Aviation Noise & Subjective Wellbeing

March 11, 2021

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Glossary

A-Weighting	A weighting scale applied when aggregating noise levels measured at different frequencies to approximate the characteristics of human hearing
Instrumental Variables	An instrumental variable is a third variable used in regression analysis to mitigate the bias caused by endogenous variables (variables that are influenced by other variables in the model).
LAeq	LAeq is the A-weighted, equivalent continuous sound level in decibels measured over a stated period of time.
LAeq (8hr)	LAeq measured during the night, between the hours of 23:00 and 07:00.
LAeq (16hr)	LAeq measured during the day, between the hours of 07:00 and 23:00.
SF-12	The Short Form (SF) -12 is a multipurpose survey with twelve questions. The questions are combined, scored, and weighted to create objective measures of overall physical and mental health.
Statistical significance	An estimated value is said to be statistically significant if it is not likely to occur by chance, but is rather likely attributable to a specific cause.
Willingness to Accept	The amount of money that an individual would need to be paid in compensation for some negative outcome (a 'bad') in order to fully compensate them for that bad (i.e. to bring them back to their original level of utility prior to experiencing the bad).
Willingness to Pay	The amount of money a person would be willing to pay to consume some non-market good, if it was traded.

Executive Summary

This report analyses the impact of aviation noise on the wellbeing of residents who live in the vicinity of Heathrow, Gatwick, and Stansted airports. This exploratory research aims to build on previous evidence commissioned by the Airports Commission (2014) by using a Wellbeing Valuation approach to analyse new data sources with the aim of capturing and measuring the impacts of aviation noise on self-reported wellbeing in a singular monetary cost. The aim of this research is to extend our understanding of the impact of aviation noise on subjective wellbeing and should be considered in conjunction with other related analyses.

We find that there is a negative association between aviation noise and wellbeing, and that the size of this association is increasing in the level of noise exposure. Wellbeing impacts are found, however, to be mitigated in areas eligible for subsidised noise insulation schemes: that is, we do not identify any evidence of an association between aviation noise and wellbeing for households who qualify for such schemes. For this reason, the wellbeing valuations presented in this report (Figures 1 and 2 below) are applicable only to residents in areas that do not qualify for subsidised insulation and this report recommends that eligible groups and non-eligible groups should be considered separately in the application of noise valuations for policy.

In this analysis we use a regression approach to estimate the impact of aviation noise on subjective wellbeing. In turn, we apply Wellbeing Valuation methodology, endorsed in HM Treasury Green Book, to the regression outputs in order to calculate the monetary equivalent value of the wellbeing impacts of aviation noise. This method, which relies solely on statistical methods and no direct questioning of affected households, yields two variants of monetary valuation - willingness to accept (WTA) and willingness to pay (WTP). WTP is defined as the monetary amount that noise-exposed households would be willing to pay per year to eradicate a given level of aviation noise, while WTA is the compensatory amount that a household would have to receive per year to bear a given level of additional aviation noise, whilst maintaining the same level of welfare. In both cases, WTP and WTA are hypothetical monetary valuations of the subjective wellbeing costs associated with aviation noise and are not based on directly asking individuals their perceived willingness to pay or accept.

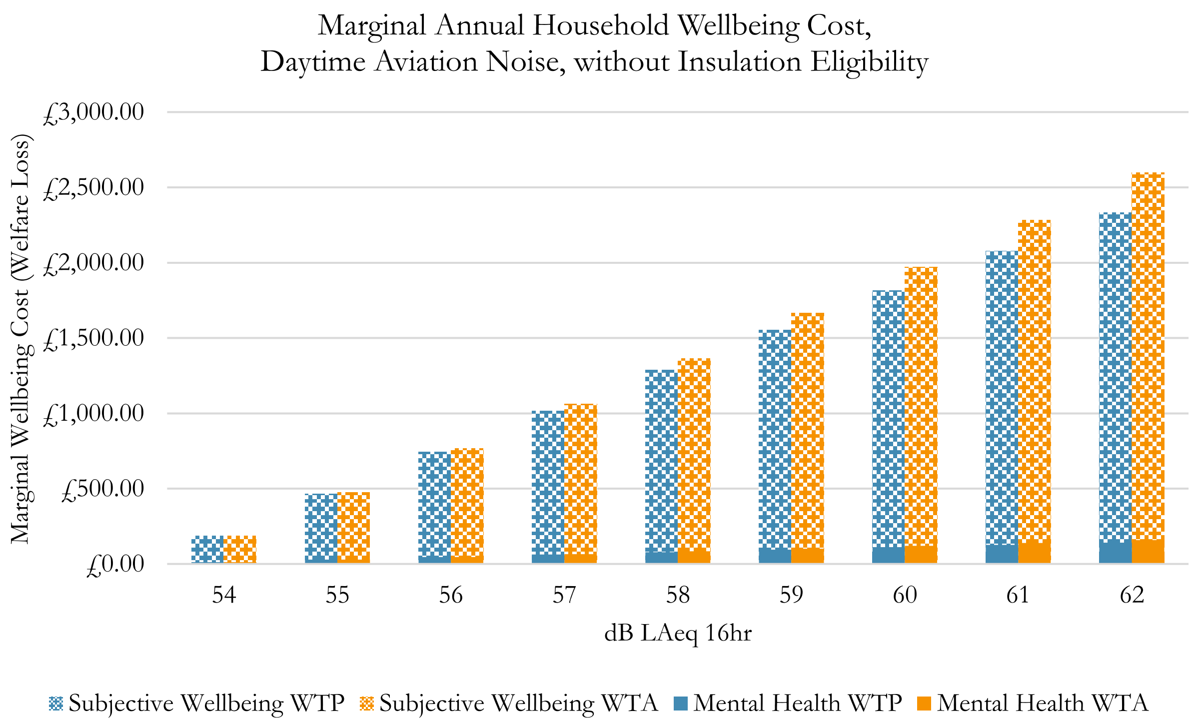

Figure 1

Figure 1 shows the marginal (additional) impact of an additional decibel of daytime aviation noise for those who do not qualify for subsidised insulation. At lower levels of aviation noise the marginal annual household wellbeing costs (including subjective wellbeing and mental health) are small, for example a WTA of approximately £200 per annum per household for an additional decibel of noise at 54 dB LAeq 16hr. At very high levels of noise exposure the marginal annual household wellbeing costs of aviation noise is large, a WTA of approximately £2,600 per annum for an additional decibel of noise at 62 dB LAeq 16hr.

We also find evidence that around 6-7% of the wellbeing impact of daytime noise occurs due to impacts on mental health, as is shown in Figure 1. We do not, however, find that this is the case for night-time noise. Moreover, we do not find evidence that that any of the total wellbeing impact is transmitted through impacts on physical health.

Figure 2 shows the marginal impact of an additional decibel of night-time aviation noise for those who do not qualify for subsidised insulation. We see that night-time noise impacts residents to a greater extent, and at lower noise levels than day-time noise. There is also less variation between impacts across noise levels: the marginal annual household wellbeing costs (measured in terms of WTA) at 49dB LAeq 8hr is approximately £2,800, compared to around £4,000 at 56 dB LAeq 8hr. We do not, however, identify any significant impact on incidence of sleep disturbance, though it should be emphasised that this result may be driven by a lack of available data on sleep quality. Beyond 56 dB LAeq 8hr there are an extremely small number of households who do not qualify for subsidised insulation, hence this is the highest noise level for which we identify wellbeing impacts on residents.

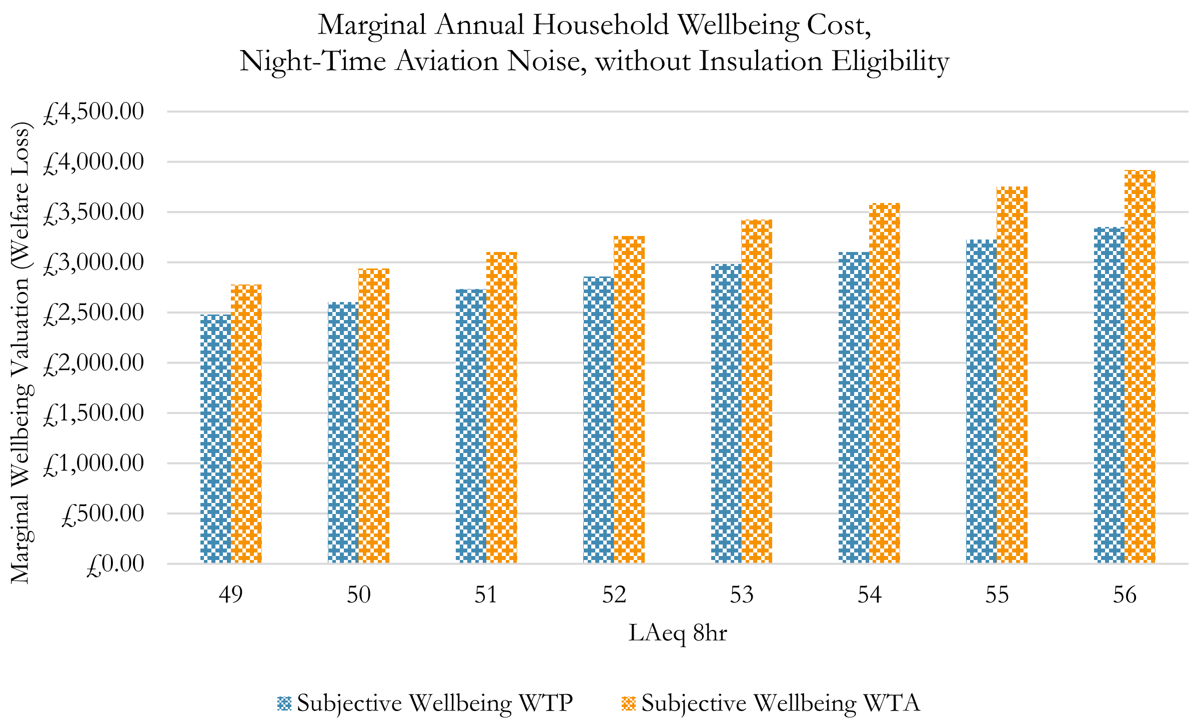

Figure 2

This research focuses on Heathrow, Gatwick and Stansted airports due to the limited availability of data on noise exposure and insulation for other airports. It should also be noted that we only observe whether households are eligible for noise insulation schemes, and do not observe which households have taken up the offer of noise insulation nor the type of insulation that is installed. Consequently, this report suggests that further research is needed to fully explain the factors that drive this result so that causality can be fully understood, including social and economic factors that determine the uptake of insulation schemes where they are available, whether wellbeing impacts vary by the type of insulation installed, and the real impact of insulation schemes on noise exposure.

1. Introduction

1.1 Project Background

Simetrica-Jacobs was commissioned by the Department for Transport to develop upon research we previously conducted for the Airports Commission in 2014 on the impact of aviation noise on quality of life. Specifically, the primary goal of this project is to expand upon the analysis on the impacts on subjective wellbeing, utilising richer Civil Aviation Authority data on aviation noise exposure at postcode level, combined with subjective wellbeing data from large nationally representative surveys (Understanding Society and Annual Population Survey) that has become available since the 2014 report.

1.2 Objectives

The primary objectives of this report are as follows:

- Analyse the impact of daytime and night-time aviation noise on subjective wellbeing
- Use the three-stage wellbeing valuation method to estimate a monetary equivalent value for local residents' willingness to accept aviation noise
- Estimate the extent of the total wellbeing impact that occurs due to impacts on mental and physical health
- Estimate the impact of aviation noise on the occurrence of sleep disturbance

As such, this report is designed to enable the Department for Transport to assess the impacts of policy decisions that involve aviation noise on wellbeing, and include these impacts in cost-benefit analyses.

1.3 Building Upon the 2014 Airports Commission Report

In 2014 Simetrica was commissioned jointly with PwC to assess the impact of aviation noise, and airport proximity, on the wellbeing of residents local to airports. The report also assessed the contemporaneous impact on those who were in or near an airport, for example to travel, or for work.

The 2014 report utilised DEFRA cross-sectional noise contour data from 2012, which recorded maximum aviation noise exposure at the census output area level, for daytime noise exposure of over 55dB LAeq, and night-time noise exposure over 50dB LAeq.

Annual Population Survey (APS) data was used to assess the impact on local resident wellbeing. Statistically significant adverse impacts of daytime noise over 55dB LAeq were identified on the four Office for National Statistics (ONS) Subjective Wellbeing (SWB) measures of Life Satisfaction, Sense of Worthwhile, Happiness, and Anxiety. It was also found that the magnitudes of these impacts were increasing with the level of noise exposure. No significant impact was identified for night-time noise (Lawton & Fujiwara, 2016).

Mappiness data was used to assess the immediate impact of being in the proximity of an airport. Mappiness was a smartphone application in which users answered wellbeing questions in real time; respondents' location coordinates were recorded using their phone's location services. Significant negative impacts on Happiness and Relaxation were identified for 66dB and 72dB LAeq noise bands (Fujiwara et al., 2017). It was not possible to include mappiness data as part of this study.

Unlike the 2014 report, this research focuses entirely on the impact of aviation noise on local residents; that is, it does not assess impacts of airport proximity nor the immediate, real-time impacts on wellbeing. This report extends the research of the 2014 report in eight key ways, which are detailed below.

Table 1.3.1: Comparisons between the 2014 and 2020 reports

Feature	2014 Report	2020 Report
Noise Contour Data	Cross-sectional DEFRA noise contour data for all UK airports in 2012. Data available for households subject to >55dB LAeq (day), and >50dB LAeq (night). Disaggregated to census output code level.	Longitudinal noise contour data from LHR/LGW/STN for 2009-17 (day), and 2013-17 (night). Data available for households subject to >50dB LAeq (day), and >48dB LAeq (night). Disaggregated to full postcode level.
Insulation Scheme Data	These data were not made available to the researchers in 2014.	The modelling presented in this report incorporates information on whether a household was entitled to subsidised noise insulation, based on the postcode location. No microdata on the households' insulation or subsidy uptake was available for use in the modelling.
Understanding Society vs APS	2012/13 Annual Population Survey (APS) data is matched to noise contour data; APS is utilised to evaluate noise impacts on wellbeing, accounting for individual-level characteristics.	This report primarily utilises 2009-2017 Understanding Society data to evaluate the wellbeing impact of aviation noise. In the context of this study, this has three key advantages over APS: 1. Understanding Society contains objective Short Form 12 (SF-12) measures of physical and mental health. This allows us to (a) more accurately control for health status in wellbeing regressions, and (b) establish the extent of the wellbeing impacts of aviation noise that are transmitted through physical and mental health. 2. The longitudinal element in Understanding Society allows the use of lagged variables to address simultaneity. 3. Understanding Society contains data on sleep disturbance.
Other Noise Sources	The 2014 report does not account for other sources of noise in its modelling, as this data was not available at the time.	The estimation in this report utilises DEFRA road and rail noise data to account for other sources of noise.
Air Pollution	The 2014 report does not account for air pollution in its modelling, as this data was not available at the time.	The estimation in this report controls for MAAQ measures of air pollutants to separate the impact of aviation noise from potentially highly correlated levels of air pollution.
House Prices	The 2014 report does not control for House Prices, so wellbeing impacts identified are those over and above the any impacts compensated through lower house prices.	This report does control for house prices; we therefore estimate the total wellbeing impact of aviation noise. Results do not significantly change where house prices are excluded.

Sleep	Impacts on sleep outcomes are not estimated, as these are not observed in the data.	This report analyses the impact of aviation noise on sleep.
Health vs Annoyance	Impacts on health or annoyance impacts are not estimated, as these are not observed in the data.	Whilst we do not directly observe a measure of annoyance, this report separates the wellbeing impacts that occur through physical and mental health from the total wellbeing impact.

Similarly to the 2014 report, we match households in survey data to noise exposure, however we are now able to match at the full household level, and across nine years (2009-17) for daytime noise and five years (2013-2017) for night-time noise. These represent considerable informational improvements on the 2014 report.

We conduct regression analysis to establish the marginal wellbeing impacts of aviation noise, and additionally perform counterfactual analysis to compare those who are subject to differing levels of aviation noise to those who are exposed to none. The availability of insulation data allows us to separate impacts for those who do, and do not, qualify for subsidised insulation; this is an important development from the 2014 report, as we find strong evidence of negative impacts for those who do not qualify for insulation, but not for those who do qualify. It should be stressed that we only have data on whether a household qualifies for insulation, not whether insulation is present; we surmise that the strength of the results in the absence of microdata on insulation take-up likely reflects that those who are most affected by higher levels of noise exposure are most likely to take up the offer of subsidised insulation.

The inclusion of data on household exposure to other noise sources has the clear advantage of avoiding the implicit assumption that aviation noise is spatially uncorrelated with other sources of pollution; those who are subject to significant levels of aviation noise will be geographically proximate to airports, which have potential to generate higher levels of rail or road noise than other areas due to the nearby ground transport infrastructure associated with the airport. In terms of the counterfactual analysis this is also important, as it avoids treating households who are not subject to aviation noise, but are subject to other forms of noise, as an effective control group for the analysis, which would necessarily downward bias the wellbeing impacts identified. To minimise the bias arising from other noise sources, we exclude from the analysis all households located in postcodes where rail or road noise levels are as high as, or higher than, the level of aviation noise.

A particular advantage of the Understanding Society data primarily used in this report is it allows us to control for objective SF-12 measures of physical and mental health. In the APS, health is measured subjectively by the respondent; physical and mental health are not distinguished from one another in the data, and the objective severity of health conditions suffered by respondents are not observed. The 2014 report acknowledges the limits of the APS measure; Clark (2018) notes the importance of controlling for objective, as opposed to subjective, health measures in wellbeing regressions, and in this report we find that inclusion of the SF-12 health measures more than doubles the explanatory power of our regression analysis across all specifications (as measured by Adjusted R-Squared – a statistical measure which captures the proportion of variance of an outcome that is explained by an estimated model). These variables also allow us to separate the wellbeing impacts of aviation noise that occur through health using mediation analysis (see Section 4.2 where this methodology is discussed at length). In Section 5.2, we find that 6-7% of the total wellbeing impact of daytime noise is transmitted through mental health impacts; we do not find evidence that any of the wellbeing impact is transmitted through physical health.

In Section 5.3 we additionally analyse the impact of both daytime and night-time noise on sleep. We do not find evidence to support that aviation noise has any significant impact on sleep, irrespective of noise insulation status.

1.4 Report Structure

The remainder of this report is structured as follows.

- Section 2 conducts a thorough review of the existing literature of the wellbeing impacts of aviation noise.
- Section 3 discusses in detail the data utilised in this report, and how the data from different sources are linked together.

- Section 4 provides a technical explanation of the methodology.
- Section 5 presents results, and discusses our findings in the context of the existing literature.
- Section 6 conducts the Wellbeing Valuation exercise, and presents the monetary equivalent willingness to accept an additional decibel of aviation noise.
- Section 7 concludes our findings.

2. Review of existing literature

2.1 Overview of Wellbeing Valuation methods

In economics, we measure the value of a good, service or outcome in terms of its impact on human welfare, expressed either as a compensating welfare measure (the amount of money, to be paid or received, that will leave the agent in their initial welfare position following a change in the status quo) or as an equivalent welfare measure (the amount of money, to be paid or received, that will leave the agent in their subsequent welfare position in absence of a change from the status quo), where a 'change' is in the form of price changes or changes to the quantity or quality of the good, service or outcome. For goods that are traded in a market, a value can be inferred from the good's market price. For goods that are not traded in a market, so called 'non-market goods', alternative methods for valuation are required.

2.1.1 Preference-based valuation

The preference account of welfare develops from the theory that "what would be best for someone is what would best fulfil his desires" (Parfit, 1986). Under this account, compensating and equivalent measures of welfare change can be estimated for a non-market good, service or outcome through people's willingness to pay (WTP) for positive outcomes or willingness to accept (WTA) negative outcomes.

Traditionally, where proxy markets for a non-market good exist, the favoured approach for valuation has been to estimate WTP or WTA from people's market behaviour using revealed preference methods, which uncover estimates of the value of nonmarket goods by using evidence of how people behave in the face of real choices. The most commonly employed method is hedonic pricing which involves examining people's purchasing decisions in markets related to the nonmarket good. It has commonly been applied using data from housing and labour markets. In the former, the intuition is that the price differential between otherwise identical houses that differ in their exposure levels to nonmarket goods (and bads), such as good schools, pollution, and crime, reveals information regarding people's WTP (WTA) for such goods.

Very often proxy markets do not exist for the nonmarket good in question, and hence economists often ask people directly about their WTP or WTA instead. Stated preference methods use surveys to ask people about the value they place on a good or some attributes of a good. One stated preference method is contingent valuation which constructs and presents hypothetical markets to survey respondents. The survey includes a detailed description of the good and how it will be provided, and information on the method and frequency of payment, which, for example, may be in the form of an increase in taxes. Following this, respondents are asked to state their maximum WTP for the good (or minimum WTA for the bad).

2.1.2 SWB-based valuation

In light of various concerns over the validity of preference-based valuation methods (see section 2.4 for a discussion), an alternative method of valuation has recently been developed called 'Wellbeing Valuation" which estimates compensating and equivalent measures of welfare change from data on people's SWB. Essentially, the impact of an outcome on an individual's subjective wellbeing (SWB) is estimated, for people who have actually experienced this outcome in their life. This impact is then converted into a monetary amount, by estimating the amount of income that would result in an equivalent change in SWB. It offers a robust method to estimate the value that individuals place on outcomes without needing to ask people directly for their willingness to pay (WTP) which, as discussed in section 2.4, can lead to biased responses.

In theory, any measure of subjective wellbeing can be used. SWB has three broad categories; evaluative, affective and eudemonic. Evaluative SWB measures refer to people's global assessments of their life or domains of their life. The most prominent measure is satisfaction with life (Fujiwara et al., 2011). A life satisfaction response will incorporate to some extent a retrospective judgement of one's life together with how one feels now (Kahneman & Krueger, 2006). To date, the use of life satisfaction has dominated the SWB and WV literature.

Affective SWB measures, like happiness and anxiety, tap into a person's feelings 'in the moment' and can encompass both positive and negative feelings (Kahneman and Tversky 1999; Pavot and Diener 1993; Schwarz and Clore 1983). Positive feelings are often measured in terms of happiness and negative feelings in terms of stress and anxiety. Affective wellbeing is typically measured on a more frequent basis than evaluative measures with the Experience Sampling Method (ESM) (Csikszentmihalyi and Hunter 2003; Hektner, Schmidt, and Csikszentmihalyi 2007) and Day Reconstruction Method (DRM) (Kahneman et al., 2004) collecting information on people's reported feelings in diary or electronic real time during selected moments of the day. The ESM approach provides the closest estimate to causal effects that can be achieved with wellbeing data.

Finally, eudemonic SWB measures conceive of people as having underlying psychological needs, such as meaning, autonomy, control and connectedness (Ryff, 1989); it may be derived from things like autonomy at work, engagement in a hobby, or an academic pursuit. These contribute towards wellbeing independently of any pleasure they may bring (Hurka, 1996).

2.2 Evidence on the impact of noise pollution

This section provides an overview of the literature surrounding the impacts of non-aviation noise, for example from road and rail. Section 2.3 then provides a more detailed review of the aviation-specific literature.

2.2.1 Preference-based evidence

To date, both stated and revealed preference methods have been used to estimate the economic value of changes in noise levels. Most studies have applied the hedonic pricing approach to the housing market to analyse how differences in property prices reflect individuals´ willingness-to-pay (WTP) for lower noise levels. However, contingent valuation has also been used to value transportation noise.

Łowicki and Piotrowska (2015) use the hedonic pricing approach to show the inhabitants of the Poznan County in Poland prefer living in a quiet environment without road noise, which is revealed by a higher price for such properties. Controlling for other factors that affect property price, they find that plots situated in a zone in which there is night noise nuisance were about 57% cheaper than properties located outside this zone. Contrastingly, this price differential was much smaller between areas with industrial plants and areas without, indicating that noise during the day doesn't have as great an impact as noise during the night. For the night noise, the authors found that the decrease in prices was about 2.9% per 1dB which is greater than an average of 0.55% with range 0.08-2.22% found in an early meta-review by Bateman et al. (2001). As noted by the authors, this may be due to type of property, as houses have been shown to lead to higher price differentials. Focussing explicitly on the effects of road and rail noise in Birmingham in the UK, Bateman, Day and Lake (2004) similarly find that higher noise levels are associated with lower property prices, with rail noise having a larger impact. Specifically, they find that a 1dB increase in road noise reduces property prices by between 0.21% and 0.53%, whilst a 1dB increase in rail noise reduces prices by 0.67%. They also find little evidence of the impact of air traffic noise, however the authors believe this is due to limitations of their identification strategy. There is also evidence in other parts of the world that noise is reflected in house prices, with an estimated decrease in price of single-family houses of 0.3–3% per 1 dB in Sweden (Wilhelmsson, 2000) and a decrease in price of 1.3% with every 1% increase in noise level found in Seoul (Kim et al., 2007). However, Rehdanz and Maddison (2008) analyse data from the German socio-economic panel finding that, whilst noise did have a negative impact on SWB, differences in noise levels were not reflected in house prices.

Navrud (2002) reviewed valuation studies that used stated preference methods and recommended a range of €2 to €32 per dB per household per annum for road noise based on six studies. The EC Working Group on Health and Socio-economic Aspects (2003) utilised his findings to recommend a value of €25 per household per decibel per year. Since then, Bristow et al. (2015) carry out an international meta-analysis of the use of stated preference techniques to value noise nuisance. The monetary valuations assembled exhibit a wide range, including a large difference between WTP for a gain and WTA for a loss. The authors state that the wide range could stem from variations in data type and survey method, the systematic influence of study and country specific factors and, importantly, intertemporal effects. However, as outlined in section 2.4, this range could be due to a number of methodological concerns inherent to the stated preference method.

2.2.2 SWB-based evidence

The majority of studies on the impact of noise on SWB to date have used either life satisfaction as the dependent variable, or satisfaction with a more specific aspect of one's life including residential satisfaction or one's satisfaction with the quality of life in a specific area.

Urban and Máca (2013) explore the link between rail and road traffic noise on both life satisfaction and residential satisfaction, using strategic noise maps drawn up pursuant to the EU Environmental Noise Directive. They find negative effects on residential but not life satisfaction, with very similar results for rail and road noise.

On the other hand, Lercher and Kofler (1996) find a significant negative effect of traffic noise (from road and rail traffic) on overall life quality in alpine rural areas. Their study suggests that the effect takes on a convex function, increasing more sharply at noise levels higher than 60dB. In addition, Rehdanz and Maddison (2008) analyse data from the German socio-economic panel, measuring differences in noise levels by how much an individual feels affected by noise exposure in their residential area. Their study suggests that, even when controlling for a range of other factors, higher local noise levels significantly diminish subjective well-being.

There is also a small literature concerning indoor noise. García-Mainar et al. (2015) consider self-perceived levels of noise pollution in the workplace, providing a monetary valuation using the wellbeing valuation approach. Their results demonstrate that high noise levels in the workplace markedly diminish life satisfaction, even after controlling for potential endogeneity by using an instrumental variable strategy. Cunha and Silva (2015) look at the correlation between hospital noise and life satisfaction finding a significant negative relationship. They also find that positive and negative affect, as measured by the Positive and Negative Affect Schedule (PANAS) by Watson et al. (1988), are respectively negatively and positively correlated with hospital noise.

Overall the balance of evidence suggests that noise level does impact negatively on life satisfaction and affective measures of wellbeing, although there have been significantly more studies concerning the former.

2.2.3 Health impacts

The preliminary environmental information report (PEIR) for Heathrow Expansion (2019) provides an extensive evidence review into the health effects of noise pollution. The report includes not only the effects of noise from aircraft, but also from road traffic and construction as these sources of noise can be also be significant at airports. For the most part, the PEIR report defers to the (WHO & Regionalbüro für Europa, 2018) which includes a systematic review of the effect of environmental noise on sleep, mental health and quality of life. Generally, the ways in which noise could affect health include a physiological response via the autonomic nervous system leading to rises in blood pressure and heart rate, stress potentially mediated by annoyance, and disturbed sleep (Babisch, 2002). The health outcomes of interest in the Heathrow report include sleep disturbance, mental health, wellbeing, quality of life and cardiovascular health.

