Department of Energy & Climate Change

Examining potential bias in the sampling methodology for the Green Deal Assessment Survey

Working Paper to examine the potential bias in the sampling methodology for the Green Deal Assessment Survey

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Any enquiries regarding this publication should be sent to us at HouseholdEnergyEfficiencyResearch@decc.gsi.gov.uk.

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Acknowledgements

This working paper was written by Professor Patrick Sturgis (University of Southampton) and Dr Ian Brunton-Smith (University of Surrey) under the guidance of ICF International.

List of acronyms used in this report

MSOA	Middle Layer Super Output Area
IMD	Index of Multiple Deprivation
WIMD	Welsh Index of Multiple Deprivation
RIGLS	Restricted Iterative Generalised Least Squares
MLWIN	Statistical software package for fitting multilevel models

Executive summary

Background

The Green Deal Assessment Surveys and Customer Journey Surveys[1] were commissioned by DECC to look in detail at how customers came to have a Green Deal Assessment, their experiences of the Assessment and their actions and intentions after the Assessment. The surveys differ slightly in focus and interview length, but both sets of surveys employ the same sampling methods. The sampling frame for the surveys is the Landmark database on which all Green Deal Assessments need to be lodged. The database extracts available for research purposes did not include householder name or any contact details other than the address, so research methods were designed to reflect this.

GfK NOP worked with DECC's Green Deal and ECO Research and Evaluation team to design a clustered, semi random sampling approach for the surveys of households that had Green Deal Assessments in 2013. The same approach was used in subsequent surveys of the Green Deal Customer Journey from November 2013 to March 2015, some of which also had larger sample sizes.

The need to evaluate the experiences of households having Assessments following the launch of the Green Deal in January 2013 afforded just two months to design the research approach before the initial survey had to be in the field[2]. The clustered approach was employed to enable fieldwork to be completed in a cost efficient and timely manner. The implications of the approach were discussed with DECC, during which time the options and costs for using different cluster sizes were considered. To draw the sample of addresses, it was agreed that clusters would be formed of addresses which could be combined with nine or more other Green Deal Assessment addresses within a postcode sector. Addresses which could not be combined with nine or more other addresses were excluded from the sampling frame. Profiles of included/ excluded (clusterable/unclusterable) addresses were shared with DECC, and the final sample was signed off before interviewing started.

At the time the samples were drawn, the 'clusterable' addresses were compared with the profile of households having a Green Deal Assessment within the relevant reference period. It was acknowledged that the sampling approach over-represented those in urban areas, tenants and flats during the Green Deal Assessment surveys although in the recent waves of the Customer Journey survey this has been diminished because the coverage rate of the sample design has increased. Over-representation was felt to have arisen because:

- Green Deal Assessments were often sought by companies delivering energy saving home improvements using the Energy Companies Obligation (ECO);
- Companies attempting to find households potentially eligible for ECO tended to work in small areas: often targeting social housing tenants. For example, a canvasser may have knocked on the doors of every house in a single road asking whether households would like to have loft insulation installed;

[1] Available at: https://www.gov.uk/government/collections/green-deal-assessments-research

[2] The Green Deal launched on 28th January 2013. Wave 1 of the Green Deal Assessment Survey was conducted between 1st April and 30th June 2013, interviewing 507 households which had a Green Deal Assessment in the period Jan-Mar 2013.

- In other cases, social housing providers had Assessments completed on whole estates or areas of their stock: for example, in one wave all flats in a large block had Green Deal Assessments lodged.

In this context, it is unsurprising that the clustered samples over-represented tenants, flats and urban areas.

Objectives

This study was commissioned by the Department of Energy and Climate Change as part of the evaluation of the Green Deal and Energy Company Obligation (ECO) programme, and was conducted by Professor Patrick Sturgis (University of Southampton) and Dr Ian Brunton-Smith (University of Surrey) under the guidance of ICF International.

The objective of this study was to assess independently the robustness of this sampling approach using the second wave of the Green Deal Assessment Surveys (which was conducted in July/August 2013), to understand whether there were biases in key survey variables, and to consider whether and how future surveys could be refined to reduce any bias as a result of the clustering of addresses or whether a different approach is needed for further household customer surveys that may be commissioned by DECC in the future.

If, in the sampling approach used, the excluded (unclusterable) addresses were systematically different from the included addresses on the key variables measured in the survey, the result will be biased estimates for these variables. This is referred to as a 'non-coverage error' because it results from particular kinds of addresses being excluded from the possibility of being selected in the sample. While it was known by GfK NOP and DECC that there were differences in the profiles of clusterable and unclusterable addresses, the impact of these on key variables was not known. To some extent this has been ameliorated in the survey analysis through weighting.

The size of a non-coverage error is a function of a) the difference between the covered and the non-covered addresses on the variable of interest and b) the proportion of the target population which is not covered on the sampling frame. This implies that non-coverage error can be quite large – even when differences between the covered and non-covered addresses are small – when the proportion of the target population which is not covered is large. For wave 2 of the Green Deal Assessment surveys - upon which the analysis conducted was based - the non-coverage rate was 53% which means that the potential for bias due to non-coverage is high. In some of the subsequent waves of the Customer Journey survey it has been much reduced.

As a consequence, this study set out to establish if there were systematic differences between the clusterable addresses and the unclusterable addresses and, if this was the case, establish if these differences were also related to survey responses. If this proved to be the case then it was likely that survey estimates would be biased (different from the true value in the population) and refinements should be considered.

This analysis focused on the second wave of the Green Deal Assessment Surveys, which sampled 900 addresses from the 30,380 households who had a Green Deal Assessment between 1st April and 30th June 2013. Interviewing was conducted between 26th July and 26th August 2013, and 499 interviews were completed (59% adjusted response rate[3]).

[3] The adjusted response rate was calculated once inaccurate and ineligible addresses had been removed from the sample

Approach, Analysis and Results

In the first stage of analysis, variables from the 2011 Census and from the English and Welsh Indices of Deprivation were linked to indicators of address clusterability for the full target population of Green Deal Assessment addresses in wave 2 of the Green Deal Assessment survey.

Descriptive statistics and logistic regression models were then employed to evaluate whether clusterable and unclusterable addresses differed significantly from each other (on these characteristics) at different 'clusterability' thresholds (the number of addresses that need to be linked together to form a cluster).

These analyses revealed systematic differences between clusterable and unclusterable addresses related to the known over-representation of urban areas, tenants and flats in the clusterable areas. Clusterable addresses were, in general, more likely to be found in socio-economically deprived areas, with more transient populations (for example students or migrants), with higher rates of vacant properties, and with more ethnically diverse populations. Reducing the clusterability threshold to five addresses did not materially affect the pattern of difference between clusterable and unclusterable addresses.

This implies that, even if the clusterability threshold had been set at five (instead of ten) then it would not have eliminated the potential for non-coverage bias. This is because the non-coverage rate (29%) would still be high at a five address clusterability threshold and because the difference between clusterable and unclusterable addresses is still evident at this threshold.

Additional analysis showed that differences between clusterable and unclusterable addresses remained even when the clusterability threshold was set at just two addresses. This implies that, for a sample design to deliver zero non-coverage bias, it would be necessary to include Middle Layer Super Output Areas (MSOAs) which contain only one Green Deal Assessment address. However, because the proportion of the target population that comprises only one address is small (4.7% in wave 2), even substantial differences between these addresses and those with more Green Deal Assessments in the same MSOA would result in only a small degree of bias.

In the next stage of analysis, logistic regression models were used to determine whether the characteristics which were found to differentiate clusterable and unclusterable addresses in the first stage of analysis were also predictive of six key survey outcomes. Results showed that for four of the six outcomes (CB_13 'Most action taken', Q7 'Awareness', Q19 'How installation paid for/funded' and whether the address was an address that had received an installation under ECO) this was indeed the case. This is perhaps not surprising because of the extent that addresses that were eligible for ECO funding for installation were targeted for Green Deal Assessments. For these variables the survey will over-estimate the true population quantity. For two variables, Q8 'Motivations' and Q9 'Paying for an Assessment', there was no clear evidence of bias as a function of the address characteristics that were considered.

The pattern of results varied across items and depending on whether the England and Wales data, or England only was considered. However, in general, MSOA level socio-economic deprivation was significantly associated with four of the survey variables.

Further discussion

This pattern of results suggests that the Green Deal Assessment surveys could have yielded biased estimates of the true population quantities for four of the six key survey variables examined.

This conclusion was drawn because address characteristics which are predictive of both being excluded from (not covered on) the sampling frame and survey variables of interest were identified. Where this is the case, estimates are likely (given plausible assumptions) to be biased.

However, while it is reasonable to draw this conclusion about the presence and direction of this bias, it is not possible to draw inferences regarding its magnitude. This is because the sample data available does not include survey responses from Green Deal Assessment addresses which are not clusterable at a threshold of ten or more addresses. Estimates of actual bias would therefore need to be based on uncertain assumptions about the relationship between area level characteristics and survey outcomes for the uncovered population.

Equally, while this conclusion about bias might apply to the Green Deal Assessment surveys, it would not necessarily apply to the Customer Journey surveys in which higher proportions of addresses were clusterable.

Considerations for action

Due to a lack of direct correspondence between clusterability indicators based on the MSOA and postcode sector geographies, it is not recommended to use the model estimates to derive corrective weights post-hoc.

It is recommended that future surveys consider using the MSOA geography to produce clusters of addresses because MSOAs can be linked to a richer set of area level characteristics and these can be used to produce more powerful correction weights, compared to postcode sectors. However, such consideration should be balanced against the loss of comparability with the waves of Green Deal Assessment and Customer Journey surveys undertaken over the last two years.

It is not recommended that the current design be retained but with a lower clusterability threshold of seven or five addresses. This is because reducing the clusterability threshold to this level would increase the cost of the survey without substantially reducing non-coverage bias. Instead, a different sample design, based on disproportionate stratification across the full range of clusterability thresholds, should be considered for future survey waves. However, this should also be balanced against the loss of comparability with the waves of Green Deal Assessment and Customer Journey surveys undertaken over the last two years.

Disproportionate stratification involves giving all addresses a known probability of selection into the sample but varying the selection probability such that less expensive to survey addresses are given a higher selection probability and more expensive addresses are given a lower selection probability. Such a design would not be subject to bias due to non-coverage.

However, the viability of a disproportionate stratified design would need to be carefully considered from a cost and from an overall accuracy perspective. This is because a disproportionate stratification design is likely to be more expensive than the current approach. Additionally, the standard error of estimates under a disproportionate stratification will be higher than the current approach, due to the necessary application of design weights, and so careful consideration would need to be given to determine the optimal sample allocation under this type of design.

Lastly, it is recommended that cost comparisons be based on the effective rather than on the achieved sample sizes under different sample designs. This is because a clustered sample produces larger standard errors than a simple random sample of the same size. The variance inflation that results from clustering should be accounted for in the production of survey estimates and in cost calculations.

1. Background and Context

1.1. This study assesses the robustness of the approach to sampling that has been employed in surveys of households who have had a Green Deal Assessment. This includes three waves of Green Deal Assessments experience research and two waves of Green Deal Customer Journey research commissioned by DECC[4].

1.2. The Green Deal Assessment Surveys and Customer Journey Surveys[5] were commissioned by DECC to look in detail at how customers came to have a Green Deal Assessment, their experiences of the Assessment and their actions and intentions after the Assessment. The surveys differed slightly in focus and interview length, but both employed the same sampling methods. The sampling frame for the surveys was the Landmark database on which all Green Deal Assessments need to be lodged. The database extracts available for research purposes did not include householder name or any contact details other than the address, so research methods were designed to reflect this.

1.3. GfK NOP worked with DECC's Green Deal and ECO Research and Evaluation team to design a clustered, semi random sampling approach for the surveys of households that had Green Deal Assessments. The same approach was then used in subsequent surveys of the Green Deal Customer Journey.

1.4. The need to evaluate the experiences of households having Assessments following the launch of the Green Deal in January 2013 afforded just two months to design the research approach before the initial survey had to be in the field[6]. The clustered approach was employed to enable fieldwork to be completed in a cost efficient and timely manner. The implications of the approach were discussed with DECC, during which time the options and costs for using different cluster sizes were considered. To draw the sample of addresses at each wave, it was agreed that within the research budget available, clusters would be formed of addresses which could be combined with nine or more other Green Deal Assessment addresses within a postcode sector[7]. Addresses which could not be combined with nine or more other addresses were excluded from the sampling frame. Profiles of included/ excluded (clusterable/ unclusterable) addresses were shared with DECC, and the final sample was signed off before interviewing started.

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[4] At the time of writing, three waves of Green Deal Assessments experience research and two waves of Green Deal Customer Journey research had been conducted. Three further waves of Green Deal Customer Journey research have since been conducted to March 2015.

[5] Available at: https://www.gov.uk/government/collections/green-deal-assessments-research

[6] The Green Deal launched on 28th January 2013. Wave 1 of the Green Deal Assessment Survey was conducted between 1st April and 30th June 2013, interviewing 507 households which had a Green Deal Assessment in the period Jan-Mar 2013.

[7] The costs for clustering at lower levels (7 and 5) were also considered but this approach was not feasible given the resources.

1.5. At the time the samples were drawn, the 'clusterable' addresses were compared with the profile of households having a Green Deal Assessment within the relevant reference period. It was acknowledged that the sampling approach over-represented those in urban areas, tenants and flats, and it was felt that this was for the following reasons:

- Green Deal Assessments were often employed by companies delivering energy saving home improvements using Energy Companies Obligation (ECO)[8];
- Companies attempting to find households potentially eligible for ECO tended to work in small areas: often targeting social housing tenants. For example, a canvasser may have knocked on the doors of every house in a single road asking whether households would like to have loft insulation installed;
- In other cases, social housing providers had Assessments completed on whole estates or areas of their stock: for example in one wave all flats in a large block had Green Deal Assessments lodged.

1.6. In this context, it is unsurprising that the clustered sample over-represented tenants, flats and urban areas because companies deliberately targeted areas with these characteristics for Green Deal Assessments in order to qualify for work that could be carried out under the ECO scheme[9].

1.7. Therefore the motivation for undertaking this project was to assess whether:

- The design of subsequent waves of the Customer Journey surveys should be refined to reduce any bias as a result of the clustering of addresses; and
- A different approach is needed for further household customer surveys that may be commissioned by DECC in the future.

1.8. The empirical part of this study comprised two linked parts. The first part was the evaluation of the extent to which 'clusterable addresses' (i.e. addresses which were included on the sampling frame for the Green Deal Assessment survey) have different characteristics from 'non-clusterable addresses' (i.e. addresses that were excluded from the sampling frame). The second part focused on where differences in characteristics were observed between included and excluded addresses, and evaluated whether these characteristics were predictive of survey variables.

