent way of putting more weight on observations close to the cut-off is to estimate a model with a rectangular kernel using smaller bandwidths. See also Malamud, Pop-Eleches (2010).

[26] Imbens, Kalyanaram (2009). The IK bandwidth varies for different estimations. It lies between 2 and 6.

[27] I am grateful to Ofer Malamud in helping me with the implementation of the non-parametric specification.

median (£20,000) and a High Income Group with a household income above the median (£20,000).[28]

We display graphs of our main outcomes using local linear regressions with a bandwidth of 5. All our regressions include number of children and labour market status as controls.

5.1 Electric Heating and Oil Heating

We begin our analysis by displaying the effect of receiving Winter Fuel Payment on the probability of using oil heating for households in our Low Income Group in Figure 10a and Table 6 (column 1).

The open circles plot the residuals from regressions of the dependent variable (using oil heating) on a set of controls for 1 year age intervals. The solid lines are fitted values of residuals from local linear regressions. The vertical line marks age 60. Households to the left of the vertical line do not receive Winter Fuel Payment, households to the right do.

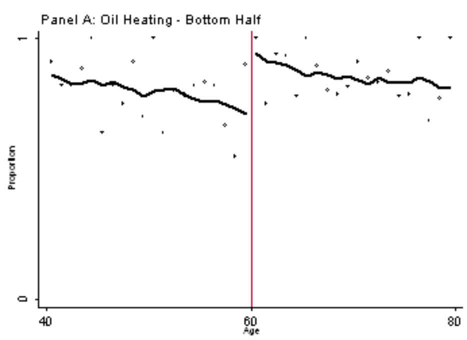

Figure 10a: RD oil heating Low-Income Group

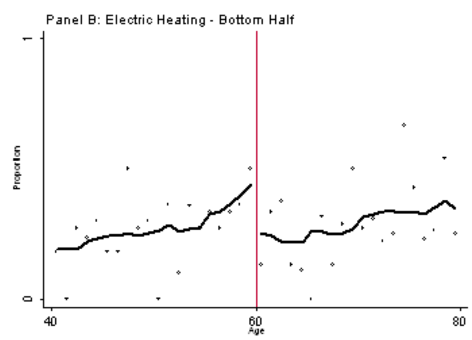

Figure 10b: RD elect. heating Low-Income Group

A striking feature of the figure is that the probability of a household to use oil as a heating fuel appears to be a continuous and smooth function of age everywhere, except at the threshold that determines whether a household receives Winter Fuel Payment or not.[29] There is a large discontinuous jump in the probability that a household uses oil to heat its home at age 60.

The size of the jump is relatively large and statistically significant. Table 6 Column 1 shows that a household which receives Winter Fuel Payment is approximately 40 percentage points more likely to use oil as a heating fuel. In Figure 10b, we plot the same relationship (as in Figure 10a) – but now for the probability that a household uses electricity to heat their home.

What we find is the mirror image to Figure 10a: The share of households using electricity as a heating fuel drops at age 60. The change is just about statistically significant. This is likely to be due to the fact that households continue to use some electric heating even after starting to use oil. However, as we will discuss in section 6.2, our estimates hide some important heterogeneity across households.

[28] We drop households with zero income.
[29] We will test this more formally in section 6.3.

In the next Figures (Figure 11a and 11b), we plot the same relationships for our High Income Group. Figure 11a shows the probability that a household uses oil for heating; Figure 11b the corresponding probability for using electricity. The vertical lines mark age 60. As would be expected, we find no significant change in the probability of using oil or electricity for heating.

Columns 3 and 4 of Table 6 provide the corresponding quantitative estimates.