The PEIR report notes that measuring sleep is challenging as “there is no one physical, physiological or psychological measure that is considered reliable”. Existing studies of environmental noise have examined both subjective measures of sleep that are self-reported and objective measures such as awakenings which are measured using polysomnography (PSG) which records biophysiological changes that occur during sleep. These measures may not agree with each other as humans are unconscious for most of their sleep, may misattribute awakenings to noise events and may report awakenings to make a political statement in relation to the noise source. For the empirical evidence, the PEIR report defers to the WHO report which finds that, when sleep is objectively measured, estimates of the impact of noise on sleep are generally similar across road, aircraft and rail with a 31-34% increase in odds for awakening for a 10dB increase in noise from each source. In terms of subjective sleep assessment, the meta-review found no association between noise and sleep in studies which asked about sleep in general (with no reference to noise). However, when studies asked specifically about how noise affected sleep, a 10dB increase in noise was associated with a 1.93 increase in sleep disturbance for aircraft noise; a 2.12 increase for road traffic noise, and a 3.05 increase for railway noise, where sleep disturbance is defined as internal / external interference with sleep onset or sleep continuity (i.e. staying asleep / sleep maintenance).

The PEIR report also defers to the 2018 WHO report when summarising the evidence on the impact of noise on mental health and self-reported quality of health. In terms of road traffic noise, it is stated that there is no evidence for an association with self-reported health and quality of life; on medication intake for anxiety and depression; on self-reported depression, anxiety and psychological symptoms; and on interview measures of depressive and anxiety disorders. However, it is noted that these conclusions are based on a small number of studies available for each of these outcomes. For construction noise there is no research evidence of effects on adult mental health, wellbeing, nor quality of life, although there is some evidence of an effect on noise annoyance, which is an indicator of quality of life.

The link between noise and cardiovascular disease, via the impact of noise on stress, is investigated by the PEIR report. Generally, exposure-response function (ERFs) find statistically significant, albeit small effects of noise. The evidence also suggests that environmental noise influences cardiovascular health independently of co-exposure to air pollution.

Overall, the WHO meta-review determines that, whilst there is some evidence for the impact of noise on health (including mental health) and quality of life, this evidence is generally of a low quality due to a lack of studies and small sample sizes.

2.3 Evidence on the impact of Aviation Noise

This section focuses on the aviation-specific literature. Due to the direct relevance to this report, this section contains deliberately more detail than in section 2.2, to ensure all relevant evidence on aviation noise impacts is considered.

2.3.1 Preference-based evidence

Building on section 2.2.1, there are also aviation-specific studies that use both stated and revealed preference approaches to value aircraft noise.

(Van Praag & Baarsma, 2005) survey 1400 individuals living within 50 km of the Amsterdam Schiphol Airport and combine subjective measures with revealed market information which allows them to use the hedonic pricing approach to derive a Noise Depreciation Index (NDI), calculated as the percentage decrease in property value corresponding to a one dB increase in noise level in the area. Meta-analyses have shown that typical aviation NDI values for owner-occupied properties range between 0% and 2.3%, with median estimates between 0.60% and 0.70% ((Nelson, 2008); (Wadud, 2009)). However, Van Praag and Baarsma (2005) found no significant effect between Kosten noise levels and house prices. Conversely, Dekkers and van der Straaten (2009), who also focus on aircraft noise around Amsterdam airport in the urban fringe of the Amsterdam region, find that, accounting for background noise, higher noise levels correspond to a statistically significant decrease in house prices. The authors also find that noise related to air traffic has the largest price impact, followed by railway traffic then road traffic. The increase in house prices on account of a noise level reduction, in theory, represents the willingness-to-pay for noise reduction. With this in mind, the authors estimate a marginal benefit of 1 dB noise reduction of €1459 per house for aircraft noise, leading to a total benefit of 1 dB noise reduction of €574m.

There have also been a number of contingent valuation studies on aircraft noise. Feitelson et al. (1996) assess the effects of changes in aircraft noise exposure on the willingness to pay for residences located within and outside of noise contours. They find that the frequency and severity of noise events have significant deleterious effects on both homeowners' and renters' WTP, regardless of regression specification, and that noise insulation only partially mitigates these effects. They determine that the frequency and severity of noise events are important determinants of WTP, regardless of tenure and the age and income differences between renters and homeowners. Interestingly, the results indicate that household WTP structures are kinked, whereby, beyond a certain disturbance threshold, households are unwilling to pay anything for the residence. The authors note that further research is required to ascertain the specific explanation for this finding. One possible explanation is that, above a certain noise threshold, household utilities drop very steeply which would indicate the significant importance of reducing noise below this threshold. However, another possibility is that households compare the hypothetical residence to some base residence (probably a function of their current residence) and that, as the noise (or total disturbance) rises above a certain level, the residential unit becomes less attractive than the base unit, and thus the household's WTP for the hypothetical unit drops to zero. In this case there wouldn't necessarily be a sharp and sudden decline in utility past a particular noise threshold. In either case, the authors suggest that this kinked WTP structure helps explain the higher noise premiums obtained in contingent valuation studies relative to hedonic price estimates. Otherwise, Bristow and Wardman (2006) estimate WTP for reductions in noise and flight frequency to derive values of aircraft noise by time of day and day of week, noting that revealed preference techniques cannot provide such useful segmentations. The findings reveal that valuations do vary by time period and in a generally plausible manner, in particular finding highest WTP values on weekday evenings and weekends.

The Attitudes to Noise from Aviation Sources in England (ANASE) carried out a contingent valuation survey of residents who live near airports in England, assessing willingness to pay to reduce aircraft noise (MVA Consultancy, 2007). The study found that annoyance was increasing at all levels of noise exposure over and above 43dB LAeq 16hr, and that at least 40% of residents were 'significantly annoyed' at levels at or above 57dB LAeq. However, Havelock & Turner (2007) raised issues around residents being present during calibration of the sound playback equipment used during the survey which lead to response bias, and Brooker (2008) called into question the statistical robustness of the analysis of the data.

The Aviation Noise Index Study (ANIS) (1985) was a stated preference survey evaluating the annoyance impact of aviation noise on residents local to UK airports. ANIS found that aviation noise annoyance sharply increases at or around 57 dB LAeq 16hr with 9% of respondence reporting high annoyance, linearly increasing beyond this threshold. The 2003 Air Transport White paper subsequently defined 57 dB LAeq 16hr as the threshold for community annoyance, citing the ANIS findings. The 2014 Survey of Noise Attitudes (SoNA) found similar annoyance trends to ANIS, however found respondents to be more sensitive to lower levels of aviation noise, with 9% of respondents reporting high annoyance at 54dB LAeq 16hr (Civil Aviation Authority, 2017). An even higher sensitivity to lower levels of noise was reported in Kaltenbach et al.'s (2008) meta-review of the evidence on the impact of aviation noise on annoyance and health outcomes, which finds 25% of the population are greatly annoyed by daytime aviation noise of 55dB.

Ipsos MORI (2020a) conducted a survey for the Independent Commission on Civil Aviation Noise (ICCAN) of approximately 2,000 adults living within the noise contours of Gatwick, Edinburgh, Manchester, and Heathrow Airports, to establish the impact of reduced air traffic resultant of the 2020 COVID-19 pandemic on attitudes towards aviation noise. The vast majority (86%) of residents reported a noticeable reduction in aviation noise during lockdown. Despite residents spending significantly more time at home as a result of the national lockdown, residents reporting that they were "extremely bothered" by daytime aviation noise reduced from 66% pre-lockdown to 28% during lockdown, and from 44% to 13% for night-time noise; similarly, those self-reporting themselves to be "moderately bothered" reduced from 19% to 3% for daytime aviation noise, and 11% to 2% for night-time noise.

Ipsos MORI (2020b) presents results of the National Air Traffic Services (NATS) Aviation Index 2020, a panel survey of 1,000 adults from across the UK designed to track attitudes towards the aviation industry. Respondents rated aviation noise as the second highest priority for the industry to address (with 36% listing it as a priority), behind air pollution (70%). However, it should be stressed that this survey does not specifically target residents living close to airports.

2.3.2 SWB-based evidence

As is the case with noise more generally, the majority of studies on aviation and SWB to date have explored evaluative measures of SWB such as life satisfaction. Lawton and Fujiwara (2016) merge English population statistics on 189,162 individuals, provided by the APS, with noise measurement maps for seventeen English airports to test for associations between aviation noise and airport proximity within 5km of an airport. They find a consistent negative association between the presence of daytime aviation noise above 55 dB and five SWB measures, including life satisfaction, eudemonic sense of worthwhile, and affective measures of happiness (yesterday) and anxiety (yesterday), as well as positive affect balance (PAB). The magnitude of the impact is equivalent to around half the effect of being a smoker for some wellbeing measures, with a marginal negative association detected with every additional decibel of aircraft noise. Notably, the study finds no significant association between living within night-time noise contours and wellbeing as well as living in close airport proximity.

Van Praag and Baarsma (2005) also assess SWB impacts from aviation noise. The study surveyed 1400 individuals living within 50 km of the Amsterdam Schiphol Airport. Questions on noise pollution were embedded within broader questions on health and wellbeing to avoid strategic (protest) bias. Wellbeing is measured by quality of life on a (1–10) scale (following Cantril 1966). The study collected data on respondents' subjective noise perception measured by subjective evaluations on a discrete scale, and objective noise linked at the postcode level. The authors found no significant effect on wellbeing from objective noise, leading them to conclude that objective measures, including the dB scale used in the UK, ignore individual characteristics like family size and the numbers of hours the individual spends at home each day. In contrast the subjective noise variable showed a significant and negative influence on wellbeing. The magnitude of the noise impact on wellbeing is smaller for those who have noise insulation. They also found evidence that non-acoustic factors, like family size and presence of a garden, increased subjective noise nuisance.

With regards to affective wellbeing, Fujiwara et al. (2017) analyse the relationship between airports and wellbeing using data from the Mappiness iPhone application, a large-scale experience sampling method (ESM) dataset for the UK. ESM is an intensive longitudinal research methodology that involves asking participants to report on their thoughts, feelings, behaviours, or environment on multiple occasions over time. In this study, respondents reported SWB is matched to their geolocated positions in airport locations and aviation noise contours around three London airports (Heathrow, Gatwick, Stanstead). Exploiting the panel nature of the ESM provides stronger levels of causal inference by controlling for time invariant fixed effects like personality, and sociodemographic characteristics. Confirming the results of previous studies, the analysis of Mappiness data reveals that being in a high-level aircraft noise contour (66 dB) was negatively associated with happiness and feeling relaxed at that time. The magnitude of the association with aviation noise was considerable compared to airport proximity and the effects of other activities in the Mappiness dataset (such as adult care, queuing, and waiting).

This study also explores the reported wellbeing of people when they are actually located in an airport. Being in an airport is associated positively with happiness but negatively with relaxation. This is almost a unique finding in the momentary SWB literature to date as typically the relationship between stress and happiness has been found to be inverse (Schiffrin & Nelson, 2010). Yet, this finding is intuitive, suggesting that airports are a place of pleasure at travelling or holidaying accompanied by the stress of organising and tight schedules. There was no difference in happiness and relaxation when comparing people who work in airports to those who work outside of airports, and so the positive association between employment and wellbeing is not weakened by the job being in an airport.

2.3.3 Health impacts

As mentioned previously, the PEIR for Heathrow Expansion (2019) provides an extensive evidence review into the health effects of noise pollution specific to aircraft, and mostly defers to the WHO Environmental Noise Guideline (2018) in doing so.

For the statistical association between aircraft noise and sleep quality, WHO Environmental Noise Guideline (2018) identifies six studies that included a total of 6371 participants (Nguyen et al. 2009, 2010, 2011, 2012, 2015; Schreckenberg et al., 2010). The majority of these studies are cross-sectional by design, and participants are otherwise healthy adults. The health outcomes are measured with self-reported data, consisting of survey questions around the impact of noise on awakening from sleep, the process of falling asleep, and/or sleep disturbance. Regression analysis in the WHO systematic review finds a rise in night-time noise levels from 40dB to 65dB is associated with an increase in sleep disturbance from 11.3% to 40% of respondents.

General health or self-rated health is typically derived from a question asking respondents to report their general health condition on a 1-5 scale. Specific evidence around the impacts of aviation noise and general health is surprisingly scarce. The studies on the impact of aviation noise and cardiovascular disease and hypertension are rated as low quality. The SoNA 2014 report (Civil Aviation Authority, 2017) finds that respondents' self-reported health measures (both general health and mental health captured using Short Warwick Edinburgh Mental Wellbeing Score, SWEMWBS) are related in a statistically significant way to annoyance with aircraft noise, but not to noise exposure levels. The former result is in line with the generally acknowledged high interdependence between different self-reported wellbeing metrics, due in a large part to unobserved characteristics specific to the respondent (see e.g. Clark (2018)). However, because the SoNA 2014 analysis is restricted to just two variables at a time, without controlling for other possible drivers of respondents' health, it is difficult to draw definite conclusions from the results.

NatCen (2020) conduct a Rapid Evidence Assessment on the relationship between aviation noise and public health. Health outcomes for which evidence is collected is categorised in terms of impacts on sleep, cardiovascular and metabolic disorders, mental health and wellbeing, and health impacts mediated through annoyance. The authors find very little quality evidence from the UK, and notably wellbeing impacts are either defined by mental health impacts or non-standard measures of wellbeing (including incidence of headaches and stomach aches) as opposed to the standardised measures contained in ONS questionnaires; the wellbeing section of the report does not present the evidence contained in Sections 2.3.1 nor 2.3.2 of this report, nor that presented in the Simetrica and PwC report for the Airports Commission (2014).

There are a number of studies on the relationship between aviation noise and psychological health. The WHO meta-review finds some evidence on the association of aviation noise with cognitive impairment. The Hypertension and Exposure to Noise near Airports (HYENA) study (Floud et al., 2011) finds that a 10dB increase in day-time or night-time aircraft noise is associated with a 28% increase in anxiety medication use; the authors do not, however, find any relationship between aircraft noise and use of sleep nor anti-depressant medication. A sub-study of the HYENA study (Selander et al., 2009) found that salivary cortisol (a stress hormone that is higher in people with depression) to be 34% higher for women exposed to aircraft noise above 60 dB LAeq 24hr compared to women exposed to less than 50 dB LAeq 24hr, but no such association was identified for men. In addition, the review suggests that there is no evidence for the association of aircraft noise on emotional and conduct disorders in children.

2.4 Discussion of preference-based versus SWB-based valuation

As alluded to in section 2.1.2, there has been recent criticism of preference-based valuation approaches of non-market goods.

Over the last few decades, there have been some concerns that revealed preferences are not a good measure of individuals' well-being. Kahneman (1994) reviews the literature from behavioural economics and psychology, which shows that people deviate from the assumptions of rationality in different ways such as making inconsistent choices, failing to learn from experience, and being reluctant to trade. If individuals have bounded rationality when they maximize (decision) utility, their observable choices do not necessarily reflect what maximizes their well-being. In addition, revealed preference approaches rely on well-functioning markets that are in equilibrium (Rosen, 1974) but in reality, the equilibrium condition is unlikely to hold and so any estimated coefficients should be interpreted with discretion (Coulson & Zabel, 2013). Essentially, the market needs to be sensitive to changes in, or levels of, the non-market good. For example, valuation of environmental amenities like clean air or noise is not possible where there are state-related interventions in the market such as caps on house rental prices. With rental caps, houses in clean and quiet areas may be restricted from increasing in price.

There are also issues with regards to stated preference methods. In the case of contingent valuation, there are issues in seeking to represent noise to respondents in hypothetical surveys, including the temptation for strategic bias from respondents (especially the risk of protest votes), the difficulty of identifying realistic payment vehicles, hypothetical response bias leading to overstatements of value, and embedding effects, whereby WTP is not significantly different regardless of the scope of impact (i.e., the same at 55 dB as 75 dB of aircraft noise, see (Bateman et al. 2002); Hausman 2012)). In addition, studies have shown that people are unable to accurately predict the pleasure or benefits they will get from different goods and services—this is true even for everyday goods such as yogurt, music, and ice cream (Kahneman & Snell, 1992; Wilson & Gilbert, 2003) and indeed is likely to be true for noise.

These issues have arguably led to the increasing prominence of the subjective wellbeing valuation (WV) approach. Stutzer and Frey (2010) claim that the WV approach “avoids some major difficulties inherent in both stated and revealed preference methods.” This is because WV is less reliant than other methods on strict rationality or behavioural assumptions, which are not always found to be an accurate reflection human behaviour empirically.

The WV method “does not rely on respondents’ ability to consider all relevant consequences of a change in the provision of a public good, as stated preference approaches require. It suffices if respondents state their own life satisfaction [SWB] with some degree of precision” (Stutzer and Frey 2010), and this is probably a cognitively less burdensome task (Frey et al., 2009). Indeed, WV does not suffer from the broad range of survey-related biases inherent to stated preference methods. Because respondents are not asked directly to state a value or pay a certain price, it is not possible, for example, for respondents to use strategic answers (Van Praag & Baarsma, 2005) or make protest values. When it comes to revealed preference methods, WV may be superior as it does not rely on market efficiency assumptions (Van Praag & Baarsma, 2005).

This discussion could help to explain some of the results outlined in this literature review. For example, the concern over well-functioning markets could help explain the surprising result from Rehdanz and Maddison (2008) who found that in Germany, despite noise having a negative impact on SWB, differences in noise levels were not reflected in house prices. The various stated preference criticisms could help explain why Bristow et al. (2015) find such a wide range of valuations in their international meta-analysis of the use of stated preference techniques to value noise nuisance.

3. Data

Noise exposure data for Heathrow, Gatwick, and Stansted is supplied by the Civil Aviation Authority (CAA). Daytime and night-time noise are reported at the postcode centroid level in LAeq (A-weighted equivalent sound levels, measured in dB), and is calculated over the 92-day summer period from 16th June to 15th September inclusive. LAeq is reported as a continuous measure to one decimal place for all values over and above 51 dB for daytime observations, and 48 dB for night-time. Below 51 dB daytime, and 48 dB night-time aviation noise exposure is low enough such that LAeq cannot be accurately modelled; however, the CAA helpfully include a binary variable indicating postcodes that are exposed to a level of aviation noise sufficiently below the 51 dB daytime / 48 dB night time threshold, such that exposure to aviation noise can be treated as non-existent. These data have been made available for 2009-2017 (day) and 2013-2017 (night). Similarly to ANIS (1985), we note that the large majority of observations are from households close to Heathrow, owing to (a) Heathrow having two runways and having comparatively higher levels of traffic, and (b) the urban location of Heathrow.

Airport	**Time of Day**	**Insulation scheme entitlement**
Gatwick	Day	2014 60 dB LAeq 16hr noise contour
Gatwick	Night	90 dB SEL footprint envelope, Boeing 747
Heathrow	Day	1994 69 dB LAeq 18hr contour
Heathrow	Night	90 dB SEL footprint envelope, Boeing 747
Stansted	Day	2005 63 dB contour
Stansted	Night	90 dBSEL footprint envelope, MD11

Table 3.1: Insulation scheme entitlement by airport

We additionally use CAA data on subsidised noise insulation schemes aimed at residents around Heathrow, Gatwick, and Stansted, to account for potential reduction in noise exposure in the home made possible by the availability of noise insulation. These data show whether or not a postcode falls within the geographical coverage of each airport's respective subsidised insulation scheme. Qualification criteria for subsidised insulation varies by airport, and the criteria as of January 2020 are set out in Table 3.1. It is also important to note that the level of subsidy, and type of insulation offered, varies between airports, year of installation, and level of noise exposure.

We observe in the data that postcodes can qualify for subsidised insulation owing to noise exposure during the daytime, night-time, or both (see Table 3.2). For modelling purposes, we therefore set a binary variable equal to one if the postcode is entitled to some form of insulation, and zero otherwise. It is important to stress that this variable is an indicator of insulation scheme entitlement, not the presence of insulation: we do not observe which households take up the offer of subsidised insulation, nor do we observe which households have noise insulation that has been installed independently of the subsidised schemes, both of which affect the precision of the impact evaluation. However, whilst qualifying for insulation does not perfectly predict the presence of insulation, this is unproblematic for our conclusion: it is reasonable to expect those most sensitive to aviation noise who don't have insulation are most likely take up the offer of the subsidy, so that the overall level of exposure to unwanted aviation noise in a postcode where a subsidised insulation scheme is available should be no greater than in a postcode exposed to an equivalent level of noise where it is not.

Air pollution is measured using DEFRA Modelling of Ambient Air Quality (MAAQ), 2000-2018 data (Department for Environment and Rural Affairs, 2018). MAAQ utilises data from monitoring sites around the UK and local area characteristics to model-specific pollutants at 1 km^2 concentration maps. Data validity is ensured by comparing modelled pollutants to primary data from measuring sites not included in the calibration process (Ricardo Energy & Environment, 2017). We utilise annualised measures of Nitrous Dioxide, Nitrous Oxide, as well as PM_{10} and $\mathrm{PM}_{2.5}$ measures of particulate matter, to capture changes in pollutants commonly associated with aviation.

Noise Exposure Quintile	Day noise Quintile dB LAeq (8hr) range	Day noise % eligible for	Day noise % eligible for	Night noise Quintile dB	Night noise % eligible for	Night noise % eligible for

		day insulation scheme	any insulation scheme	LAeq (16hr) range	insulation scheme	any insulation scheme
Quintile 1	51-51.9	-	-	48-52.1	<5	<5
Quintile 2	51.9-53.3	-	-	52.1-53.4	6	6
Quintile 3	53.3-54.9	-	-	53.4-54.8	7	11
Quintile 4	54.9-57.9	<5	<5	54.8-57.6	58	71
Quintile 5	57.9-99	23	51	57.6-90.3	92	100

Table 3.2: Subsidised noise insulation entitlement by quintile of noise exposure. Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.

House prices are measured using cross-sectional Land Registry Price Paid data (HM Land Registry, 2018), which records quarterly residential property sales, and sale prices, for flats, terraced houses, semi-detached houses and detached houses at the postcode sector level (i.e. XX# #); we merge annual data across time to generate a panel.

Department for Environment, Food, and Rural Affairs (DEFRA) LAeq (day and night) data on road and rail noise are included to mitigate misidentification. These data are cross sectional (available only for 2012 and 2017), and are recorded at the postcode level. LAeq is recorded at 5dB bands for all noise levels over and above 51dB. We identify the postcodes where aviation noise level is lower than the top of either the road or the rail noise band in any year for which the road and rail noise data is available, and exclude from further the analysis all respondents located in any of those postcodes.

We use Secure-Access Understanding Society (USoc) data (waves 1-8, corresponding to years 2010-2017) to measure Life Satisfaction, physical and mental health, sleep disturbance, and a full set of individual socioeconomic characteristics. USoc surveys approximately 40,000 households per wave, interviewing around 100,000 individual respondents. Life Satisfaction is measured on a 1-7 scale ranging from completely dissatisfied to completely satisfied. Physical and Mental health are measured using the SF-12 Health Survey: these are derived variables based on a number of standardised health-related questions, measured on a 0-100 scale. We utilise the pooled cross-sectional data across all years for our primary analysis to maximise the available sample; we additionally utilise smaller longitudinal element for robustness. It should be noted that because Understanding Society collects data on sleep quality only in two waves: 4 and 7, the sample size available for the analysis of sleep disturbance is significantly lower, which limits the scope for possible research. Data are spatially disaggregated to the full postcode level; to maintain respondent anonymity these are available only as square-mile grid reference centroids.

We additionally use Annual Population Survey (APS) data from 2010-2017 for alternate specifications. The APS is a cross-sectional survey derived from the quarterly Labour Force Survey, a rolling panel survey of approximately 12,000 households, following respondents for five consecutive quarters (Waves 1-5). The APS is comprised of Wave 1 and 5 LFS data for four consecutive quarters, achieving a representative sample of approximately 80,000 households. The APS additionally includes data from three annual boost samples, achieving a total sample size of around 120,000 households. APS measures Life Satisfaction on a 0-10 scale; unlike USoc there is no derived continuous measure of physical or mental health: health is instead measured subjectively by self-reported "General Health" on a 0-10 scale.

Aviation noise contour, insulation scheme, road, and rail noise data are merged at the full postcode level, for both day and night datasets. MAAQ data are matched to postcodes within 0.5 km of each $1\ \mathrm{km}^2$ MAAQ centroid. These data are merged with house price data by postcode sector and year. Postcode centroid co-ordinates in Understanding Society are matched to the appropriate postcode by minimising the distances in co-ordinates within a maximum tolerance of 0.5 miles. Where APS is utilised for analysis, data are merged by postcode and year.

4. Identification Strategy

This section provides an overview of the intuition behind the econometric methodology used to identify the impacts of aviation noise on wellbeing. A more technical Identification Strategy can be found in **Appendix G** of this report.

4.1 Life Satisfaction

4.1.1 Marginal Impact of Aviation Noise

We used pooled cross-sectional data from Understanding Society to estimate the marginal impact (the additional impact of a 1 dB increase) of aviation noise on Life Satisfaction through ordinary least squares (OLS) regression. We estimate this separately for those who are subjected to daytime aviation noise at or above 50 dB LAeq (16hr), and night-time aviation noise at or above 48 dB LAeq (8hr). The results of this analysis are presented in Section 5.1.

A detailed description of the equation estimated can be found in **Appendix G**.

Within each of the daytime and night-time models, the impact of noise exposure is separated for those who do, and do not, qualify for noise insulation using separate binary indicator (dummy) variables (i.e. noise level interacted with insulation eligibility indicator). This is because we expect the relationship between noise levels and Life Satisfaction to be affected by the availability of subsidised insulation schemes. The impact of noise exposure on wellbeing is modelled as a quadratic function, as this model is found to best fit the data; the implication of this is that the marginal impact of noise exposure is increasing in the level of exposure.

In each regression we control for a number of standard covariates known to affect Life Satisfaction, such as age, gender, demographic and socio-economic characteristics, in line current best-practice in the subjective wellbeing literature (see Fujiwara and Campbell (2011); the complete list of covariates can be found in the full regression output tables in Appendix A. We additionally control for house prices to account for hedonic pricing, SF-12 measures of physical and mental health, as well as Nitrous Dioxide, Nitrous Oxide, PM_{10} and $\mathrm{PM}_{2.5}$ measures of air pollution. The covariate matrix also contains local authority fixed effects to account for unobserved local factors affecting wellbeing (these are alternatively specified using pooled CAS wards for robustness).

For robustness, we also estimate this equation using IV (instrumental variables), to account for potential simultaneity between wellbeing and physical/mental health. The respondents' current physical and mental health are instrumented using values of the respective variable reported by the same individual in the previous survey wave. **This process is explained in full detail in Appendix G**; results are unchanged.

4.1.2 Counterfactual Analysis

We additionally analyse the impact of aviation noise on those subjected to it, in comparison to a counterfactual group of nearby households who are not subject to any significant aviation noise, as identified by the CAA. This has two main benefits in conjunction with the continuous specification presented in the previous section: first, it provides a robustness check for the results in that specification; second, the counterfactual observations increase the total sample size, which allows for the estimation of mediation effects through health, as presented in Section 4.2. The results of the counterfactual analysis are presented in Section 5.2.

In this type of model, it is not possible to specify noise as a continuous function; we must therefore categorise noise by range of exposure. The definition of these ranges is of crucial importance: each range must have a sufficient number of observations to avoid spurious results; it is also important that the researcher doesn't 'specification search', that is, choose ranges that give convenient results. We therefore categorise noise, for both daytime and night-time, by quintile of exposure; this ensures that there are a similar number of observations in each category, and also prevents the possibility of specification searching. Table 4.1.2.1 presents the dB range of these quintiles, and sample sizes.

We estimate using OLS a model equivalent to that discussed in Section 4.1.1, but instead of the quadratic noise function we include a set of dummy variables, one for each noise quintile; once again the noise variables are separated for those who do and do not qualify for insulation. A detailed description of the equation being estimated can be found in Appendix G.