1.9. If clusterable addresses have different characteristics from non-clusterable addresses, and these characteristics are predictive of survey variables, then it is likely that survey estimates will be biased. If neither, or only one of these conditions holds, it is likely (though not certain) that survey estimates are not subject to bias as a result of under-coverage of non-clusterable addresses in the sample design.

1.10. This analysis focused on the second wave of the Green Deal Assessment Surveys, which sampled 900 addresses from the 30,380 households in England and Wales who had a Green Deal Assessment between 1st April and 30th June 2013[10].

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[8] For more information see: https://www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills/supporting-pages/energy-companies-obligation-eco

[9] Any overrepresentation of ECO households could be verified by data matching all households that had a Green Deal Assessment in the period corresponding to the survey wave to a database of all installations carried out under ECO (as far as this is practicable) and comparing this to the achieved survey sample.

[10] The sample for waves 1 and 2 comprised households in England and Wales only; Scotland was added to the sample for wave 3. This is due a data agreement not being in place at the times of waves 1 and 2 and therefore Scottish data only being available for wave 3.

Interviewing was conducted between 26th July and 26th August 2013, and 499 interviews were completed (59% adjusted response rate[11]).

1.11. The report is structured as follows. First, the issues at hand are set within the theoretical framework of survey errors, specifically coverage error and variance inflation due to clustering. The methodological approach to test for bias is then described, before an interpretation of the results of the analyses is set out. The concluding section considers the implications of the findings for the accuracy of the existing survey estimates, the limitations of the approach adopted in this report, and the scope for improvements in the sample design for future surveys.

Coverage Error

1.12. In the survey methodology literature, the problem that this report seeks to evaluate is one of the coverage error. A coverage error results when there is a mismatch between the target population and how the population units are listed on the frame from which the sample is drawn. There are a number of different forms of coverage error but here the concern is with bias due to non-coverage. When particular sub-groups are not covered (excluded) on the sampling frame, then the survey will produce biased estimates if the un-covered units differ systematically from the covered units on the variables measured in the survey. This can be seen in the following equation for coverage error:

- $YC - Y = U/N\ (YC - YU)$ (1)

- Where: Y is the mean of the entire target population, YC is the mean of the population on the sampling frame, YU is the mean of the population not on the sampling frame and U/N is the proportion of the total target population (N) that is not covered by the sampling frame (U).

1.13. The equation (1) points to two important features of the coverage error which are relevant to the current investigation. First, as noted above, a coverage bias will be apparent if the uncovered units differ systematically from the covered units on the survey variable of interest. Second, the magnitude of the bias is a function of the product of a) the difference between covered and uncovered units and b) the proportion of the target population which is not covered.

1.14. In practice, this means that even large differences between covered and uncovered units will result in only small biases, if the non-coverage rate is low. Conversely, non-coverage bias will be large if the non-coverage rate is high, even if the difference between covered and non-covered units is small. The stylized example in Table 1.1 below illustrates this.

1.15. Specifically, column 1 in Table 1.1 shows different non-coverage rates, column 2 shows the mean amount spent by households (in pounds) following a Green Deal Assessment for the covered population, column 3 shows the mean amount spent following an Assessment for the uncovered population, and column 4 shows the resultant coverage bias for each combination of values in columns 1 to 3 according to equation (1).

[11] The adjusted response rate was calculated once inaccurate and ineligible addresses had been removed from the sample

Table 1.1 Stylized Illustration of Non-Coverage Error

Non-coverage rate	Mean (£ spent) covered population	Mean (£ spent) uncovered population	Coverage bias (£ spent)
5%	650	620	1.50
20%	650	620	6.00
53%	650	620	15.90
5%	650	640	0.50
20%	650	640	2.00
53%	650	640	5.30
5%	650	400	12.50
20%	650	400	50.00
53%	650	400	132.50

1.16. When the difference between the covered and non-covered units is moderate (£30), the coverage error is only of substantial magnitude (£15.90) when the non-coverage rate is high (53%)[12]. When the difference is small (£10), the coverage error is also small (£5.30), even when the non-coverage rate is high (53%). When the difference is large (£150), then coverage error is substantial (£12.50), even at low rates of non-coverage (5%). When the difference between the covered and non-covered units is large (£150) and the non-coverage rate is high (53%), then coverage bias is significant (£132.50).

1.17. Another important point to note about the coverage error is that it is variable-specific. This is to say, coverage error may be apparent for some variables but not for others within the same survey.

1.18. Table 1.2 shows the target population sizes and the number and proportion of target addresses that were defined as clusterable (and therefore covered on the sampling frame) for the three waves of the Green Deal Assessments experience survey. In wave 1, eight in ten addresses were not covered on the sampling frame. In waves 2 and 3 this figure declined to just over half of all target addresses. Still, it is clear that the non-coverage rate is high and that the potential for bias due to non-coverage is therefore also quite substantial.

[12] 53% is the non-coverage rate for the of the Green Deal Assessment experience wave 2 survey.

Table 1.2 Coverage Rate per survey wave using postcode sectors

Reference period	Wave 1	Wave 2	Wave 3
	January – March 2013	April – June 2013	July –September 2013
Universe of GREEN DEAL ASSESSMENT Addresses	9,224	30,380	37,044
Covered population: (10+ GREEN DEAL ASSESSMENT addresses in a cluster)	1,982 (21%)	14,406 (47%)	18,186 (49%)

Variance Inflation due to Clustering

1.19. A second consequence of the decision to select clusters of addresses is that the sampling error of survey estimates will be larger than for a simple random sample of the same size. For a fixed cost, clustering generally produces more precise population estimates than a simple random design would achieve. However, for a fixed sample size, clustered designs are subject to larger standard errors. This is because there tend to be greater similarities, on many attributes, between members of the same geographical sub-unit than between independently selected members of the total population. For instance, the size of garden, number of bedrooms and household income are all variables that are likely to be more similar within than they are between postcode sectors. Clustering, therefore, underestimates true population variance and this is reflected in standard errors that are larger, if correctly estimated, than those that would have been obtained from a simple random sample of the same size.

1.20. The difference in the precision of the estimates produced by a clustered design relative to a simple random sample is referred to as the design effect (deff). The design effect is the ratio of the actual variance, under the sampling method used, to the variance calculated under the assumption of simple random sampling.

1.21. The design effect is calculated as follows:

- deff = 1 + rho (n - 1) (2)
- where: deff is the design effect, rho is the intra-class correlation for the variable in question, and n is the size of the cluster.

1.22. From this formula, it can be seen that the design effect increases as the cluster size (in most instances the number of addresses sampled within a primary sampling unit) increases, and as rho (within cluster homogeneity) increases. From equation (2) it is also possible to calculate the effective sample size, n, which gives the sample size that would have been required to obtain the same level of precision in a simple random sample.

1.23. Variance inflation due to clustering is relevant in the current context because apparent cost-savings which accrue to clustering may not be as large as they initially seem, if the effective rather than the achieved sample size is used in the denominator of the cost calculation. Table 1.3 presents the variance inflation factors and effective sample sizes for the six 'key variables'[13] – see paragraph 3.29 for details – considered in the second stage of this study (estimates are based on Taylor-series linearization). This shows that, on average, the effective sample size is less than half the achieved sample size. On some variables, the effective sample size is considerably less than half the achieved sample size.

Table 1.3 Variance Inflation due to clustering (for wave 2)

Variable	Variance inflation factor	Effective sample size	Achieved sample size*
CB_13 Most action taken	2.31	203	468
Q9. Paying for an Assessment	1.93	243	468
Q7. How heard about Green Deal Assessment	2.42	207	499
Q8. Why had Green Deal Assessment	1.39	351	486
ECO match	3.59	139	499
Q19_R. How did you pay for measure	1.48	175	259

* sample sizes are not all equal to the total achieved sample size (499) as question routing within the questionnaire means that not all questions were asked of all respondents

1.24. Further, these variance inflation factors are based on a sample drawn using the 10+ clusterability threshold. The figures would be likely to change if a lower clusterability threshold were employed. Nonetheless, they clearly reflect the fact that – as we might expect given the way that the Green Deal Assessments have been marketed and delivered – there is a high degree of similarity between addresses which are clusterable within the same MSOA (Middle Layer Super Output Area). A reflection of this is included later in the report (see section 4: Further discussion).

[13] The 6 'key variables' were selected by DECC analysts on the basis that they were the survey outcomes that were most likely to be related to the suspected sources of bias.

2. Methodology

2.1. The methodology for this study had six steps from data preparation to the analysis. Step 1 combined Green Deal Assessment addresses in wave 2 of the Green Deal Assessment experience research into clusters within MSOAs. MSOAs were preferred in this study to postcode sectors because it is possible to link them to a considerably larger and more diverse set of variables from external sources. Lower Super Output Areas (LSOA) were also considered as the areal unit of aggregation but these are considerably smaller than postcode sectors, containing an average of 600 households, compared to 2,500 for MSOAs. This means that LSOAs would yield too few clusterable addresses to make fieldwork cost-efficient.

2.2. Step 2 linked the derived binary 'clusterability' variable for each MSOA to (1) the 2010 English Indices of Deprivation (2) the 2010 Welsh Indices of Deprivation and (3) data from the 2011 Census. The Indices of Deprivation are produced at the Lower Super Output Area level, so Step 3 aggregated the Indices up to MSOA level, with a weight proportional to LSOA population size.

2.3. The 2011 Census variables are, at the MSOA level, counts of all variables included on the census form. Including all census variables individually would be time-consuming and would produce results which are difficult to interpret. Therefore, in Step 4, data reduction was undertaken via principal components analysis to produce a smaller number (approximately five or six) of variables which reflect the factors identified from the principal components analysis. These are termed 'factorial ecology' variables.

2.4. Step 5 fitted the binary logistic regression models, where the outcome was the binary clusterability indicator and the predictors were the factorial ecology variables from the 2011 Census and the indices of deprivation. So, whether an address was clusterable or un-clusterable was the dependent variable (one indicating clusterable and zero indicating un-clusterable) and the predictors were variables from the census. Because the indices of deprivation are not directly comparable between England and Wales, it was necessary to fit separate models for the two countries when the Indices were included as predictors. For models which include only the census variables as predictors joint models were fitted for England and Wales.

2.5. In Step 6, the MSOA-level variables were linked to the survey data for wave 2 and used as predictors of survey outcomes in multi-level regression models. The key survey variables were chosen by DECC, based on assumptions regarding which were potentially biased. The models included a random intercept at the MSOA level to account for the non-independence of addresses within MSOAs.

3. Results

Deriving Clusterability Indicators Using MSOA

3.1. GfK NOP supplied a dataset from wave 2 of the Assessment Survey which was labelled with a variable 'Cluster_Level (adds in MSOA)'. Three different levels of clusterability are distinguished in the analyses presented here, based on the number of households within each MSOA where a Green Deal Assessment had been carried out: ten households or more, seven households or more, and five households or more. Only those MSOAs containing at least one Green Deal Assessment address are included, leading to the exclusion of 1,172 MSOAs (16.3% of all MSOAs in England and Wales).

3.2. A total of 30,380 eligible Green Deal Assessments were identified as having taken place at addresses between April and June 2013 (inclusive). Eligible addresses covered 6,028 MSOAs in England and Wales (83.7% of all MSOAs in England and Wales). Table 3.1 shows the cross-classification of the clusterability indicator for ten or more addresses using both the MSOA and the postcode sector geographies. Just under half (46.4%) of all Green Deal Assessment addresses were not identified as clusterable on either spatial scale. Of the clusterable addresses (n=16,287), 70% were clusterable using both MSOA and postcode sector, while 18.7% were only clusterable by postcode sector (10% of the total Green Deal Assessment addresses). Slightly fewer (11.5%) were only clusterable by MSOA (6.2% of the total Green Deal Assessment addresses).

Table 3.1. Clusterability of addresses using postcode sectors and MSOA (for wave 2)

		Clusterable postcode (10+)		
		No	**Yes**	**Total**
Clusterable MSOA (10+)	**No**	14,093 (46.4%)	3,049 (10.0%)	17,142
	Yes	1,881 (6.2%)	11,357 (37.4%)	13,238
	Total	15,974	14,406	30,380

3.3. Looking at the distribution of all MSOAs based on the number of clusterable addresses (Table 3.2), with a clusterability threshold of ten, households are sampled from approximately 11% of eligible MSOAs in England and Wales. If the clusterability threshold is reduced to at least seven addresses, approximately 20% of all MSOAs are covered. With at least five addresses 32.4% of MSOAs are covered. This indicates that even with a comparatively low clusterability threshold, households from most MSOAs in England and Wales will not be included in the sampling frame. This is because nearly half of all MSOAs (43.4%) have only a single address (n=1,416 MSOAs) or two addresses (n=1,202 MSOAs) where a Green Deal Assessment was carried out.

3.4. Looking at the cumulative percentage of addresses covered at different clusterability thresholds, it can be seen that using ten or more addresses as the criterion covers 43.5% of all target addresses. This is comparable to the figure obtained for wave 2 when using postcode sectors (47%).

Table 3.2. Distribution of Green Deal Assessment addresses across MSOAs in England and Wales (for Wave 2)

Green Deal Assessment addresses in MSOA	MSOA frequency	MSOA cumulative %	n Green Deal Assessment addresses	cumulative n	cumulative %
26+	113	1.9%	5356	5356	17.7%
25	11	2.1%	275	5631	18.6%
24	8	2.2%	192	5823	19.2%
23	11	2.4%	253	6076	20.0%
22	13	2.6%	286	6362	21.0%
21	12	2.8%	252	6614	21.8%
20	22	3.2%	440	7054	23.3%
19	14	3.4%	266	7320	24.1%
18	21	3.7%	378	7698	25.4%
17	21	4.1%	357	8055	26.6%
16	37	4.7%	592	8647	28.5%
15	34	5.3%	510	9157	30.2%
14	49	6.1%	686	9843	32.5%
13	43	6.8%	559	10402	34.3%
12	79	8.1%	948	11350	37.4%
11	76	9.4%	836	12186	40.2%
10	100	11.0%	1000	13186	43.5%
9	140	13.3%	1260	14446	47.6%
8	186	16.4%	1488	15934	52.5%
7	218	20.0%	1526	17460	57.6%
6	330	25.5%	1980	19440	64.1%
5	416	32.4%	2080	21520	71.0%
4	620	42.7%	2480	24000	79.1%
3	836	56.6%	2508	26508	87.4%
2	1202	76.5%	2404	28912	95.3%
1	1416	100.0%	1416	30328	100.0%

Stage 1 Results: Derivation of MSOA level characteristics

3.5. The next stage of the analysis derived address characteristic variables at the MSOA level. The following 2011 Census data and other administrative information about each MSOA in England and Wales were obtained from the ONS website (http://infuse.mimas.ac.uk and http://www.neighbourhood.statistics.gov.uk/). Census and administrative data covers:

- Accommodation type (terraced house, flat, vacant)
- Lone parent status (single parent households)
- Economic activity (manual, professional/managerial, unemployed, part-time, students)
- Health status (long-term limiting illness)
- Age structure (aged under 16, aged over 65)
- Cars/vans in household (no cars/vans)
- Communal establishment (living in communal residence)
- Household composition (single, non-pensioner)
- Household size (2 fewer rooms than required)
- Length of residence in UK (fewer than 2 years)
- Tenure (non-mortgage owner, social)
- Population density
- Income support
- Ethnicity (Herfindahl index)[14]

3.6. These data were combined using a factorial ecology approach to produce a subset of dimensions of neighbourhood difference (Table 3.3). Larger component loadings in Table 3.3 identify characteristics that tend to be shared by the same MSOA. The component loadings can be interpreted as the correlation between the indicator in column 1 and the four dimensions in the remaining columns. These dimensions are similar, although not identical, to the dimensions of neighbourhood variability identified using 2001 Census data[15]. They have been labelled:

- Neighbourhood disadvantage
- Urbanicity
- Student/ transitory population
- Age structure and vacant property

[14] Ethnic diversity is not included in the factorial ecology analysis.