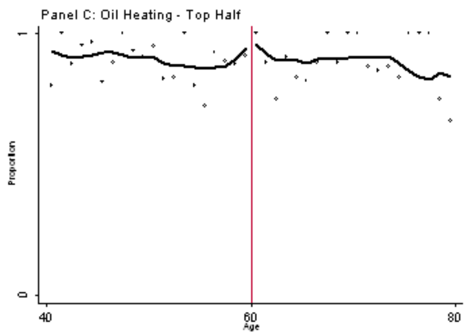

Figure 11a: RD oil heating High-Income Group

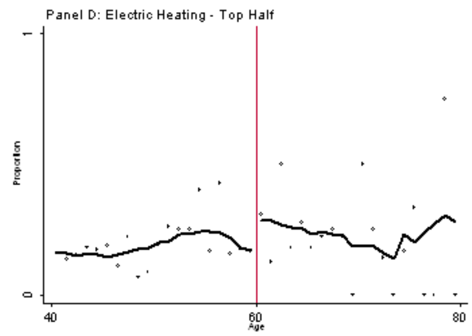

Figure 11b: RD elect heating High-Income Group

Intuitively, households in our High Income Group are unlikely to face problems financing the purchase of heating oil (upfront/in bulk). So, it is not surprising that receiving Winter Fuel Payment does not lead to a significant change in the heating pattern of these households. Our results are robust to including/excluding households for which we are not sure about the reference age.

	Low Income Group		High Income Group	
	Oil Heating	Elec Heating	Oil Heating	Elec Heating
Nonparam.	0.47***	-0.40*	0.02	0.19
BW=5	(0.19)	(0.21)	(0.11)	(0.19)
Nonparam.	0.63*	-0.55	0.03	0.17
BW=2.5	(0.34)	(0.35)	(0.17)	(0.25)
Nonparam.	0.35***	-0.27	0.05	0.18
BW=7.5	(0.14)	(0.16)	(0.09)	(0.14)
Param.	0.20**	-0.22**	0.03	0.06
Linear Spline	(0.09)	(0.11)	(0.07)	(0.09)
Param.	0.20**	-0.21*	-0.02	0.15
Cubic Spline	(0.10)	(0.13)	(0.09)	(0.12)

Table 6: RD estimates for using oil/electricity heating
Statistically Significant at 1% ***; 5% **; 10% *.

5.2 Selection Bias

A possible alternative explanation for the findings in the last section is that the changes in the probability of using oil/electricity for heating are driven by selection issues: by dropping parts of our sample to avoid confounding our estimates with the effects of retirement at age 60, we may have introduced a bias.

More specifically, the idea is that to the extent that households with a 'reference age' between 60 and 62 and a retired household member are less (more) likely to use oil (electricity) for heating, the changes in the probability of using oil/electric heating may simply reflect the effect of excluding these households from our sample.

We test this possibility by re-doing our analysis – but now using data from before the introduction of Winter Fuel Payment: The underlying idea is that if the changes in the probability of using oil/electricity for heating are primarily due to selection issues, we would expect to find the same jumps in probabilities in a sample prior to the introduction of Winter Fuel Payment.