Noise Exposure Quintile	Day noise Quintile dB LAeq (16hr) range	Number of Observations	% Eligible for Any Insulation	Night noise Quintile dB LAeq (8hr) range	Number of Observations	% Eligible for Any Insulation
Quintile 1	51-51.9	965	-	48-52.1	214	<5%
Quintile 2	51.9-53.3	993	-	52.1-53.4	206	6%
Quintile 3	53.3-54.9	907	-	53.4-54.8	197	11%
Quintile 4	54.9-57.9	934	<5%	54.8-57.6	211	71%
Quintile 5	57.9-99	938	51%	57.6-90.3	200	100%

Table 4.1.2.1: Day/Night noise quintile ranges and sample sizes. Number of observations includes both those eligible for insulation and those not eligible. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

For robustness, we again estimate this equation by IV with physical and mental health instrumented using values of the respective variable reported by the same individual in the previous survey wave. Again, this process is explained in full detail in Appendix G, and results remain similar.

Finally, we test the extent to which noise impacts on subjective wellbeing vary by demographic characteristics, as an indicative measure of external validity to airports not covered by this study. This is achieved by interacting the quintile dummies with demographic characteristics; this methodology is discussed in detail in Appendix G. Results of these regressions are discussed in Section External Validity; full result tables can be found in Appendix C.

4.2 Health Mediation Analysis

As identified in Section 2.3.3 of this report, some of the impact of noise on wellbeing has potential to be transmitted through impacts on health. We therefore employ mediation analysis to identify the extent of the total wellbeing impacts that are transmitted through both physical and mental health.

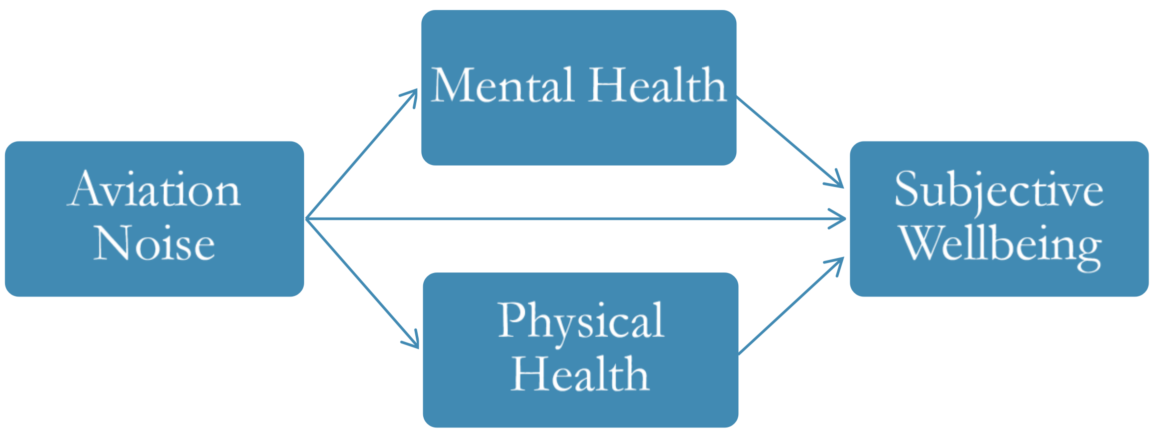

Figure 4.2.1: Illustration of direct, and indirect, impacts of aviation noise on subjective wellbeing.

As illustrated in Figure 4.2.1, aviation noise may have a direct effect on subjective wellbeing (for example, through annoyance). However, if aviation noise also has an effect on mental or physical health, those health impacts will have their own impact on subjective wellbeing. It is therefore important to separate the direct effects from those effects that are mediated through health impacts; this type of analysis is known as mediation analysis.

We utilise the counterfactual specification presented in Section 4.1.2 for these purposes, due to its larger sample size. The methodology requires that coefficients on the health variables are unbiased; we therefore use the IV estimates, as these prevent bias arising from simultaneity between health and wellbeing.

We use the Sobel (1982) Product of Coefficients approach; this involves estimating a second-stage equation with subjective wellbeing omitted, and multiplying the coefficient on the mediator variable in the first stage with the coefficient on noise exposure in the second stage. Standard errors are then iterated using a first order Taylor series approximation. A technical explanation of the process is contained in Appendix G; results are presented in Section 5.2.

4.3 Sleep

Understanding Society collects data on sleep quality only in two waves: 4 and 7. It is therefore not possible to treat sleep as a mediator variable as in Section 4.2, because (a) there does not exist a single-period lag on sleep quality that would be required for an IV specification, and (b) the cross-sectional sample size is insufficient.

We therefore follow the logistic regression approach of Maun et al. (2020) to estimate the relationship between aviation noise and the probability of sleep problems; it turns out to be unproblematic that we cannot go the additional step investigating the relationship between additional sleep problems and wellbeing, as no significant relationship between aviation noise and sleep is identified.

In the equation below, SP_{it} is specified as a binary variable equal to one if a respondent self-reports having difficulty in at least two of: getting to sleep, staying asleep, and sleep quality, and zero otherwise. $\mathbf{Z}$ is a covariate matrix, consisting of equivalised household income, age (specified as a quadratic), and binary indicator variables for gender, ethnicity, education level, having dependent children, living with a partner, living in an urban area, and caring responsibilities. Other elements unchanged from Section 4.1.

$$\ln\left(\frac{P[SP_{it} = 1|LAeq_{it}, \mathbf{X}]}{1 - P[SP_{it} = 1|LAeq_{it}, \mathbf{X}]}\right) = \alpha + \beta_Q(\bar{I}_{it} \cdot LAeq_{it}) + \gamma_Q(I_{it} \cdot LAeq_{it}) + \mathrm{Wave}_t\kappa + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\mu_{gh}H_{hit}^{g} + \mathbf{Z\beta} + u_{it}$$

This equation is estimated separately for day and night noise; clearly night noise would be expected to have a more significant direct impact on sleep, however we estimate the impact of day noise to capture any sleep impacts that occur more indirectly (e.g. through health impacts). β_Q and γ_Q are interpretable as the change in the log odds ratio of experiencing sleep problems versus not for those who do not, and do, qualify for subsidised noise insulation, and are reported separately for day and night-time samples.

5. Results

5.1 Life Satisfaction

5.1.1 Marginal Impact of Aviation Noise

Table 5.1.1.1 presents daytime estimation results of the model discussed in Section 4.1.1, with each column corresponding to a parametric specification shown in the header. The coefficients in the top panel determine the shape of the quadratic curve representing the contribution of daytime aviation noise to overall Life Satisfaction for those entitled to subsidised insulation. For example, in case of the OLS model with local authority fixed effects the negative coefficient estimate on the quadratic LAeq16h term (-0.0068) indicates that the curve has an inverse-U shape. The subsequent rows show that the noise level at which the curve peaks is 52.84559 dB LAeq16h, and that the linear and quadratic coefficient estimates are jointly significantly different from zero (p-value = 0.0240). The non-linear shape of the curve means that changes in Life Satisfaction resulting from a unit change in daytime noise level of 1 dB LAeq16hr cannot be predicted using the coefficient estimates alone, but will depend on the initial noise level – this is shown in more detail in Table 5.1.1.2 below.

Overall, for those who are not entitled to subsidised insulation, we find that Life Satisfaction is decreasing for levels of daytime noise exposure beyond 53 dB LAeq16h, and that the marginal impact on Life Satisfaction is increasing in noise exposure. Across both OLS specifications, and IV with local authority fixed effects, the joint significance of the linear and quadratic LAeq16h terms is significant at the 5% level, and at the 10% level in the IV specification with shortward fixed effects. For those who do qualify for subsidised insulation, we find the threshold beyond which Life Satisfaction decreases occurs at a higher noise level (around 60-61 dB across specifications), but results are not jointly significant at the 10% level in any specification. Above the threshold of 62dB LAeq there are a much smaller number of observations who do not qualify for insulation (approximately 18%), which explains the divergence between specifications beyond this point (as illustrated in Figure 5.1.1.1); for this reason we do not present valuations for noise above this threshold in Section 6.

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq16hr; Insulation Not Eligible	0.7187 (1.72)*	0.8190 (1.93)*	0.8120 (1.50)	0.8884 (1.62)
LAeq16hr (squared); Insulation Not Eligible	-0.0068 (-1.80)*	-0.0077 (-2.01)**	-0.0076 (-1.57)	-0.0083 (-1.68)*
Argmax (insulation not eligible)	52.84559	53.18182	53.42105	53.51807
Joint Significance (P-Val)	0.0240**	0.0215**	0.0476**	0.0665*
LAeq16hr; Insulation Eligible	0.6274 (1.66)*	0.7255 (1.90)*	0.7229 (1.48)	0.7896 (1.60)
LAeq16hr (squared); Insulation Eligible	-0.0051 (-1.65)*	-0.0059 (-1.89)*	-0.0060 (-1.50)	-0.0065 (-1.61)
Argmax (insulation eligible)	61.5098	61.48305	60.24167	60.73846
Joint Significance (P-Val)	0.2485	0.1660	0.3170	0.2754
N	3025	3049	1876	1891
Adjusted R squared	0.305	0.304	0.315	0.315

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.1.1.1.: Impact of daytime aviation noise on Life Satisfaction, parametric specification. Abbreviated table; full regression output in Table A1, Appendix A. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

The findings for those who do not qualify for subsidised insulation are broadly in line with those of Civil Aviation Authority (2017) (SoNA 2014), in that impacts on local residents begin to occur at 53 dB LAeq 16hr, a threshold similar in magnitude to 54 dB in SoNA 2014, and much lower than the 57 dB found in ANIS (1985). On the other hand, for those who do qualify for insulation we cannot reject the null hypothesis of zero impact – and where both the linear and quadratic noise coefficients are individually significant, the results indicate a much higher threshold beyond which the relationship between noise exposure and SWB becomes negative. Whilst qualifying for insulation does not perfectly predict the presence of insulation (as is discussed at length in Section 3 of this report) this is unproblematic for our conclusion: it is reasonable to expect those most sensitive to aviation noise will take up the offer of the subsidy.

The finding that insulation does play some role in determining negative impacts of noise does not align perfectly with the findings in SoNA (2014), which reports that insulation is not a significant factor on noise annoyance levels. However, there are number of possible reasons for this. Firstly, a different extent of insulation is captured in this study – whilst SoNA incorporates only the effects of double glazing, the subsidised insulation measured here tends to also include aspects such as treble glazing and loft and wall insulation. Further to this, the SoNA estimations are based on a small sample size and as the report itself states, along with a likely correlation between social grade and double glazing, this is likely to explain the lack of relationship identified.

Table 5.1.1.2 presents the marginal impacts of daytime aviation noise on Life Satisfaction for all four modelling specifications presented in Table 5.1.1.1. Because the relationship is modelled as a non-linear function, the marginal impacts cannot be inferred from the coefficient estimates alone, but will depend on the initial noise level. For example, based on the OLS model with local authority fixed effects for those not eligible for insulation, the impact of an increase from 54 to 55 dB LAeq16h would be calculated as $0.7187 \times (55 - 54) - 0.0068 \times (55^2 - 54^2) = -0.0089$. Marginal impacts are only presented for those who do not qualify for subsidised insulation, as no statistically significant impacts were identified for those who do qualify for insulation in Table 5.1.1.1. Impacts are broadly similar across specifications. In both OLS specifications and IV with Local Authority fixed effects, the marginal impact at 54 dB LAeq 16h is close to zero but negative; it is very small and positive in the IV specification with shortward fixed effects. Across all specifications, negative impacts of daytime aviation noise occur at 55 dB LAeq16h and above, as is compatible with Airports Commission (2014), Civil Aviation Authority (2017) (SoNA 2014) and the findings of the meta-review of Kaltenbach et al. (2008). At higher noise levels, estimated impacts are slightly larger when specifying shortward as opposed to local authority fixed effects in both OLS and IV specifications, but the magnitude of this difference is very small (approx. 0.015 at 65 dB LAeq16hr). The derived cumulative relationship between noise and wellbeing for those who do not qualify for insulation is presented in Figure 5.1.1.1.

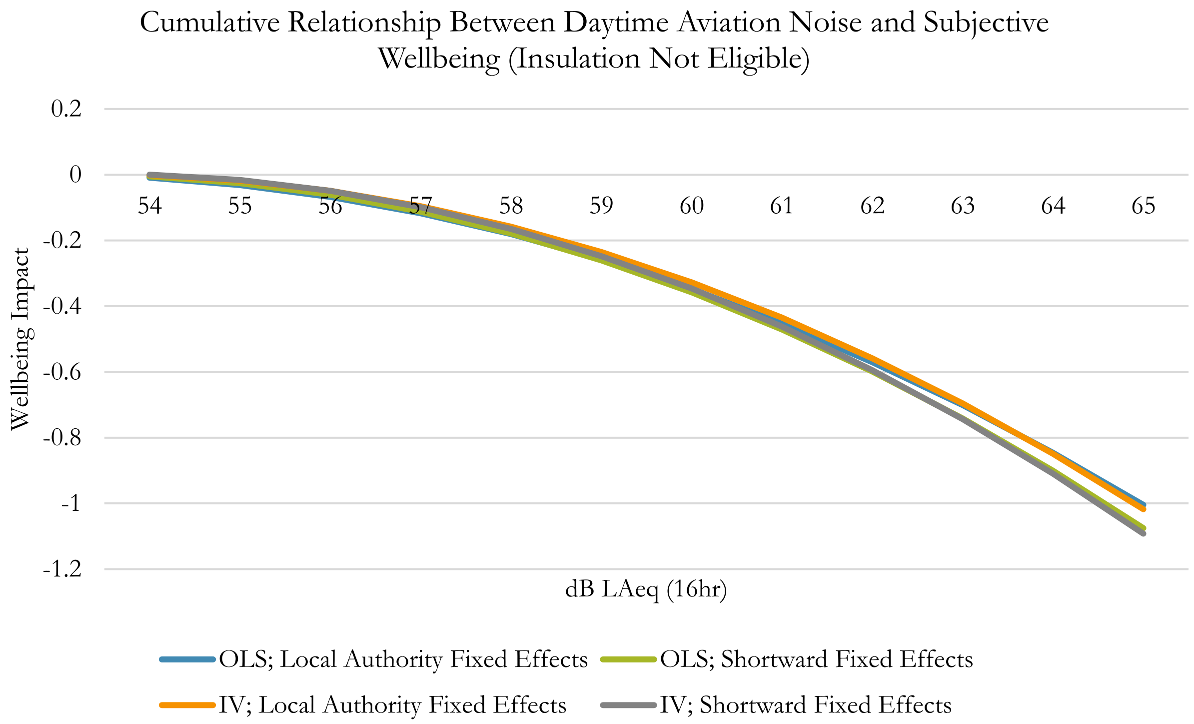

Figure 5.1.1.1.: Cumulative impacts of daytime aviation noise on Life Satisfaction, for those who do not qualify for subsidised insulation. (Based on regression results from Table 5.1.1.1)

LAeq 16hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
54	-0.0089	-0.0049	-0.0012	0.0003
55	-0.0225	-0.0203	-0.0164	-0.0163
56	-0.0361	-0.0357	-0.0316	-0.0329
57	-0.0497	-0.0511	-0.0468	-0.0495
58	-0.0633	-0.0665	-0.062	-0.0661
59	-0.0769	-0.0819	-0.0772	-0.0827
60	-0.0905	-0.0973	-0.0924	-0.0993
61	-0.1041	-0.1127	-0.1076	-0.1159
62	-0.1177	-0.1281	-0.1228	-0.1325
63	-0.1313	-0.1435	-0.138	-0.1491
64	-0.1449	-0.1589	-0.1532	-0.1657
65	-0.1585	-0.1743	-0.1684	-0.1823

Table 5.1.1.2.: Marginal impacts of daytime aviation noise on Life Satisfaction (as measured on a 1-7 scale), for those who do not qualify for subsidised insulation. (Based on regression results from Table 5.1.1.1, using pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq8hr; Insulation Not Eligible	0.2044 (0.19)	0.7685 (0.72)
LAeq8hr (squared); Insulation Not Eligible	-0.0034 (-0.32)	-0.0089 (-0.85)
Argmax (insulation not eligible)	30.05882	43.17416
Joint Significance	0.0246**	0.0163**
LAeq8hr; Insulation Eligible	0.0911 (0.09)	0.6194 (0.63)
LAeq8hr (squared); Insulation Eligible	-0.0010 (-0.12)	-0.0058 (-0.67)
Argmax (insulation eligible)	45.55	53.39655
Joint Significance	0.8672	0.5893
N	656	657
Adjusted R squared	0.409	0.420

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.1.1.3.: Impact of night-time aviation noise on Life Satisfaction, parametric specification. Abbreviated table; full regression output in Table A2, Appendix A. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

Table 5.1.1.3 presents night-time results under the two OLS modelling specifications; note we do not present IV results as the lower night-time sample size is prohibitive due to the asymptotic properties of IV – IV estimators tend to perform with greater error under small sample sizes. Similarly to the daytime results, we find coefficients are significant (jointly at the 5% level) for those who do not qualify for subsidised insulation, but cannot reject the null of zero impact for those who do qualify for insulation. Notably in both specifications the quadratic's maximum point for those without subsidised insulation occurs at a lower level than the minimum noise observation (of 48 dB); this means Life Satisfaction is strictly decreasing in noise (i.e. at all noise levels), and does so at an increasing rate.

The OLS specifications differ more substantially in the night-time sample than the daytime sample. This is likely due to the lower night-time sample size, and also the relatively small number of observations who do not qualify for subsidised insulation at higher levels of aviation noise exposure. Table 3.2 in Section 3 shows that 71% of those exposed to 54.8-57.6 dB LAeq 8hr, and 100% of those exposed to >57.6 dB LAeq 8hr, are eligible for subsidised insulation. We therefore consider the night-time non-insulated marginal impacts to be robust up to a maximum threshold of around 56dB LAeq8h. In Figure 5.1.1.2 we therefore present the cumulative relationship between aviation noise and wellbeing up to and including 56db LAeq 8hr.

Appendix F presents results of the parametric specification using APS data. We do not find significant impacts for insulated nor non-insulated households. However, as discussed in Section 1 of this report, the APS contains only subjective measures of health, which are found to be very strongly related to subjective wellbeing (at the 1% level), indicative of strong simultaneity between the two subjective measures, in line with the findings of Clark (2018); as there is no longitudinal aspect of APS we cannot correct for this using the IV approach. The model fit (as measured by adjusted R^2) is also significantly higher in the Understanding Society data comparative to APS, at 0.305 and 0.409 versus 0.180 and 0.166 for day and night regressions respectively. We therefore elect to rely on Understanding Society data for the remainder of this report.

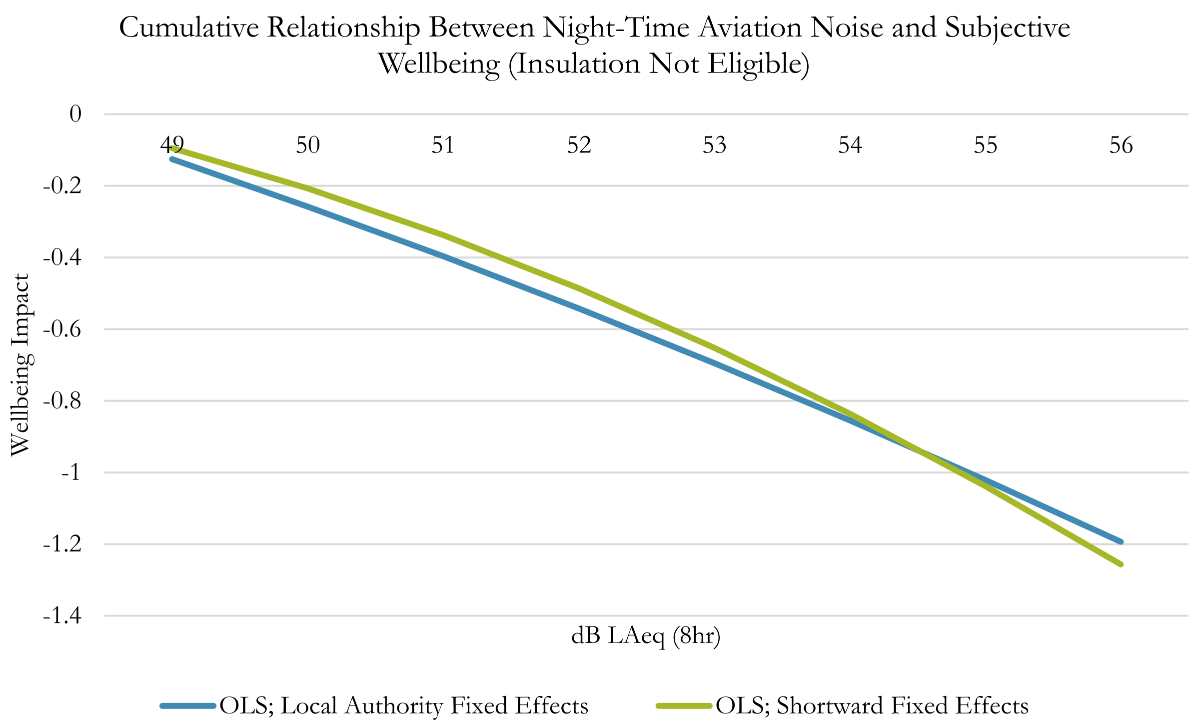

Figure 5.1.1.2.: Cumulative impacts of night-time aviation noise on Life Satisfaction, for those who do not qualify for subsidised insulation. (Based on regression results from Table 5.1.1.3)

LAeq 8hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
49	-0.1254	-0.0948
50	-0.1322	-0.1126
51	-0.139	-0.1304
52	-0.1458	-0.1482
53	-0.1526	-0.166
54	-0.1594	-0.1838
55	-0.1662	-0.2016
56	-0.173	-0.2194
57	-0.1798	-0.2372
58	-0.1866	-0.255
59	-0.1934	-0.2728
60	-0.2002	-0.2906
61	-0.207	-0.3084
62	-0.2138	-0.3262
63	-0.2206	-0.344
64	-0.2274	-0.3618
65	-0.2342	-0.3796

Table 5.1.1.4.: Marginal impacts of night-time aviation noise on Life Satisfaction (as measured on a 1-7 scale), for those who do not qualify for subsidised insulation. (Based on regression results from Table 5.1.1.3, using pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

5.1.2 Counterfactual Analysis

Table 5.1.2.1 presents daytime results for the model discussed in Section 4.1.2 under all four model specifications; results for those who do not qualify for subsidised insulation are also presented graphically in Figure 5.1.2.1. For those who do not qualify for subsidised insulation we find a negative impact of aviation noise on Life Satisfaction, comparative to a counterfactual of no aviation noise exposure, in Quintile 4 (54.9-57.9 dB LAeq 16hr) of between -0.15 and -0.22; this is significant at the 5% level in both OLS specifications and the IV specification with local authority fixed effects, and at the 10% level in the IV specification with shortward fixed effects. We find a larger negative impact in Quintile 5 (57.9 dB LAeq and above), of between -0.21 and -0.26; this is significant at the 5% level in both OLS specifications, but is only significant at the 10% level in the IV specification with Local Authority fixed effects.

This result provides significant robustness to the marginal impacts presented in Table 5.1.1.1 in the previous section: the quintile in which residents who do not qualify for subsidised insulation begin to experience significant negative wellbeing impacts of aviation noise corresponds to the same noise level at which we begin to identify sizeable negative impacts in the parametric specification: between 54 and 55 dB LAeq 16hr; this also supports that wellbeing impacts are increasing with increasing noise level. This is once again in line with existing research, particularly the findings of Civil Aviation Authority (2017) (SoNA 2014) and the meta-review of Kaltenbach et al. (2008).

We do not identify any significant negative impacts of daytime aviation noise on Life Satisfaction comparative to a counterfactual of no noise exposure for those who do qualify for subsidised insulation; once again, this adds credence to our findings in the parametric specification presented in Section 4.1.1.1. We identify a positive (and significant) coefficient for those in Quintile 5 (57.9-99 dB LAeq 16hr) of exposure; this result is not entirely surprising: these individuals conceivably enjoy other benefits deriving from insulation, e.g. warmth or reduced energy bills, however this is outside the scope of this study. Notably these findings are in line with Van Praag and Baarsma (2005), who find negative subjective wellbeing impacts of subjective noise on residents which is smaller in magnitude for those who have noise insulation.

Dependent Variable: Life Satisfaction	dB range (LAeq 16hr)	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq16hr (Quintile 1); Insulation Not Eligible	51-51.9	0.0040 (0.06)	-0.0036 (-0.05)	-0.0159 (-0.18)	-0.0170 (-0.19)
LAeq16hr (Quintile 2); Insulation Not Eligible	51.9-53.3	0.0315 (0.42)	0.0270 (0.36)	0.1211 (1.32)	0.1177 (1.29)
LAeq16hr (Quintile 3); Insulation Not Eligible	53.3-54.9	0.0174 (0.21)	0.0362 (0.43)	0.0905 (0.93)	0.1195 (1.22)
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-0.1746 (-2.28)**	-0.1509 (-1.99)**	-0.2185 (-2.24)**	-0.1754 (-1.83)*
LAeq16hr (Quintile 5); Insulation Not Eligible	57.9-99	-0.2547 (-2.42)**	-0.2625 (-2.41)**	-0.2336 (-1.82)*	-0.2148 (-1.60)
LAeq16hr (Quintile 1); Insulation Eligible	51-51.9	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 2); Insulation Eligible	51.9-53.3	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 3); Insulation Eligible	53.3-54.9	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 4); Insulation Eligible	54.9-57.9	-0.1237 (-0.45)	-0.0701 (-0.25)	0.0846 (0.25)	0.0359 (0.11)
LAeq16hr (Quintile 5); Insulation Eligible	57.9-99	0.2588 (2.29)**	0.3104 (2.75)***	0.2724 (2.15)**	0.3738 (2.99)***
N		27902	28144	17773	17935
Adjusted R squared		0.298	0.301	0.311	0.314

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.1.2.1.: Impact of daytime aviation noise on Life Satisfaction (as measured on a 1-7 scale), compared to a counterfactual of no aviation noise exposure. Abbreviated table; full regression output in Appendix B1. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

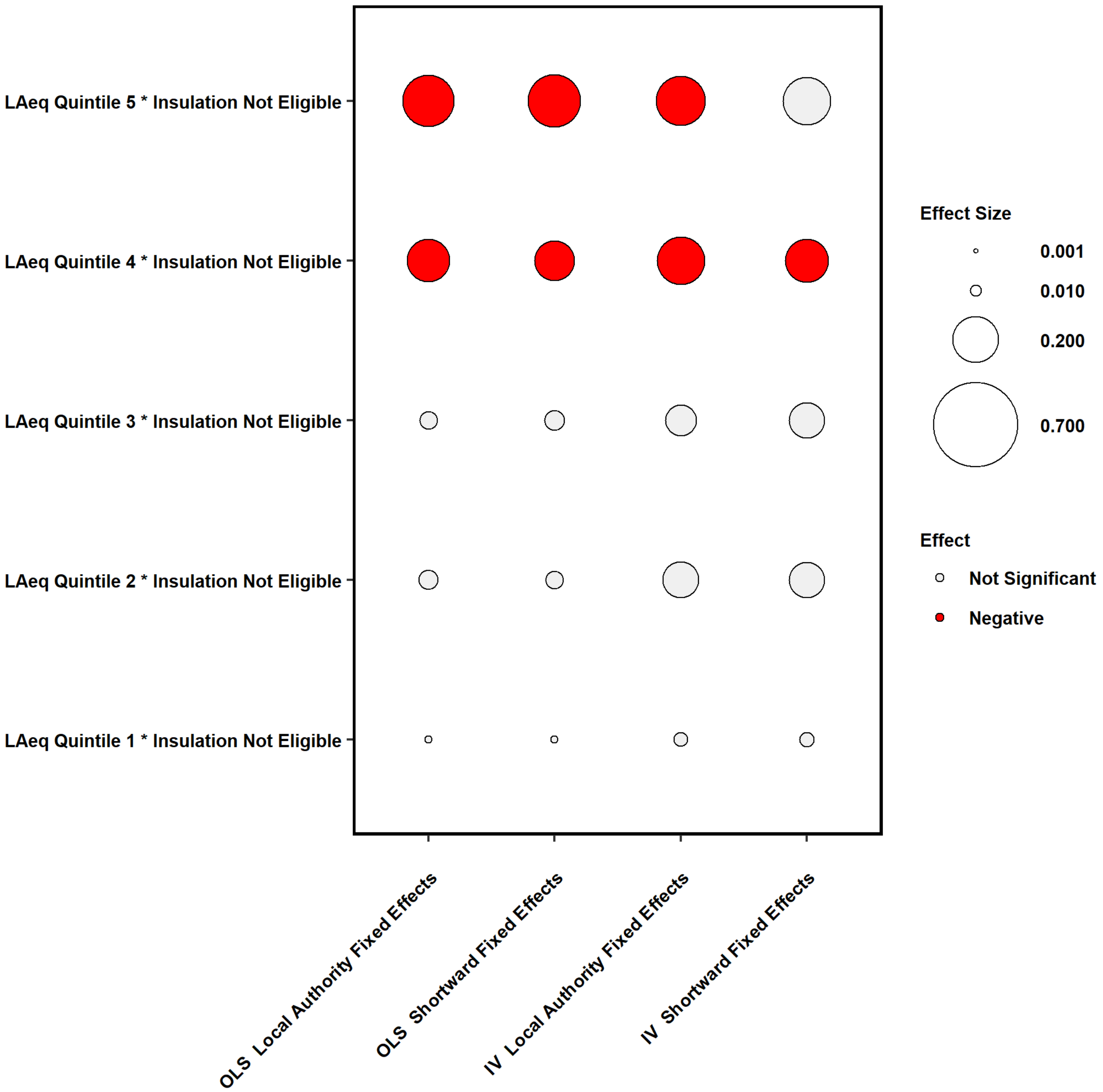

Figure 5.1.2.1.: Impact of daytime aviation noise on Life Satisfaction (as measured on a 1-7 scale), compared to a counterfactual of no aviation noise exposure, for those who do not qualify for subsidised noise insulation. (Based on regression results from Table 5.1.2.1, using pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

Table 5.1.2.2 presents counterfactual results for the night-time aviation noise under four modelling specifications; Figure 5.1.2.2 graphically presents these results for those who do not qualify for subsidised noise insulation. We find significant (at 1%) negative impacts of aviation noise on Life Satisfaction for those who do not qualify for noise insulation in the third quintile of noise exposure (53.2-54.8 dB LAeq 8hr). Results are smaller and insignificant in the fourth quintile, but as noted in Section 5.1.1, the majority (71%) of observations within this quintile qualify for subsidised insulation, thus reducing the sample size; there are no observations who do not qualify for insulation in the fifth quintile of night-time noise exposure.