[15] Data on in and out migration, as well as the proportion of land space designated as green and commercial, was not available from the 2011 Census, perhaps explaining the difference.

Table 3.3. Factorial ecology using Principal Components analysis+ (wave 2)

Indicator	Neighbourhood disadvantage	Urbanicity	Student/ transitory population	Age structure and vacant property
% long-term limiting illness	**0.89**	0.07	-0.09	0.17
% in manual occupations	**0.88**	-0.06	0.19	-0.08
% in professional/ managerial	**-0.85**	0.22	-0.12	0.10
% unemployed	**0.85**	0.38	-0.07	-0.12
% on income support	**0.84**	0.43	-0.06	0.02
% single parent households	**0.84**	0.25	-0.14	-0.22
% housing designated social	**0.65**	0.30	-0.05	-0.11
% terraced accommodation	**0.53**	0.12	0.11	-0.26
% flats	0.00	**0.93**	-0.05	0.17
% with poor occupancy rating	0.14	**0.90**	0.13	-0.05
% single non-pensioner	0.24	**0.85**	0.02	0.19
Population density	0.12	**0.79**	0.02	-0.18
% moved to UK < 2yrs ago	-0.11	**0.79**	0.38	0.05
% no car	0.57	**0.77**	0.07	0.09
% owners (no mortgage)	-0.50	**-0.75**	-0.01	0.27
% over 65	-0.22	**-0.71**	-0.10	**0.52**
% students	-0.02	0.43	**0.81**	-0.10
% living in communal residences	-0.14	0.19	**0.71**	0.22

Indicator	Neighbourhood disadvantage	Urbanicity	Student/ transitory population	Age structure and vacant property
% working part-time	0.35	-0.34	**0.68**	0.04
% properties vacant	0.01	0.04	0.05	**0.78**
% under 16	0.46	-0.02	-0.21	**-0.68**

[+] Principal Components analysis uses an orthogonal rotation. Similar results are evident when using an oblique rotation.

3.7. In addition to the four dimensions above, a measure of ethnic diversity is also included - derived using the Herfindahl concentration index[16]. It ranges, in principle, from zero (complete ethnic homogeneity) to one (complete ethnic diversity) based on a detailed ethnic breakdown[17]. It can be interpreted as the probability that two randomly drawn individuals from the same spatial unit will be from different ethnic groups.

3.8. In addition to the factorial ecology measures, the Index of Multiple Deprivation (IMD) is also used. The IMD includes separate domains of deprivation as well as an overall deprivation score. IMD scores are derived at LSOA level, therefore to generate equivalent scores at MSOA level a population weighted average score for each MSOA is taken, based on the LSOA that are nested within it. Aggregating up from LSOA to MSOA is likely to entail some weakening of the relationship between area level characteristics and the address clusterability indicator. This is because of the within MSOA variability between LSOAs which is lost due to aggregation. For instance, it may be that an MSOA contains five LSOAs, four of which are quite deprived, while the fifth is quite affluent. The aggregated score at the MSOA level for addresses in the affluent LSOA will not represent an accurate indication of the level of affluence of households in the affluent LSOA.

3.9. A small number of MSOA boundaries (n=30) changed between 2001 and 2011, leading to a degree of misclassification between the IMD scores (calculated using the 2001 boundaries) and the census measures for each MSOA (calculated using 2011 boundaries). For these 30 MSOAs, the final IMD score is the population weighted average across the MSOA (from 2001) that cross the new boundaries.

3.10. To check for multicollinearity of the predictor variables, the correlations between the factorial ecology variables and the IMD variables for the sample of MSOA where Green Deal Assessments had been carried out are examined (Appendix Table A3.1 and Table A3.2). This shows high correlations between a number of the IMD domains (Figure 3.1 below), in particular income, employment, health, and education when considering IMD, and income, employment, health, education, and safety when considering WIMD (Welsh Index of Multiple Deprivation). These domains are also highly correlated with neighbourhood disadvantage (derived from the factorial ecology).

[16] This a measure of concentration in a population of different sizes of groups or in a sector of different sizes of businesses

[17] This covers the following groups: white, mixed white and Black Caribbean, mixed white and Black African, mixed white and Asian, other mixed, Indian, Pakistani, Bangladeshi, Chinese, other Asian, African, Caribbean, other Black, Arab, and other ethnic group.

Figure 3.1. List of IMD domains

Overall IMD score

- IMD (income)
- IMD (employment)
- IMD (health)
- IMD (education)
- IMD (housing)
- IMD (crime)
- IMD (environment)

Overall WIMD score

- WIMD (employment)
- WIMD (income)
- WIMD (education)
- WIMD (health)
- WIMD (safety)
- WIMD (access to services)
- WIMD (environment)
- WIMD (housing)

3.11. Inclusion of these variables simultaneously leads to substantial changes to coefficient estimates. The final analyses were therefore restricted to the subset of IMD domains – housing, crime, and environment for England; access to services, environment, and housing for Wales. The overall IMD score is also highly correlated with a number of the component sub-domains. Therefore, the overall score was also examined independently. A correlation of .7 for England and .8 for Wales between ethnic diversity and urbanicity was also evident. However, exploratory analyses showed no significant changes to coefficient estimates when ethnic diversity and urbanicity were included together, therefore both variables were included in subsequent analyses[18].

3.12. In summary, stage 1 of the analysis produced a range of indicators of socio-economic position linked to the census Green Deal Assessment addresses for the period 1st April to 30th June 2013 at the MSOA level.

Stage 2 Results: Predicting Address Clusterability

3.13. Table 3.4 presents mean comparisons for all factorial ecology and IMD variables between clusterable and non-clusterable MSOAs at each of the three levels of clusterability. These were used to provide a preliminary indication of whether clusterable and non-clusterable MSOAs differ in terms of their structural

[18] Model diagnostics show no Variance Inflation Factors above 1.5 indicating that multicollinearity should not be a concern for these estimates.

characteristics. Those MSOAs where no Green Deal Assessments were carried out are shown in the final column for completeness.

3.14. Comparing clusterable and non-clusterable MSOAs, differences in the mean values for all factorial ecology and IMD variables are evident. For example, with a clusterability threshold of ten or more addresses the level of neighbourhood disadvantage is 0.55 higher (approximately half a standard deviation) in clusterable MSOAs compared to non-clusterable MSOAs. If there were no differences between clusterable and non-clusterable addresses then the scores on these variables would be the same. Table 3.4 also suggests that the differences observed for a 10+ clusterability criterion do not change markedly by reducing the threshold to seven, or to five households, with mean differences of similar magnitudes at these lower thresholds.

Table 3.4. Factorial ecology and IMD scores – mean comparisons between clusterable vs non-clusterable MSOAs (wave 2)

	10+ clusterable addresses		7+ clusterable addresses		5+ clusterable addresses		
	Non-clusterable	**Clusterable**	**Non-clusterable**	**Clusterable**	**Non-clusterable**	**Clusterable**	**No Green Deal Assessment**
Disadvantage	0.00	0.55	-0.06	0.53	-0.11	0.42	-0.31
Urbanicity	-0.05	0.30	-0.07	0.21	-0.08	0.11	0.08
Transitory population	-0.01	0.02	-0.01	0.02	-0.01	-0.01	0.04
Age status/vacant	-0.02	-0.14	-0.01	-0.12	-0.01	-0.08	0.16
Ethnic diversity	0.19	0.29	0.19	0.27	0.19	0.24	0.19
Number of MSOAs *(England and Wales)*	5364	664	4820	1208	4074	1954	1172
IMD (income)	0.15	0.21	0.14	0.20	0.13	0.19	0.12
IMD (employment)	0.10	0.13	0.10	0.13	0.09	0.12	0.08
IMD (health)	-0.02	0.35	-0.06	0.34	-0.10	0.28	-0.19
IMD (education)	21.57	29.29	20.73	29.12	19.97	27.52	17.06
IMD (housing)	21.55	23.16	21.58	22.32	21.64	21.91	22.87
IMD (crime)	-0.02	0.39	-0.05	0.35	-0.08	0.27	-0.18
IMD (environment)	21.08	29.52	20.35	28.65	19.96	26.30	19.89

	10+ clusterable addresses		7+ clusterable addresses		5+ clusterable addresses		
	Non-clusterable	**Clusterable**	**Non-clusterable**	**Clusterable**	**Non-clusterable**	**Clusterable**	**No Green Deal Assessment**
IMD	21.36	30.39	20.49	29.76	19.70	27.89	17.59
Number of MSOAs *(England only)*	5042	636	4526	1152	3823	1855	1112
WIMD (employment)	23.00	34.75	21.31	37.70	20.44	32.79	13.49
WIMD (income)	21.39	38.93	20.10	36.92	19.41	31.38	13.72
WIMD (education)	21.26	39.22	19.83	37.73	19.00	32.06	13.98
WIMD (health)	21.75	35.95	20.28	36.56	19.61	31.20	13.18
WIMD (safety)	21.30	40.97	20.34	36.16	19.52	31.38	13.33
WIMD (access to services)	21.28	10.58	22.10	11.59	23.28	13.18	31.73
WIMD (environment)	21.61	28.84	21.52	25.72	21.05	25.08	19.38
WIMD (housing)	20.50	31.35	20.43	26.27	20.92	22.50	24.22
WIMD	21.75	33.96	20.67	33.50	20.17	29.20	16.22
Number of MSOAs *(Wales only)*	322	28	294	56	251	99	60

3.15. The comparisons in Table 3.4 are bivariate comparisons and, due to the arbitrary scales of the factor scores and the IMD variables, somewhat difficult to interpret. Therefore, to identify which neighbourhood characteristics are significantly (and independently) associated with differences between clusterable and non-clusterable MSOAs, logistic regression models were fitted for each clusterability threshold. The model for England and Wales at the 10+ clusterability threshold has the following form:

- $$\Pr(Y = 1) = a + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 \quad (3)$$
- where $\Pr(Y = 1)$ is the probability that an MSOA contains 10 or more Green Deal Assessment addresses, a is the intercept, x_1 is disadvantage, x_2 is Urbanicity, x_3 is Transitory Population, x_4 is Age structure/vacant properties and x_5 is ethnic diversity.

3.16. Table 3.5 includes the MSOA attributes derived using the factorial ecology approach and ethnic diversity as predictors of clusterability. Tables 3.6 and 3.7 add in the IMD domain variables while Table 3.8 shows the results from models which include only the overall IMD score.

3.17. Looking first at Table 3.5, significant differences are evident between clusterable and non-clusterable MSOAs based on the levels of neighbourhood disadvantage, urbanicity and ethnic diversity. The columns headed ‘O.R’ show the odds ratio which can be interpreted as the proportional increase in the odds of an MSOA being clusterable for each unit increase in the predictor variable. For instance, in the model for 10+ clusterable addresses, the odds of an MSOA being clusterable at this threshold increase by 59% for each increase in level of neighbourhood disadvantage. The age structure/presence of vacant properties dimension is also significantly related to clusterabilty, but only when the cut-off criterion is seven addresses.

3.18. Clusterable addresses are more likely to be found in MSOAs with higher levels of neighbourhood disadvantage, which are more urban in structure, and which have higher levels of ethnic diversity. For the degree of MSOA urbanicity and ethnic diversity, there is some evidence that reducing the clusterability criterion from ten to seven, and from seven to five, reduces the magnitude of the difference between clusterable and non-clusterable MSOA (the logit values tend towards zero). However, the same is not true when considering the level of disadvantage.

Table 3.5. MSOA attributes derived from factorial ecology (wave 2)[19]

	10 Clusterable addresses				7 Clusterable addresses				5 Clusterable addresses			
	Logit	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**
Disadvantage	0.46	0.04	1.59	0.00	0.51	0.03	1.67	0.00	0.49	0.03	1.62	0.00
Urbanicity	0.27	0.06	1.31	0.00	0.21	0.05	1.24	0.00	0.13	0.05	1.13	0.01
Transitory population	0.00	0.04	1.00	0.97	0.01	0.03	1.01	0.78	-0.03	0.03	0.97	0.36
Age structure/vacant	-0.08	0.05	0.92	0.10	-0.08	0.04	0.92	0.04	-0.05	0.03	0.95	0.16
Ethnic diversity	0.52	0.28	1.68	0.07	0.48	0.23	1.62	0.03	0.41	0.20	1.51	0.04
Constant	-2.37	0.07		0.00	-1.63	0.06		0.00	-0.90	0.05		0.00
Sample/ approx. R^2	6028	0.0583			6028	0.065			6028	0.052		

[19] "Logit" refers to the log of the odds ratio.

"SE" refers to Standard Error which is a measure of how precise the estimated coefficient is. In other words the standard errors of the coefficients are the (estimated) standard deviations of the errors in estimating them. The larger the standard error of the coefficient estimate, the less precise the measurement of the coefficient.