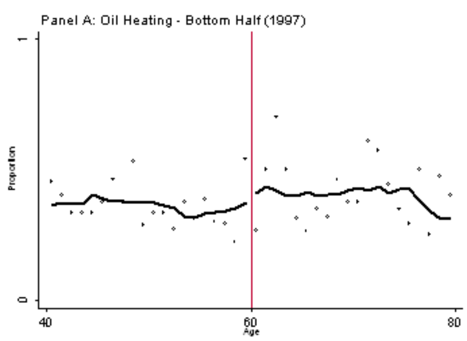

Figure 12a: RD oil heating Low-Income Group - 1997 Sample

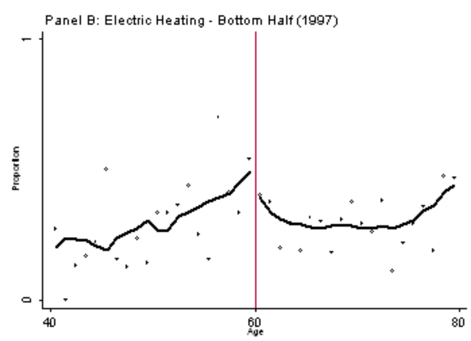

Figure 12b: RD elect heating Low-Income Group - 1997 Sample

Figure 12a and 12b show the relevant plots for the 1996/1997 sample of the Continuous Household Survey. They show no significant change in the probability of a household (in our Low Income Group) to use oil/electricity for heating. This suggests that the restrictions on our sample are unlikely to drive the changes in the use of oil/electric heating in our 2008/2009 sample.

Table 7 sows the corresponding quantitative estimates.

	Low Income Group	
	Oil Heating	Electricity Heating
Nonparam.	0.27	-0.04
BW=5	(0.18)	(0.20)
Nonparam.	0.34	-0.12
BW=2.5	(0.28)	(0.30)
Nonparam.	0.27	-0.13
BW=7.5	(0.14)	(0.15)
Param.	0.10	-0.20*
Linear Spline	(0.10)	(0.10)
Param.	0.09	-0.13
Cubic Spline	(0.10)	(0.09)

Table 7: RD estimates for using oil/electricity heating 1997 sample
Statistically Significant at 1% ***; 5% **; 10% *.

5.3 Capital Stock

So far, we have assumed that capital stock is fixed. That is, we have assumed that households are stuck with a particular type of central heating – which is oil – and have no way of switching to a different system.

To the extent that households do have the possibility of changing their capital stock – e.g. by moving house or by buying a new central heating – a possible alternative explanation for the change in the probability of using oil/electricity for heating is that it reflects the decision to move house/get a new central heating at age 60 (rather than reduced liquidity constraints).

To test this possibility, we redo our analysis – this time looking at the probability of a household to have an oil/electricity central heating. Figures 13a, 13b and Table 8 show our results.[30]

[30] The data for our analysis comes from the 2008 Living Condition Survey. The Continuous Household Survey does not cover the type of central heating. Because of the much smaller sample (approximately 600 observations for NI) - we do not include controls in our estimation.

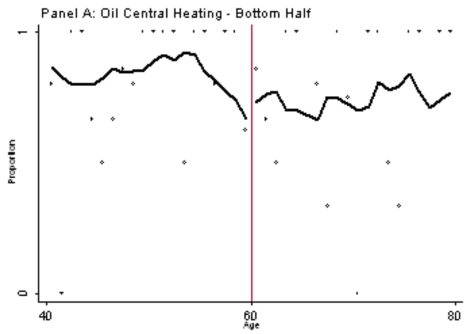

Figure 13a: RD oil central heating
Low-Income Group

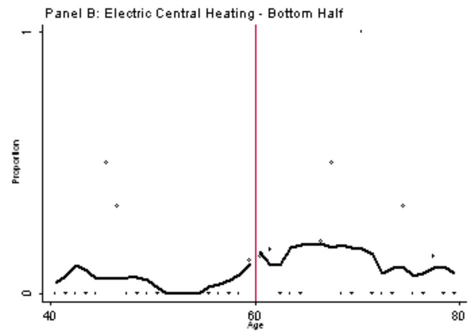

Figure 13b: RD elect. central heating
Low-Income Group

The figures and estimates in Table 8 do not suggest a significant change in the probability of a household to have an oil or electricity central heating at the cut-off point. This suggests that our assumption of taking capital stock as given is valid and that a change in capital stock does not drive our main findings.

	Low Income Group	
	Oil Heating	Electricity Heating
Nonparam.	0.33	-0.0001
BW=5	(0.27)	(0.20)
Nonparam.	0.59	-0.08
BW=2.5	(0.37)	(0.27)
Nonparam.	0.23	-0.02
BW=7.5	(0.23)	(0.17)
Param.	0.01	0.07
Linear Spline	(0.16)	(0.10)
Param.	-0.04	0.06
Cubic Spline	(0.16)	(0.10)

Table 8: RD estimates for capital stock
Statistically Significant at 1% ***; 5% **; 10% *.