Similarly to in Section 5.1.1, we do not observe significant negative impacts of night-time aviation noise on Life Satisfaction for those who do qualify for noise insulation. In Quintiles 1, 2, and 3, only a very small portion of the sample qualifies for noise insulation: <5%, 6%, and 11% respectively; insulation-interacted results for these quintiles therefore have a very low sample size and we do not consider them to be reliable. Similarly to the day-time results, many of the Life Satisfaction impacts of night-time noise on the those who do qualify for insulation, compared to the counterfactual group, are not statistically significant (at 10% level). However, all of the significant coefficients we observe are positive.

We again surmise that these are likely caused by the positive impacts of subsidised insulation on outcomes other than aviation noise mitigation.

Dependent Variable: Life Satisfaction	dB range (LAeq 8hr)	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq8hr (Quintile 1); Insulation Not Eligible	48-52.1	-0.1752 (-1.24)	-0.1457 (-1.02)	-0.2706 (-1.64)	-0.2387 (-1.42)
LAeq8hr (Quintile 2); Insulation Not Eligible	52.1-53.4	-0.0046 (-0.04)	0.0178 (0.15)	-0.0245 (-0.19)	0.0024 (0.02)
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	-0.6826 (-3.99)***	-0.6185 (-3.91)***	-0.6415 (-3.46)***	-0.5779 (-3.46)***
LAeq8hr (Quintile 4); Insulation Not Eligible	54.8-57.6	-0.2676 (-1.36)	-0.2386 (-1.21)	-0.1860 (-1.01)	-0.1376 (-0.73)
LAeq8hr (Quintile 5); Insulation Not Eligible	57.6-90.3	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 1); Insulation Eligible	48-52.1	-0.6797 (-0.75)	-0.6496 (-0.72)	-1.2004 (-1.11)	-1.1873 (-1.09)
LAeq8hr (Quintile 2); Insulation Eligible	52.1-53.4	0.5372 (2.41)**	0.5596 (2.54)**	0.5345 (2.03)**	0.5499 (2.11)**
LAeq8hr (Quintile 3); Insulation Eligible	53.4-54.8	0.0932 (0.29)	0.0784 (0.24)	-0.0073 (-0.02)	-0.0307 (-0.09)
LAeq8hr (Quintile 4); Insulation Eligible	54.8-57.6	0.2612 (1.85)*	0.3480 (2.50)**	0.2180 (1.58)	0.3227 (2.43)**
LAeq8hr (Quintile 5); Insulation Eligible	57.6-90.3	0.1895 (1.11)	0.2040 (1.21)	0.4015 (2.00)**	0.4178 (2.11)**
N		27902	28144	17773	17935
Adjusted R squared		0.298	0.301	0.311	0.314

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.1.2.2.: Impact of night-time aviation noise on Life Satisfaction (as measured on a 1-7 scale), compared to a counterfactual of no aviation noise exposure. Abbreviated table; full regression output in Appendix B2. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

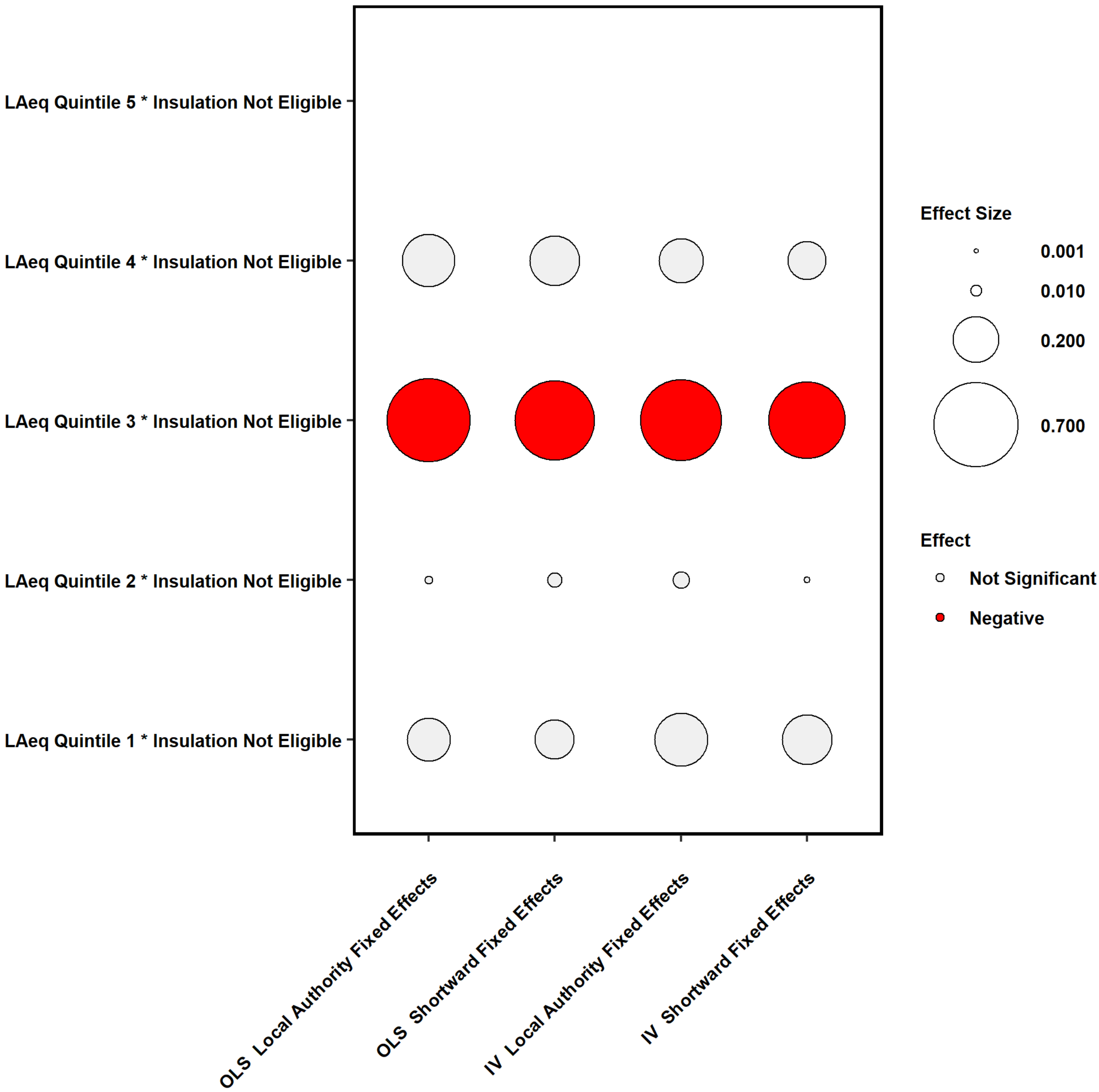

Figure 5.1.2.2.: Impact of night-time aviation noise on Life Satisfaction (as measured on a 1-7 scale), compared to a counterfactual of no aviation noise exposure, for those who do not qualify for subsidised noise insulation. (Based on regression results from Table 5.1.2.2, using pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

5.1.3 External Validity

Tables C1 and C2 in Appendix C present results of Equation 6 in Appendix G for daytime and night-time noise respectively, in which we interact noise exposure with a number of demographic characteristics. We limit discussion to interaction terms for those who do not qualify for insulation, as we do not posit wellbeing valuations of aviation noise for those who do qualify for insulation, as we do not find the main results to be significant in either the continuous nor semi-parametric specifications.

For both daytime and night-time noise, homeowners are found to be less impacted than renters. This might conceivably be due to owner-occupiers being more likely to take advantage of subsidised insulation schemes than renters, though as we do not observe who does and does not take up the offer of subsidised insulation this is merely conjecture. This could also be explained by hedonic pricing: it would seem likely that owner-occupiers might benefit more from any reduction in house prices, ceteris paribus, in a noisy area comparative to an area that is not subject to significant aviation noise. This would mean they are monetarily compensated, thus dampening the magnitude of any wellbeing impact.

We find some evidence that those living in urban areas are significantly more affected by daytime aviation noise than others, but only in Quintiles 3 and 4 of noise exposure, and this result is not replicated for night-time noise. We also find some evidence that those who are in poor health are significantly more affected than healthy individuals in the daytime sample, in Quintiles 2, 3, and 4; once again, however, this is not replicated in the night-time sample.

We find evidence that Over 70s are significantly less affected by night-time aviation noise than younger residents, though this is not replicated in the daytime sample.

We do not find evidence that wellbeing impacts of aviation noise significantly vary across other demographic characteristics, strongly suggesting that these results are largely externally valid to the areas around airports that are not observed in this study. However, if the areas around airports for which data were not supplied for this study significantly differ in terms of homeownership, health, or local elderly population, valuations applied could conceivably be weighted to account for these differences.

5.2 Health Mediation Analysis

In this section we present the results of the mediation analysis, whereby we separate the total impact on Life Satisfaction from the impact that is transmitted through physical and mental health. We perform this analysis only for quintiles in which we identify a significant causal impact of aviation noise on Life Satisfaction (as identified in Tables 5.2.1.1 and 5.2.1.2), as where there is no total impact on Life Satisfaction, identification of a mediated impact is necessarily spurious. SF-12 measures of physical and mental health are both measured on a 1-100 scale, with a higher number indicating higher levels of health.

It should be noted that the first stage regressions of the mediation analysis, i.e. Equations 7 and 8 in Appendix G, cannot be interpreted as the casual impact of aviation noise on physical and mental health: a separate literature exists on the health impacts of aviation noise, as is reviewed in Section 2 of this report; this literature accounts for long-term impacts and targets specific diseases which are known to be related to noise exposure. Estimation of Equations 7 and 8 is purely for the process of estimation of the extent to which wellbeing impacts are transmitted through health, as per Sobel (1982).

5.2.1 Physical Health

Table 5.2.1.1 presents the proportion of the total daytime Life Satisfaction impact that is transmitted through physical health; daytime results for intermediate Equation 7 of Appendix G are presented in Table C1 in Appendix C. We identify no statistically significant mediation effects of aviation noise through physical health on Life Satisfaction.

Mediation Effects: Physical Health (Day)	dB range (LAeq 16hr)	Local Authority Fixed Effects	Shortward Fixed Effects
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-0.01388 (-0.55)	0.025255 (0.98)
Percentage of Total Effect		**0% (n.s.)**	**0% (n.s.)**
LAeq16hr (Quintile 5); Insulation Not Eligible	57.9-99	-0.02687 (-0.49)	0.02005 (0.32)
Percentage of Total Effect		**0% (n.s.)**	**0% (n.s.)**

Robust z-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.2.1.1.: Mediation effect of daytime aviation noise on Life Satisfaction (as measured on a 1-7 scale) transmitted through physical health. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

Table 5.2.1.2 presents the proportion of the total night-time Life Satisfaction impact that is transmitted through physical health; night-time results for intermediate Equation 8 of Appendix G are presented in Table C2 in Appendix C. Similarly to the daytime results, we do not identify evidence of an impact of aviation noise on Life Satisfaction mediated through physical health.

These results mean that we cannot reject the null hypothesis that no portion of the wellbeing impact of aviation noise is transmitted through physical health. It is important to stress that this does not imply that aviation noise has no impact on physical health, but rather that none of the wellbeing impact identified in this report is as a result of physical health impacts.

Given the existence of an established literature linking noise to physical health (see Sections 2.2.3 and 2.3.3 of this report), this, at face value, is surprising. However, it is important to consider this in the context of adaptation: there is a body of evidence to suggest that in terms of subjective wellbeing, agents adapt more quickly to physical than to mental health conditions (e.g. see Dolan, 2011). It is also possible that physical health impacts are not captured due to limitations of the available data: physical health impacts of noise are most associated with long-term exposure, however this report uses data on noise exposure from 2009-2017. It is therefore possible that only a small proportion of the residents observed have been exposed to aviation noise for a sufficient period for physical health impacts to manifest, hence the total (longer term) wellbeing impact mediated through physical health, should one exist, would not be identified.

Mediation Effects: Physical Health (Night)	dB range (LAeq 8hr)	Local Authority Fixed Effects	Shortward Fixed Effects
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	-0.03371 (0.38)	0.045329 (0.51)
Percentage of Total Effect		**0% (n.s.)**	**0% (n.s.)**

Robust z-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.2.1.2.: Mediation effect of night-time aviation noise on Life Satisfaction (as measured on a 1-7 scale) *transmitted through physical health. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)*

5.2.2 Mental Health

Table 5.2.2.1 presents the derived mediation effect of mental health on Life Satisfaction; daytime results for intermediate Equation 7 of Appendix G are presented in Table C3 in Appendix C. We identify that approximately 6% of the impact of aviation noise on Life Satisfaction is transmitted through mental health in Quintile 4, and approximately 7% in Quintile 5. The mediator variable is significant at the 1% level in both specifications for Quintile 4, and at the 5% and 10% level in Quintile 5 for local authority and shortward fixed effect specifications respectively.

Mediation Effects: Mental Health (Day)	dB range (LAeq 16hr)	Local Authority Fixed Effects	Shortward Fixed Effects
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-0.0134 (-3.83)***	-0.0105 (-3.00)***
Percentage of Total Effect		**6.13%**	**5.99%**
LAeq16hr (Quintile 5); Insulation Not Eligible	57.9-99	-0.01645 (-2.30)**	-0.01464 (-1.95)*
Percentage of Total Effect		**7.04%**	**6.82%**

Robust z-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.2.2.1.: Mediation effect of daytime aviation noise on Life Satisfaction transmitted through mental health. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

Table 5.2.2.2 presents the derived mediation effects of mental health on Life Satisfaction; night-time results for intermediate Equation 8 of Appendix G are presented in Table C3 in Appendix C. We do not find that there are any significant impacts of night-time aviation noise on Life Satisfaction that are transmitted through mental health.

Mediation Effects: Mental Health (Night)	dB range (LAeq 8hr)	Local Authority Fixed Effects	Shortward Fixed Effects
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	0.008768 (0.95)	0.008287 (1.03)
Percentage of Total Effect		**0% (n.s.)**	**0% (n.s.)**

Robust z-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.2.2.2.: Mediation effect of night-time aviation noise on Life Satisfaction transmitted through mental health. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

5.3 Sleep

Similar to Floud et al. (2011), we do not identify any significant impact of daytime nor night-time aviation noise on incidence of sleep disturbance. Tables 5.3.1 and 5.3.2 present the results of the specification introduced in Section 4.3 for daytime and night-time noise respectively. For daytime noise, coefficients are negative, but are very close to zero and are not significant. Coefficients for night-time noise are positive and of larger magnitude, with aviation noise being associated with approximately a 0.04 log odds increase in the probability of sleep disturbance irrespective of insulation entitlement. This corresponds to 1 dB of additional night-time aviation noise increasing the probability of sleep disturbance by approximately 50%. However, these results remain insignificant.

Outcome variable: Sleep Disturbance	
LAeq16hr; Insulation Not Eligible	-0.0044 (-0.10)
LAeq16hr; Insulation Eligible	-0.0021 (-0.05)
N	904
Pseudo R-squared	0.154

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.3.1: Impact of an additional decibel of daytime aviation noise on incidence of sleep disturbance. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

It should be noted that the sample sizes in these logistic regressions are extremely small, with 904 daytime observations and 259 night-time observations, as questions about sleep disturbance are only asked in two waves of the Understanding Society, so these results should be interpreted with some caution. Given the increased size of the night-time coefficients comparative to daytime, it is conceivable that with a larger sample size a significant impact might be identified.

Outcome variable: Sleep Disturbance	
LAeq8hr; Insulation Not Eligible	0.0403 (0.39)
LAeq8hr; Insulation Eligible	0.0364 (0.39)
N	259
Pseudo R-squared	0.276

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 5.3.2: Impact of an additional decibel of night-time aviation noise on incidence of sleep disturbance. (Sample: pooled cross-sectional Understanding Society data, matched with aviation noise and insulation scheme data.)

6. Valuation

6.1 Methodology

In order to estimate the monetary equivalent of the aviation noise impact on individuals we use the wellbeing valuation method. This approach relies on a comparison between the change in wellbeing from the outcome to be valued (in this case, aviation noise) with the change in wellbeing from income. The value of the outcome is then calculated as the marginal rate of substitution (MRS) between income and the outcome itself, expressed in monetary terms.

In principle, there are two ways of measuring the monetary equivalent of an outcome:

1. Equivalent Surplus (ES) represents willingness to pay (WTP) to avoid the negative impacts of aviation noise – that is, the amount of income that would need to be taken away from an individual who does not suffer from aviation noise to bring their utility/wellbeing to the (lower) level they would experience in the presence of aviation noise:

   $$u(P^1,\, X,\, M) = \mathrm{u}(P^0,\, X,\, M + ES)$$

   where P refers to aviation noise (with the superscript 0 in its absence and 1 in its presence), M is income and X are other factors that affect utility besides income and aviation noise.

2. Compensating Surplus (CS) represents willingness to accept (WTA) the negative impacts of aviation noise – that is, the amount of income that should be given to an individual who suffers from aviation noise to bring their utility/wellbeing to the (higher) level they would experience in the absence of aviation noise:

   $$u(P^0,\, X,\, M) = \mathrm{u}(P^1,\, X,\, M - CS)$$

Both WTP and WTA valuations are presented throughout the remainder of this section.

In practice, wellbeing is usually measured in terms of life satisfaction, which represents “the closest measure to the economist’s notion of utility” (Fujiwara & Campbell, 2011). Life satisfaction questions are commonly found in national statistics, including Understanding Society and Annual Population Survey data.

Next, regression analysis is used to estimate wellbeing as a function of the outcome of interest (LAeq), income (M) and other factors (X), as outlined in equation (1). The logarithmic transformation of income allows for diminishing returns of income on wellbeing – that is, it allows for those with lower incomes to experience a greater wellbeing benefit for a given increase in income, as compared to those with higher incomes.

6.1.1 Standard Wellbeing Valuation

Combining the definition of CS from point 2 above with the empirical wellbeing function described earlier in equation (1) yields an equation which can be solved for CS:

$$CS = M\left[1 - e^{-\left(\frac{\beta_2(P^1 - P^0)}{\beta_1}\right)}\right] \qquad (5)$$

The standard WV approach outlined above is subject to a number of technical problems, mainly associated with the use of a single wellbeing regression model to estimate CS:

First, using the empirical wellbeing function specified in Equation (1) introduces a parametric restriction to the wellbeing model which does not account for possible interdependencies between the non-market outcome (P), income (M) and other factors (X). This is of particular concern with respect to the income coefficient β_1, which is likely to be a significant underestimate of the total impact of income on wellbeing, therefore forcing up the monetary equivalent values in Equation (5).

- Second, because the interdependencies mentioned above are likely to interact further with the life satisfaction measure on the left-hand side of Equation (1), unbiased estimates of the effect of the non-market outcome and income on wellbeing cannot be obtained using ordinary least squares regression. The standard solution in this case is to apply the two-stage least squares regression approach instead. However, even if perfect instrumental variables are found for both income and the non-market outcome, within a single-equation model such as that given by Equation (1) it is still not possible to calculate the total derivatives of wellbeing with respect to both income and the non-market good needed to estimate CS.

- Finally, the coefficients on income and the non-market outcome may refer to different sub-populations of compliers, making the estimated CS value difficult to interpret in terms of to whom it would apply.

To remedy these problems, Fujiwara (2013) suggests using a wellbeing valuation strategy in three stages to tackle these problems and produce robust estimates that are consistent with welfare economic theory and can be used for Cost-Benefit Analysis.

6.1.2 Three-Stage Wellbeing Valuation

Three-stage wellbeing valuation represents the latest development in WV methodology, in line with the UK's *HM Treasury Green Book* recommendations (2018) and the OECD's guidance on wellbeing (2013). The strategy involves estimating two separate models for wellbeing: one for the impact of income and one for the impact of the outcome considered.

Stage I: Income Model

$$WB_{it} = f(\ln(M_{it})) \qquad (6)$$

Stage II: Outcome Model

$$WB_{it} = g(P_{it}) \qquad (7)$$

The compensating surplus (willingness to accept) is then calculated using total derivatives from stages I and II.

Stage III: Monetary Equivalent Value

$$CS = M\left[1 - e^{-\left(\frac{g'_P(P^1-P^0)}{f'_{\ln(M)}}\right)}\right] \qquad (8)$$

Empirically, the values of g'_{P} and $f'_{\ln(M)}$ in Equation (8) are given by regression coefficients estimated is stages I and II. What distinguishes this strategy from the previous WV approach described in Equation (5) is the fact that here the regression coefficients come from two different models rather than from a single one: instead of β_1 we now use the impact of income estimated in stage I, instead of β_2 we now use the impact of the project outcome estimated in stage II, and M is the average household income in the sample.

The equivalent surplus (willingness to pay) can be calculated using total derivatives from stages I and II.

$$ES = M\left[e^{\left(\frac{g'_P(P^1-P^0)}{f'_{\ln(M)}}\right)} - 1\right] \qquad (9)$$

The Stage I model will likely be affected by endogeneity due to simultaneity (income is to some extent determined by wellbeing), omitted variables (unobservable characteristics that influence both income and wellbeing e.g., attitude) and measurement error. As this will produce biased estimators, lottery wins can be used as an instrumental variable for income. Being randomly assigned, lottery wins represent an exogenous income shock, which allows us to derive robust causal estimates of the impact of income on wellbeing. Fujiwara (2013) uses this estimation strategy and data from the British Household Panel Survey to calculate a β_1 coefficient of 1.1, which is the result we apply when calculating the monetary equivalent of aviation noise impact on individuals.

Stage II coefficients of aviation noise impact on individuals' wellbeing are based on the previously described regression model given in equation (1) in **Appendix G**.

6.2 Results

Tables 6.2.1 and 6.2.2 respectively present marginal valuations for daytime and night-time aviation noise, utilising the marginal wellbeing effects derived using Equation 1 as presented in Tables 5.1.1.1 to 5.1.1.4. All valuations presented below are for those who do not qualify for subsidised insulation, as marginal wellbeing impacts for those who do qualify for subsidised insulation are not statistically different from zero, and therefore, implicitly, nor are the wellbeing valuations.

In each case the valuations we present are based on the OLS specifications with Local Authority fixed effects. As discussed in Section 4, the IV specifications are presented to address potential simultaneity between Life Satisfaction and SF-12 health measures, which, if present, would not bias noise coefficients; basing valuations on IV coefficients would therefore only serve to reduce the sample size on which valuations are based. We favour Local Authorities over Shortwards as a spatial measure as these are ONS-derived; as discussed in Section 4 Shortward specifications are presented only for robustness. All valuations utilise the equivalised household income from the respective regression sample.

LAeq 16hr	Marginal Valuation (WTA)	Cumulative Valuation (WTA)	Marginal Valuation (WTP)	Cumulative Valuation (WTP)
54	-£187	-£187	-£185	-£185
55	-£475	-£662	-£466	-£651
56	-£767	-£1,429	-£743	-£1,394
57	-£1,063	-£2,493	-£1,016	-£2,410
58	-£1,362	-£3,855	-£1,286	-£3,696
59	-£1,665	-£5,520	-£1,553	-£5,249
60	-£1,972	-£7,493	-£1,817	-£7,065
61	-£2,283	-£9,776	-£2,077	-£9,142
62	-£2,597	-£12,373	-£2,334	-£11,476

Table 6.2.1: Wellbeing Valuations (willingness to accept, and willingness to pay to avoid) daytime aviation noise.

Marginal valuations of the impact of daytime noise are of similar magnitude to Dekkers and van der Straaten (2009), however we additionally find impacts become larger in magnitude for higher levels of daytime aviation noise. It should be reiterated that these valuations are for households who do not qualify for subsidised insulation, and that wellbeing impacts are not statistically different from zero for households who do qualify for insulation. Marginal valuations for all levels of night-time noise are much higher comparative to equivalent daytime noise, but once again this wellbeing impact is mitigated in its entirety by the availability of subsidised insulation.

As per the discussion in Subsection 5.1.1, we present daytime only up to 62dB LAeq 16hr, and night-time valuations only up to 56dB LAeq 8hr, due to the overwhelming majority of households qualifying for subsidised insulation beyond this threshold. However, we do think it reasonable to assume that marginal valuations continue to increase in noise exposure at a similar rate beyond these thresholds.

LAeq 8hr	Marginal Valuation (WTA)	Cumulative Valuation (WTA)	Marginal Valuation (WTP)	Cumulative Valuation (WTP)
49	-£2,777	-£2,777	-£2,478	-£2,478
50	-£2,937	-£5,714	-£2,605	-£5,083
51	-£3,098	-£8,812	-£2,730	-£7,813
52	-£3,260	-£12,072	-£2,855	-£10,668
53	-£3,423	-£15,495	-£2,979	-£13,647
54	-£3,586	-£19,081	-£3,103	-£16,750
55	-£3,751	-£22,833	-£3,225	-£19,975
56	-£3,917	-£26,750	-£3,347	-£23,322

Table 6.2.2: Wellbeing Valuations (willingness to accept, and willingness to pay to avoid) night-time aviation noise.

For robustness, we additionally present wellbeing valuations for the statistically significant quintiles in the counterfactual regressions; these are presented in Table 6.2.3 and 6.2.4. Similarly to the valuations presented above, valuations are only presented for those who do not qualify for noise insulation, as we do not identify statistically significant impacts of aviation noise for those who do qualify for insulation. It should be noted that the interpretation of these valuations are different to those presented above: these figures represent the total value of the difference in wellbeing between individuals whose aviation noise exposure falls within a particular quintile, comparative to those who are not exposed to aviation noise.

	dB range (LAeq 16hr)	Valuation (WTA)	Valuation (WTP)
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-£3,956	-£3,376
LAeq16hr (Quintile 5); Insulation Eligible	57.9-99	-£5,993	-£4,754

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 6.2.3.: Wellbeing Valuations (willingness to accept, and willingness to pay to avoid) daytime aviation noise, comparative to counterfactual group who are not exposed to aviation significant noise.

	dB range (LAeq 8hr)	Valuation (WTA)	Valuation (WTP)
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	-£19,779	-£10,634

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 6.2.4.: Wellbeing Valuations (willingness to accept, and willingness to pay to avoid) night-time aviation noise, comparative to counterfactual group who are not exposed to aviation significant noise.