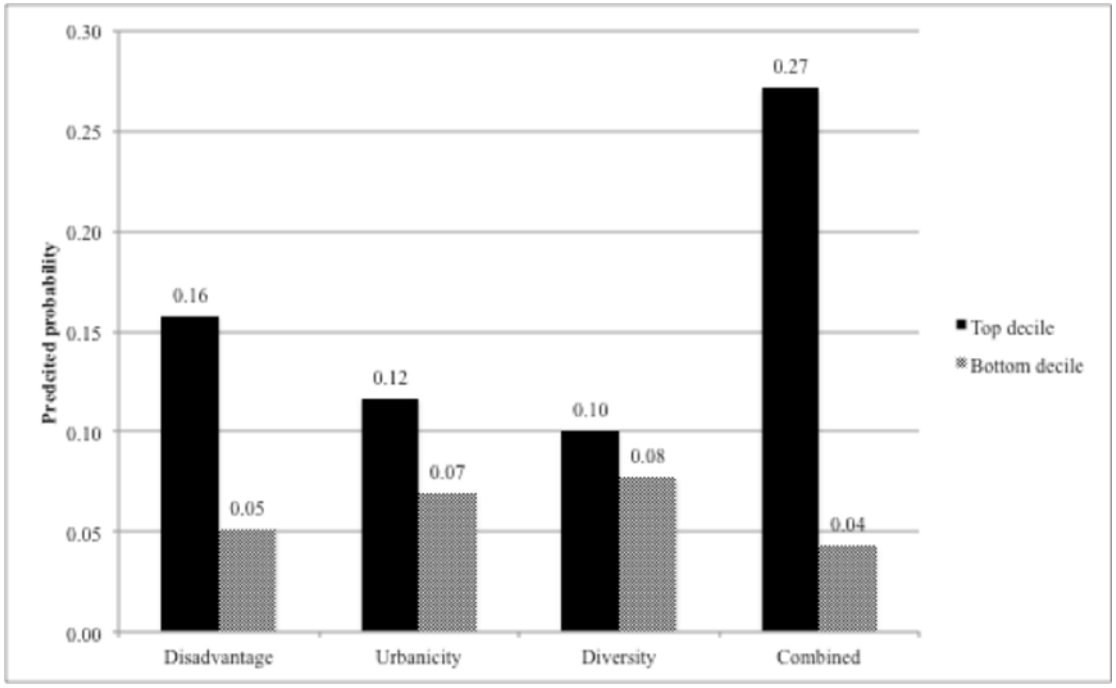
"O.R." refers to Odds Ratio. It evaluates whether the odds of an event or outcome is the same for two groups. Specifically, the OR measures the ratio of the odds that an event or result will occur to the odds of the event not happening. Odds are determined from the probabilities estimated by the logistic regressions, and range between 0 and infinity. Odds are defined as the ratio of the probability of success and the probability of failure.

"Sig" refers to statistical significance. It is a way of assessing whether something we see in the sample is likely to be true in the whole population, or whether it is just due to chance variation. A value of Sig below 0.05 is generally taken as indicating that the sample value is likely to be the same in the whole population.

3.19. Figure 3.2 shows predicted probabilities for the three significant factorial ecology variables, comparing the top and bottom deciles based on a clusterability threshold of ten or more (all other MSOA characteristics are fixed at their median). This shows a large difference in the probability of an MSOA being clusterable based on the level of disadvantage, ranging from 5% for an MSOA in the bottom decile of disadvantage to 16% for an MSOA in the top disadvantage decile. This means that the model predicts that addresses in the top decile of disadvantage have a 16% probability of being clusterable, compared to a 5% probability for addresses in the bottom decile of disadvantage (when all other predictor variables in the model are set at their median value).

3.20. The difference is also quite large when considering urbanicity (7% - 12%), and of a smaller magnitude when comparing MSOA based on ethnic diversity (8% - 10%). For an MSOA in the top decile of all three dimensions, the probability of being clusterable is 27%, compared to a probability of 4% for an MSOA in the bottom decile on all three dimensions.

Figure 3.2. Predicted probabilities for significant factorial ecology variables across MSOAs in England and Wales (top and bottom deciles) for 10+ clusterability threshold (wave 2)



3.21. Tables 3.6 and 3.7 add the IMD domain variables for England and Wales, respectively, to the model in equation (3). Looking first at England (Table 3.6), consistent differences between clusterable and non-clusterable MSOAs are evident when considering the level of area disadvantage, housing deprivation, crime, and environmental deprivation, with more deprived MSOAs on all these dimensions more likely to be clusterable[20]. All four effects are significant for all clusterability thresholds. The age structure of the area and whether there are vacant properties is also significantly associated with clusterability when the clusterability threshold is seven households. At a threshold of five households, urbanicity becomes significant.

[20] The small logit values for the IMD housing and environment reflect the scales of these variables which run from 0 to 100. The crime score ranges from -2.2 to 2.

Table 3.6. MSOA attributes derived from factorial ecology and IMD (England) (wave 2)[21]

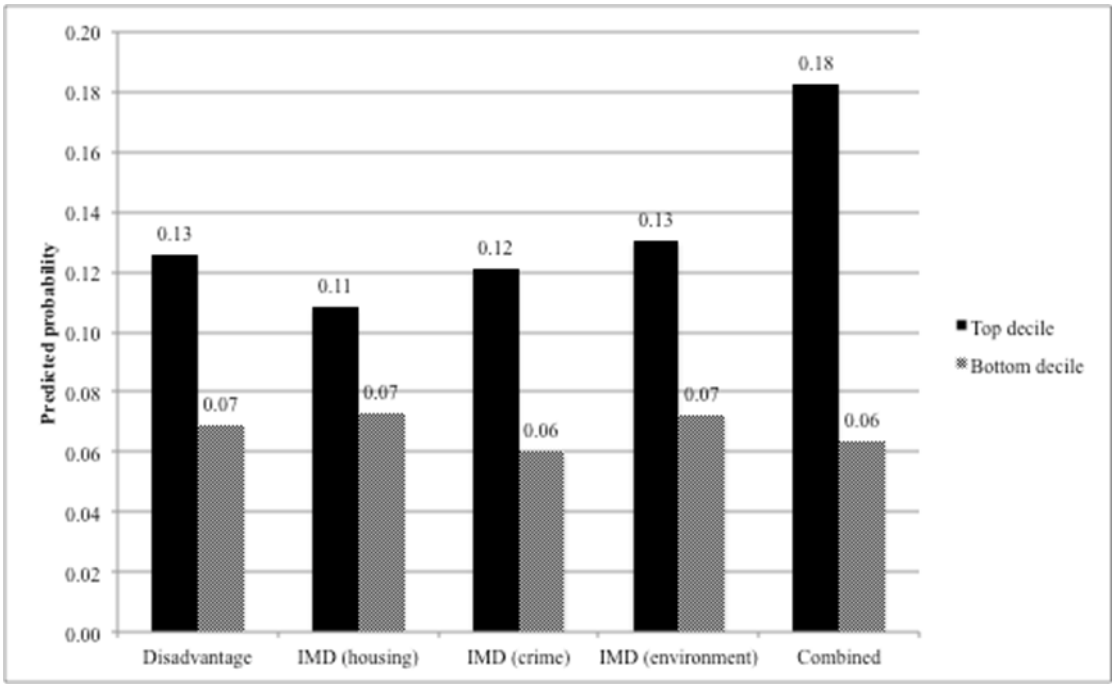
	10 Clusterable addresses				7 Clusterable addresses				5 Clusterable addresses			
	Logit	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**
Disadvantage	0.25	0.06	1.28	0.00	0.26	0.05	1.30	0.00	0.25	0.04	1.28	0.00
Urbanicity	-0.03	0.08	0.97	0.74	-0.08	0.06	0.93	0.22	-0.15	0.06	0.86	0.01
Transitory population	-0.03	0.05	0.97	0.52	-0.01	0.04	0.99	0.70	-0.04	0.03	0.96	0.20
Age structure/vacant	-0.09	0.05	0.91	0.10	-0.11	0.04	0.89	0.01	-0.05	0.04	0.95	0.19
Ethnic diversity	-0.11	0.30	0.90	0.73	-0.13	0.25	0.88	0.61	-0.08	0.22	0.93	0.73
IMD (housing)	0.02	0.01	1.02	0.00	0.01	0.00	1.01	0.02	0.01	0.00	1.01	0.01
IMD (crime)	0.42	0.11	1.52	0.00	0.41	0.09	1.51	0.00	0.45	0.07	1.57	0.00
IMD (environment)	0.02	0.00	1.02	0.00	0.02	0.00	1.02	0.00	0.02	0.00	1.02	0.00
Constant	-3.03	0.14		0.00	-2.20	0.11		0.00	-1.36	0.10		0.00
Sample/ approx. R^2	5678	0.068			5678	0.076			5678	0.062		

[21] Table 3.5 above explains the statistical terms used, i.e. Logit, SE, O.R., and Sig.

3.22. Turning to the predicted probabilities derived from the 10+ clusterability threshold model in Table 3.6 (Figure 3.3) allows a more direct comparison between the significant factorial ecology and IMD variables. This shows quite large differences between the top and bottom deciles for all four significant MSOA characteristics, with a slightly smaller difference when considering housing deprivation; addresses in the top decile of disadvantage, housing deprivation, crime and environmental deprivation are all more likely to be clusterable than addresses in the top decile on these measures.

3.23. For an address in the top decile of disadvantage, the probability of being clusterable is 13%, compared to 7% for addresses in the bottom decile of disadvantage. For an address in the top decile on all four variables (disadvantage, housing deprivation, crime, environmental deprivation), the predicted probability of being clusterable is three times higher, at 18%, than an address which is in the bottom decile on all four variables (6%).

Figure 3.3. Predicted probabilities for significant factorial ecology and IMD variables across MSOAs in England (top and bottom deciles) (wave 2)



3.24. Turning to the models for Wales only (Table 3.7), only the disadvantage area is significantly related to whether an MSOA is clusterable. Reducing the clusterability threshold to five households, significant differences are also evident between areas based on access to services, and housing deprivation.

3.25. It should be noted that the standard errors are considerably larger for the Wales only model because the number of MSOAs upon which the model is based is just 350, compared to 5,678 for the England only estimates.

Table 3.7. MSOA attributes derived from factorial ecology and WIMD (Wales) (wave 2)[22]

	10 Clusterable addresses				7 Clusterable addresses				5 Clusterable addresses			
	Logit	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**
Disadvantage	0.98	0.29	2.66	0.00	1.17	0.25	3.23	0.00	0.81	0.19	2.25	0.00
Urbanicity	0.78	0.63	2.17	0.22	0.13	0.56	1.14	0.81	0.01	0.49	1.01	0.98
Tranistory population	-0.01	0.20	0.99	0.97	-0.03	0.20	0.97	0.90	-0.10	0.18	0.90	0.58
Age structure/vacant	-0.33	0.28	0.72	0.23	0.02	0.22	1.02	0.92	-0.16	0.18	0.86	0.39
Ethnic diversity	3.73	2.89	41.66	0.20	3.51	2.58	33.56	0.17	1.52	2.25	4.56	0.50
WIMD (access to services)	-0.02	0.03	0.98	0.55	-0.04	0.03	0.96	0.12	-0.05	0.02	0.95	0.01
WIMD (environment)	-0.01	0.01	0.99	0.42	-0.01	0.01	0.99	0.55	0.00	0.01	1.00	0.90
WIMD (housing)	-0.01	0.02	0.99	0.53	-0.02	0.01	0.98	0.24	-0.02	0.01	0.98	0.07
Constant	-2.58	0.86		0.00	-1.83	0.70		0.01	-0.28	0.54		0.60
Sample/ approx. R^2	350	0.21			350	0.22			350	0.17		

[22] Table 3.5 above explains the statistical terms used, i.e. Logit, SE, O.R., and Sig.

3.26. Finally, including only the overall IMD score (Table 3.8) shows that significant differences in this overall measure are evident between clusterable and non-clusterable addresses when using ten, seven and five addresses as the clusterability threshold. There are, again, no clear grounds for supposing that reducing the clusterability threshold to as low as five addresses would remove the differences between clusterable and non-clusterable addresses that are observed when a threshold of ten or more addresses is used.

Table 3.8. Overall IMD score (wave 2)

	10 Clusterable addresses				**7 Clusterable addresses**				**5 Clusterable addresses**			
	Logit	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**	**Logit**	**SE**	**O.R**	**Sig**
IMD	0.04	0.00	1.04	0.00	0.04	0.00	1.04	0.00	0.04	0.00	1.04	0.00
Constant	-3.09	0.09		0.00	-2.44	0.07		0.00	-1.69	0.06		0.00
Sample/ approx. R^2 *(England)*	5678	0.053			5678	0.065			5678	0.058		
WIMD	0.08	0.02	1.08	0.00	0.09	0.01	1.09	0.00	0.07	0.01	1.07	0.00
Constant	-4.51	0.54		0.00	-4.04	0.44		0.00	-2.55	0.31		0.00
Sample/ approx. R^2 *(Wales)*	350	0.124			350	0.1696			350	0.0987		

3.27. In summary, the first stage models have demonstrated that significant and quite substantial differences exist between MSOA that are classified as clusterable and unclusterable, whether the clusterability threshold is specified as being ten, seven, or five households. Clusterable addresses are, in general, more likely to be found in socio-economically deprived areas, with more transient populations, with higher rates of vacant properties, and with more ethnically diverse populations.

3.28. Additional analyses conducted but not reported here show that further reducing the clusterability thresholds results in only marginal reductions in the magnitude and significance of MSOA predictors. For example, with a clusterability threshold of just two addresses, significant differences are still evident based on the level of disadvantage. This suggests that those MSOAs with two or more Green Deal Assessment addresses are significantly more disadvantaged than MSOAs with a single Green Deal Assessment address (with an odds ratio of 1.4). The practical implication of this is that, for a sample design to deliver zero non-coverage bias, it would be necessary to include MSOAs which contain only one Green Deal Assessment address. However, because the proportion of the target population that comprises only one address is small (4.7% in wave 2), even substantial differences between these addresses and those with more Green Deal Assessments in the same MSOA would result in only a small degree of bias.

Stage 3 Results: Predicting Survey Outcomes

3.29. Having demonstrated that the clusterable MSOA are significantly different from the unclusterable MSOA on a number of different socio-economic and demographic variables, the remaining question is whether these same characteristics are predictive of survey outcomes. Rather than making this Assessment for all survey variables, the focus is on six key variables that were selected by DECC analysts. These were chosen as they were the survey outcomes that were most likely to be related to the suspected sources of bias. Specifically, they were based on the following survey questions from the Green Deal Assessment experience research:

- Awareness (Q7). How did you hear about Green Deal Assessments?
- Motivations (Q8). Why did you have a Green Deal Assessment?
- Paying for an Assessment (Q9). Some companies who carry out Green Deal Assessments charge a fee for doing so. Which of the following best describes how the Assessment was paid for?
- Most action taken (CB_13, derived from Q18). For each of the improvements that were recommended, which of the following best describes what, if anything, has been done or is intended to be done, even if the work will not be done as part of the Green Deal?
    - Q18 was asked for each energy saving measure recommended to a household by their Green Deal Advice Report (GDAR) as part of their Green Deal Assessment. Therefore, the CB_13 variable showed the 'most action taken' by a household; as an example, if a household had been recommended two measures and responded that they 'definitely will' install one measure and 'definitely will not' install the other measure, then they would be classified as 'definitely will install' at CB_13 based on their uppermost action/intention
- How installation paid for/funded (Q19). How did you pay/how are you paying for (measure)?