5.4 Efficiency and Electric Heating

Another explanation for the changes in the probability of households using oil/electricity heating is that Winter Fuel Payment may allow some households to heat more than one room/a few rooms.

To the extent that it is more efficient to heat one room by means of electricity, while it is more efficient to heat several rooms by means of oil, the move from heating a few rooms to heating several rooms should lead to a jump in the probability of using oil/electricity for heating in line with the ones we observe.

One way of testing this explanation is by checking the effect of Winter Fuel Payment for households owning/renting a few rooms: If a household owns/rents a few rooms, there should not come a point where it becomes more efficient to heat by oil. So, receiving Winter Fuel Payment should not lead to a jump in the probability of using oil/electricity for heating if the reason for using electricity is efficiency.

If, on the other hand, households use electric heating because they are liquidity constrained – we would expect that households owning/renting a few rooms switch to oil heating as soon as they can afford doing so (just as households owning/renting several rooms). We test the effect of Winter Fuel Payment for different types of households by estimating equations in which the variable for receiving Winter Fuel Payment is interacted with a dummy variable equal to one if the household owns/rents a few rooms only.

In the interest of saving space and to improve the precision of our estimates, all of the specifications in this section are based on linear splines and the standard set of controls (labour market status and number of children). Tables 9 and 10 provide our estimation results. We provide estimates for households owning/renting three rooms and four rooms. (Typically, these households have one/two bedrooms, one kitchen and one bathroom).[31]

	Low Income Group			
	Oil Heating		Elec Heating	
	≤3 Rooms	≤4 Rooms	≤3 Rooms	≤4 Rooms
WFP	0.15*	0.15*	-0.19*	-0.19*
	(0.09)	(0.09)	(0.11)	(0.11)
Few Rooms	-0.35***	-0.27***	0.29***	0.19***
	(0.07)	(0.04)	(0.08)	(0.05)
WFP * Few Rooms	-0.12	-0.0002	0.02	-0.04
	(0.10)	(0.06)	(0.12)	(0.08)

Table 9: RD interaction with 'few rooms' - Low Income Sample

Statistically Significant at 1% ***; 5% **; 10% *.

To ensure the robustness of our findings, we provide estimates for our Low Income Group (Table 9) and the combined dataset of Low Income Group and High Income Group (Table 10).

In line with our liquidity constraint argument, we find that the interaction is very small and statistically insignificant in all cases.[32] That is, the effect of Winter Fuel Payment on

[31]We include households age <40 and age>80 in our analysis in order to increase the power of our sample.

[32]Please note that the coefficient of WFP now gives the effect of WFP for households with more than 3 (4) rooms. The effect of WFP for households with 3 (4) rooms or less is given by the sum of the coefficients of WFP and the interaction term.

the probability of using oil/electricity for heating is no lower for households owning/renting a few rooms than for households owning/renting several rooms.

	Low Income Group and High Income Group			
	Oil Heating		Elec Heating	
	≤3 Rooms	≤4 Rooms	≤3 Rooms	≤4 Rooms
WFP	0.11*	0.11*	-0.08	-0.08
	(0.05)	(0.05)	(0.07)	(0.07)
Few Rooms	-0.38***	-0.28***	0.29***	0.29***
	(0.05)	(0.03)	(0.06)	(0.06)
WFP * Few Rooms	-0.07	0.01	0.05	0.05
	(0.08)	(0.05)	(0.10)	(0.10)

Table 10: RD interaction with 'few rooms'- Combined Sample
Statistically Significant at 1% ***; 5% **; 10% *.

6 Further Results

In this section, we examine a number of additional results that build on our main findings. We explore whether the effects of Winter Fuel Payment are mediated by whether households use pre-payment electricity metering; rent from the Northern Ireland Housing Executive and/or have strong environmental views.