Valuations for daytime aviation noise derived from the counterfactual specification are broadly similar to, but slightly higher than, equivalent valuations from the continuous specification. Observations in Quintile 4 (who are exposed to 54.9-57.9 dB LAeq 16hr of aviation noise) exhibit £3,986 WTP and £3,376 WTA valuations, which are most similar to cumulative valuations at 58dB LAeq in the continuous specifications (which £3,855 £3,696 for WTA and WTP respectively). Daytime Quintile 5 (those exposed to 57.9 dB LAeq 16hr and above) exhibit WTA and WTP valuations somewhere between the cumulative valuations at 59dB and 60dB LAeq 16hr in the continuous specification.

For night-time noise, the story is similar for WTA valuations: those exposed to between 53.4 and 54.8 dB LAeq 8hr exhibit a WTA valuation approximately equivalent to the cumulative valuation at 54dB LAeq 8hr in the continuous specification (£19,779 in the counterfactual specification compared to £19,081 in the continuous specification); however at higher levels of noise exposure the WTP valuations differ substantially (£10,634 in the counterfactual specification comparative to £16,750 in the continuous specification). This is due to the following two effects working in the same direction:

- **Concavity**: Because the WTP monetisation function is concave, higher value is going to be placed on a sequence of small (marginal) wellbeing changes (as obtained from the continuous model) than on a single large change of equivalent size (as obtained from the quintile model). Concavity of WTP implies that the `first’ unit of wellbeing gained (from avoided noise) is more valuable than the next units gained. However, when a single change in wellbeing is split into smaller parts, each of those parts ends up being monetised as a ‘first’ unit, so that the resulting sum of WTPs for the parts is going to be higher than the WTP for the whole.

- **Monotonicity**: The total wellbeing impact of night-time aviation noise estimated in the continuous model (-0.85) is higher compared to the quintile model (-0.68). This increases the WTP based on the continuous model, reinforcing the concavity effect.

7. Conclusion

We find a strong negative relationship between aviation noise and subjective wellbeing; the impact of a unit increase in noise increases with the initial level of noise exposure, and is of larger magnitude for night-time noise than daytime noise. These results are found only for those households which do not qualify for noise insulation subsidies (which we use as an indicator for the household having noise insulation). This relationship is not found to be statistically different from zero for households who qualify for subsidised noise insulation, suggesting that subsidised insulation schemes are effective in abating the wellbeing impacts of aviation noise.

Approximately 6-7% of the daytime relationship between aviation noise and subjective wellbeing is transmitted through mental health impacts. There is no evidence to suggest that wellbeing impacts of night-time noise are transmitted through mental health, nor that daytime nor night-time wellbeing impacts are transmitted through physical health. There is no evidence that aviation noise has a statistically significant impact on incidence of sleep disturbance, however we emphasise that this is not a claim that no effect exists: a lack of statistical significance is likely due to the small sample size in the sleep regressions, owing to questions pertaining to sleep patterns being asked only in two waves of Understanding Society.

It is a recommendation of this report that the valuation of aviation noise impacts used in cost-benefit analysis should routinely account for the local availability and uptake of noise insulation, to avoid biasing cumulative valuations. It follows that this might also be necessary for sources of noise other than aviation, however discussion of other sources of noise is outside of the scope of this report and would require further research.

It should be noted that the analysis presented in this report is split according to eligibility for subsidised insulation (or lack thereof): we do not observe which households have taken up the offer of insulation, nor which version of the various insulation schemes is installed. Given the strength of the finding that the relationship between aviation noise exposure and subjective wellbeing is dependent on insulation entitlement, further research is needed into (a) the drivers of the uptake of subsidised insulation, and (b) heterogeneity in the reduction of the wellbeing impact of aviation noise by insulation type.

Due to limited availability of noise exposure and insulation data, the attention in this report is restricted to Heathrow, Gatwick, and Stansted airports. Whilst we conduct sensitivity tests and find strong evidence to support the external validity of the results presented, should comparable data for other UK airports become available this report would ideally be extended to incorporate these data.

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9. Appendix A: Marginal Effects – Full Tables

9.1 Daytime Noise

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq16hr; Insulation Not Eligible	0.7187 (1.72)*	0.8190 (1.93)*	0.8120 (1.50)	0.8884 (1.62)
LAeq16hr; Insulation Eligible	0.6274 (1.66)*	0.7255 (1.66)*	0.7229 (1.48)	0.7896 (1.60)
LAeq16hr (squared); Insulation Not Eligible	-0.0068 (-1.80)*	-0.0077 (-2.01)**	-0.0076 (-1.57)	-0.0083 (-1.68)*
LAeq16hr (squared); Insulation Eligible	-0.0051 (-1.65)*	-0.0059 (-1.89)*	-0.0060 (-1.50)	-0.0065 (-1.61)
SF-12: Physical health	0.0217 (1.12)	0.0228 (1.18)	0.0079 (0.12)	0.0116 (0.17)
SF-12: Physical health (squared)	0.0001 (0.47)	0.0001 (0.39)	0.0003 (0.36)	0.0002 (0.30)
SF-12: Mental health	0.0793 (3.88)***	0.0787 (3.88)***	0.0182 (0.17)	0.0079 (0.07)
SF-12: Mental health (squared)	-0.0001 (-0.57)	-0.0001 (-0.58)	0.0007 (0.60)	0.0008 (0.68)
House Prices	0.0000 (0.88)	0.0000 (0.88)	0.0000 (0.01)	-0.0000 (-0.04)
NO2	0.0075 (0.22)	0.0103 (0.30)	0.0108 (0.24)	0.0162 (0.36)
NOx	-0.0098 (-0.74)	-0.0101 (-0.73)	-0.0065 (-0.36)	-0.0062 (-0.34)
PM10	-0.1008 (-1.74)*	-0.1008 (-1.73)*	-0.1766 (-2.49)**	-0.1892 (-2.58)***
PM25	0.1085 (1.40)	0.1050 (1.35)	0.1763 (2.02)**	0.1781 (2.03)**
Log Equivalised Household Income	0.0848 (2.67)***	0.0780 (2.44)**	0.1138 (2.51)**	0.1076 (2.36)**
Age	-0.0573 (-4.61)***	-0.0579 (-4.68)***	-0.0663 (-4.66)***	-0.0658 (-4.63)***
Age (squared)	0.0005 (3.26)***	0.0005 (3.31)***	0.0005 (3.31)***	0.0005 (3.28)***
Female (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Male	-0.0586 (-1.00)	-0.0596 (-1.02)	-0.1071 (-1.53)	-0.1125 (-1.62)

Married	0.4590 (5.43)***	0.4591 (5.39)***	0.4162 (4.03)***	0.4136 (4.00)***
Divorced	0.5786 (3.76)***	0.5651 (3.65)***	0.8025 (4.78)***	0.7597 (4.51)***
Widowed	0.3790 (2.31)**	0.3303 (2.02)**	0.5992 (3.09)***	0.5199 (2.71)***
Separated	-0.0277 (-0.11)	-0.0235 (-0.09)	0.0343 (0.12)	0.0308 (0.11)
Single (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: A Level or GCSE	-0.3483 (-3.00)***	-0.3550 (-3.06)***	-0.1260 (-0.89)	-0.1445 (-1.02)
Education: Other qualification	-0.2231 (-1.55)	-0.2280 (-1.56)	-0.1521 (-0.86)	-0.1055 (-0.58)
Education: Degree or higher	-0.2073 (-1.80)*	-0.2161 (-1.86)*	-0.0448 (-0.32)	-0.0603 (-0.43)
Education: Unknown	-0.1053 (-0.43)	-0.1549 (-0.62)	0.4379 (1.11)	0.3308 (0.88)
Self employed	0.0265 (0.19)	0.0270 (0.19)	-0.0071 (-0.04)	-0.0148 (-0.08)
In paid employment	0.0921 (0.78)	0.0969 (0.83)	0.0469 (0.29)	0.0331 (0.21)
Unemployed (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Retired	0.5390 (2.78)***	0.5865 (3.03)***	0.5529 (2.38)**	0.6208 (2.67)***
Maternity leave	0.1301 (0.31)	0.1269 (0.30)	0.4939 (1.76)*	0.4689 (1.64)
Looking after family	0.2052 (1.28)	0.2140 (1.34)	0.1050 (0.51)	0.1017 (0.50)
Full-time student	-0.0175 (-0.10)	-0.0240 (-0.14)	-0.0999 (-0.41)	-0.1129 (-0.47)
Long-term sick/ disabled	0.4229 (1.77)*	0.4260 (1.78)*	0.4037 (1.37)	0.4117 (1.42)
Gov. training scheme	0.5636 (0.58)	0.5772 (0.59)	-0.4261 (-0.51)	-0.4208 (-0.48)
Unpaid in family business	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)

Apprenticeship	-1.6805 (-1.39)	-1.6907 (-1.44)	1.7685 (4.42)***	1.6708 (4.14)***
Employment: Other	0.2305 (0.57)	0.2472 (0.61)	0.4175 (0.79)	0.4369 (0.81)
Not Urban Area (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Urban Area	-0.1861 (-1.05)	-0.1863 (-1.02)	-0.1732 (-0.70)	-0.1173 (-0.46)
No children (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Number of children: 1	-0.1095 (-1.02)	-0.1117 (-1.03)	-0.0609 (-0.50)	-0.0632 (-0.52)
Number of children: 2	-0.0427 (-0.46)	-0.0354 (-0.38)	0.0162 (0.14)	0.0244 (0.21)
Number of children: 3	0.0125 (0.10)	0.0217 (0.18)	0.1763 (1.22)	0.1919 (1.34)
Number of children: 4	0.2928 (1.10)	0.3061 (1.15)	0.8538 (2.06)**	0.8800 (2.13)**
Number of children: 5 or more	0.2983 (0.75)	0.3400 (0.88)	-0.1911 (-0.29)	-0.0925 (-0.15)
Religious: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.0815 (1.31)	0.0771 (1.22)	0.0646 (0.87)	0.0518 (0.70)
Religious: Unknown	0.0929 (0.65)	0.1080 (0.76)	-0.0756 (-0.35)	-0.0320 (-0.15)
Carer: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.1784 (-1.36)	-0.1970 (-1.49)	-0.0841 (-0.68)	-0.1180 (-0.94)
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	-0.0088 (-0.10)	-0.0155 (-0.18)	-0.1071 (-0.96)	-0.1154 (-1.02)
Homeownership: Shared ownership	-0.1855 (-0.36)	-0.2476 (-0.47)	-0.3743 (-0.45)	-0.4352 (-0.53)
Homeownership: Rented	-0.1534 (-1.63)	-0.1709 (-1.79)*	-0.2720 (-2.21)**	-0.2968 (-2.35)**

Homeownership: Rent free	0.6083 (2.34)**	0.6136 (2.32)**	0.5368 (1.60)	0.5372 (1.58)
Homeownership: Other	-0.4500 (-0.85)	-0.4693 (-0.88)	-0.7774 (-1.48)	-0.8054 (-1.54)
Homeownership: Missing	-0.2335 (-0.69)	-0.2482 (-0.72)	-0.9448 (-2.40)**	-0.9618 (-2.39)**
House Move: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2347 (3.83)***	0.2264 (3.69)***	0.1995 (2.65)***	0.1814 (2.42)**
House Move: Unknown	-0.0166 (-0.05)	-0.0325 (-0.09)	0.0456 (0.09)	0.0388 (0.08)
Ethnicity: White (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Ethnicity: Mixed	0.2252 (1.97)**	0.2048 (1.79)*	0.3561 (2.56)**	0.3269 (2.34)**
Ethnicity: Asian	0.0251 (0.25)	0.0246 (0.24)	0.1303 (1.01)	0.1241 (0.96)
Ethnicity: Black	0.1292 (1.17)	0.1078 (0.99)	0.1336 (0.92)	0.0932 (0.67)
Ethnicity: Other	0.3745 (1.64)	0.3572 (1.56)	0.9234 (3.44)***	0.8898 (3.36)***
Ethnicity: Unknown	-0.1098 (-0.34)	-0.1131 (-0.34)	0.0779 (0.19)	0.0451 (0.11)
Wave: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Wave: 2	0.1592 (1.24)	0.1620 (1.26)	0.0416 (0.20)	0.0688 (0.33)
Wave: 3	0.0637 (0.49)	0.0713 (0.54)	-0.1898 (-1.10)	-0.1705 (-0.99)
Wave: 4	-0.0015 (-0.01)	-0.0054 (-0.05)	-0.3985 (-2.46)**	-0.3993 (-2.49)**
Wave: 5	0.0254 (0.20)	0.0106 (0.08)	-0.3306 (-1.96)*	-0.3432 (-2.04)**
Wave: 6	0.1913 (1.36)	0.1772 (1.26)	-0.1212 (-0.88)	-0.1270 (-0.92)
Wave: 7	0.3544 (2.17)**	0.3489 (2.15)**	0.1088 (0.88)	0.1051 (0.86)
Wave: 8	0.2804 (1.85)*	0.2861 (1.89)*	0.0000 (.)	0.0000 (.)

Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Interview month: 2	0.1805 (1.41)	0.1545 (1.20)	0.1027 (0.62)	0.0762 (0.47)
Interview month: 3	0.0023 (0.02)	-0.0290 (-0.20)	0.0017 (0.01)	-0.0314 (-0.17)
Interview month: 4	0.1036 (0.81)	0.0940 (0.73)	0.1557 (0.99)	0.1677 (1.07)
Interview month: 5	-0.1707 (-1.13)	-0.1353 (-0.89)	-0.0474 (-0.26)	0.0159 (0.09)
Interview month: 6	0.1276 (0.95)	0.1276 (0.95)	0.1531 (0.95)	0.1704 (1.06)
Interview month: 7	0.3571 (2.84)***	0.3437 (2.75)***	0.3651 (2.44)**	0.3545 (2.40)**
Interview month: 8	0.2282 (1.61)	0.2046 (1.44)	0.1882 (1.13)	0.1759 (1.05)
Interview month: 9	0.1779 (1.37)	0.1586 (1.23)	0.0543 (0.31)	0.0422 (0.24)
Interview month: 10	0.0475 (0.38)	0.0438 (0.35)	0.0218 (0.14)	0.0298 (0.19)
Interview month: 11	0.0643 (0.52)	0.0625 (0.50)	0.0007 (0.00)	0.0071 (0.05)
Interview month: 12	0.1921 (1.35)	0.1832 (1.29)	0.1996 (1.13)	0.2045 (1.15)
Aviation related occupation (dummy)	-0.2287 (-0.60)	-0.2248 (-0.59)	-0.3699 (-0.63)	-0.3961 (-0.68)
Constant	-17.1197 (-1.46)	-20.5579 (-1.74)*	-18.7555 (-1.25)	-20.3657 (-1.35)
N	3025	3049	1876	1891
Adjusted R squared	0.305	0.304	0.315	0.315

t statistics in parentheses; p<0.1, ** p<0.05, *** p<0.01

Table A1: Impact of daytime aviation noise on Life Satisfaction, parametric specification.

9.2 Night-Time Noise

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq8hr; Insulation Not Eligible	0.2044 (0.19)	0.7685 (0.72)
LAeq8hr; Insulation Eligible	0.0911 (0.09)	0.6194 (0.63)
LAeq8hr (squared); Insulation Not Eligible	-0.0034 (-0.32)	-0.0089 (-0.85)
LAeq8hr (squared); Insulation Eligible	-0.0010 (-0.12)	-0.0058 (-0.67)
SF-12: Physical health	0.0585 (1.23)	0.0670 (1.45)
SF-12: Physical health (squared)	-0.0003 (-0.65)	-0.0005 (-0.87)
SF-12: Mental health	0.1087 (3.30)***	0.1077 (3.15)***
SF-12: Mental health (squared)	-0.0004 (-1.06)	-0.0004 (-1.09)
House Prices	0.0000 (0.38)	0.0000 (0.62)
NO2	-0.1658 (-2.05)**	-0.1126 (-1.40)
NOx	0.0641 (2.04)**	0.0435 (1.33)
PM10	-0.0973 (-0.60)	-0.0532 (-0.31)
PM25	0.1088 (0.56)	0.0689 (0.36)
Log Equivalised Household Income	0.0159 (0.26)	0.0043 (0.07)
Age	-0.1399 (-5.37)***	-0.1509 (-6.18)***
Age (squared)	0.0013 (4.90)***	0.0014 (5.61)***
Female (reference)	0.0000 (.)	0.0000 (.)
Male	-0.2532 (-2.19)**	-0.2557 (-2.23)**

Married	0.7195 (3.32)***	0.7684 (3.64)***
Divorced	0.9520 (2.66)***	0.8605 (2.46)**
Widowed	0.9464 (2.45)**	0.7288 (2.01)**
Separated	0.1361 (0.22)	0.2314 (0.38)
Single (reference)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)
Education: A Level or GCSE	-0.0908 (-0.37)	-0.2190 (-0.92)
Education: Other qualification	-0.0722 (-0.25)	-0.2536 (-0.85)
Education: Degree or higher	-0.0861 (-0.34)	-0.2231 (-0.92)
Education: Unknown	0.1159 (0.24)	-0.0284 (-0.06)
Self employed	0.3719 (1.11)	0.4051 (1.21)
In paid employment	0.3487 (1.21)	0.3697 (1.30)
Unemployed (reference)	0.0000 (.)	0.0000 (.)
Retired	0.5280 (1.36)	0.5967 (1.54)
Maternity leave	0.8382 (1.51)	0.7837 (1.46)
Looking after family	0.2350 (0.49)	0.2854 (0.61)
Full-time student	0.2204 (0.56)	0.2141 (0.57)
Long-term sick/ disabled	0.1726 (0.35)	0.2427 (0.51)
Gov. training scheme	0.0000 (.)	0.0000 (.)
Unpaid in family business	0.0000 (.)	0.0000 (.)

Apprenticeship	0.3159 (0.58)	0.0683 (0.13)
Other	-0.9378 (-1.90)*	-0.9640 (-1.95)*
Not Urban Area (reference)	0.0000 (.)	0.0000 (.)
Urban Area	-0.2925 (-0.78)	-0.0612 (-0.16)
No children (reference)	0.0000 (.)	0.0000 (.)
Number of children: 1	0.0443 (0.21)	0.0229 (0.11)
Number of children: 2	-0.0666 (-0.30)	-0.0735 (-0.32)
Number of children: 3	-0.0034 (-0.01)	-0.0561 (-0.16)
Number of children: 4	-0.4070 (-0.68)	-0.5920 (-0.97)
Religious: No (reference)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.2621 (1.85)*	0.2341 (1.64)
Religious: Unknown	-0.0976 (-0.28)	-0.1225 (-0.35)
Carer: No (reference)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.0043 (-0.02)	0.0157 (0.09)
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	0.2390 (1.19)	0.2442 (1.20)
Homeownership: Shared ownership	0.0096 (0.01)	0.2306 (0.33)
Homeownership: Rented	0.2506 (1.09)	0.2886 (1.29)
Homeownership: Rent free	1.0314 (1.63)	0.7922 (1.26)
Homeownership: Other	-0.0229 (-0.05)	0.0655 (0.14)

Homeownership: Missing	0.2884 (0.70)	0.3011 (0.70)
House Move: No (reference)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2991 (2.20)**	0.3114 (2.27)**
House Move: Unknown	-0.9739 (-2.20)**	-1.0381 (-2.15)**
Ethnicity: White (reference)	0.0000 (.)	0.0000 (.)
Ethnicity: Mixed	0.6008 (2.14)**	0.6657 (2.37)**
Ethnicity: Asian	0.0628 (0.39)	0.1147 (0.70)
Ethnicity: Black	-0.0735 (-0.27)	-0.0619 (-0.23)
Ethnicity: Other	1.0640 (2.13)**	1.0973 (2.34)**
Ethnicity: Unknown	0.8367 (3.14)***	0.9422 (3.50)***
Wave: 1 (reference)	0.0000 (.)	0.0000 (.)
Wave: 2	0.0000 (.)	0.0000 (.)
Wave: 3	0.0000 (.)	0.0000 (.)
Wave: 4	-0.8989 (-1.33)	-0.9080 (-1.37)
Wave: 5	-1.1167 (-1.69)*	-1.1003 (-1.71)*
Wave: 6	-0.8817 (-1.24)	-0.8079 (-1.17)
Wave: 7	-0.8682 (-1.18)	-0.7851 (-1.10)
Wave: 8	-1.1013 (-1.53)	-1.0227 (-1.46)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)
Interview month: 2	0.3556 (1.13)	0.2685 (0.88)

Interview month: 3	0.0344 (0.12)	-0.1522 (-0.54)
Interview month: 4	0.2415 (0.87)	0.2572 (0.95)
Interview month: 5	0.2770 (0.95)	0.4655 (1.62)
Interview month: 6	0.3320 (1.13)	0.4882 (1.69)*
Interview month: 7	0.8145 (2.92)***	0.8353 (3.06)***
Interview month: 8	0.5479 (1.63)	0.5873 (1.78)*
Interview month: 9	0.4172 (1.53)	0.4846 (1.81)*
Interview month: 10	0.1869 (0.62)	0.1971 (0.66)
Interview month: 11	-0.1030 (-0.31)	-0.0579 (-0.18)
Interview month: 12	0.1449 (0.55)	0.1619 (0.62)
Aviation related occupation (dummy)	0.3408 (0.59)	0.2579 (0.46)
Constant	1.1788 (0.04)	-13.5476 (-0.48)
N	656	657
Adjusted R squared	0.409	0.420

t statistics in parentheses; p<0.1, ** p<0.05, *** p<0.01

Table A2: Impact of night-time aviation noise on Life Satisfaction, parametric specification.

10. Appendix B: Counterfactual Analysis – Full Tables

10.1 Daytime Noise

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq16hr (control); Insulation Not Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (control); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 1); Insulation Not Eligible	0.0038 (0.05)	-0.0039 (-0.05)	-0.0159 (-0.18)	-0.0170 (-0.19)
LAeq16hr (Quintile 1); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 2); Insulation Not Eligible	0.0296 (0.39)	0.0251 (0.33)	0.1211 (1.32)	0.1177 (1.29)
LAeq16hr (Quintile 2); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 3); Insulation Not Eligible	0.0170 (0.20)	0.0357 (0.43)	0.0905 (0.93)	0.1195 (1.22)
LAeq16hr (Quintile 3); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 4); Insulation Not Eligible	-0.1751 (-2.29)**	-0.1514 (-2.00)**	-0.2185 (-2.24)**	-0.1754 (-1.83)*
LAeq16hr (Quintile 4); Insulation Eligible	-0.1240 (-0.45)	-0.0704 (-0.25)	0.0846 (0.25)	0.0359 (0.11)
LAeq16hr (Quintile 5); Insulation Not Eligible	-0.2551 (-2.42)**	-0.2630 (-2.42)**	-0.2336 (-1.82)*	-0.2148 (-1.60)
LAeq16hr (Quintile 5); Insulation Eligible	0.2582 (2.29)**	0.3097 (2.75)***	0.2724 (2.15)**	0.3738 (2.99)***
SF-12: Physical health	0.0204 (2.88)***	0.0202 (2.87)***	0.0124 (0.66)	0.0122 (0.64)
SF-12: Physical health (squared)	0.0001 (0.87)	0.0001 (0.91)	0.0001 (0.45)	0.0001 (0.46)
SF-12: Mental health	0.1038 (15.78)***	0.1052 (16.12)***	0.0907 (4.19)***	0.0948 (4.38)***
SF-12: Mental health (squared)	-0.0004 (-5.82)***	-0.0004 (-6.08)***	-0.0000 (-0.19)	-0.0001 (-0.41)
House Prices	-0.0000 (-0.28)	-0.0000 (-0.48)	-0.0000 (-0.45)	-0.0000 (-0.71)
NO2	-0.0079 (-0.69)	-0.0050 (-0.43)	-0.0075 (-0.53)	-0.0052 (-0.35)

NOx	0.0022 (0.45)	0.0011 (0.21)	0.0014 (0.23)	-0.0000 (-0.00)
PM10	-0.0028 (-0.14)	0.0014 (0.07)	-0.0038 (-0.14)	0.0037 (0.14)
PM25	0.0109 (0.41)	0.0050 (0.19)	0.0277 (0.89)	0.0188 (0.61)
Log Equivalised Household Income	0.0871 (6.37)***	0.0861 (6.27)***	0.1052 (6.44)***	0.1039 (6.40)***
Age	-0.0299 (-6.82)***	-0.0310 (-7.06)***	-0.0273 (-5.01)***	-0.0283 (-5.19)***
Age (squared)	0.0003 (5.45)***	0.0003 (5.67)***	0.0002 (3.49)***	0.0002 (3.69)***
Female (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Male	-0.1162 (-5.85)***	-0.1203 (-6.06)***	-0.1491 (-6.33)***	-0.1579 (-6.70)***
Married	0.2459 (7.98)***	0.2436 (7.94)***	0.2227 (6.16)***	0.2151 (5.97)***
Divorced	0.0077 (0.15)	0.0082 (0.16)	0.0145 (0.25)	0.0096 (0.17)
Widowed	0.0291 (0.47)	0.0209 (0.34)	0.0142 (0.19)	-0.0008 (-0.01)
Separated	0.0022 (0.03)	-0.0092 (-0.11)	-0.0158 (-0.16)	-0.0291 (-0.29)
Single (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: A level or GCSE	-0.1890 (-4.27)***	-0.1916 (-4.26)***	-0.1655 (-2.91)***	-0.1622 (-2.79)***
Education: Other qualification	-0.1912 (-3.39)***	-0.2088 (-3.67)***	-0.2122 (-3.02)***	-0.2208 (-3.12)***
Education: Degree or higher	-0.1576 (-3.58)***	-0.1649 (-3.70)***	-0.1499 (-2.66)***	-0.1523 (-2.66)***
Education: Unknown	0.1811 (2.20)**	0.1642 (2.00)**	0.2380 (1.74)*	0.2191 (1.59)
Self employed	0.0994 (1.77)*	0.0915 (1.63)	0.1059 (1.54)	0.0898 (1.31)
In paid employment	0.1550 (3.25)***	0.1461 (3.07)***	0.1210 (1.93)*	0.1077 (1.72)*

Unemployed (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Retired	0.5007 (8.14)***	0.4949 (8.04)***	0.4783 (6.26)***	0.4668 (6.11)***
Maternity leave	0.4870 (4.20)***	0.4837 (4.17)***	0.4669 (3.34)***	0.4580 (3.28)***
Looking after family	0.2285 (3.73)***	0.2056 (3.30)***	0.2125 (2.73)***	0.1689 (2.10)**
Full-time student	0.2845 (4.62)***	0.2627 (4.28)***	0.2693 (3.25)***	0.2462 (2.99)***
Long-term sick/ disabled	0.0118 (0.14)	0.0050 (0.06)	0.0495 (0.43)	0.0322 (0.28)
Gov. training scheme	-0.1854 (-0.38)	0.0815 (0.16)	-0.5615 (-1.35)	-0.1652 (-0.32)
Unpaid in family business	0.3131 (0.85)	0.2993 (0.82)	0.5120 (1.25)	0.4615 (1.15)
Apprenticeship	-0.0967 (-0.20)	-0.1319 (-0.28)	0.1295 (0.50)	0.0863 (0.33)
Employment: Other	-0.1579 (-0.84)	-0.1420 (-0.76)	-0.0626 (-0.31)	-0.0528 (-0.26)
Not Urban Area (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Urban Area	-0.1115 (-2.32)**	-0.1463 (-2.83)***	-0.1498 (-2.52)**	-0.1677 (-2.58)***
No children (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Number of children: 1	-0.0525 (-1.64)	-0.0475 (-1.48)	-0.0046 (-0.12)	0.0014 (0.04)
Number of children: 2	0.0216 (0.70)	0.0259 (0.83)	0.0407 (1.08)	0.0515 (1.36)
Number of children: 3	0.1168 (2.44)**	0.1288 (2.60)***	0.1948 (3.18)***	0.2094 (3.26)***
Number of children: 4	-0.0418 (-0.24)	-0.0249 (-0.15)	0.2127 (0.93)	0.2189 (0.96)
Number of children: 5 or more	-0.0005 (-0.00)	-0.0175 (-0.09)	-0.0199 (-0.07)	-0.0065 (-0.02)
Religious: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.0276 (1.24)	0.0217 (0.97)	0.0324 (1.26)	0.0248 (0.96)