3.30. Additionally, consideration was also given to a variable based on linkage to DECC administrative data on installations of energy saving measures carried out under the Energy Companies Obligation (ECO) which is a binary indicator of whether the household could be linked to an ECO installation or not.

3.31. Because some of the survey variables have multi-coded response scales, it was necessary to first transform these into a more manageable format for analysis. For ease of interpretation and consistency with the models fitted in Stage 1, all variables were recoded into binary form and a logistic link function employed for the model fitting. Details of the recoding procedures employed can be found in Appendix 1. For each of the six selected survey variables, five multilevel regression models were fitted, with a random intercept at the MSOA level:

- Model 1 – null model
- Model 2 – model including 4 factorial ecology variables, ethnic diversity [Full sample]
- Model 3 – as above, but also including individual controls for age, gender, and ethnicity.
- Model 4 – model including 4 factorial ecology variables, ethnic diversity, and IMD [England only]

- Model 5 – as above, but also including individual controls for age, gender, and ethnicity.

3.32. This model sequence allowed the examination of whether systematic differences in each of the outcome variables were evident between MSOAs (Model 1), and then allowed the exploration of whether this was linked to the observed characteristics of these MSOAs (Models 2 and 4). The inclusion of individual control variables (Models 3 and 5) then adjusted these estimates for the potential impact of uneven sample composition within each selected MSOA. As there were only 23 respondents from Wales nested within 6 MSOA at wave 2, it was not possible to run separate models for Wales. The estimates for the models for CB_13 ('Most action taken') are presented in Table 3.9.

3.33. Model 2 in Table 3.9 shows that, for the combined England and Wales data, individuals who live within MSOAs characterized by higher levels of socio-economic disadvantage are significantly more likely to have had something done (or be in the process of having something done) following a Green Deal Assessment . For every increase in the housing deprivation score, the odds of reporting having had something done following an Assessment increase by 42%. However, it should be noted that the standard error of this estimate is quite large, giving a 95% confidence interval of 1.13 to 1.71. The remaining coefficients are not significantly different from zero, although these estimates are rather imprecise as they are based on less than 500 observations.

3.34. This pattern remains when individual level controls are included in model 3. For the England only model (Model 4), which also includes the IMD variables, the socio-economic deprivation index is no longer significant. However, variables which are alternative/proxy measures of deprivation – crime, vacant properties, and housing stock - are significant in the England only models.

Table 3.9. Survey Outcome Prediction Models: CB_13 Most action taken (Had something done/ in process = 1) (wave 2)

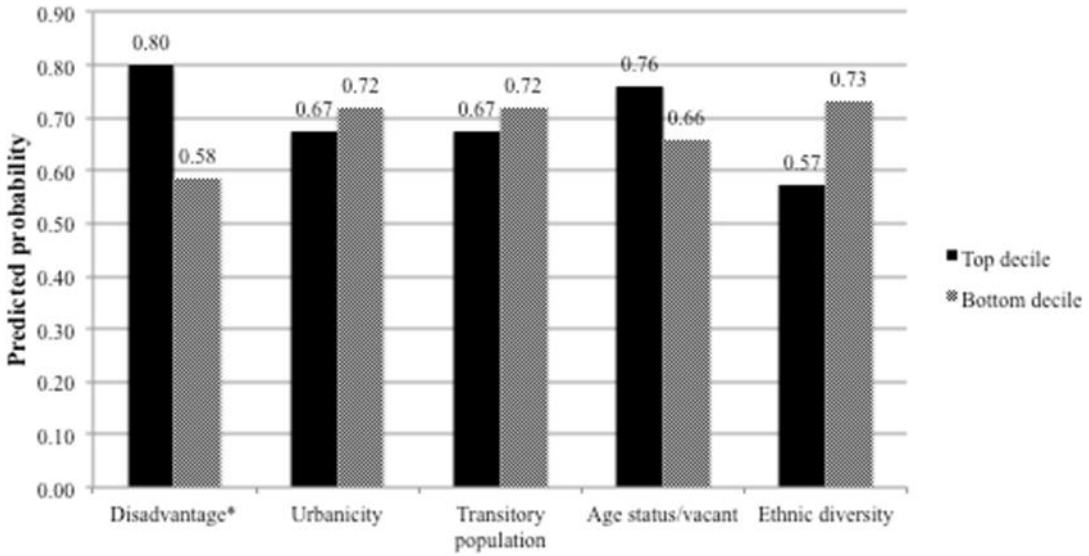
	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig
Disadvantage					0.35	0.15	1.42	0.02	0.37	0.15	1.44	0.02	0.16	0.21	1.17	0.47	0.15	0.22	1.17	0.48
Urbanicity					-0.10	0.28	0.91	0.73	-0.07	0.29	0.93	0.81	-0.32	0.31	0.72	0.29	-0.32	0.32	0.73	0.31
Transitory population					-0.13	0.23	0.88	0.57	-0.13	0.24	0.88	0.60	-0.08	0.21	0.92	0.71	-0.09	0.22	0.92	0.70
Age status/ vacant					0.23	0.19	1.26	0.23	0.20	0.20	1.22	0.31	0.31	0.18	1.37	0.09	0.28	0.19	1.33	0.13
Ethnic diversity					-1.06	1.10	0.35	0.34	-0.97	1.19	0.38	0.41	-0.61	1.11	0.54	0.58	-0.57	1.16	0.56	0.62
IMD (housing)													-0.04	0.02	0.96	0.04	-0.04	0.02	0.96	0.03
IMD (crime)													0.76	0.44	2.15	0.08	0.80	0.45	2.24	0.07
IMD (environment)													0.01	0.01	1.01	0.58	0.01	0.01	1.01	0.48
Male									-0.36	0.26	0.70	0.17					-0.36	0.26	0.70	0.17
Age (ref: 16-44)[23]																				

[23] This means that the reference category is those aged 16-44. For example, if the odds ratio is 1.18, for those aged 45-64 it means that the odds of having had the action taken are 18% higher for this age group compared to the reference group (16-44).

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
45-64									0.16	0.29	1.18	0.58					0.15	0.29	1.16	0.61
65+									0.83	0.36	2.29	0.02					0.89	0.37	2.45	0.01
	Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
BME									-0.21	0.42	0.81	0.61					-0.15	0.41	0.86	0.72
Constant	0.79	0.18	2.2	0.00	0.87	0.31	2.39	0.01	0.78	0.40	2.18	0.05	1.41	0.53	4.10	0.01	1.30	0.60	3.68	0.03
RANDOM EFFECTS																				
MSOA	2.15	0.76			1.73	0.65			1.91	0.72			1.21	0.54			1.30	0.58		
Sample size																				
Individuals	468				468				465				446				443			
MSOA	161				161				161				155				155			

3.35. Figure 3.4 plots predicted probabilities from model 2 in Table 3.9 to provide a more intuitive feel for the magnitude of these differences. Addresses in MSOAs in the top decile of disadvantage have a predicted probability of 80% of having had something done following an Assessment, compared to 58% for addresses in MSOAs in the bottom decile. Therefore it is evident that households from addresses in more deprived areas are more likely to have had an installation following Green Deal Assessment than those in less deprived areas. This is almost certainly linked to ECO funding. Other differences in the predicted probabilities can be seen in figure 3.4 but it should be noted that these cannot be reliably distinguished from zero, given the sample size.

Figure 3.4. Predicted Probabilities, Model 2 CB_13 Most action taken by Top and Bottom Deciles (wave 2)



3.36. Based on their own analysis of over-representation of particular address types in the covered population, GfK NOP produced a weight variable. Because this weight includes characteristics which are similar in nature to those included as predictors in the models here, it is possible that the differences observed might be partially or fully offset by fitting these models to the weighted data.

3.37. To check this, the models in Table 3.9 were re-estimated using weighted data, specifying both a two-level and a single-level model specification. Application of the weight produced essentially identical results to those presented in Table 3.9 (tables of weighted estimates are presented in Appendix 4). Hence using this weight would not appear to materially reduce bias due to non-coverage on the variables included in the analyses in this report.

3.38. The results for the remaining five variables are summarized in Tables 3.10 and 3.11 (CB_13 'Most action taken' is also included for completeness). Full tables of results and predicted probability plots are included in Appendix 2.

3.39. Table 3.11 (England and Wales) shows a significant effect of disadvantage for four out of six variables, with higher odds of responding positively to each item in more disadvantaged MSOA. For Q7, i.e. how the respondent heard about the Green Deal Assessment, the age status/vacant property dimension is positively associated with this variable, although only at the 90% level of confidence. None of the remaining MSOA level characteristics are significantly associated with the six survey outcomes.

Table 3.10. Summary regression results Models 2 and 3 (England and Wales) (wave 2)

	CB_13 Most action taken	Q9. Paying for an Assessment	Q7. How heard about Green Deal Assessment	Q8. Why had Green Deal Assessment	ECO match	Q19_R. How did you pay for measure [all]
Disadvantage	+		+		+	+
Urbanicity						
Transitory population						
Age status/vacant			++			
Ethnic diversity						
constant						
Sample size (individual/ MSOA)	465/161	465/160	496/162	483/160	496/162	257/111

Key: empty cells indicate non-significant relationships, '+' indicates a significant positive relationship ($p<0.05$), '++' indicates a significant positive relationship ($p<0.1$)

3.40. A similar pattern, albeit slightly less consistent, emerges when considering the results from models restricted to addresses in England only and including the IMD variables. Table 3.11 also shows evidence that being situated in a socio-economically deprived area is associated with the survey outcomes of significant differences based on IMD (housing).

Table 3.11. Summary regression results Models 4 and 5 (England only) (wave 2)

	CB_13 Most action taken	Q9. Paying for an Assessment	Q7. How heard about Green Deal Assessment	Q8. Why had Green Deal Assessment	ECO match	Q19_R. How did you pay for measure?
Disadvantage			+ (p<0.1)		+	+
Urbanicity				-	- -	
Transitory population						
Age status/vacant			- -			
Ethnic diversity						
IMD (housing)	-		+	+		
IMD (crime)	++				+	
IMD (environment)						
Constant						
Sample size (individual/ MSOA)	443/155	442/154	472/156	459/154	472/156	248/107

Key: empty cells indicate non-significant relationships, '+' indicates a significant positive relationship (p<0.05), '++' indicates a significant positive relationship (p<0.1), '-' indicates a significant negative relationship (p<0.05), '- -' indicates a significant negative relationship (p<0.1)

3.41. In summary, stage 3 of the analysis has shown that for four out of the six variables considered, addresses which were clusterable at the 10+ threshold were significantly different from non-clusterable addresses. These are: CB_13 'Most action taken', Q7 'Awareness', Q19 'How installation paid for/funded' and whether the address was an ECO address (that is, had had an energy saving measure installed under ECO). Given the approach taken to target addresses likely to be eligible for an installation through ECO for Green Deal Assessments, this is perhaps unsurprising considering the impact of targeting (on 'awareness') and receipt of ECO funded installations (on 'most action taken' and how installations are funded).

3.42. For two variables, Q8 'Motivations' and Q9 'Paying for an Assessment', there is no evidence of bias as a function of the address characteristics that have been considered.

4. Further discussion

4.1. An objective of this research was to assess the potential for the sample design used for the Green Deal Assessment experience and Green Deal Customer Journey research to have produced biased estimates on key survey variables due to the non-coverage error. The primary conclusion, based on the analyses undertaken, is that some survey estimates are indeed likely to differ systematically from the true value in the target population, as a result of the exclusion of distinct sub-groups of addresses from the sampling frame.

4.2. This is because the address characteristics which are predictive of both being excluded from (not covered on) the sampling frame and survey variables of interest were identified. Where this is the case, estimates are likely (given plausible assumptions) to be biased.

4.3. For instance, for the variable denoting whether a household had had any work carried out following a Green Deal Assessment (based on Q.18), addresses in more deprived areas were considerably more likely to be included on the sampling frame than addresses in less deprived areas. Because addresses in more deprived areas were more likely to report having had work done following an Assessment, the survey will (ceteris paribus) over-estimate the number of installations of energy saving measures undertaken in the target population.

4.4. To summarise the pattern for all six variables considered, the results indicate that for England and Wales, four of the six variables will over-estimate the true population quantity. These are: CB_13 ‘Most action taken’, Q7 ‘Awareness’, Q19 ‘How installation paid for/funded’ and whether the address was an ECO address (that is, had had an energy saving measure installed under ECO). For two variables, Q8 ‘Motivations’ and Q9 ‘Paying for an Assessment’, there is no clear evidence of bias as a function of the address characteristics that have been considered here.

4.5. It is important to note that this does not mean that the estimates for these variables are un-biased. They could be biased due to other features of the research design, such as non-response or measurement error. Additionally, there could be unobserved variables which are predictive of both under-coverage and these two survey items. These conclusions, therefore, relate to the variables that were possible to measure and included in the statistical models.

4.6. Although it is possible to draw conclusions regarding the likely presence and direction of bias in survey estimates, it is not possible to come to robust judgments about the magnitude of the bias. It would be possible, in principle, to use the estimates from the Stage 2 models to simulate the population distribution for the relationship between the MSOA characteristics and the survey outcomes and then make random draws from the simulated data to produce range estimates of the bias. However, this approach is limited by the fact that only the relationship between the address characteristic variables and the survey outcomes for addresses which are clusterable at the 10+ threshold are observed.

4.7. While it is plausible to assume some consistency in the direction and magnitude of the coefficients between the covered and the uncovered units, it is unlikely that the multivariate distributions are identical across the full population. It would therefore be necessary, using this approach, to make assumptions about these coefficients and to

test their sensitivity to variation. This would likely be quite complex and time-consuming.

4.8. In summary, it seems very likely that estimates produced using the wave 2 Green Deal Assessment Survey data on the four variables identified above will contain some bias due to non-coverage. However, while the likely direction of this bias is known, it is not possible to draw robust inferences regarding its magnitude.

4.9. Consideration can then be given to the key objectives of the study which are to indicate whether the design of subsequent waves of the Customer Journey research could be refined to reduce this bias.

4.10. A possible extension of the models fitted in Stage 1 of this research would be to use the predicted probabilities to produce inverse probability weights to compensate for non-coverage. However, while this might in practice yield some reductions in bias, the quality of the weighted estimates that would be produced would be uncertain. This approach is therefore not recommended.