We also investigate whether the effects of Winter Fuel Payment are affected by household demographics – such as gender of the household head; family status; and housing type. As before, in the interest of saving space and to improve the precision of our estimates, we base our estimates on models with linear splines and the standard set of controls.

6.1 Mediating Variables

To better understand the role of using pre-payment electricity metering; renting from the NI Housing Executive and environmental attitudes on our main results, we estimate equations in which the variable for receiving Winter Fuel Payment is interacted with these variables.

The motivation for including a pre-payment variable in our analysis is to test the hypothesis that households using pre-payment metering are more likely to be liquidity constraint - and so should show a larger jump in the probability of using oil/electricity for heating.[33]

The underlying idea of testing for a mediating effect of renting from the NI Housing Executive is to see if the Housing Executive (successfully) addresses the issue of liquidity constraints – e.g. by purchasing oil upfront and charging households 'as they go' or by organising bulk purchases among households renting from it.

Finally, we include an interaction term of Winter Fuel Payment and the environmental attitude of the household head: To the extent that oil heating is associated with a larger carbon footprint, we would expect to find a smaller jump in the probability of using

[33] Because we are primarily intereted in the new technology, we only use keypad customers in this category – i.e. no customers using slot meters.

oil/electricity among households with a higher level of environmental concern. Note that our variables are potentially endogenous, so the results of the analysis need to be interpreted with care.

Columns1/4 of Table 11 display the interaction of Winter Fuel Payment with a variable indicating whether or not a household uses pre-payment electricity metering. As hypothesised, the interaction is positive and significant in the case of oil - indicating that the effect of Winter Fuel Payment on the probability of using oil is signficaintly higher for households using pre-payment metering.

In terms of the absolute effect of using pre-payment metering: Our estimation results suggest that Winter Fuel Payment leads to a 18 percentage point increase in the probability of using oil for heating for households using no pre-payment electricity meter, while it leads to a 47 percentage point increase for households which do use pre-payment electricity metering.

Interestingly, we do not find a signficant difference in the effect of Winter Fuel Payment on the probability that households use electricity for heating. This suggests that many pre-payment customers keep on using electricity for heating (as a complementary fuel) even after starting to use oil for heating.

	Low Income Group					
	Oil Heating			Electric Heating		
	PPM	Env. Att	Hous. Exec	PPM	Env. Att	Hous. Exec
WFP	0.18*	0.24***	0.15*	-0.22**	-0.26**	-0.22**
	(0.09)	(0.09)	(0.09)	(0.11)	(0.11)	(0.11)
Mediator	-0.22***	-0.05	-0.29***	0.16**	-0.004	0.14***
	(0.07)	(0.03)	(0.04)	(0.08)	(0.04)	(0.05)
WFP*	0.29*	-0.07	0.08	0.19	0.007	0.03
Mediator	(0.14)	(0.05)	(0.07)	(0.16)	(0.06)	(0.08)

Table 11: RD interaction with 'mediators'

Statistically Significant at 1% ***; 5% **; 10% *.

We do not find a significant difference in the effect of Winter Fuel Payment on the jump in the probability of using oil/electric heating for households renting from the NI Housing Executive. This suggets that the Housing Executive is not effective in addressing the problem of liquidity constraints among its customers.

This finding is important to the extent that our results also suggest that households renting from the NI Housing Executive are significantly less (more) likely to use oil (electricity) for heating to start with. Finally, we do not find a mediating effect of strong environmental attitudes on the effect of Winter Fuel Payment.

6.2 Heterogeneity

Table 12 below explores the differential impact of household characteristics on the effect of Winter Fuel Payment on the probability that a household uses oil/electricity for heating. We estimate equations in which Winter Fuel Payment is interacted with gender of the household head; number of occupants; and housing type.