Religious: Unknown	0.0358 (0.87)	0.0350 (0.85)	0.0316 (0.48)	0.0285 (0.43)
Carer: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.2004 (-4.49)***	-0.1951 (-4.30)***	-0.1909 (-3.51)***	-0.1904 (-3.41)***
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	-0.0520 (-1.87)*	-0.0504 (-1.80)*	-0.0463 (-1.41)	-0.0451 (-1.36)
Homeownership: Shared ownership	-0.1348 (-1.01)	-0.1035 (-0.77)	-0.0714 (-0.39)	-0.0572 (-0.31)
Homeownership: Rented	-0.1213 (-3.84)***	-0.1227 (-3.87)***	-0.1250 (-3.28)***	-0.1295 (-3.38)***
Homeownership: Rent free	-0.0465 (-0.39)	-0.0682 (-0.57)	0.0164 (0.13)	-0.0239 (-0.19)
Homeownership: Other	0.1235 (0.55)	0.1208 (0.53)	0.1771 (0.69)	0.1697 (0.66)
Homeownership: Missing	-0.1835 (-1.76)*	-0.1776 (-1.70)*	-0.1973 (-1.47)	-0.1979 (-1.48)
House Move: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2382 (11.36)***	0.2366 (11.31)***	0.2140 (8.32)***	0.2114 (8.25)***
House Move: Unknown	0.0497 (0.49)	0.0377 (0.37)	-0.0410 (-0.29)	-0.0596 (-0.43)
Ethnicity: White (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Ethnicity: Mixed	-0.0233 (-0.50)	-0.0196 (-0.43)	-0.0094 (-0.17)	-0.0067 (-0.12)
Ethnicity: Asian	-0.0271 (-0.93)	-0.0220 (-0.75)	-0.0802 (-2.26)**	-0.0738 (-2.06)**
Ethnicity: Black	-0.0629 (-1.80)*	-0.0666 (-1.91)*	-0.1208 (-2.86)***	-0.1252 (-2.95)***
Ethnicity: Other	-0.0379 (-0.57)	-0.0444 (-0.67)	-0.0548 (-0.66)	-0.0613 (-0.73)
Ethnicity: Unknown	-0.2597 (-2.70)***	-0.2776 (-2.91)***	-0.3271 (-2.48)**	-0.3459 (-2.64)***
Wave: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)

Wave: 2	0.0177 (0.41)	0.0166 (0.38)	-0.1939 (-2.93)***	-0.2026 (-3.06)***
Wave: 3	-0.0119 (-0.27)	-0.0049 (-0.11)	-0.2305 (-4.18)***	-0.2292 (-4.18)***
Wave: 4	-0.0859 (-2.00)**	-0.0851 (-1.97)**	-0.2728 (-5.15)***	-0.2752 (-5.25)***
Wave: 5	-0.0485 (-1.07)	-0.0443 (-0.98)	-0.2452 (-4.83)***	-0.2437 (-4.84)***
Wave: 6	0.1260 (2.74)***	0.1233 (2.68)***	-0.0761 (-1.75)*	-0.0841 (-1.95)*
Wave: 7	0.1906 (3.73)***	0.1922 (3.78)***	0.0163 (0.40)	0.0081 (0.20)
Wave: 8	0.1495 (3.09)***	0.1559 (3.23)***	0.0000 (.)	0.0000 (.)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Interview month: 2	-0.0793 (-1.86)*	-0.0723 (-1.71)*	-0.1060 (-2.02)**	-0.1026 (-1.98)**
Interview month: 3	-0.0314 (-0.74)	-0.0252 (-0.59)	-0.0732 (-1.38)	-0.0657 (-1.25)
Interview month: 4	-0.0408 (-0.94)	-0.0384 (-0.88)	-0.0463 (-0.89)	-0.0452 (-0.87)
Interview month: 5	-0.0864 (-1.91)*	-0.0801 (-1.76)*	-0.0836 (-1.54)	-0.0855 (-1.56)
Interview month: 6	-0.0428 (-0.95)	-0.0578 (-1.28)	0.0299 (0.55)	0.0079 (0.14)
Interview month: 7	-0.0139 (-0.31)	-0.0218 (-0.49)	0.0196 (0.37)	0.0058 (0.11)
Interview month: 8	0.0341 (0.79)	0.0290 (0.67)	0.0262 (0.50)	0.0106 (0.20)
Interview month: 9	0.0187 (0.42)	0.0086 (0.19)	0.0106 (0.20)	-0.0056 (-0.10)
Interview month: 10	0.0205 (0.47)	0.0169 (0.38)	0.0070 (0.13)	0.0030 (0.06)
Interview month: 11	-0.0143 (-0.33)	-0.0065 (-0.15)	-0.0516 (-0.96)	-0.0479 (-0.89)
Interview month: 12	-0.0406 (-0.84)	-0.0478 (-0.99)	-0.0226 (-0.39)	-0.0381 (-0.66)
Aviation related occupation (dummy)	-0.2197 (-1.12)	-0.2298 (-1.18)	-0.1379 (-0.70)	-0.1480 (-0.76)

Constant	-0.1545	0.0874	-0.1105	0.1980
	(-0.52)	(0.23)	(-0.17)	(0.30)
N	27899	28141	17773	17935
Adjusted R squared	0.298	0.301	0.311	0.314

t statistics in parentheses; p<0.1, ** p<0.05, *** p<0.01

Table B1: Impact of daytime aviation noise on Life Satisfaction, compared to a counterfactual of no aviation noise exposure.

10.2 Night-Time Noise

Dependent Variable: Life Satisfaction	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects	IV; Local Authority Fixed Effects	IV; Shortward Fixed Effects
LAeq8hr (control); Insulation Not Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (control); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 1); Insulation Not Eligible	-0.1752 (-1.24)	-0.1457 (-1.02)	-0.2706 (-1.64)	-0.2387 (-1.42)
LAeq8hr (Quintile 1); Insulation Eligible	-0.6797 (-0.75)	-0.6496 (-0.72)	-1.2004 (-1.11)	-1.1873 (-1.09)
LAeq8hr (Quintile 2); Insulation Not Eligible	-0.0046 (-0.04)	0.0178 (0.15)	-0.0245 (-0.19)	0.0024 (0.02)
LAeq8hr (Quintile 2); Insulation Eligible	0.5372 (2.41)**	0.5596 (2.54)**	0.5345 (2.03)**	0.5499 (2.11)**
LAeq8hr (Quintile 3); Insulation Not Eligible	-0.6826 (-3.99)***	-0.6185 (-3.91)***	-0.6415 (-3.46)***	-0.5779 (-3.46)***
LAeq8hr (Quintile 3); Insulation Eligible	0.0932 (0.29)	0.0784 (0.24)	-0.0073 (-0.02)	-0.0307 (-0.09)
LAeq8hr (Quintile 4); Insulation Not Eligible	-0.2676 (-1.36)	-0.2386 (-1.21)	-0.1860 (-1.01)	-0.1376 (-0.73)
LAeq8hr (Quintile 4); Insulation Eligible	0.2612 (1.85)*	0.3480 (2.50)**	0.2180 (1.58)	0.3227 (2.43)**
LAeq8hr (Quintile 5); Insulation Not Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 5); Insulation Eligible	0.1895 (1.11)	0.2040 (1.21)	0.4015 (2.00)**	0.4178 (2.11)**
SF-12: Physical health	0.0192 (2.31)**	0.0193 (2.32)**	-0.0055 (-0.28)	-0.0047 (-0.24)
SF-12: Physical health (squared)	0.0001 (0.88)	0.0001 (0.87)	0.0003 (1.41)	0.0003 (1.35)
SF-12: Mental health	0.1037 (13.71)***	0.1051 (14.04)***	0.0877 (4.31)***	0.0859 (4.27)***
SF-12: Mental health (squared)	-0.0004 (-5.02)***	-0.0004 (-5.26)***	-0.0000 (-0.11)	-0.0000 (-0.03)
House Prices	-0.0000 (-0.12)	-0.0000 (-0.27)	0.0000 (0.39)	0.0000 (0.09)
NO2	-0.0053 (-0.36)	-0.0067 (-0.46)	-0.0126 (-0.75)	-0.0145 (-0.86)

NOx	-0.0008 (-0.12)	-0.0006 (-0.10)	0.0026 (0.36)	0.0026 (0.36)
PM10	0.0286 (0.86)	0.0372 (1.11)	0.0314 (0.83)	0.0435 (1.15)
PM25	-0.0075 (-0.24)	-0.0131 (-0.42)	0.0030 (0.08)	-0.0046 (-0.13)
Log Equivalised Household Income	0.0854 (5.50)***	0.0853 (5.50)***	0.0882 (5.32)***	0.0870 (5.29)***
Age	-0.0337 (-6.45)***	-0.0351 (-6.75)***	-0.0310 (-5.11)***	-0.0324 (-5.37)***
Age (squared)	0.0003 (5.76)***	0.0003 (6.10)***	0.0003 (4.13)***	0.0003 (4.41)***
Female (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Male	-0.1162 (-4.73)***	-0.1187 (-4.88)***	-0.1279 (-4.71)***	-0.1335 (-4.95)***
Married	0.2780 (7.44)***	0.2712 (7.29)***	0.2077 (5.14)***	0.2014 (4.99)***
Divorced	0.0515 (0.85)	0.0475 (0.80)	-0.0060 (-0.09)	-0.0095 (-0.15)
Widowed	0.0647 (0.85)	0.0465 (0.61)	0.0023 (0.03)	-0.0135 (-0.16)
Separated	-0.0218 (-0.22)	-0.0332 (-0.33)	-0.1137 (-1.15)	-0.1199 (-1.20)
Single (reference) (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: A level or GCSE	-0.1358 (-2.45)**	-0.1463 (-2.63)***	-0.1120 (-1.73)*	-0.1240 (-1.91)*
Education: Other qualification	-0.1635 (-2.24)**	-0.1874 (-2.57)**	-0.1208 (-1.50)	-0.1378 (-1.71)*
Education: Degree or higher	-0.1028 (-1.84)*	-0.1130 (-2.02)**	-0.0913 (-1.42)	-0.1044 (-1.62)
Education: Unknown	0.1138 (1.19)	0.0918 (0.96)	0.1049 (0.78)	0.0816 (0.60)
Self employed	0.0604 (0.84)	0.0572 (0.80)	0.1343 (1.73)*	0.1218 (1.58)
In paid employment	0.1013 (1.62)	0.1030 (1.66)*	0.1112 (1.56)	0.1036 (1.46)

Unemployed (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Retired	0.4249 (5.47)***	0.4228 (5.46)***	0.4558 (5.19)***	0.4464 (5.11)***
Maternity leave	0.4644 (2.60)***	0.4780 (2.69)***	0.4176 (2.03)**	0.4225 (2.08)**
Looking after family	0.1899 (2.34)**	0.1852 (2.29)**	0.1957 (2.12)**	0.1696 (1.84)*
Full-time student	0.3200 (3.98)***	0.2999 (3.78)***	0.2963 (3.13)***	0.2753 (2.97)***
Long-term sick/ disabled	-0.0042 (-0.04)	-0.0045 (-0.04)	0.0685 (0.51)	0.0526 (0.39)
Gov. training scheme	-1.1842 (-1.53)	-1.2299 (-1.60)	-1.4700 (-1.93)*	-1.5060 (-1.99)**
Unpaid in family business	0.2919 (1.16)	0.2682 (1.09)	0.4483 (1.78)*	0.4138 (1.63)
Apprenticeship	0.1519 (0.55)	0.0978 (0.34)	0.0843 (0.31)	0.0293 (0.10)
Employment: other	-0.1621 (-0.71)	-0.1254 (-0.56)	0.0990 (0.54)	0.1202 (0.67)
Not Urban Area (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Urban Area	-0.0923 (-1.62)	-0.1215 (-1.98)**	-0.1455 (-2.19)**	-0.1600 (-2.22)**
No children (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Number of children: 1	-0.0262 (-0.61)	-0.0203 (-0.48)	0.0150 (0.33)	0.0238 (0.52)
Number of children: 2	0.0295 (0.74)	0.0319 (0.79)	0.0625 (1.39)	0.0673 (1.48)
Number of children: 3	0.1347 (2.11)**	0.1534 (2.37)**	0.2008 (2.75)***	0.2287 (3.11)***
Number of children: 4	-0.2230 (-1.22)	-0.2295 (-1.24)	0.2824 (1.30)	0.2733 (1.23)
Number of children: 5 or more	0.0778 (0.31)	0.0423 (0.17)	0.3351 (1.27)	0.3229 (1.26)
Religious: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.0144 (0.53)	0.0104 (0.38)	0.0277 (0.95)	0.0189 (0.65)

Religious: Unknown	0.1124 (1.64)	0.1095 (1.61)	0.0006 (0.01)	-0.0005 (-0.00)
Carer: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.1874 (-3.29)***	-0.1741 (-3.04)***	-0.1753 (-2.74)***	-0.1597 (-2.49)**
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	-0.0407 (-1.18)	-0.0323 (-0.93)	-0.0258 (-0.68)	-0.0175 (-0.46)
Homeownership: Shared ownership	0.0917 (0.55)	0.1105 (0.66)	0.1348 (0.66)	0.1504 (0.74)
Homeownership: Rented	-0.0679 (-1.74)*	-0.0621 (-1.60)	-0.0632 (-1.46)	-0.0592 (-1.37)
Homeownership: Rent free	0.2032 (1.20)	0.1737 (1.05)	0.1774 (1.07)	0.1307 (0.79)
Homeownership: Other	0.6197 (2.61)***	0.6325 (2.59)***	0.7572 (2.25)**	0.7656 (2.27)**
Homeownership: Missing	-0.1515 (-1.34)	-0.1431 (-1.27)	-0.1230 (-0.91)	-0.1161 (-0.86)
House Move: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2672 (9.90)***	0.2632 (9.83)***	0.2372 (7.87)***	0.2341 (7.84)***
House Move: Unknown	0.0440 (0.38)	0.0293 (0.25)	0.0858 (0.57)	0.0684 (0.46)
Ethnicity: White (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Ethnicity: Mixed	-0.0719 (-1.22)	-0.0629 (-1.10)	-0.0624 (-0.99)	-0.0547 (-0.88)
Ethnicity: Asian	0.0044 (0.12)	0.0075 (0.21)	-0.0721 (-1.79)*	-0.0736 (-1.81)*
Ethnicity: Black	-0.0559 (-1.28)	-0.0670 (-1.54)	-0.1332 (-2.76)***	-0.1470 (-3.05)***
Ethnicity: Other	-0.1035 (-1.18)	-0.1396 (-1.62)	-0.0711 (-0.69)	-0.0983 (-0.95)
Ethnicity: Unknown	-0.0366 (-0.39)	-0.0583 (-0.64)	-0.0650 (-0.55)	-0.0870 (-0.75)
Wave: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)

Wave: 2	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Wave: 3	0.0000 (.)	0.0000 (.)	-0.0333 (-0.19)	-0.0605 (-0.36)
Wave: 4	-0.2987 (-2.43)**	-0.2938 (-2.40)**	-0.2231 (-3.72)***	-0.2243 (-3.76)***
Wave: 5	-0.2956 (-2.43)**	-0.2829 (-2.34)**	-0.2205 (-4.34)***	-0.2166 (-4.31)***
Wave: 6	-0.1075 (-0.87)	-0.1049 (-0.86)	-0.0526 (-1.18)	-0.0569 (-1.30)
Wave: 7	-0.0506 (-0.40)	-0.0473 (-0.38)	0.0309 (0.76)	0.0271 (0.67)
Wave: 8	-0.0773 (-0.61)	-0.0730 (-0.58)	0.0000 (.)	0.0000 (.)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Interview month: 2	-0.0778 (-1.59)	-0.0646 (-1.33)	-0.0802 (-1.39)	-0.0659 (-1.16)
Interview month: 3	-0.1221 (-2.34)**	-0.1137 (-2.20)**	-0.1095 (-1.84)*	-0.1010 (-1.72)*
Interview month: 4	-0.0916 (-1.75)*	-0.0829 (-1.59)	-0.0705 (-1.21)	-0.0577 (-0.99)
Interview month: 5	-0.0737 (-1.31)	-0.0641 (-1.14)	-0.0518 (-0.83)	-0.0435 (-0.70)
Interview month: 6	-0.0285 (-0.51)	-0.0464 (-0.83)	-0.0034 (-0.05)	-0.0162 (-0.25)
Interview month: 7	-0.0382 (-0.70)	-0.0414 (-0.76)	0.0459 (0.79)	0.0382 (0.66)
Interview month: 8	0.0214 (0.41)	0.0217 (0.41)	0.0564 (0.96)	0.0475 (0.80)
Interview month: 9	-0.0018 (-0.03)	-0.0065 (-0.12)	-0.0077 (-0.13)	-0.0147 (-0.25)
Interview month: 10	-0.0348 (-0.65)	-0.0377 (-0.71)	-0.0059 (-0.10)	-0.0071 (-0.11)
Interview month: 11	-0.0230 (-0.45)	-0.0144 (-0.28)	-0.0173 (-0.29)	-0.0056 (-0.09)
Interview month: 12	-0.1150 (-2.01)**	-0.1211 (-2.13)**	-0.0781 (-1.21)	-0.0838 (-1.31)
Aviation related occupation (dummy)	-0.0695 (-0.31)	-0.0758 (-0.36)	-0.2701 (-1.14)	-0.2605 (-1.13)

Constant	-0.1862	-0.1839	0.0808	0.4732
	(-0.48)	(-0.39)	(0.13)	(0.71)
N	17659	17812	13222	13340
Adjusted R squared	0.323	0.327	0.320	0.324

t statistics in parentheses; p<0.1, ** p<0.05, *** p<0.01

Table B2: Impact of night-time aviation noise on Life Satisfaction, compared to a counterfactual of no aviation noise exposure.

11. Appendix C: Demographic Interactions

11.1 Daytime Interactions

Dependent Variable: Life Satisfaction	Male	Marital Status: With Partner	Employed	Education: Degree or higher	Urban Area	Has dependent children	Houseowner: Yes	Ethnicity: White	General health: Poor	Age: Above 30	Age: Above 50	Age: Above 70
LAeq16hr (control); Insulation Not Eligible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
LAeq16hr (control); Insulation Eligible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
LAeq16hr (Quintile 1); Insulation Not Eligible	-0.0356	-0.0806	-0.0199	-0.1085	-0.6035	-0.0480	0.0299	0.0281	-0.0067	-0.1750	-0.0522	-0.0065
	(-0.43)	(-0.90)	(-0.20)	(-1.29)	(-1.74)*	(-0.72)	(0.31)	(0.27)	(-0.11)	(-1.34)	(-0.75)	(-0.11)
LAeq16hr (Quintile 1); Insulation Eligible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
LAeq16hr (Quintile 2); Insulation Not Eligible	0.0090	0.0126	0.0262	-0.0588	0.1401	0.0321	-0.0491	0.1270	0.0162	0.0842	0.0132	0.0093
	(0.11)	(0.15)	(0.24)	(-0.67)	(0.72)	(0.48)	(-0.58)	(1.31)	(0.25)	(0.71)	(0.20)	(0.15)
LAeq16hr (Quintile 2); Insulation Eligible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
LAeq16hr (Quintile 3); Insulation Not Eligible	-0.1067	0.0336	0.0865	-0.1216	0.8809	-0.0086	-0.1275	0.0050	0.0145	-0.1740	-0.1059	-0.0363
	(-0.96)	(0.31)	(0.71)	(-1.07)	(7.02)***	(-0.10)	(-0.99)	(0.05)	(0.20)	(-1.09)	(-1.24)	(-0.50)
LAeq16hr (Quintile 3); Insulation Eligible	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
LAeq16hr (Quintile 4); Insulation Not Eligible	-0.0987	-0.1545	-0.1447	-0.1179	0.3680	-0.1290	-0.2246	-0.0506	-0.0817	0.0142	-0.1186	-0.1791
	(-1.21)	(-1.32)	(-1.40)	(-1.16)	(1.59)	(-1.65)*	(-2.03)**	(-0.48)	(-1.28)	(0.13)	(-1.68)*	(-2.79)***
LAeq16hr (Quintile 4); Insulation Eligible	0.5566	-1.0661	-0.0030	-0.3056	-0.4093	-0.5719	0.4748	-0.1750	-0.0848	-0.1805	0.6357	-0.1982
	(3.09)***	(-1.27)	(-0.01)	(-1.14)	(-1.59)	(-1.85)*	(0.87)	(-0.16)	(-0.30)	(-0.17)	(2.47)**	(-0.69)

LAeq16hr (Quintile 5); Insulation Not Eligible	-0.2186 (-1.68)*	-0.3078 (-1.80)*	-0.0539 (-0.37)	-0.1945 (-1.48)	-0.2571 (-1.87)*	-0.2008 (-1.82)*	-0.0077 (-0.05)	0.0261 (0.24)	-0.0915 (-0.87)	-0.2961 (-1.45)	-0.1814 (-1.50)	-0.1846 (-1.90)*
LAeq16hr (Quintile 5); Insulation Eligible	0.2339 (1.73)*	0.2592 (1.43)	0.3278 (2.37)**	0.2862 (2.29)**	-0.0918 (-0.39)	0.2963 (2.32)**	0.5215 (3.63)***	0.3525 (2.56)**	0.3769 (3.93)***	0.6409 (2.74)***	0.3595 (3.11)***	0.3741 (3.97)***
Log Equivalised Household Income	0.0880 (6.47)***	0.0884 (6.49)***	0.0883 (6.48)***	0.0921 (6.45)***	0.0882 (6.48)***	0.0878 (6.45)***	0.0879 (6.45)***	0.0876 (6.48)***	0.0879 (6.47)***	0.0876 (6.47)***	0.0878 (6.45)***	0.0881 (6.48)***
Age	-0.0300 (-6.80)***	-0.0301 (-6.80)***	-0.0300 (-6.80)***	-0.0302 (-6.81)***	-0.0299 (-6.78)***	-0.0293 (-6.57)***	-0.0301 (-6.81)***	-0.0300 (-6.79)***	-0.0291 (-6.59)***	-0.0330 (-5.68)***	-0.0285 (-6.30)***	-0.0257 (-4.81)***
Age (squared)	0.0003 (5.43)***	0.0003 (5.42)***	0.0003 (5.43)***	0.0003 (5.45)***	0.0003 (5.41)***	0.0003 (5.25)***	0.0003 (5.44)***	0.0003 (5.40)***	0.0003 (5.26)***	0.0003 (4.98)***	0.0003 (5.36)***	0.0002 (3.36)***
Female (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Male	-0.1267 (-6.03)***	-0.1218 (-6.11)***	-0.1231 (-6.19)***	-0.1216 (-6.06)***	-0.1239 (-6.23)***	-0.1234 (-6.20)***	-0.1238 (-6.23)***	-0.1227 (-6.17)***	-0.1216 (-6.10)***	-0.1222 (-6.14)***	-0.1234 (-6.20)***	-0.1245 (-6.26)***
Married	0.2470 (8.10)***	0.3166 (1.51)	0.2463 (8.08)***	0.2395 (7.80)***	0.2471 (8.10)***	0.2504 (8.16)***	0.2435 (7.99)***	0.2475 (8.12)***	0.2419 (7.96)***	0.2460 (8.07)***	0.2493 (8.20)***	0.2488 (8.17)***
Divorced	0.0097 (0.19)	0.0125 (0.25)	0.0105 (0.21)	0.0065 (0.13)	0.0036 (0.07)	0.0123 (0.24)	0.0049 (0.10)	0.0101 (0.20)	0.0061 (0.12)	0.0093 (0.18)	0.0121 (0.24)	0.0101 (0.20)
Widowed	0.0321 (0.51)	0.0332 (0.53)	0.0310 (0.50)	0.0263 (0.42)	0.0305 (0.49)	0.0348 (0.56)	0.0281 (0.45)	0.0338 (0.54)	0.0178 (0.28)	0.0278 (0.44)	0.0244 (0.39)	0.0289 (0.46)
Separated	0.0268 (0.31)	0.0315 (0.37)	0.0196 (0.23)	0.0151 (0.18)	0.0186 (0.22)	0.0275 (0.32)	0.0196 (0.23)	0.0254 (0.30)	0.0173 (0.20)	0.0206 (0.24)	0.0215 (0.25)	0.0240 (0.28)
Single (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)

Education: A level or GCSE	-0.1831 (-4.09)***	-0.1829 (-4.08)***	-0.1798 (-4.01)***	-0.1857 (-4.14)***	-0.1812 (-4.04)***	-0.1827 (-4.07)***	-0.1789 (-4.00)***	-0.1813 (-4.05)***	-0.1858 (-4.15)***	-0.1797 (-4.00)***	-0.1797 (-4.01)***	-0.1805 (-4.03)***
Education: Other qualification	-0.1780 (-3.16)***	-0.1796 (-3.19)***	-0.1756 (-3.11)***	-0.1798 (-3.19)***	-0.1772 (-3.14)***	-0.1790 (-3.18)***	-0.1766 (-3.13)***	-0.1779 (-3.16)***	-0.1823 (-3.23)***	-0.1743 (-3.09)***	-0.1749 (-3.10)***	-0.1788 (-3.17)***
Education: Degree or higher	-0.1485 (-3.33)***	-0.1480 (-3.32)***	-0.1458 (-3.27)***	0.0030 (0.02)	-0.1461 (-3.27)***	-0.1486 (-3.33)***	-0.1460 (-3.27)***	-0.1471 (-3.30)***	-0.1529 (-3.42)***	-0.1459 (-3.27)***	-0.1476 (-3.31)***	-0.1493 (-3.35)***
Education: Unknown	0.1776 (2.18)**	0.1820 (2.24)**	0.1827 (2.25)**	not included in regression	0.1776 (2.18)**	0.1797 (2.21)**	0.1744 (2.12)**	0.1848 (2.28)**	0.1705 (2.10)**	0.1847 (2.29)**	0.1805 (2.22)**	0.1732 (2.13)**
Self employed	0.0899 (1.60)	0.0917 (1.63)	0.0628 (0.33)	0.0937 (1.65)*	0.0931 (1.65)*	0.0933 (1.66)*	0.0938 (1.67)*	0.0916 (1.63)	0.0884 (1.57)	0.0921 (1.63)	0.0889 (1.58)	0.0894 (1.59)
In paid employment	0.1412 (2.96)***	0.1409 (2.96)***	0.1116 (0.59)	0.1441 (2.99)***	0.1404 (2.95)***	0.1416 (2.97)***	0.1421 (2.98)***	0.1411 (2.96)***	0.1394 (2.93)***	0.1420 (2.98)***	0.1379 (2.88)***	0.1379 (2.89)***
Unemployed (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Retired	0.4862 (7.88)***	0.4871 (7.89)***	0.4898 (7.92)***	0.4857 (7.81)***	0.4888 (7.91)***	0.4806 (7.76)***	0.4904 (7.95)***	0.4872 (7.88)***	0.4862 (7.88)***	0.4911 (7.95)***	0.4823 (7.75)***	0.4831 (7.83)***
Maternity leave	0.4786 (4.11)***	0.4773 (4.10)***	0.4791 (4.12)***	0.4783 (4.08)***	0.4773 (4.10)***	0.4782 (4.10)***	0.4773 (4.10)***	0.4778 (4.11)***	0.4713 (4.06)***	0.4756 (4.11)***	0.4808 (4.13)***	0.4735 (4.06)***
Looking after family	0.1864 (2.97)***	0.1876 (2.99)***	0.1866 (2.98)***	0.1838 (2.88)***	0.1857 (2.96)***	0.1887 (3.01)***	0.1845 (2.94)***	0.1874 (2.99)***	0.1833 (2.92)***	0.1873 (2.99)***	0.1872 (2.98)***	0.1853 (2.95)***
Full-time student	0.2778 (4.52)***	0.2811 (4.56)***	0.2785 (4.53)***	0.2836 (4.57)***	0.2788 (4.54)***	0.2823 (4.59)***	0.2787 (4.53)***	0.2787 (4.54)***	0.2791 (4.55)***	0.2795 (4.54)***	0.2886 (4.68)***	0.2883 (4.67)***
Long-term sick/ disabled	0.0019 (0.02)	0.0033 (0.04)	0.0052 (0.06)	0.0032 (0.04)	0.0035 (0.04)	-0.0001 (-0.00)	0.0079 (0.09)	0.0023 (0.03)	0.0115 (0.13)	0.0046 (0.05)	0.0040 (0.05)	0.0068 (0.08)
Gov. training scheme	0.0751 (0.14)	0.0860 (0.16)	0.0763 (0.15)	-0.1156 (-0.22)	0.0610 (0.12)	0.0716 (0.14)	0.0506 (0.10)	0.0645 (0.12)	0.1003 (0.19)	0.0909 (0.17)	0.0715 (0.14)	0.0676 (0.13)