4.11. This is because (as showed in Table 1.3), for a substantial minority of addresses, whether they are clusterable or not is dependent on whether MSOA or postcode sectors are used. Specifically, 6% of addresses which are clusterable within MSOA (at the 10+ threshold) are not clusterable at the same threshold within postcode sectors. This means that it would be problematic to apply weights derived using the MSOA clusterability variable to the sample drawn using postcode sectors.

4.12. However, if the same approach to sampling is to be maintained for future waves, it would be sensible to give consideration to using MSOA rather than postcode sectors to cluster addresses. The potential advantage of this approach is that MSOAs provide a larger and more diverse set of characteristics from which corrective weights can be derived. However, this consideration should be balanced against the loss of comparability with the waves of Green Deal Assessment and Customer Journey surveys undertaken over the last two years.

4.13. Another approach that merits consideration in future survey waves would be to employ disproportionate stratification across the full range of clusterability thresholds. The analyses in this report have shown that, even MSOAs containing only one Green Deal Assessment address are systematically different from MSOAs containing two or more such addresses. Therefore, to completely remove non-coverage bias, it would be necessary to include MSOAs with only one Green Deal Assessment address on the sampling frame. However, because the cost of interviews is inversely related to the number of Green Deal Assessments in an MSOA, the cost of doing this is likely to be high. Disproportionate stratification would provide a compromise between bias reduction and cost-efficiency.

4.14. The basic idea behind this approach to drawing the sample is to partition the full sampling frame into ‘strata’ which vary according to the average cost of obtaining an interview at an address within the stratum. The sampling fraction (proportion of addresses sampled within each stratum) would be varied across strata, with a higher probability of selection given to addresses in ‘cheaper’ strata and a lower probability of selection given to more addresses in ‘expensive’ strata. Unbiased population estimates (with regard to coverage) could then be produced through weighting survey estimates by the inverse of the selection probability for each stratum.

4.15. This is illustrated by a stylized example in Table 4.1 below which assumes 30,000 Green Deal Assessment addresses in a particular quarter. This universe of addresses

is divided into three equal sized strata which vary in a) the clusterability of addresses within MSOA and b) the average cost of obtaining an interview.

Table 4.1. Stylized example of proportionate stratification

Stratum	n of addresses	% of total	sampling fraction (proportionate)	n of interviews	weight	average interview cost	proportionate stratification
1	10,000	0.33	0.0333	333	1	£50	£16,650
2	10,000	0.33	0.0333	333	1	£100	£33,300
3	10,000	0.33	0.0333	333	1	£150	£49,950
						Total	**£99,900**

4.16. So, in stratum 1, the average cost of obtaining an interview is £50, in stratum 2 £100, and in stratum 3 £150. The current approach to drawing the sample effectively takes all sample units from the 'cheap' stratum which (based on wave 2) gives coverage of approximately 50 per cent of all addresses. So, drawing a random sample from stratum 1 only to achieve 1000 interviews would give a total cost of £50,000. This approach serves to minimize costs but at the expense of non-coverage bias[24].

4.17. Table 4.1 shows how a sample could be drawn by allocating selection probabilities which are proportionate to the size of each stratum. Each stratum contains 33% of all addresses, so the sampling fraction to obtain 1000 interviews is set at 0.033, yielding 333 interviews in each stratum. This approach to drawing the sample would eliminate non-coverage bias but only by doubling the cost of the survey (total cost would be £99,900).

4.18. Table 4.2 shows how full-coverage of the target population can be obtained at a lower expense by applying a disproportionate sampling fraction across strata. A higher sampling fraction of 0.06 is applied to the 'cheap' stratum, yielding 600 interviews, while in the most expensive stratum, the sampling fraction is set at 0.01, yielding a total of 100 interviews.

4.19. This provides coverage of the full target population and therefore has an expected non-coverage bias of zero. The total cost of the survey has now been reduced to £75,000. However, because addresses from the 'cheap' stratum are now over-represented in the sample and more expensive addresses under-represented, survey estimates must be weighted by a factor which is the inverse of the selection probability within strata (e.g. 0.55 for addresses in stratum 1, 1.1 for stratum 2, and 3.3 for stratum 3).

[24] In wave 2 900 addresses were selected to obtain 500 responses

Table 4.2. Stylized example of disproportionate stratification

stratum	n of addresses	% of total	sampling fraction (proportionate)	n of interviews	weight	average interview cost	disproportionate stratification
1	10,000	0.33	0.06	600	0.55	£50	£30,000
2	10,000	0.33	0.03	300	1.1	£100	£30,000
3	10,000	0.33	0.01	100	3.3	£150	£15,000
							£75,000

4.20. Statistically, the downside of the disproportionate stratification design is that the standard error of an estimator increases as a function of the variance of the weights. So, the more addresses are up and down weighted as a result of disproportionate sampling fractions, the less reliable the estimate will be. In essence, this approach to sampling involves a trade-off between reducing bias and increasing variance. The more bias is reduced by up-weighting more expensive addresses, the larger the standard error will become.

4.21. This is a stylized example and it may be that the costs of adopting such an approach to the sample design may still prove to be prohibitively expensive. However, it should be noted that the true cost of the current design may be higher than it appears when the cost calculation is based on achieved interviews. This is because, as noted in Table 1.3, the clustering of addresses results in an inflation of the variance due to non-independence of sample units within clusters. In practice, this means that the effective sample size is generally smaller than the actual number of interviews achieved. And it is the effective rather than the actual sample size that cost calculations should be based on.

5. Conclusions

5.1. The analyses suggested that the Green Deal Assessment surveys could have yielded biased estimates of the true population quantities for four of the six key survey variables examined.

5.2. This conclusion was drawn because address characteristics which are predictive of both being excluded from (not covered on) the sampling frame and survey variables of interest were identified. Where this is the case, estimates are likely (given plausible assumptions) to be biased.

5.3. However, while it is reasonable to draw this conclusion about the presence and direction of this bias, it is not possible to draw inferences regarding its magnitude. Equally, while this conclusion about bias might apply to the Green Deal Assessment surveys it would not necessarily apply to the Customer Journey surveys in which higher proportions of addresses were clusterable.

5.4. In light of these findings, the research identified a number of considerations for action:

- It is recommended that future surveys consider using the MSOA geography to produce clusters of addresses because MSOAs can be linked to a richer set of area level characteristics and these can be used to produce more powerful correction weights, compared to postcode sectors. However, such consideration should be balanced against the loss of comparability with the waves of Green Deal Assessment and Customer Journey surveys undertaken over the last two years.
- It is not recommended that the current design be retained but with a lower clusterability threshold of seven or five addresses. This is because reducing the clusterability threshold to this level would increase the cost of the survey without substantially reducing non-coverage bias.
- It is recommended that a different sample design, based on disproportionate stratification across the full range of clusterability thresholds, be considered for future survey waves. However, such consideration should again be balanced against the loss of comparability with the waves of Green Deal Assessment and Customer Journey surveys undertaken over the last two years.
- However, the viability of a disproportionate stratified design would need to be carefully considered from a cost and from an overall accuracy perspective. This is because a disproportionate stratification design is likely to be more expensive than the current approach. Additionally, the standard error of estimates under a disproportionate stratification will be higher than the current approach, due to the necessary application of design weights, and so careful consideration would need to be given to determining the optimal sample allocation under this type of design.
- Lastly, it is recommended that cost comparisons be based on the effective rather than on the achieved sample sizes under different sample designs. This is because a clustered sample produces larger standard errors than a simple random sample of the same size. The variance inflation that results from clustering should be accounted for in the production of survey estimates and in cost calculations.

Appendix 1 Coding Of Survey Outcomes

Most action taken

This first question summarises whether the respondent had installed at least one of the energy saving measures recommended to them following their Green Deal Assessment (and if not then what the 'furthest' stage was that they had reached for at least one of the recommended measures). Over half of all respondents reported that they had something done.

CB_13 Most action taken

	Frequency	Percent	Cum.
Had something done	274	58.6	58.6
In the process of having something done	32	6.8	65.4
Definitely/probably will do something:	89	19.0	84.4
Might/ might not do anything	42	9.0	93.4
Definitely/probably won't do anything	31	6.6	100
Total	468	100	

Coding decision:

Had something done/in the process vs else

How Green Deal Assessment paid for

The second question covers who paid for the Green Deal Assessment. Specifically, the distinction is made between those respondents that paid for the Assessment themselves, and those that benefitted from a free Green Deal Assessment.

Q9 Some companies who carry out Green Deal Assessments charge a fee for doing so. Which of the following best describes how the Assessment was paid for?

	Frequency	Percent	Cum.
Paid Assessment fee in full myself	43	8.6	8.6
Paid Assessment fee in full, but the fee will be refunded if the improvements are made	9	1.8	10.4
Paid Assessment fee partially myself and partially paid for by landlord/local authority/other organisation	10	2.0	12.4

	Frequency	Percent	Cum.
Assessment fee paid in full by landlord/local authority/other organisation	94	18.8	31.3
Company who carried out the Assessment did not charge a fee	306	61.3	92.6
Other	6	1.2	93.8
Don't know	31	6.2	100
Total	499	100	

Coding decision

Paid in full/refunded if improvements made/partially paid vs landlord/company (paid in some way vs free).

How heard about Green Deal Assessment

The next question details how respondents heard about the Green Deal Assessment. Here, we make the primary distinction between those that were made aware of the Green Deal Assessment via some form of direct marketing or cold calling, and all other answers.

Q7 The next few questions are about the Green Deal Assessment that you had recently. How did you hear about Green Deal Assessments?

1	q07:Cold call/door-to-door sales (they knocked on my door):
2	q07:Received a telephone call
3	q07:Approached by salesperson in the street/in-store
4	q07:Leaflet through my door
5	q07:Advert in newspaper/magazine
6	q07:Advert online
7	q07:TV advertising
8	q07:Advert in store
9	q07:News (e.g. TV/radio news, newspaper article)
10	q07:Energy Saving Advice Service
11	q07:From an energy company
12	q07:From a friend or relative/Word of Mouth

13	q07:From my landlord/local authority/housing association
14	q07:From a charity/community group/other advice service
15	q07:After an Assessment was arranged by my landlord/local authority/ housing association/ other organisation
16	q07:Other
17	q07:Don't know /can't remember

Coding decision

1-4 vs 5-15 (direct marketing vs other)

Why had Green Deal Assessment

Respondents are also asked why they had the Green Deal Assessment. Response options include saving money, environmental issues, and because the Assessment was free. Here we select the most frequent response option, and compare against all other options.

Q8 Why did you have a Green Deal Assessment?	
1	q08:To find out how to make property more energy efficient
2	q08:To save money on energy bills
3	q08:To reduce energy use for environmental reasons
4	q08:The Assessment didn't cost much
5	q08:The Assessment was free
6	q08:Availability of cashback schemes/discounts to make improvements
7	q08:To allow you to pay for improvements using the Green Deal finance/ cashback schemes (i.e. pay back through your energy bills)
8	q08:To meet Renewable Heat Incentive/Renewable Heat Premium Payment criteria
9	q08:Recommendation by friend/relative/word of mouth
10	q08:Assessment was arranged by your landlord/local authority/housing association/other organisation
11	q08:Recommendation by other person
12	q08:Recommended by Energy Saving Advice Service
13	q08:Recommended by energy company
14	q08:Other

15 q08:Don't know/can't remember

Coding decision

Selecting the most common option (to save money) vs all others

ECOmatch

This is a derived variable included in the survey datafile that is pre-coded. Here the distinction is made between those that had been matched to DECC admin data on properties that have had an energy saving measure installed under ECO, and those that hadn't.

- Pre-coded binary variable

1.1.

How paid for home improvement

The final question is rather complex. For each of 5 different types of installed energy saving measures, there are 16 different payment options (plus DK). For each of the 5 different types of measure, there are relatively few responses (with a maximum of 259 in use if we use the all category, which combines all responses across the 5 measures). Here, the most common payment option across all energy saving measures is selected – which identifies energy companies as the most common payment method.

Q19 (R) How did you pay/how are you paying for (measure)?

Q19_01 (loft insulation)	Q19_02 (cavity wall insulation)	Q19_03 (solid wall insulation)	Q19_07 (new boiler)	Q19_08 (upgrade/new windows/doors)	Q19_R (all)
n=115	n=107	n=32	n=35	n=5	n = 259

q19_R:Savings or regular income from current account

q19_R:Loan from bank/building society

q19_R:Mortgage extension

q19_R:Loan/finance scheme through installer/provider

q19_R:Other finance (credit card, high street loan etc)

q19_R:Local authority/Council

q19_R:Housing Association

q19_R:Landlord

q19_R:Energy company

q19_R:Other Green Deal provider/installer (not an energy company)

Q19_01 (loft insulation)	Q19_02 (cavity wall insulation)	Q19_03 (solid wall insulation)	Q19_07 (new boiler)	Q19_08 (upgrade/new windows/doors)	Q19_R (all)
n=115	n=107	n=32	n=35	n=5	n = 259

q19_R:Green Deal finance scheme (loan paid back through savings on your electricity bill)

q19_R:Green Deal cashback scheme (apply for cashback from the government to help pay for the improvement)

q19_R:Paid for in some other way

q19_R:Don't know

q19_R:Other

q19_R:Free (nfs)

q19_R:Government scheme/grant (nfs)

Q19 also includes a further 5 measures that are not measured as above. We do not explore these options further.

Q19 How did you pay/how are you paying for the Flat Roof Insulation

Q19 How did you pay/how are you paying for the Room In Roof Insulation

Q19 How did you pay/how are you paying for the Floor Insulation

Q19 How did you pay/how are you paying for the Solar Photovoltaic

Q19 How did you pay/how are you paying for the Solar Thermal

Coding decision

Combining details from all [measures], compare the most common payment option against all others (Energy company vs else).

The frequency distributions for all six variables after re-coding are presented below.