Interestingly, columns 1/2 and 4/5 do not reveal any significant differences in the effect of Winter Fuel Payment for households with a male or female household head; households with a single occupant or multiple occupants, respectively. This is surprising, since there are substantial differences in the mean levels of our outcome variables (at least in the case of 'number of adults').

Columns 3/6 display the interaction between Winter Fuel Payment and housing type. What we find is that - despite a significant increase in the probability of using oil for heating - families living in a detached building are less likely to stop using electric heating (once they receive Winter Fuel Payment).

In terms of the absolute effect of living in a detached building: Our estimation results suggest that Winter Fuel Payment leads to a 27 percentage point decrease in the probability of using electricity for heating for households living in a non-detached building, while it leads to a 8 percentage point decrease for households which live in a detached building.

This finding is consistent with the idea that the optimal amount of electric heating is positive for households living in large/detached houses (complementing oil heating) and zero for smaller non-detached houses.

	Low Income Group					
	Oil Heating			Electric Heating		
	Female	# of adults	Detached	Female	# of adults	Detached
WFP	0.22**	0.19*	0.19**	-0.28**	-0.18	-0.27***
	(0.09)	(0.11)	(0.09)	(0.11)	(0.13)	(0.11)
Mediator	0.005	0.05**	0.03	-0.03	-0.02	-0.14
	(0.04)	(0.02)	(0.06)	(0.05)	(0.02)	(0.07)
WFP*	0.02	0.01	0.06	0.07	-0.03	0.19**
Mediator	(0.06)	(0.04)	(0.08)	(0.07)	(0.04)	(0.09)

Table 12: RD interaction with 'background characteristics'
Statistically Significant at 1% ***; 5% **; 10% *.

6.3 Specification Checks

Our analysis rests on two critical assumptions: To make a valid inference

- The underlying functions (to the left and to the right of the cut-off point) need to be continuous in age
- Winter Fuel Payment must be the only source of variation affecting electricity use that changes discretely at age 60

The intuition of the first condition is that only if electricity use is a continuous function in age (close to the cut-off point), it seems plausible to use the average outcome of those right below the cut-off as a valid counterfactual for those right above the cut-off (See Lee and Lemieux, 2010).

Similarly, Winter Fuel Payment has to be the only source of variation (affecting electricity use) that changes discretely, since otherwise it is not clear what causes the changes in electricity use at age 60. We test the first assumption by plotting a series of 'placebo' regression discontinuities. That is, in line with treatment effect literature, we test for a zero effect in settings where it is known that the effect should be zero.[34]

Specifically, what we do is, we take the subsample of households with a reference age below 60 and test for a jump at the median of the age variable. Splitting the subsample at the median increases the power of the test to find jumps. In addition, by only using observations on the left of the cut-off value, we avoid estimating the regression function at a point where it is known to have a discontinuity.[35]

To implement our test, we use the same method as before. We repeat the test for the subsample of households with a references age of 60 or older. Figures 14a to 14d show the corresponding plots.