Unpaid in family business	0.2662	0.2683	0.2724	0.2734	0.2642	0.2579	0.2661	0.2630	0.2529	0.2716	0.2734	0.2687
	(0.74)	(0.75)	(0.76)	(0.77)	(0.74)	(0.72)	(0.74)	(0.73)	(0.71)	(0.76)	(0.77)	(0.75)
Apprenticeship	-0.1044	-0.0944	-0.1005	-0.0815	-0.0919	-0.0876	-0.0898	-0.0898	-0.0921	-0.0902	-0.0722	-0.0846
	(-0.22)	(-0.20)	(-0.21)	(-0.18)	(-0.20)	(-0.19)	(-0.20)	(-0.19)	(-0.20)	(-0.20)	(-0.16)	(-0.18)
Employment: other	-0.1788	-0.1769	-0.1729	-0.1708	-0.1720	-0.1786	-0.1742	-0.1743	-0.1728	-0.1745	-0.1749	-0.1755
	(-0.95)	(-0.94)	(-0.91)	(-0.90)	(-0.91)	(-0.94)	(-0.92)	(-0.92)	(-0.91)	(-0.92)	(-0.93)	(-0.93)
Not Urban Area (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Urban Area	-0.0310	-0.0322	-0.0298	-0.0372	-0.0426	-0.0379	-0.0430	-0.0416	-0.0329	-0.0343	-0.0396	-0.0416
	(-0.78)	(-0.81)	(-0.74)	(-0.92)	(-1.01)	(-0.94)	(-1.07)	(-1.03)	(-0.82)	(-0.86)	(-0.99)	(-1.04)
No children (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Number of children: 1	-0.0533	-0.0535	-0.0530	-0.0498	-0.0572	0.0390	-0.0545	-0.0541	-0.0557	-0.0574	-0.0647	-0.0606
	(-1.66)*	(-1.66)*	(-1.65)*	(-1.54)	(-1.78)*	(0.67)	(-1.70)*	(-1.68)*	(-1.73)*	(-1.78)*	(-1.97)**	(-1.87)*
Number of children: 2	0.0248	0.0247	0.0260	0.0251	0.0234	0.1146	0.0239	0.0228	0.0226	0.0194	0.0064	0.0169
	(0.81)	(0.80)	(0.84)	(0.81)	(0.76)	(2.00)**	(0.78)	(0.74)	(0.74)	(0.61)	(0.20)	(0.54)
Number of children: 3	0.1316	0.1297	0.1323	0.1400	0.1318	0.2229	0.1322	0.1316	0.1270	0.1263	0.1118	0.1199
	(2.60)***	(2.55)**	(2.60)***	(2.73)***	(2.60)***	(3.19)***	(2.60)***	(2.59)***	(2.50)**	(2.43)**	(2.15)**	(2.35)**
Number of children: 4	-0.0137	-0.0137	-0.0152	0.0000	-0.0202	0.0738	-0.0179	-0.0210	-0.0128	-0.0161	-0.0336	-0.0294
	(-0.08)	(-0.08)	(-0.09)	(0.00)	(-0.12)	(0.41)	(-0.10)	(-0.12)	(-0.07)	(-0.09)	(-0.19)	(-0.17)
Number of children: 5 or more	-0.0110	-0.0046	-0.0100	-0.0710	-0.0144	0.0750	0.0092	-0.0158	-0.0274	-0.0246	-0.0197	-0.0220
	(-0.06)	(-0.02)	(-0.05)	(-0.34)	(-0.07)	(0.38)	(0.05)	(-0.08)	(-0.14)	(-0.13)	(-0.10)	(-0.11)
Religious: No (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Religious: Yes	0.0225	0.0222	0.0227	0.0234	0.0230	0.0224	0.0223	0.0233	0.0207	0.0238	0.0243	0.0215
	(1.03)	(1.02)	(1.04)	(1.07)	(1.06)	(1.03)	(1.02)	(1.07)	(0.95)	(1.09)	(1.11)	(0.99)

Religious: Unknown	0.0271 (0.66)	0.0267 (0.65)	0.0260 (0.64)	0.0251 (0.61)	0.0285 (0.70)	0.0283 (0.69)	0.0239 (0.59)	0.0264 (0.65)	0.0267 (0.65)	0.0272 (0.67)	0.0296 (0.73)	0.0281 (0.69)
Carer: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.1824 (-4.00)***	-0.1834 (-4.02)***	-0.1817 (-3.98)***	-0.1793 (-3.90)***	-0.1833 (-4.02)***	-0.1806 (-3.96)***	-0.1805 (-3.96)***	-0.1815 (-3.98)***	-0.1846 (-4.06)***	-0.1830 (-4.02)***	-0.1848 (-4.05)***	-0.1843 (-4.05)***
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	-0.0491 (-1.78)*	-0.0501 (-1.82)*	-0.0493 (-1.79)*	-0.0516 (-1.86)*	-0.0504 (-1.82)*	-0.0490 (-1.78)*	-0.0473 (-1.72)*	-0.0493 (-1.79)*	-0.0463 (-1.68)*	-0.0524 (-1.89)*	-0.0542 (-1.95)*	-0.0508 (-1.84)*
Homeownership: Shared ownership	-0.0864 (-0.65)	-0.0880 (-0.66)	-0.0876 (-0.66)	-0.0708 (-0.51)	-0.0857 (-0.64)	-0.0884 (-0.67)	0.2671 (1.18)	-0.0925 (-0.70)	-0.0843 (-0.63)	-0.0921 (-0.69)	-0.0929 (-0.70)	-0.0900 (-0.68)
Homeownership: Rented	-0.1058 (-3.38)***	-0.1067 (-3.41)***	-0.1054 (-3.37)***	-0.1059 (-3.35)***	-0.1050 (-3.34)***	-0.1063 (-3.40)***	0.2498 (1.35)	-0.1090 (-3.47)***	-0.1044 (-3.34)***	-0.1070 (-3.42)***	-0.1092 (-3.48)***	-0.1073 (-3.42)***
Homeownership: Rent free	0.0103 (0.09)	0.0093 (0.08)	0.0106 (0.09)	0.0130 (0.11)	0.0100 (0.08)	0.0098 (0.08)	0.3645 (1.67)*	0.0088 (0.07)	0.0095 (0.08)	0.0077 (0.06)	0.0024 (0.02)	0.0076 (0.06)
Homeownership: Other	0.1062 (0.48)	0.1114 (0.50)	0.1105 (0.50)	0.1044 (0.47)	0.1034 (0.47)	0.1134 (0.51)	0.4524 (1.59)	0.0969 (0.44)	0.1015 (0.46)	0.1061 (0.48)	0.0986 (0.45)	0.1173 (0.54)
Homeownership: Missing	-0.1927 (-1.81)*	-0.1914 (-1.81)*	-0.1888 (-1.79)*	-0.1817 (-1.71)*	-0.1919 (-1.81)*	-0.1906 (-1.80)*	0.1664 (0.80)	-0.1921 (-1.81)*	-0.1977 (-1.86)*	-0.1938 (-1.84)*	-0.1972 (-1.85)*	-0.1909 (-1.80)*
House Move: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2461 (11.78)***	0.2466 (11.79)***	0.2458 (11.76)***	0.2458 (11.66)***	0.2456 (11.74)***	0.2474 (11.82)***	0.2458 (11.76)***	0.2463 (11.78)***	0.2445 (11.71)***	0.2467 (11.80)***	0.2465 (11.79)***	0.2463 (11.78)***
House Move: Unknown	0.0533 (0.52)	0.0535 (0.52)	0.0578 (0.56)	0.0527 (0.51)	0.0536 (0.52)	0.0558 (0.54)	0.0570 (0.56)	0.0552 (0.54)	0.0543 (0.53)	0.0594 (0.58)	0.0580 (0.56)	0.0601 (0.58)

Ethnicity: White (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Ethnicity: Mixed	-0.0277	-0.0237	-0.0262	-0.0192	-0.0242	-0.0229	-0.0262	0.0440	-0.0245	-0.0263	-0.0256	-0.0231
	(-0.60)	(-0.51)	(-0.57)	(-0.41)	(-0.53)	(-0.50)	(-0.57)	(0.23)	(-0.53)	(-0.57)	(-0.56)	(-0.50)
Ethnicity: Asian	-0.0454	-0.0438	-0.0446	-0.0507	-0.0458	-0.0425	-0.0442	0.0227	-0.0460	-0.0486	-0.0454	-0.0456
	(-1.64)	(-1.59)	(-1.62)	(-1.81)*	(-1.65)*	(-1.54)	(-1.60)	(0.12)	(-1.67)*	(-1.76)*	(-1.64)	(-1.65)*
Ethnicity: Black	-0.0668	-0.0672	-0.0687	-0.0660	-0.0675	-0.0655	-0.0660	0.0010	-0.0671	-0.0670	-0.0662	-0.0694
	(-2.00)**	(-2.01)**	(-2.05)**	(-1.96)**	(-2.02)**	(-1.96)*	(-1.97)**	(0.01)	(-2.01)**	(-2.01)**	(-1.98)**	(-2.08)**
Ethnicity: Other	-0.0658	-0.0644	-0.0653	-0.0817	-0.0665	-0.0625	-0.0667	0.0050	-0.0749	-0.0657	-0.0663	-0.0662
	(-1.01)	(-0.99)	(-1.00)	(-1.23)	(-1.02)	(-0.96)	(-1.03)	(0.03)	(-1.14)	(-1.01)	(-1.02)	(-1.02)
Ethnicity: Unknown	-0.2538	-0.2478	-0.2555	-0.2385	-0.2524	-0.2514	-0.2540	-0.1878	-0.2534	-0.2584	-0.2526	-0.2527
	(-2.68)***	(-2.61)***	(-2.70)***	(-2.08)**	(-2.67)***	(-2.66)***	(-2.69)***	(-0.91)	(-2.69)***	(-2.74)***	(-2.67)***	(-2.67)***
Wave: 1 (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Wave: 2	0.0040	0.0034	0.0038	0.0062	0.0021	0.0048	0.0045	0.0034	0.0028	0.0017	0.0034	0.0041
	(0.10)	(0.08)	(0.09)	(0.15)	(0.05)	(0.11)	(0.11)	(0.08)	(0.07)	(0.04)	(0.08)	(0.10)
Wave: 3	-0.0132	-0.0144	-0.0132	-0.0115	-0.0141	-0.0129	-0.0143	-0.0142	-0.0140	-0.0140	-0.0135	-0.0114
	(-0.31)	(-0.34)	(-0.31)	(-0.27)	(-0.33)	(-0.30)	(-0.34)	(-0.33)	(-0.33)	(-0.33)	(-0.32)	(-0.27)
Wave: 4	-0.0863	-0.0871	-0.0853	-0.0849	-0.0871	-0.0862	-0.0886	-0.0873	-0.0888	-0.0885	-0.0869	-0.0846
	(-2.03)**	(-2.05)**	(-2.01)**	(-1.99)**	(-2.05)**	(-2.03)**	(-2.08)**	(-2.05)**	(-2.09)**	(-2.08)**	(-2.04)**	(-1.99)**
Wave: 5	-0.0484	-0.0496	-0.0465	-0.0466	-0.0481	-0.0493	-0.0502	-0.0488	-0.0514	-0.0498	-0.0498	-0.0460
	(-1.08)	(-1.11)	(-1.04)	(-1.04)	(-1.08)	(-1.10)	(-1.12)	(-1.09)	(-1.15)	(-1.11)	(-1.12)	(-1.03)
Wave: 6	0.1174	0.1152	0.1176	0.1191	0.1185	0.1177	0.1171	0.1179	0.1145	0.1151	0.1190	0.1191
	(2.61)***	(2.56)**	(2.61)***	(2.63)***	(2.63)***	(2.61)***	(2.60)***	(2.62)***	(2.54)**	(2.55)**	(2.64)***	(2.64)***
Wave: 7	0.1763	0.1743	0.1758	0.1764	0.1751	0.1757	0.1761	0.1764	0.1711	0.1731	0.1766	0.1762
	(3.52)***	(3.48)***	(3.50)***	(3.49)***	(3.49)***	(3.50)***	(3.51)***	(3.52)***	(3.41)***	(3.45)***	(3.52)***	(3.52)***

Wave: 8	0.1365	0.1351	0.1361	0.1369	0.1351	0.1365	0.1356	0.1360	0.1321	0.1339	0.1373	0.1365
	(2.91)***	(2.89)***	(2.91)***	(2.91)***	(2.88)***	(2.92)***	(2.90)***	(2.91)***	(2.82)***	(2.86)***	(2.93)***	(2.92)***
Interview month: 1 (reference)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Interview month: 2	-0.0625	-0.0621	-0.0630	-0.0658	-0.0624	-0.0632	-0.0640	-0.0627	-0.0627	-0.0642	-0.0629	-0.0604
	(-1.50)	(-1.48)	(-1.51)	(-1.57)	(-1.49)	(-1.51)	(-1.53)	(-1.50)	(-1.50)	(-1.54)	(-1.50)	(-1.44)
Interview month: 3	-0.0217	-0.0213	-0.0216	-0.0215	-0.0212	-0.0220	-0.0210	-0.0204	-0.0230	-0.0212	-0.0204	-0.0196
	(-0.52)	(-0.51)	(-0.52)	(-0.51)	(-0.51)	(-0.53)	(-0.51)	(-0.49)	(-0.55)	(-0.51)	(-0.49)	(-0.47)
Interview month: 4	-0.0294	-0.0303	-0.0306	-0.0272	-0.0295	-0.0303	-0.0302	-0.0281	-0.0299	-0.0305	-0.0280	-0.0268
	(-0.68)	(-0.71)	(-0.71)	(-0.63)	(-0.69)	(-0.71)	(-0.71)	(-0.66)	(-0.70)	(-0.71)	(-0.65)	(-0.63)
Interview month: 5	-0.0693	-0.0695	-0.0700	-0.0728	-0.0645	-0.0734	-0.0684	-0.0666	-0.0725	-0.0672	-0.0690	-0.0641
	(-1.55)	(-1.55)	(-1.56)	(-1.61)	(-1.44)	(-1.64)	(-1.53)	(-1.49)	(-1.62)	(-1.50)	(-1.54)	(-1.43)
Interview month: 6	-0.0390	-0.0405	-0.0405	-0.0460	-0.0370	-0.0416	-0.0388	-0.0363	-0.0385	-0.0373	-0.0389	-0.0364
	(-0.89)	(-0.92)	(-0.93)	(-1.04)	(-0.84)	(-0.95)	(-0.89)	(-0.83)	(-0.88)	(-0.85)	(-0.89)	(-0.83)
Interview month: 7	-0.0165	-0.0161	-0.0182	-0.0176	-0.0155	-0.0187	-0.0142	-0.0184	-0.0164	-0.0158	-0.0141	-0.0144
	(-0.38)	(-0.37)	(-0.42)	(-0.40)	(-0.36)	(-0.43)	(-0.33)	(-0.42)	(-0.38)	(-0.36)	(-0.32)	(-0.33)
Interview month: 8	0.0460	0.0453	0.0452	0.0443	0.0482	0.0445	0.0443	0.0452	0.0462	0.0453	0.0473	0.0493
	(1.10)	(1.08)	(1.08)	(1.05)	(1.15)	(1.06)	(1.06)	(1.08)	(1.10)	(1.08)	(1.13)	(1.17)
Interview month: 9	0.0191	0.0187	0.0193	0.0159	0.0213	0.0175	0.0172	0.0185	0.0174	0.0186	0.0210	0.0215
	(0.44)	(0.43)	(0.44)	(0.36)	(0.49)	(0.40)	(0.39)	(0.42)	(0.40)	(0.43)	(0.49)	(0.50)
Interview month: 10	0.0256	0.0247	0.0251	0.0273	0.0272	0.0248	0.0235	0.0263	0.0248	0.0264	0.0256	0.0278
	(0.59)	(0.57)	(0.58)	(0.63)	(0.63)	(0.57)	(0.54)	(0.60)	(0.57)	(0.61)	(0.59)	(0.64)
Interview month: 11	-0.0005	-0.0000	-0.0009	-0.0027	0.0008	-0.0020	-0.0001	-0.0002	-0.0010	-0.0002	0.0019	-0.0000
	(-0.01)	(-0.00)	(-0.02)	(-0.06)	(0.02)	(-0.05)	(-0.00)	(-0.00)	(-0.02)	(-0.01)	(0.04)	(-0.00)
Interview month: 12	-0.0383	-0.0399	-0.0391	-0.0446	-0.0377	-0.0398	-0.0390	-0.0390	-0.0390	-0.0393	-0.0381	-0.0359
	(-0.80)	(-0.83)	(-0.82)	(-0.92)	(-0.79)	(-0.83)	(-0.81)	(-0.81)	(-0.81)	(-0.82)	(-0.79)	(-0.75)

Aviation related occupation (dummy)	-0.2253 (-1.15)	-0.2195 (-1.12)	-0.2219 (-1.14)	-0.2312 (-1.19)	-0.1996 (-1.01)	-0.2168 (-1.11)	-0.2126 (-1.09)	-0.2310 (-1.18)	-0.2313 (-1.19)	-0.2102 (-1.08)	-0.2255 (-1.16)	-0.2266 (-1.16)
SF-12: Physical health	0.0179 (2.52)**	0.0181 (2.56)**	0.0182 (2.58)**	0.0175 (2.45)**	0.0181 (2.56)**	0.0180 (2.55)**	0.0184 (2.60)***	0.0179 (2.53)**	0.0138 (1.92)*	0.0184 (2.59)***	0.0188 (2.66)***	0.0187 (2.64)***
SF-12: Physical health (squared)	0.0001 (1.28)	0.0001 (1.24)	0.0001 (1.22)	0.0001 (1.33)	0.0001 (1.23)	0.0001 (1.24)	0.0001 (1.19)	0.0001 (1.26)	0.0001 (1.42)	0.0001 (1.20)	0.0001 (1.14)	0.0001 (1.17)
SF-12: Mental health	0.1049 (16.08)***	0.1050 (16.09)***	0.1048 (16.05)***	0.1046 (15.92)***	0.1052 (16.12)***	0.1052 (16.10)***	0.1052 (16.12)***	0.1049 (16.08)***	0.1035 (15.79)***	0.1051 (16.12)***	0.1053 (16.14)***	0.1051 (16.12)***
SF-12: Mental health (squared)	-0.0004 (-5.96)***	-0.0004 (-5.97)***	-0.0004 (-5.93)***	-0.0004 (-5.84)***	-0.0004 (-6.01)***	-0.0004 (-6.00)***	-0.0004 (-6.00)***	-0.0004 (-5.96)***	-0.0004 (-5.94)***	-0.0004 (-5.99)***	-0.0004 (-6.02)***	-0.0004 (-5.97)***
NO2	-0.0055 (-0.55)	-0.0050 (-0.50)	-0.0057 (-0.57)	-0.0055 (-0.55)	-0.0055 (-0.54)	-0.0050 (-0.50)	-0.0058 (-0.58)	-0.0046 (-0.45)	-0.0055 (-0.55)	-0.0055 (-0.55)	-0.0056 (-0.56)	-0.0052 (-0.51)
NOx	0.0018 (0.40)	0.0015 (0.34)	0.0019 (0.41)	0.0019 (0.42)	0.0017 (0.38)	0.0016 (0.35)	0.0020 (0.43)	0.0014 (0.31)	0.0019 (0.41)	0.0019 (0.40)	0.0019 (0.41)	0.0017 (0.36)
PM10	0.0129 (0.70)	0.0129 (0.70)	0.0137 (0.74)	0.0137 (0.74)	0.0131 (0.71)	0.0120 (0.65)	0.0119 (0.65)	0.0123 (0.67)	0.0126 (0.68)	0.0130 (0.70)	0.0122 (0.66)	0.0131 (0.71)
PM25	-0.0065 (-0.25)	-0.0065 (-0.25)	-0.0072 (-0.28)	-0.0075 (-0.29)	-0.0062 (-0.24)	-0.0058 (-0.23)	-0.0049 (-0.19)	-0.0062 (-0.24)	-0.0072 (-0.28)	-0.0069 (-0.27)	-0.0054 (-0.21)	-0.0070 (-0.27)
House Prices	0.0000 (0.30)	0.0000 (0.37)	0.0000 (0.32)	0.0000 (0.17)	0.0000 (0.37)	0.0000 (0.31)	0.0000 (0.29)	0.0000 (0.34)	0.0000 (0.33)	0.0000 (0.36)	0.0000 (0.30)	0.0000 (0.33)
LAeq16hr (control); Insulation Not Eligible; interacted with column header dummy	0.0000 (.)	-0.0732 (-0.35)	0.0360 (0.20)	-0.1673 (-0.91)	0.0000 (.)	-0.1017 (-1.85)*	0.3518 (1.91)*	0.0817 (0.44)	-0.1113 (-3.06)***	0.0398 (0.78)	-0.0616 (-1.56)	0.0940 (1.61)
LAeq16hr (control); Insulation Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)

LAeq16hr (Quintile 1); Insulation Not Eligible; interacted with column header dummy	0.0424 (0.37)	0.0514 (0.22)	0.0486 (0.22)	0.0252 (0.12)	0.6130 (1.74)*	0.0289 (0.21)	0.2757 (1.27)	0.0280 (0.13)	-0.1474 (-0.89)	0.2340 (1.55)	0.0335 (0.28)	0.0458 (0.18)
LAeq16hr (Quintile 1); Insulation Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 2); Insulation Not Eligible; interacted with column header dummy	-0.0115 (-0.10)	-0.0918 (-0.38)	0.0012 (0.01)	-0.0521 (-0.24)	-0.1429 (-0.70)	-0.1911 (-1.32)	0.4590 (2.11)**	-0.0834 (-0.38)	-0.2162 (-1.31)	-0.0661 (-0.47)	-0.1039 (-0.68)	-0.0083 (-0.04)
LAeq16hr (Quintile 2); Insulation Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 3); Insulation Not Eligible; interacted with column header dummy	0.1811 (1.31)	-0.1741 (-0.70)	-0.1308 (-0.56)	0.0324 (0.14)	-0.9113 (-6.35)***	-0.1139 (-0.78)	0.5509 (2.36)**	0.0566 (0.25)	-0.4022 (-1.69)*	0.2632 (1.46)	0.2618 (1.83)*	0.4017 (1.92)*
LAeq16hr (Quintile 3); Insulation Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq16hr (Quintile 4); Insulation Not Eligible; interacted with column header dummy	-0.0459 (-0.38)	-0.0235 (-0.10)	0.0727 (0.33)	-0.1775 (-0.80)	-0.5118 (-2.13)**	-0.0891 (-0.68)	0.5155 (2.30)**	-0.0126 (-0.06)	-0.3705 (-1.90)*	-0.1430 (-1.05)	-0.0799 (-0.57)	0.7027 (3.30)***
LAeq16hr (Quintile 4); Insulation Eligible; interacted with column header dummy	-1.4877 (-3.55)***	1.0229 (1.14)	-0.2075 (-0.35)	1.1449 (3.42)***	0.6314 (1.06)	1.2904 (3.78)***	-0.3980 (-0.62)	0.0776 (0.07)	-1.1276 (-1.64)	0.0486 (0.04)	-1.2896 (-3.13)***	0.5084 (1.73)*
LAeq16hr (Quintile 5); Insulation Not Eligible; interacted with column header dummy	0.0621 (0.35)	0.1061 (0.37)	-0.1611 (-0.62)	-0.1604 (-0.63)	0.1138 (0.62)	-0.0604 (-0.31)	0.0591 (0.23)	-0.3190 (-1.26)	-0.5405 (-2.69)***	0.1965 (0.87)	-0.0717 (-0.41)	0.0423 (0.15)

LAeq16hr (Quintile 5); Insulation Eligible; interacted with column header dummy	0.1319 (0.71)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.4764 (1.86)*	-0.0750 (-0.41)	0.0000 (.)	0.0000 (.)	-0.7142 (-2.32)**	-0.3918 (-1.53)	-0.2403 (-1.27)	-0.7306 (-1.94)*
Constant	-0.3615 (-1.28)	-0.3653 (-1.29)	-0.3770 (-1.33)	-0.3638 (-1.27)	-0.3705 (-1.31)	-0.3707 (-1.31)	-0.7168 (-2.12)**	-0.4264 (-1.26)	-0.0982 (-0.34)	-0.3156 (-1.09)	-0.4141 (-1.46)	-0.4512 (-1.56)
N	28141	28141	28141	27589	28141	28141	28141	28141	28141	28141	28141	28141
Adjusted R squared	0.295	0.295	0.295	0.294	0.296	0.295	0.295	0.295	0.296	0.295	0.295	0.296

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table C1

11.2 Night-Time Interactions

Dependent Variable: Life Satisfaction	Male	Marital Status: With Partner	Employed	Education: Degree or higher	Urban Area	Has dependent children	Houseowner: Yes	Ethnicity: White	General health: Poor	Age: Above 30	Age: Above 50	Age: Above 70
LAeq8hr (control); Insulation Not Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (control); Insulation Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 1); Insulation Not Eligible	0.0642 (0.27)	-0.1085 (-0.42)	-0.1499 (-0.52)	-0.0902 (-0.44)	-0.0670 (-0.26)	-0.1332 (-0.83)	-0.0627 (-0.34)	0.2900 (1.80)*	-0.0897 (-0.61)	-0.1822 (-0.61)	-0.1910 (-1.08)	-0.1976 (-1.39)
LAeq8hr (Quintile 1); Insulation Eligible	0.6058 (1.39)	-2.5915 (-2.62)***	0.3651 (1.63)	-0.5007 (-0.50)	-0.4693 (-0.53)	-1.1835 (-0.96)	0.5724 (5.75)***	-0.6381 (-0.66)	-1.0121 (-0.79)	-0.4189 (-0.47)	0.7723 (3.37)***	-0.4765 (-0.54)
LAeq8hr (Quintile 2); Insulation Not Eligible	0.0878 (0.52)	0.2211 (1.57)	0.0719 (0.45)	0.2888 (1.99)**	0.1707 (0.80)	0.0675 (0.58)	0.0266 (0.16)	0.1124 (0.40)	-0.0215 (-0.19)	0.3436 (1.65)*	-0.0434 (-0.31)	-0.0806 (-0.71)
LAeq8hr (Quintile 2); Insulation Eligible	0.5213 (2.47)**	-0.2563 (-2.49)**	-0.2434 (-2.37)**	0.8649 (4.52)***	0.7410 (3.63)***	0.4447 (1.43)	0.7729 (8.37)***	0.5771 (1.38)	0.8527 (4.50)***	0.7880 (3.72)***	0.8930 (3.58)***	0.7372 (3.63)***
LAeq8hr (Quintile 3); Insulation Not Eligible	-0.4133 (-2.31)**	-0.5137 (-1.75)*	-0.6173 (-2.61)***	-0.5086 (-2.08)**	-0.0859 (-0.35)	-0.5525 (-2.84)***	-0.9411 (-2.48)**	-0.2040 (-1.03)	-0.2572 (-1.66)*	0.1861 (0.72)	-0.2135 (-1.14)	-0.6104 (-3.62)***