CB_13 Most action taken (Had something done/ in process = 1)

	Frequency	Percentage
Nothing done	162	34.6
Had something done	306	65.4

Total	468	100

Q9. Paying for an Assessment (Paid in full/ refunded if improvements made/ partially paid = 1)

	Frequency	Percentage
Not paid in full	406	86.8
Paid in full	62	13.3
Total	468	100

Q8. Why had Green Deal Assessment (To save money on energy bills = 1)

	Frequency	Percentage
Other	188	38.7
Save money on bills	298	61.3
Total	486	100

Q7. How heard about Green Deal Assessment (Cold call/ telephone call/ salesperson/ leaflet = 1)

	Frequency	Percentage
Not direct marketing	275	55.1
Direct marketing	224	44.9
Total	499	100

ECO match = 1

	Frequency	Percentage
No	266	53.3
Yes	233	46.7
Total	499	100

Q19_R. How did you pay for measure [all] (Energy company paid = 1)

	Frequency	Percentage
Other	213	82.2
Energy company	46	17.8
Total	259	100

Appendix 2: Survey Outcome Prediction Models

Table A2.1 Q9. Paying for an Assessment (Paid in full/ refunded if improvements made/ partially paid = 1)

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig
Disadvantage					0.12	0.18	1.13	0.52	0.12	0.19	1.13	0.51	0.32	0.30	1.37	0.29	0.34	0.30	1.41	0.26
Urbanicity					-0.31	0.35	0.73	0.38	-0.31	0.36	0.73	0.38	0.14	0.42	1.16	0.73	0.19	0.43	1.20	0.67
Transitory population					0.33	0.29	1.39	0.25	0.32	0.29	1.37	0.28	0.35	0.28	1.42	0.22	0.34	0.30	1.40	0.25
Age status/ vacant					0.16	0.22	1.18	0.45	0.18	0.22	1.20	0.41	0.12	0.22	1.13	0.59	0.15	0.23	1.17	0.51
Ethnic diversity					-0.02	1.35	0.98	0.99	-0.24	1.44	0.79	0.87	0.75	1.45	2.12	0.60	0.57	1.54	1.77	0.71
IMD (housing)													-0.02	0.03	0.98	0.38	-0.03	0.03	0.97	0.33
IMD (crime)													-0.72	0.60	0.49	0.23	-0.77	0.62	0.46	0.22
IMD (environment)													-0.02	0.02	0.98	0.36	-0.02	0.02	0.98	0.31

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit		**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
Male										0.35	0.33	1.42	0.29					0.52	0.35	1.68	0.15
Age (ref: 16-44)																					
45-64										-0.18	0.39	0.84	0.65					-0.41	0.42	0.66	0.33
65+										-0.29	0.47	0.75	0.54					-0.41	0.49	0.67	0.41
BME										0.32	0.56	1.38	0.56					0.44	0.57	1.55	0.45
constant	-2.39		0.29	0.09	0.00	-2.40	0.43	0.09	0.00	-2.43	0.53	0.09	0.00	-1.64	0.69	0.19	0.02	-1.54	0.79	0.21	0.05
RANDOM EFFECTS																					
MSOA	2.16		1.03			1.88	0.96			1.95	0.99			1.65	0.89			1.83	0.97		
Sample size																					
Individuals	468					468				465				445				442			
MSOA	160					160				160				154				154			

Table A2.2 Q7. How heard about Green Deal Assessment (Cold call/ telephone call/ salesperson/ leaflet = 1)

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig
Disadvantage					0.44	0.15	1.55	0.00	0.46	0.15	1.58	0.00	0.38	0.22	1.47	0.09	0.40	0.23	1.49	0.08
Urbanicity					-0.06	0.26	0.94	0.83	-0.04	0.27	0.96	0.87	-0.26	0.32	0.77	0.41	-0.26	0.32	0.77	0.41
Transitory population					-0.05	0.23	0.95	0.81	-0.05	0.23	0.95	0.84	-0.08	0.23	0.93	0.75	-0.07	0.24	0.94	0.78
Age status/vacant					0.30	0.17	1.35	0.08	0.30	0.18	1.35	0.09	0.30	0.18	1.36	0.09	0.31	0.18	1.36	0.09
Ethnic diversity					1.60	1.05	4.94	0.13	1.46	1.11	4.31	0.19	0.81	1.13	2.25	0.48	0.71	1.18	2.03	0.55
IMD (housing)													0.05	0.02	1.05	0.02	0.05	0.02	1.05	0.02
IMD (crime)													0.32	0.45	1.38	0.48	0.35	0.46	1.41	0.45
IMD (environment)													0.00	0.01	1.00	0.97	0.00	0.01	1.00	0.97
Male									0.01	0.24	1.01	0.98					-0.02	0.24	0.98	0.95
Age (ref: 16-44)																				
45-64									-0.08	0.27	0.92	0.76					-0.14	0.28	0.87	0.62
65+									0.11	0.32	1.12	0.73					0.07	0.33	1.08	0.82

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
BME									0.16	0.39	1.18	0.67					0.07	0.40	1.07	0.86
constant	-0.25	0.16	0.8	0.1	-0.93	0.31	0.39	0.00	-0.95	0.38	0.39	0.01	-1.84	0.57	0.16	0.00	-1.86	0.63	0.16	0.00
RANDOM EFFECTS																				
MSOA	1.96	0.64			1.72	0.58			1.76	0.60			1.70	0.60			1.76	0.62		
Sample size																				
Individuals	499				499				496				475				472			
MSOA	162				162				162				156				156			

Table A2.3 Q8. Why had Green Deal Assessment (To save money on energy bills = 1)

Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
Disadvantage				-0.05	0.11	0.95	0.65	-0.06	0.11	0.94	0.55	-0.21	0.16	0.81	0.19	-0.22	0.16	0.80	0.17
Urbanicity				-0.13	0.20	0.88	0.52	-0.17	0.20	0.84	0.40	-0.40	0.23	0.67	0.08	-0.45	0.22	0.64	0.04
Transitory population				0.00	0.17	1.00	0.99	0.02	0.17	1.02	0.91	0.01	0.18	1.01	0.95	0.05	0.17	1.06	0.76
Age status/vacant				0.04	0.13	1.04	0.77	0.08	0.13	1.08	0.55	0.00	0.13	1.00	1.00	0.04	0.13	1.04	0.74
Ethnic diversity				0.00	0.77	1.00	1.00	-0.03	0.80	0.97	0.97	-1.24	0.85	0.29	0.14	-1.20	0.84	0.30	0.15
IMD (housing)												0.04	0.01	1.04	0.01	0.04	0.01	1.04	0.00
IMD (crime)												0.41	0.33	1.51	0.22	0.45	0.33	1.57	0.16
IMD (environment)												0.02	0.01	1.02	0.02	0.02	0.01	1.02	0.03
Male								-0.13	0.21	0.88	0.54					-0.10	0.21	0.91	0.64
Age (ref: 16-44)																			
45-64								-0.17	0.24	0.85	0.49					-0.26	0.25	0.77	0.29
65+								-0.61	0.28	0.54	0.03					-0.70	0.29	0.50	0.02
BME								0.02	0.33	1.02	0.96					-0.12	0.34	0.89	0.72

	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
constant	0.54	0.12	1.72	0.00	0.60	0.22	1.82	0.01	0.89	0.29	2.42	0.00	-0.58	0.40	0.56	0.15	-0.29	0.44	0.75	0.50
RANDOM EFFECTS																				
MSOA	0.49	0.27			0.46	0.26			0.41	0.25			0.38	0.26			0.28	0.24		
Sample size																				
Individuals	486				486				483				462				459			
MSOA	160				160				160				154				154			

Table A2.4 ECO match = 1

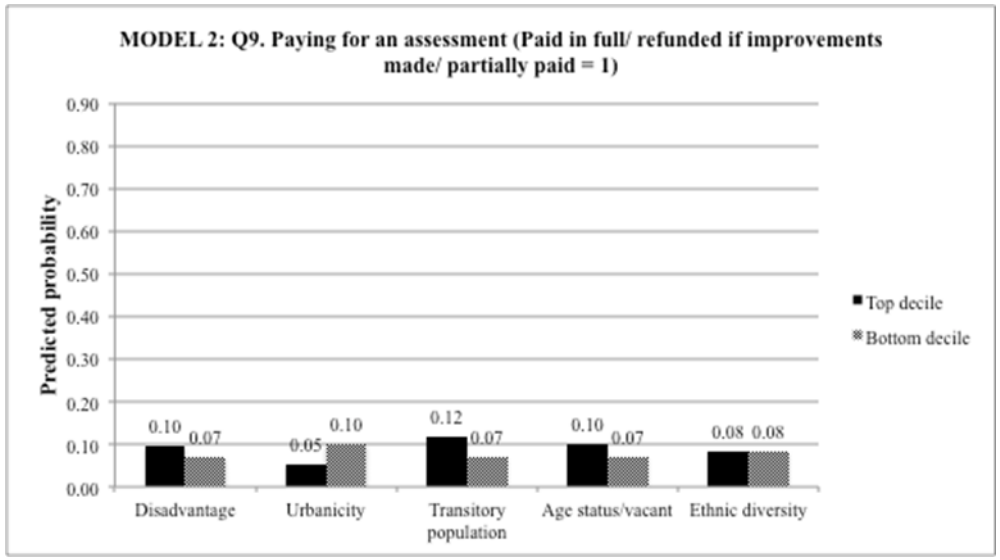
	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig
Disadvantage					1.08	0.25	2.93	0.00	1.13	0.26	3.10	0.00	0.65	0.30	1.92	0.03	0.69	0.31	2.00	0.03
Urbanicity					-0.14	0.40	0.87	0.72	-0.14	0.41	0.87	0.74	-0.75	0.43	0.47	0.08	-0.79	0.44	0.45	0.08
Transitory population					0.04	0.34	1.04	0.91	0.10	0.35	1.10	0.78	0.10	0.30	1.11	0.74	0.17	0.31	1.18	0.59
Age status/vacant					0.11	0.27	1.12	0.68	0.11	0.28	1.11	0.70	0.24	0.25	1.28	0.32	0.24	0.25	1.28	0.34
Ethnic diversity					0.86	1.57	2.36	0.59	0.70	1.65	2.00	0.67	0.64	1.50	1.90	0.67	0.38	1.57	1.46	0.81
IMD (housing)													-0.02	0.03	0.98	0.47	-0.02	0.03	0.98	0.51
IMD (crime)													1.82	0.64	6.15	0.01	1.92	0.66	6.79	0.00
IMD (environment)													0.00	0.02	1.00	0.87	0.00	0.02	1.00	0.87
Male									-0.17	0.29	0.85	0.57					-0.25	0.29	0.78	0.40
Age (ref: 16-44)																				
45-64									0.27	0.34	1.31	0.43					0.30	0.35	1.35	0.38
65+									0.22	0.39	1.24	0.58					0.30	0.40	1.36	0.44
BME									0.22	0.49	1.25	0.65					0.30	0.48	1.35	0.53

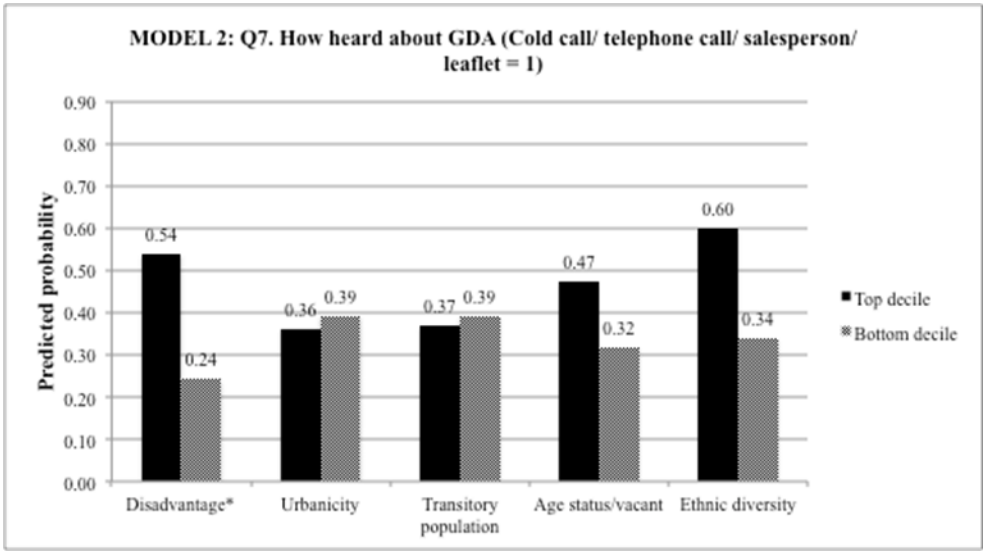
	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
constant	-0.53	0.26	0.59	0.04	-1.44	0.48	0.24	0.00	-1.61	0.57	0.20	0.01	-1.14	0.76	0.32	0.13	-1.33	0.84	0.26	0.11
RANDOM EFFECTS																				
MSOA	6.16	1.83			5.18	1.56			5.50	1.66			3.61	1.21			3.84	1.29		
Sample size																				
Individuals	499				499				496				475				472			
MSOA	162				162				162				156				156			

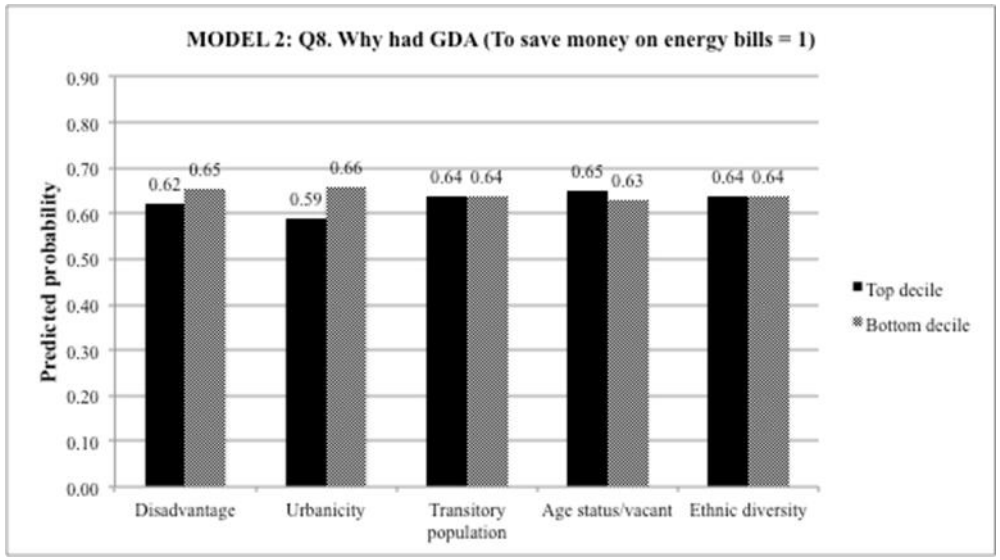
Table A2.5 Q19_R. How did you pay for measure [all] (Energy company paid = 1)