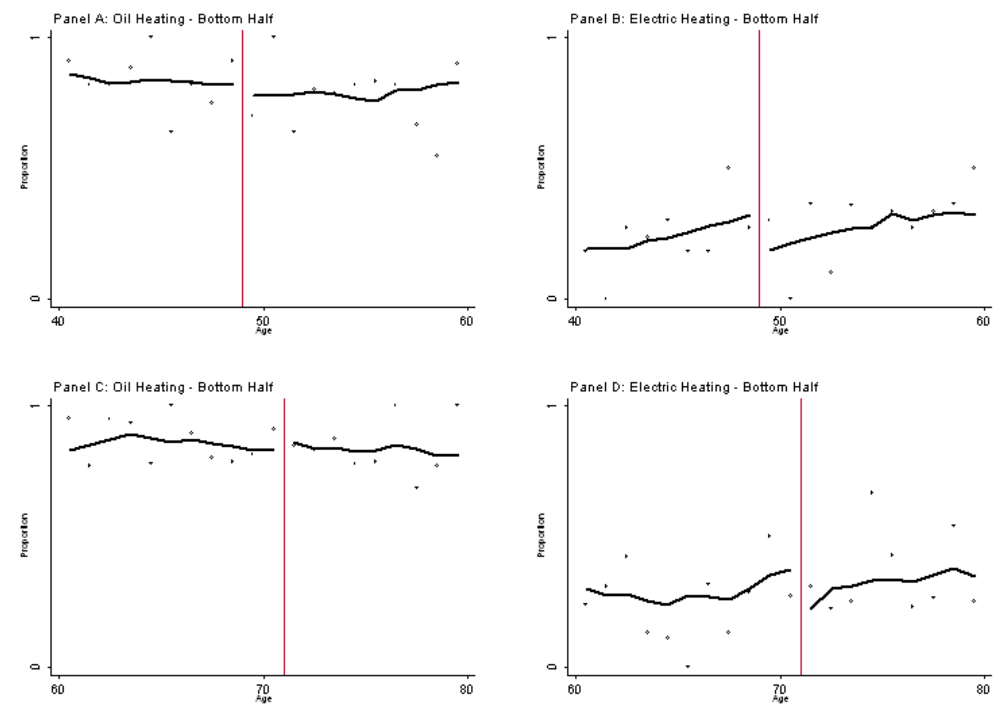

Figure 14: Placebo RD

The figures show that – in line with our first identification assumption – there is no significant change in the probability of a household using oil/electricity for heating at the cut-off points (ages 49 and 71). There are smaller changes in the probabilities that a household uses electricity for heating, but neither of them is statistically significant.

While we cannot verify our second identification assumption for unobserved characteristics, we can check whether various control variables indeed vary continuously around the

[34] See Imbens and Lemieux (2008)
[35] Ibid.

cut-off point. In Table 13, we provide evidence to support this assumption. The table shows that as we compare households closer and closer in age to the cut-off point, the pre-determined characteristics of households receiving Winter Fuel Payment and those not receiving Winter Fuel Payment become more and more similar.

		a<60	a≥60	50<a<60	60≤a<70	58<a<60	60≤a<62
Income	Low	10,855	10,267	10,121	10,904	9,711	10,637
	Inc.	(4,915)	(4,209)	(5,021)	(4,460)	(5,028)	(4,863)
	High	46,661	36,199	49,237	39,157	52,848	47,007
	Inc.	(23,968)	(17,179)	(25,301)	(20,094)	(30,358)	(22,420)
Retired	Low	0.005	0.73	0	0.39	0	0
	Inc.	(0.07)	(0.45)	0	(0.49)	(0)	(0)
	High	0.002	0.55	0.01	0.30	0	0
	Inc.	(0.039)	(0.50)	(0.08)	(0.46)	(0)	(0)
Econ.	Low	0.36	0.88	0.41	0.71	0.43	0.55
Inactive	Inc.	(0.48)	(0.33)	(0.49)	(0.46)	(0.51)	(0.51)
	High	0.05	0.66	0.11	0.46	0.28	0.10
	Inc.	(0.23)	(0.47)	(0.31)	(0.50)	(0.45)	(0.30)
#	Low	5.13	5.16	5	5.39	4.90	5.48
Rooms	Inc.	(1.26)	(1.31)	(1.50)	(1.21)	(1.26)	(1.42)
	High	6.30	6.60	6.60	6.81	6.41	7.62
	Inc.	(1.82)	(1.82)	(1.82)	(2.02)	(1.55)	(2.56)
Rent	Low	0.57	0.24	0.43	0.23	0.52	0.33
	Inc.	(0.50)	(0.43)	(0.50)	(0.42)	(0.51)	(0.48)
	High	0.16	0.05	0.08	0.05	0.07	0
	Inc.	(0.36)	(0.22)	(0.28)	(0.21)	(0.26)	(0)