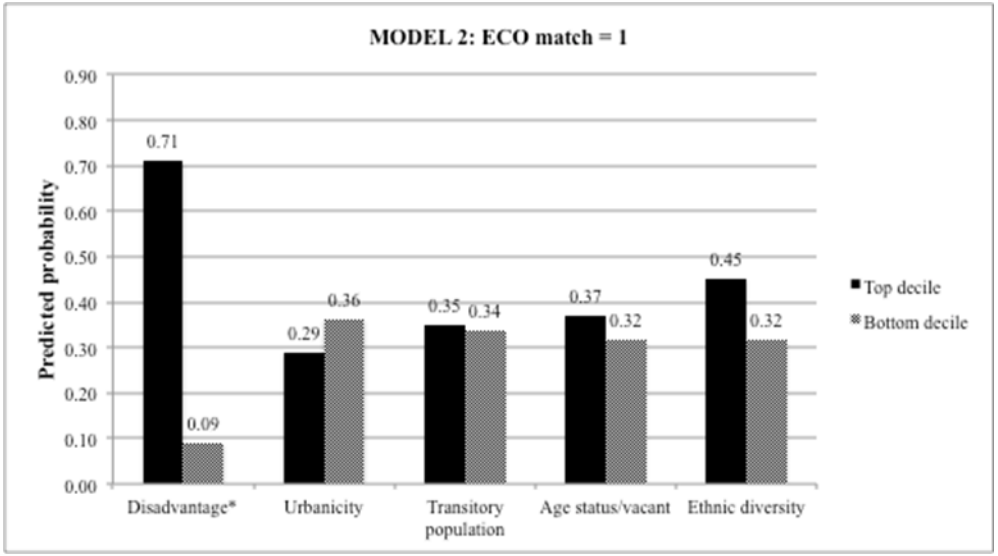
	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig	Logit	S.E	OR	Sig
Disadvantage					0.78	0.28	2.19	0.01	0.77	0.29	2.16	0.01	1.05	0.38	2.84	0.01	1.04	0.38	2.82	0.01
Urbanicity					-0.64	0.54	0.53	0.23	-0.68	0.55	0.51	0.22	-0.54	0.60	0.58	0.37	-0.55	0.61	0.58	0.37
Transitory population					0.49	0.43	1.63	0.26	0.51	0.44	1.67	0.24	0.43	0.45	1.54	0.34	0.46	0.46	1.59	0.31
Age status/vacant					-0.26	0.28	0.77	0.35	-0.19	0.28	0.82	0.49	-0.29	0.27	0.75	0.29	-0.24	0.28	0.79	0.40
Ethnic diversity					0.66	1.54	1.94	0.67	0.70	1.64	2.01	0.67	0.38	1.67	1.46	0.82	0.54	1.71	1.71	0.75
IMD (housing)													0.02	0.03	1.02	0.52	0.02	0.03	1.02	0.56
IMD (crime)													-0.71	0.74	0.49	0.34	-0.74	0.75	0.48	0.32
IMD (environment)													0.00	0.02	1.00	0.97	0.00	0.02	1.00	0.99
Male									0.25	0.45	1.29	0.58					0.24	0.46	1.27	0.61
Age (ref: 16-44)																				
45-64									-0.54	0.49	0.58	0.27					-0.37	0.49	0.69	0.45
65+									-1.54	0.66	0.21	0.02					-1.43	0.66	0.24	0.03
BME									-0.20	0.84	0.82	0.82					-0.35	0.87	0.70	0.69

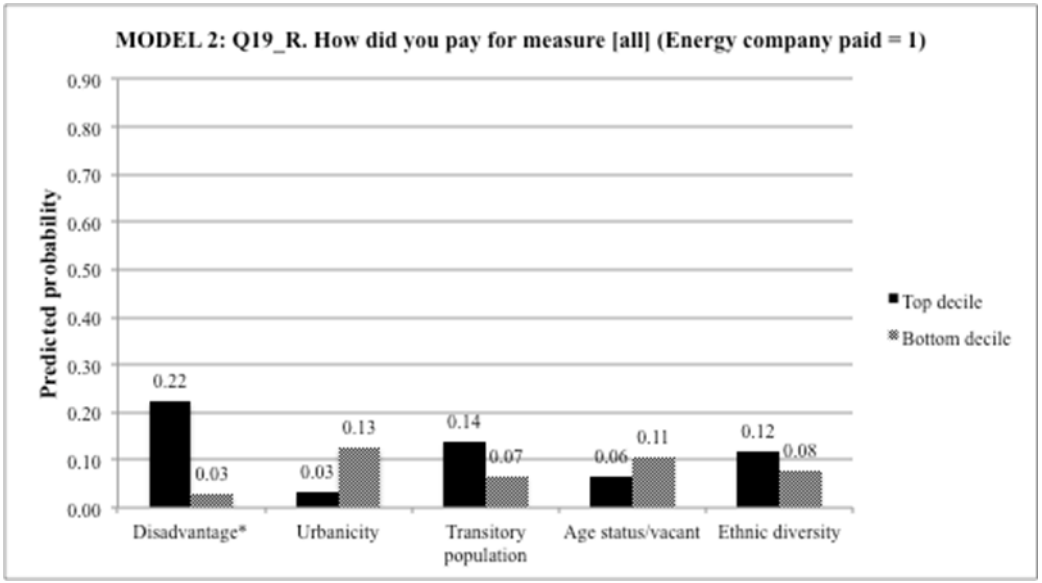
	Model 1: Empty (England and Wales)				Model 2: Factorial ecology (England and Wales)				Model 3: Factorial + individual (England and Wales)				Model 4: Factorial + IMD (England only)				Model 5: Factorial + IMD + individual (England only)			
	Logit	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**	**Logit**	**S.E**	**OR**	**Sig**
constant	-2.16	0.39	0.11	0.00	-3.02	0.65	0.05	0.00	-2.53	0.76	0.08	0.00	-3.27	0.98	0.04	0.00	-2.81	1.12	0.06	0.01
RANDOM EFFECTS																				
MSOA	2.80	1.55			1.99	1.26			2.06	1.34			1.88	1.27			1.87	1.33		
Sample size																				
Individuals	259				259				257				250				248			
MSOA	112				112				111				108				107			


MODEL 2: Q9. Paying for an assessment (Paid in full/ refunded if improvements made/ partially paid = 1)
Predicted probability
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.10 0.07
0.05 0.10
0.12 0.07
0.10 0.07
0.08 0.08
Disadvantage
Urbanicity
Transitory population
Age status/vacant
Ethnic diversity
Top decile
Bottom decile


MODEL 2: Q7. How heard about GDA (Cold call/ telephone call/ salesperson/ leaflet = 1)
Predicted probability
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.54 0.24
0.36 0.39
0.37 0.39
0.47 0.32
0.60 0.34
Disadvantage*
Urbanicity
Transitory population
Age status/vacant
Ethnic diversity
Top decile
Bottom decile


MODEL 2: Q8. Why had GDA (To save money on energy bills = 1)
Predicted probability
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.62 0.65
0.59 0.66
0.64 0.64
0.65 0.63
0.64 0.64
Disadvantage
Urbanicity
Transitory population
Age status/vacant
Ethnic diversity
Top decile
Bottom decile


MODEL 2: ECO match = 1
Predicted probability
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.71 0.09
0.29 0.36
0.35 0.34
0.37 0.32
0.45 0.32
Disadvantage*
Urbanicity
Transitory population
Age status/vacant
Ethnic diversity
Top decile
Bottom decile


MODEL 2: Q19_R. How did you pay for measure [all] (Energy company paid = 1)
Predicted probability
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.22
0.03
0.03
0.13
0.14
0.07
0.06
0.11
0.12
0.08
Disadvantage*
Urbanicity
Transitory population
Age status/vacant
Ethnic diversity
Top decile
Bottom decile

Appendix 3: Correlation Matrices for MSOA Variables

Table A3.1 Correlation matrix factorial ecology and IMD (England)

Disadvantage	1.00												
Urbanicity	0.01	1.00											
Transitory population	0.01	-0.01	1.00										
Age status/vacant	-0.02	0.02	0.00	1.00									
Ethnic diversity	0.12	**0.70**	0.13	-0.28	1.00								
IMD (income)	**0.86**	0.40	0.02	-0.06	0.47	1.00							
IMD (employment)	**0.90**	0.22	-0.04	0.13	0.20	**0.91**	1.00						
IMD (health)	**0.79**	0.28	0.06	0.13	0.23	**0.80**	**0.88**	1.00					
IMD (education)	**0.91**	0.01	0.03	-0.06	0.06	**0.78**	**0.81**	**0.71**	1.00				
IMD (housing)	-0.19	0.33	0.04	0.05	0.38	0.05	-0.15	-0.15	-0.22	1.00			
IMD (crime)	0.57	0.54	0.02	-0.14	0.51	0.69	0.62	0.63	0.57	-0.05	1.00		
IMD (environment)	0.36	0.58	0.08	0.13	0.52	0.56	0.45	0.48	0.29	0.26	0.51	1.00	
IMD	**0.88**	0.39	0.03	0.04	0.40	**0.97**	**0.94**	**0.87**	**0.82**	0.05	**0.73**	0.62	1.00

Table A3.2 Correlation matrix factorial ecology and WIMD (Wales)

Disadvantage	1.00													
Urbanicity	-0.01	1.00												
Transitory population	-0.17	0.38	1.00											
Age status/vacant	0.00	-0.13	-0.03	1.00										
Ethnic diversity	-0.05	**0.80**	0.42	-0.19	1.00									
WIMD (employment)	**0.91**	0.14	-0.19	0.03	0.05	1.00								
WIMD (income)	**0.90**	0.30	-0.13	-0.09	0.27	**0.91**	1.00							
WIMD (education)	**0.89**	0.23	-0.06	-0.13	0.19	**0.88**	**0.94**	1.00						
WIMD (health)	**0.84**	0.24	-0.11	-0.03	0.15	**0.92**	**0.87**	**0.87**	1.00					
WIMD (community safety)	**0.77**	0.47	0.04	-0.17	0.40	**0.78**	**0.89**	**0.84**	**0.77**	1.00				
WIMD (access to services)	-0.42	-0.48	-0.17	0.35	-0.39	-0.49	-0.50	-0.47	-0.52	-0.61	1.00			
WIMD (environment)	0.12	0.41	-0.02	-0.21	0.45	0.16	0.30	0.21	0.17	0.33	-0.32	1.00		
WIMD (housing)	0.32	0.48	0.31	0.21	0.40	0.24	0.41	0.36	0.27	0.49	-0.16	0.15	1.00	
WIMD	**0.92**	0.25	-0.13	-0.01	0.19	**0.95**	**0.98**	**0.95**	**0.92**	**0.86**	-0.43	0.27	0.41	1.00

Appendix 4: Replication Using Survey Weights

Table A4.1 Replication of Table 3.9 Applying the survey weight MLWIN estimates: RIGLS with 2nd order PQL

	Model 3: Unweighted			Model 3: standardized weight			Model 3: Raw weight			Model 5: Unweighted			Model 5: standardized weight			Model 5: Raw weight		
	Logit	S.E	Sig	Logit	S.E	Sig	Logit	S.E	Sig	Logit	S.E	Sig	Logit	S.E	Sig	Logit	S.E	Sig
Disadvantage	0.37	0.15	*	0.37	0.15	*	0.36	0.15	*	0.16	0.20		0.16	0.20		0.16	0.20	
Urbanicity	-0.06	0.30		-0.06	0.30		0.01	0.30		-0.31	0.33		-0.32	0.33		-0.24	0.34	
Transitory population	-0.12	0.22		-0.12	0.22		-0.09	0.23		-0.08	0.21		-0.09	0.21		-0.06	0.21	
Age status/ vacant	0.19	0.20		0.17	0.20		0.12	0.21		0.27	0.20		0.25	0.20		0.21	0.21	
Ethnic diversity	-1.01	1.11		-0.94	1.11		-1.15	1.12		-0.66	1.10		-0.64	1.11		-0.87	1.12	
IMD (housing)										-0.04	0.02	*	-0.04	0.02	*	-0.04	0.02	
IMD (crime)										0.81	0.43		0.80	0.43		0.75	0.43	
IMD (environment)										0.01	0.01		0.01	0.01		0.01	0.01	
Male	-0.36	0.25		-0.34	0.25		-0.44	0.25		-0.38	0.26		-0.37	0.26		-0.46	0.26	

	Model 3: Unweighted			Model 3: standardized weight			Model 3: Raw weight			Model 5: Unweighted			Model 5: standardized weight			Model 5: Raw weight		
	Logit	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**
Age (ref: 16-44)																		
45-64	0.16	0.26		0.18	0.26		0.34	0.28		0.17	0.28		0.19	0.28		0.36	0.29	
65+	0.84	0.35	**	0.86	0.35	**	0.97	0.37	**	0.92	0.37	**	0.96	0.37	**	1.06	0.39	**
BME	-0.21	0.42		-0.20	0.42		-0.22	0.43		-0.15	0.42		-0.15	0.42		-0.19	0.43	
Constant	0.77	0.37		0.73	0.37		0.73	0.38		1.35	0.59		1.26	0.59		1.17	0.60	
RANDOM EFFECT																		
MSOA	1.85	0.32		1.87	0.31		2.05	0.34		1.52	0.29		1.53	0.29		1.65	0.29	
Sample size																		
Individuals	465			465			465			443			443			443		
MSOA	161			161			161			155			155			155		

Table A4.2 Replication of Table 3.9 Applying the survey weight, no random intercept

	Model 3: Unweighted			Model 3: Raw weight			Model 5: Unweighted			Model 5: Raw weight		
	Logit	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**
Disadvantage	0.29	0.09	**	0.28	0.10	**	0.08	0.15		0.11	0.15	
Urbanicity	-0.13	0.18		-0.03	0.18		-0.35	0.21		-0.25	0.21	
Transitory population	-0.15	0.15		-0.11	0.15		-0.08	0.15		-0.05	0.15	
Age status/ vacant	0.21	0.12		0.14	0.11		0.29	0.13	**	0.23	0.12	*
Ethnic diversity	-0.16	0.71		-0.43	0.71		-0.18	0.79		-0.45	0.78	
IMD (housing)							-0.03	0.01	**	-0.03	0.01	**
IMD (crime)							0.79	0.31	**	0.71	0.30	**
IMD (environment)							0.01	0.01		0.01	0.01	
Male	-0.17	0.21		-0.24	0.21		-0.25	0.22		-0.33	0.22	
Age (ref: 16-44)												
45-64	0.02	0.23		0.15	0.24		0.04	0.25		0.19	0.25	
65+	0.65	0.29	**	0.70	0.30	**	0.76	0.31	**	0.83	0.32	**
BME	-0.19	0.32		-0.22	0.33		-0.10	0.34		-0.17	0.35	
Constant	0.47	0.26		0.49	0.27		0.90	0.41		0.81	0.44	

	Model 3: Unweighted			Model 3: Raw weight			Model 5: Unweighted			Model 5: Raw weight		
	Logit	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**	**Logit**	**S.E**	**Sig**
Sample size												
Individuals	465			465			443			443		

Key: empty cells indicate non-significant relationships, '*' indicates a significant positive relationship ($p<0.05$), '**' indicates a significant positive relationship ($p<0.1$).

Department of Energy & Climate Change
3 Whitehall Place
London SW1A 2AW
www.gov.uk/decc
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