		a<60	a≥60	50<a<60	60≤a<70	58<a<60	60≤a<62
#	Low	2.60	1.47	1.89	1.68	1.81	1.81
Persons	Inc.	(1.54)	(0.68)	(1.26)	(0.84)	(1.63)	(1.04)
	High	3.23	2.24	3.01	2.35	2.76	2.62
	Inc.	(1.40)	(0.89)	(1.33)	(0.91)	(1.12)	(0.86)
Eff.	Low	0.12	0.19	0.18	0.15	0.19	0.11
Grant	Inc.	(0.32)	(0.39)	(0.38)	(0.36)	(0.40)	(0.32)
	High	0.11	0.20	0.12	0.18	0.14	0.14
	Inc.	(0.32)	(0.40)	(0.33)	(0.38)	(0.35)	(0.36)
Pension	Low	0	0.18	0	0.17	0	0.33
Credit	Inc.	0	(0.38)	(0)	(0.38)	(0)	(0.48)
	High	0	0.02	0	0.01	0	0
	Inc.	0	(0.15)	(0)	(0.10)	(0)	(0)

Table 13: Variation in pre-determined characteristics close to the cut-off point

Consider, for example, the fraction of households retired. There are sizeable differences in the sample. Averaging over the entire sample, households below age 60 are significantly less likely to be retired than households above age 60. However, as we start restricting the sample to closer and closer age profiles, the differences in retirement decrease.

For households that are only two years from the threshold, the differences are not statistically significant. In only one of 9 control variables (pension credit) do we reject the null hypothesis. The discontinuity in pension credit suggests that we cannot exclude that part of the jump in the probability that households use oil/electricity for heating is due to the receipt of this benefit.

This is not problematic, however, since our argument is based on the idea of a (quasi-) randomly allocated positive income shock. That is, for the purpose of our argument, it does not matter whether our income shock comes from the receipt of Winter Fuel Payment; pension credit or a combination of the two.

7 Conclusion and Policy Implications

In this paper, we studied the high electricity use among a large part of low-income households. Using the findings from a semi-parametric Engel curve estimation and the distribution of key household characteristics across income levels, we suggested that electric heating is an important driver of high electricity use among low-income households.

We hypothesised that the widespread use of electric heating among low-income households can be explained (at least in part) by the fact that these households find it difficult to pay for heating oil upfront/in bulk. The background to our hypothesis is the widespread use of oil central heating in Northern Ireland. We developed a simple two-period model to motivate our hypothesis.

We used a regression discontinuity design – exploiting the allocation rule of Winter Fuel Payment – to test our hypothesis. In line with our reasoning, we found that the probability that households use oil for heating jumps up (among households in our Low Income Group) once they receive a positive income shock. Analogously, we found that the probability that these households use electricity jumps down.

The jumps are equally strong for households owning/renting few rooms and several rooms. This provides evidence that the effects we observe are driven by a combination of liquidity constraints and a binding minimum purchase amount – rather than a higher efficiency of heating few rooms with electricity and several rooms with oil.

Several policy implications arise from our analysis:

- Introducing a two-part electricity tariff – without addressing the problem of liquidity constraints – is likely to make a large part of low-income households worse off (rather than better off).
- Electricity use among low-income household could be reduced significantly by helping these households to finance the purchase of heating oil. Possible policy instruments include special savings/loan vehicles or ways to coordinate oil purchases.

Future research will look at the effectiveness of oil stamp programmes – as used in parts of Northern Ireland – in addressing the problem of liquidity constraints and a binding minimum purchase amount when it comes to purchasing heating oil.

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8 Appendix A

The figures below plot the conditional relationship between household income and electricity use - separately for different values of our background characteristics. The plots were created using the estimation approach outlined in section 2.1.

The figures show that - if anything - the effect of electric heating on electricity use is larger for lower levels of household income.