LAeq8hr (Quintile 3); Insulation Eligible	0.3219 (1.17)	-0.9654 (-3.92)***	0.4208 (0.86)	0.1333 (0.25)	-0.7544 (-1.04)	-0.1448 (-0.36)	0.4688 (1.20)	1.1439 (4.59)***	0.3239 (1.05)	0.1872 (0.57)	0.7888 (3.14)***	0.1371 (0.42)
LAeq8hr (Quintile 4); Insulation Not Eligible	-0.1422 (-0.56)	-0.4488 (-1.64)	0.2689 (0.71)	-0.3813 (-1.47)	-0.1803 (-0.59)	-0.3113 (-1.51)	-0.4628 (-2.19)**	-0.4033 (-1.58)	-0.3025 (-1.34)	-0.8166 (-3.55)***	-0.5007 (-2.25)**	-0.3337 (-1.84)*
LAeq8hr (Quintile 4); Insulation Eligible	0.2903 (1.38)	0.6385 (2.28)**	0.3738 (1.68)*	0.2659 (1.76)*	-0.2660 (-1.00)	0.2841 (1.57)	0.6625 (3.90)***	0.8192 (7.15)***	0.4116 (3.38)***	1.0193 (4.22)***	0.5123 (3.73)***	0.4755 (3.88)***
LAeq8hr (Quintile 5); Insulation Not Eligible	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 5); Insulation Eligible	0.3941 (2.10)**	0.4306 (2.57)**	0.4392 (2.66)***	0.3336 (1.97)**	0.6592 (2.48)**	0.4118 (2.54)**	0.5700 (2.73)***	0.2470 (1.71)*	0.3804 (2.83)***	0.7212 (3.44)***	0.2850 (1.52)	0.2811 (2.01)**
Log Equivalised Household Income	0.0878 (5.68)***	0.0878 (5.66)***	0.0877 (5.68)***	0.0914 (5.51)***	0.0874 (5.67)***	0.0868 (5.62)***	0.0880 (5.71)***	0.0884 (5.74)***	0.0870 (5.64)***	0.0869 (5.62)***	0.0867 (5.63)***	0.0864 (5.61)***
Age	-0.0343 (-6.56)***	-0.0343 (-6.55)***	-0.0344 (-6.56)***	-0.0348 (-6.60)***	-0.0347 (-6.62)***	-0.0330 (-6.24)***	-0.0341 (-6.53)***	-0.0346 (-6.59)***	-0.0336 (-6.44)***	-0.0374 (-5.46)***	-0.0305 (-5.58)***	-0.0320 (-5.28)***
Age (squared)	0.0003 (5.91)***	0.0003 (5.90)***	0.0003 (5.91)***	0.0003 (5.92)***	0.0003 (5.98)***	0.0003 (5.64)***	0.0003 (5.90)***	0.0003 (5.93)***	0.0003 (5.81)***	0.0003 (5.37)***	0.0003 (5.72)***	0.0003 (4.43)***
Female (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Male	-0.1138 (-4.54)***	-0.1203 (-4.91)***	-0.1198 (-4.89)***	-0.1208 (-4.88)***	-0.1207 (-4.92)***	-0.1214 (-4.95)***	-0.1199 (-4.90)***	-0.1190 (-4.86)***	-0.1171 (-4.78)***	-0.1190 (-4.87)***	-0.1205 (-4.93)***	-0.1204 (-4.91)***
Married	0.2805 (7.63)***	-0.0083 (-0.03)	0.2815 (7.65)***	0.2771 (7.42)***	0.2837 (7.71)***	0.2909 (7.86)***	0.2779 (7.57)***	0.2839 (7.71)***	0.2786 (7.60)***	0.2794 (7.60)***	0.2835 (7.71)***	0.2858 (7.77)***
Divorced	0.0585 (0.98)	0.0610 (1.02)	0.0588 (0.98)	0.0499 (0.83)	0.0555 (0.93)	0.0627 (1.05)	0.0534 (0.89)	0.0588 (0.98)	0.0515 (0.87)	0.0555 (0.93)	0.0625 (1.05)	0.0576 (0.96)
Widowed	0.0691 (0.92)	0.0791 (1.05)	0.0673 (0.89)	0.0642 (0.84)	0.0643 (0.85)	0.0814 (1.08)	0.0668 (0.89)	0.0714 (0.94)	0.0573 (0.76)	0.0650 (0.86)	0.0577 (0.76)	0.0717 (0.95)

Separated	-0.0006 (-0.01)	0.0107 (0.11)	0.0028 (0.03)	0.0025 (0.02)	-0.0058 (-0.06)	0.0067 (0.07)	-0.0041 (-0.04)	0.0009 (0.01)	-0.0081 (-0.08)	-0.0043 (-0.04)	0.0020 (0.02)	0.0028 (0.03)
Single (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: No qualification (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education: A level or GCSE	-0.1478 (-2.65)***	-0.1456 (-2.61)***	-0.1471 (-2.64)***	-0.1511 (-2.71)***	-0.1431 (-2.57)**	-0.1468 (-2.63)***	-0.1448 (-2.60)***	-0.1459 (-2.62)***	-0.1480 (-2.66)***	-0.1360 (-2.44)**	-0.1397 (-2.52)**	-0.1501 (-2.70)***
Education: Other qualification	-0.1571 (-2.17)**	-0.1590 (-2.20)**	-0.1591 (-2.20)**	-0.1569 (-2.17)**	-0.1593 (-2.20)**	-0.1580 (-2.18)**	-0.1596 (-2.21)**	-0.1609 (-2.22)**	-0.1627 (-2.26)**	-0.1511 (-2.09)**	-0.1555 (-2.15)**	-0.1614 (-2.23)**
Education: Degree or higher	-0.1035 (-1.85)*	-0.1019 (-1.82)*	-0.1053 (-1.88)*	-0.1237 (-0.44)	-0.1016 (-1.82)*	-0.1025 (-1.83)*	-0.1020 (-1.83)*	-0.1032 (-1.84)*	-0.1075 (-1.93)*	-0.0960 (-1.72)*	-0.1021 (-1.83)*	-0.1082 (-1.94)*
Education: Unknown	0.0994 (1.06)	0.0931 (0.99)	0.0995 (1.06)	not included in regression	0.0978 (1.04)	0.1009 (1.08)	0.0935 (0.99)	0.1085 (1.16)	0.0928 (0.99)	0.1188 (1.27)	0.0891 (0.95)	0.0893 (0.95)
Self employed	0.0420 (0.57)	0.0460 (0.63)	-0.2951 (-1.04)	0.0410 (0.55)	0.0448 (0.61)	0.0407 (0.55)	0.0478 (0.65)	0.0414 (0.56)	0.0395 (0.54)	0.0453 (0.62)	0.0363 (0.49)	0.0414 (0.56)
In paid employment	0.0816 (1.29)	0.0872 (1.39)	-0.2557 (-0.91)	0.0801 (1.24)	0.0841 (1.34)	0.0828 (1.31)	0.0872 (1.39)	0.0812 (1.29)	0.0824 (1.31)	0.0877 (1.40)	0.0786 (1.24)	0.0811 (1.29)
Unemployed (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Retired	0.3976 (5.09)***	0.4052 (5.20)***	0.4027 (5.16)***	0.3959 (5.01)***	0.3997 (5.12)***	0.3887 (4.96)***	0.4085 (5.24)***	0.3989 (5.10)***	0.4042 (5.20)***	0.4100 (5.27)***	0.3921 (5.00)***	0.3985 (5.10)***
Maternity leave	0.4476 (2.54)**	0.4446 (2.52)**	0.4419 (2.50)**	0.4414 (2.48)**	0.4446 (2.52)**	0.4367 (2.48)**	0.4490 (2.54)**	0.4402 (2.49)**	0.4404 (2.50)**	0.4529 (2.56)**	0.4496 (2.54)**	0.4419 (2.50)**
Looking after family	0.1505 (1.81)*	0.1562 (1.88)*	0.1519 (1.82)*	0.1274 (1.49)	0.1479 (1.78)*	0.1571 (1.89)*	0.1505 (1.81)*	0.1502 (1.80)*	0.1482 (1.78)*	0.1522 (1.83)*	0.1575 (1.89)*	0.1481 (1.78)*

Full-time student	0.3064 (3.78)***	0.3090 (3.82)***	0.3049 (3.76)***	0.2957 (3.60)***	0.3052 (3.78)***	0.3092 (3.82)***	0.3113 (3.85)***	0.3085 (3.81)***	0.3044 (3.77)***	0.2963 (3.66)***	0.3238 (3.97)***	0.3117 (3.84)***
Long-term sick/ disabled	-0.0368 (-0.33)	-0.0378 (-0.34)	-0.0355 (-0.32)	-0.0407 (-0.37)	-0.0332 (-0.30)	-0.0390 (-0.35)	-0.0315 (-0.29)	-0.0358 (-0.33)	-0.0202 (-0.18)	-0.0323 (-0.29)	-0.0321 (-0.29)	-0.0342 (-0.31)
Gov. training scheme	-1.2353 (-1.65)*	-1.2276 (-1.64)	-1.2307 (-1.65)*	-1.2351 (-1.65)*	-1.2305 (-1.65)*	-1.2359 (-1.65)*	-1.2273 (-1.64)	-1.2330 (-1.65)*	-1.2393 (-1.66)*	-1.2216 (-1.63)	-1.2240 (-1.65)*	-1.2359 (-1.65)*
Unpaid in family business	0.2141 (0.85)	0.2153 (0.86)	0.2165 (0.86)	0.2176 (0.88)	0.2133 (0.85)	0.2182 (0.85)	0.2187 (0.87)	0.2128 (0.85)	0.2034 (0.81)	0.2200 (0.87)	0.2172 (0.89)	0.2100 (0.83)
Apprenticeship	0.1541 (0.54)	0.1458 (0.51)	0.1593 (0.56)	0.1642 (0.57)	0.1448 (0.51)	0.1676 (0.59)	0.1434 (0.51)	0.1271 (0.45)	0.1549 (0.54)	0.1159 (0.41)	0.1725 (0.60)	0.1525 (0.54)
Employment: other	-0.2110 (-0.90)	-0.2090 (-0.90)	-0.2056 (-0.88)	-0.2088 (-0.90)	-0.2064 (-0.89)	-0.1996 (-0.84)	-0.2015 (-0.87)	-0.2068 (-0.89)	-0.2127 (-0.91)	-0.2018 (-0.87)	-0.1949 (-0.84)	-0.2050 (-0.88)
Not Urban Area (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Urban Area	-0.0201 (-0.41)	-0.0215 (-0.43)	-0.0195 (-0.39)	-0.0238 (-0.48)	-0.0229 (-0.44)	-0.0271 (-0.55)	-0.0245 (-0.50)	-0.0183 (-0.37)	-0.0166 (-0.34)	-0.0136 (-0.28)	-0.0255 (-0.52)	-0.0308 (-0.62)
No children (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Number of children: 1	-0.0356 (-0.83)	-0.0343 (-0.80)	-0.0362 (-0.84)	-0.0316 (-0.72)	-0.0370 (-0.86)	0.1476 (1.96)*	-0.0343 (-0.80)	-0.0341 (-0.79)	-0.0368 (-0.86)	-0.0402 (-0.93)	-0.0655 (-1.47)	-0.0416 (-0.96)
Number of children: 2	0.0238 (0.60)	0.0226 (0.57)	0.0244 (0.62)	0.0222 (0.55)	0.0240 (0.61)	0.2038 (2.75)***	0.0259 (0.65)	0.0206 (0.52)	0.0223 (0.56)	0.0148 (0.36)	-0.0143 (-0.34)	0.0172 (0.43)
Number of children: 3	0.1357 (2.07)**	0.1347 (2.05)**	0.1364 (2.08)**	0.1392 (2.10)**	0.1359 (2.07)**	0.3146 (3.47)***	0.1418 (2.16)**	0.1366 (2.08)**	0.1316 (2.01)**	0.1268 (1.88)*	0.0927 (1.37)	0.1269 (1.92)*
Number of children: 4	-0.2135 (-1.16)	-0.2158 (-1.17)	-0.2183 (-1.19)	-0.1982 (-1.03)	-0.2248 (-1.23)	-0.0416 (-0.21)	-0.2235 (-1.22)	-0.2132 (-1.16)	-0.2133 (-1.16)	-0.2243 (-1.22)	-0.2626 (-1.43)	-0.2310 (-1.26)

Number of children: 5 or more	0.0128 (0.05)	0.0137 (0.06)	0.0126 (0.05)	-0.0983 (-0.34)	0.0161 (0.07)	0.1945 (0.77)	0.0202 (0.08)	0.0171 (0.07)	0.0033 (0.01)	-0.0029 (-0.01)	-0.0235 (-0.10)	0.0038 (0.02)
Religious: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.0124 (0.46)	0.0133 (0.49)	0.0119 (0.44)	0.0099 (0.36)	0.0138 (0.51)	0.0117 (0.43)	0.0114 (0.42)	0.0133 (0.49)	0.0103 (0.38)	0.0121 (0.45)	0.0143 (0.53)	0.0130 (0.48)
Religious: Unknown	0.0999 (1.49)	0.1010 (1.51)	0.1015 (1.51)	0.1007 (1.48)	0.0966 (1.44)	0.1004 (1.50)	0.0964 (1.44)	0.0979 (1.46)	0.0951 (1.42)	0.0898 (1.35)	0.1027 (1.53)	0.1024 (1.53)
Carer: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Carer: Yes	-0.1713 (-2.95)***	-0.1696 (-2.92)***	-0.1717 (-2.96)***	-0.1651 (-2.83)***	-0.1711 (-2.95)***	-0.1703 (-2.92)***	-0.1698 (-2.93)***	-0.1731 (-2.98)***	-0.1736 (-3.00)***	-0.1693 (-2.91)***	-0.1744 (-3.01)***	-0.1709 (-2.95)***
Homeownership: Owned outright (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Homeownership: Mortgage	-0.0390 (-1.15)	-0.0381 (-1.13)	-0.0378 (-1.12)	-0.0422 (-1.24)	-0.0384 (-1.13)	-0.0355 (-1.05)	-0.0352 (-1.04)	-0.0375 (-1.11)	-0.0316 (-0.94)	-0.0410 (-1.21)	-0.0464 (-1.36)	-0.0388 (-1.15)
Homeownership: Shared ownership	0.1162 (0.69)	0.1146 (0.68)	0.1153 (0.69)	0.1273 (0.72)	0.1164 (0.69)	0.1138 (0.68)	0.5774 (1.83)*	0.1149 (0.68)	0.1212 (0.72)	0.1059 (0.63)	0.1056 (0.63)	0.1133 (0.68)
Homeownership: Rented	-0.0407 (-1.07)	-0.0422 (-1.11)	-0.0419 (-1.10)	-0.0462 (-1.19)	-0.0426 (-1.11)	-0.0406 (-1.06)	0.4170 (1.54)	-0.0425 (-1.11)	-0.0376 (-0.99)	-0.0432 (-1.13)	-0.0470 (-1.23)	-0.0426 (-1.12)
Homeownership: Rent free	0.2678 (1.63)	0.2607 (1.58)	0.2655 (1.61)	0.2569 (1.55)	0.2655 (1.61)	0.2674 (1.63)	0.7257 (2.31)**	0.2679 (1.63)	0.2604 (1.59)	0.2723 (1.66)*	0.2519 (1.53)	0.2656 (1.62)
Homeownership: Other	0.6114 (2.60)***	0.5980 (2.53)**	0.6173 (2.63)***	0.6331 (2.57)**	0.6072 (2.59)***	0.6077 (2.57)**	1.0541 (3.01)***	0.5982 (2.53)**	0.5955 (2.56)**	0.6194 (2.66)***	0.5973 (2.56)**	0.6150 (2.59)***
Homeownership: Missing	-0.1436 (-1.25)	-0.1455 (-1.26)	-0.1474 (-1.27)	-0.1432 (-1.22)	-0.1464 (-1.27)	-0.1376 (-1.18)	0.3055 (1.07)	-0.1398 (-1.21)	-0.1478 (-1.27)	-0.1461 (-1.26)	-0.1484 (-1.28)	-0.1440 (-1.24)

House Move: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
House Move: Yes	0.2780 (10.29)***	0.2776 (10.28)***	0.2771 (10.26)***	0.2746 (10.06)***	0.2784 (10.31)***	0.2787 (10.31)***	0.2790 (10.32)***	0.2778 (10.28)***	0.2749 (10.19)***	0.2765 (10.24)***	0.2788 (10.33)***	0.2767 (10.25)***
House Move: Unknown	0.0398 (0.33)	0.0399 (0.33)	0.0403 (0.34)	0.0472 (0.40)	0.0407 (0.34)	0.0386 (0.32)	0.0414 (0.35)	0.0403 (0.34)	0.0402 (0.34)	0.0380 (0.32)	0.0439 (0.37)	0.0408 (0.34)
Ethnicity: White (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Ethnicity: Mixed	-0.0725 (-1.24)	-0.0718 (-1.23)	-0.0717 (-1.22)	-0.0606 (-1.03)	-0.0709 (-1.21)	-0.0673 (-1.15)	-0.0695 (-1.19)	-0.2462 (-0.66)	-0.0694 (-1.18)	-0.0689 (-1.18)	-0.0678 (-1.16)	-0.0712 (-1.22)
Ethnicity: Asian	-0.0090 (-0.26)	-0.0097 (-0.28)	-0.0081 (-0.24)	-0.0275 (-0.78)	-0.0076 (-0.22)	-0.0060 (-0.18)	-0.0036 (-0.10)	-0.1864 (-0.51)	-0.0102 (-0.30)	-0.0096 (-0.28)	-0.0085 (-0.25)	-0.0114 (-0.33)
Ethnicity: Black	-0.0562 (-1.32)	-0.0550 (-1.29)	-0.0557 (-1.31)	-0.0543 (-1.26)	-0.0536 (-1.26)	-0.0500 (-1.17)	-0.0535 (-1.26)	-0.2290 (-0.62)	-0.0559 (-1.32)	-0.0539 (-1.27)	-0.0531 (-1.25)	-0.0564 (-1.33)
Ethnicity: Other	-0.1238 (-1.44)	-0.1207 (-1.40)	-0.1230 (-1.43)	-0.1629 (-1.84)*	-0.1237 (-1.44)	-0.1204 (-1.40)	-0.1232 (-1.43)	-0.2969 (-0.79)	-0.1295 (-1.51)	-0.1205 (-1.40)	-0.1181 (-1.37)	-0.1250 (-1.46)
Ethnicity: Unknown	-0.0302 (-0.33)	-0.0405 (-0.45)	-0.0334 (-0.37)	-0.0003 (-0.00)	-0.0466 (-0.51)	-0.0381 (-0.42)	-0.0490 (-0.55)	-0.2194 (-0.58)	-0.0430 (-0.48)	-0.0682 (-0.76)	-0.0401 (-0.44)	-0.0358 (-0.39)
Wave: 3	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Wave: 4	-0.3000 (-2.55)**	-0.3000 (-2.55)**	-0.3004 (-2.55)**	-0.2950 (-2.50)**	-0.3023 (-2.57)**	-0.3041 (-2.57)**	-0.2985 (-2.54)**	-0.2940 (-2.50)**	-0.3043 (-2.58)***	-0.2978 (-2.53)**	-0.2975 (-2.52)**	-0.3077 (-2.61)***
Wave: 5	-0.3000 (-2.57)**	-0.3001 (-2.57)**	-0.3016 (-2.59)***	-0.2974 (-2.54)**	-0.3011 (-2.58)***	-0.3027 (-2.58)***	-0.2998 (-2.57)**	-0.2948 (-2.53)**	-0.3085 (-2.64)***	-0.2976 (-2.55)**	-0.2986 (-2.55)**	-0.3054 (-2.62)***
Wave: 6	-0.1195 (-1.01)	-0.1182 (-1.00)	-0.1217 (-1.03)	-0.1186 (-1.00)	-0.1221 (-1.04)	-0.1215 (-1.02)	-0.1191 (-1.01)	-0.1148 (-0.98)	-0.1269 (-1.07)	-0.1194 (-1.01)	-0.1147 (-0.97)	-0.1253 (-1.06)

Wave: 7	-0.0716 (-0.59)	-0.0700 (-0.58)	-0.0726 (-0.60)	-0.0717 (-0.59)	-0.0741 (-0.61)	-0.0732 (-0.60)	-0.0706 (-0.58)	-0.0672 (-0.55)	-0.0798 (-0.66)	-0.0720 (-0.59)	-0.0675 (-0.55)	-0.0767 (-0.63)
Wave: 8	-0.1013 (-0.84)	-0.0966 (-0.80)	-0.1024 (-0.85)	-0.1014 (-0.84)	-0.1048 (-0.87)	-0.1021 (-0.84)	-0.1004 (-0.83)	-0.0973 (-0.81)	-0.1104 (-0.92)	-0.1016 (-0.84)	-0.0956 (-0.79)	-0.1068 (-0.89)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Interview month: 2	-0.0657 (-1.36)	-0.0679 (-1.41)	-0.0646 (-1.34)	-0.0660 (-1.36)	-0.0646 (-1.34)	-0.0664 (-1.38)	-0.0661 (-1.37)	-0.0642 (-1.33)	-0.0618 (-1.29)	-0.0668 (-1.39)	-0.0676 (-1.40)	-0.0631 (-1.31)
Interview month: 3	-0.1290 (-2.55)**	-0.1301 (-2.57)**	-0.1296 (-2.56)**	-0.1263 (-2.47)**	-0.1284 (-2.53)**	-0.1296 (-2.55)**	-0.1294 (-2.55)**	-0.1264 (-2.49)**	-0.1300 (-2.57)**	-0.1282 (-2.53)**	-0.1308 (-2.58)***	-0.1278 (-2.53)**
Interview month: 4	-0.0809 (-1.57)	-0.0831 (-1.61)	-0.0802 (-1.56)	-0.0723 (-1.39)	-0.0822 (-1.59)	-0.0802 (-1.55)	-0.0845 (-1.64)	-0.0767 (-1.49)	-0.0814 (-1.59)	-0.0821 (-1.60)	-0.0815 (-1.58)	-0.0761 (-1.48)
Interview month: 5	-0.0586 (-1.05)	-0.0625 (-1.12)	-0.0573 (-1.03)	-0.0618 (-1.10)	-0.0562 (-1.01)	-0.0638 (-1.14)	-0.0565 (-1.02)	-0.0562 (-1.01)	-0.0595 (-1.07)	-0.0556 (-1.00)	-0.0603 (-1.09)	-0.0525 (-0.94)
Interview month: 6	-0.0441 (-0.80)	-0.0426 (-0.77)	-0.0414 (-0.75)	-0.0374 (-0.67)	-0.0404 (-0.73)	-0.0438 (-0.79)	-0.0397 (-0.72)	-0.0380 (-0.69)	-0.0403 (-0.73)	-0.0374 (-0.68)	-0.0433 (-0.79)	-0.0381 (-0.69)
Interview month: 7	-0.0392 (-0.72)	-0.0405 (-0.75)	-0.0382 (-0.71)	-0.0324 (-0.59)	-0.0402 (-0.74)	-0.0418 (-0.77)	-0.0371 (-0.69)	-0.0374 (-0.69)	-0.0388 (-0.72)	-0.0372 (-0.69)	-0.0383 (-0.71)	-0.0358 (-0.66)
Interview month: 8	0.0383 (0.76)	0.0369 (0.73)	0.0398 (0.79)	0.0410 (0.80)	0.0402 (0.79)	0.0380 (0.75)	0.0402 (0.79)	0.0417 (0.82)	0.0383 (0.76)	0.0404 (0.80)	0.0383 (0.76)	0.0420 (0.83)
Interview month: 9	-0.0153 (-0.30)	-0.0146 (-0.28)	-0.0137 (-0.26)	-0.0162 (-0.31)	-0.0131 (-0.25)	-0.0154 (-0.30)	-0.0143 (-0.28)	-0.0074 (-0.14)	-0.0189 (-0.37)	-0.0126 (-0.24)	-0.0148 (-0.29)	-0.0154 (-0.30)
Interview month: 10	-0.0372 (-0.71)	-0.0399 (-0.76)	-0.0360 (-0.69)	-0.0338 (-0.64)	-0.0356 (-0.68)	-0.0380 (-0.72)	-0.0361 (-0.69)	-0.0360 (-0.68)	-0.0382 (-0.73)	-0.0346 (-0.66)	-0.0388 (-0.74)	-0.0355 (-0.68)
Interview month: 11	-0.0196 (-0.38)	-0.0181 (-0.35)	-0.0187 (-0.36)	-0.0174 (-0.34)	-0.0165 (-0.32)	-0.0209 (-0.41)	-0.0155 (-0.30)	-0.0147 (-0.29)	-0.0159 (-0.31)	-0.0170 (-0.33)	-0.0197 (-0.39)	-0.0170 (-0.33)

Interview month: 12	-0.1199 (-2.10)**	-0.1205 (-2.11)**	-0.1185 (-2.08)**	-0.1242 (-2.16)**	-0.1182 (-2.07)**	-0.1196 (-2.09)**	-0.1177 (-2.06)**	-0.1178 (-2.06)**	-0.1179 (-2.07)**	-0.1182 (-2.07)**	-0.1196 (-2.10)**	-0.1163 (-2.04)**
Aviation related occupation (dummy)	-0.0504 (-0.24)	-0.0459 (-0.21)	-0.0492 (-0.23)	-0.0593 (-0.28)	-0.0361 (-0.17)	-0.0413 (-0.19)	-0.0407 (-0.19)	-0.0614 (-0.29)	-0.0627 (-0.29)	-0.0469 (-0.22)	-0.0587 (-0.27)	-0.0580 (-0.27)
SF-12: Physical health	0.0187 (2.27)**	0.0184 (2.23)**	0.0187 (2.27)**	0.0177 (2.14)**	0.0185 (2.25)**	0.0184 (2.24)**	0.0185 (2.25)**	0.0185 (2.25)**	0.0144 (1.73)*	0.0189 (2.30)**	0.0190 (2.31)**	0.0188 (2.30)**
SF-12: Physical health (squared)	0.0001 (0.98)	0.0001 (1.02)	0.0001 (0.98)	0.0001 (1.08)	0.0001 (1.00)	0.0001 (1.01)	0.0001 (1.00)	0.0001 (1.00)	0.0001 (1.15)	0.0001 (0.95)	0.0001 (0.96)	0.0001 (0.98)
SF-12: Mental health	0.1064 (14.24)***	0.1064 (14.24)***	0.1061 (14.19)***	0.1046 (13.88)***	0.1064 (14.26)***	0.1067 (14.28)***	0.1067 (14.29)***	0.1066 (14.26)***	0.1051 (13.95)***	0.1063 (14.24)***	0.1068 (14.32)***	0.1061 (14.21)***
SF-12: Mental health (squared)	-0.0005 (-5.39)***	-0.0005 (-5.39)***	-0.0005 (-5.34)***	-0.0004 (-5.06)***	-0.0005 (-5.42)***	-0.0005 (-5.44)***	-0.0005 (-5.44)***	-0.0005 (-5.42)***	-0.0005 (-5.36)***	-0.0005 (-5.39)***	-0.0005 (-5.46)***	-0.0005 (-5.35)***
NO2	-0.0054 (-0.44)	-0.0051 (-0.42)	-0.0053 (-0.43)	-0.0043 (-0.35)	-0.0057 (-0.47)	-0.0054 (-0.44)	-0.0056 (-0.46)	-0.0054 (-0.45)	-0.0056 (-0.46)	-0.0059 (-0.49)	-0.0057 (-0.47)	-0.0053 (-0.44)
NOx	0.0005 (0.09)	0.0006 (0.11)	0.0006 (0.10)	0.0002 (0.03)	0.0007 (0.12)	0.0007 (0.12)	0.0008 (0.13)	0.0005 (0.09)	0.0009 (0.16)	0.0008 (0.14)	0.0008 (0.14)	0.0007 (0.11)
PM10	0.0365 (1.41)	0.0344 (1.33)	0.0361 (1.39)	0.0366 (1.40)	0.0377 (1.45)	0.0341 (1.32)	0.0353 (1.37)	0.0384 (1.48)	0.0348 (1.35)	0.0371 (1.44)	0.0347 (1.34)	0.0351 (1.36)
PM25	-0.0207 (-0.72)	-0.0191 (-0.67)	-0.0208 (-0.73)	-0.0219 (-0.76)	-0.0217 (-0.76)	-0.0185 (-0.65)	-0.0199 (-0.70)	-0.0224 (-0.78)	-0.0211 (-0.74)	-0.0215 (-0.75)	-0.0189 (-0.66)	-0.0199 (-0.70)
House Prices	-0.0000 (-0.16)	-0.0000 (-0.26)	-0.0000 (-0.18)	-0.0000 (-0.21)	-0.0000 (-0.17)	-0.0000 (-0.17)	-0.0000 (-0.19)	-0.0000 (-0.20)	-0.0000 (-0.19)	-0.0000 (-0.12)	-0.0000 (-0.19)	-0.0000 (-0.19)
LAeq8hr (control); Insulation Not Eligible; interacted with column header dummy	0.0000 (.)	0.2951 (1.08)	0.3417 (1.24)	0.0196 (0.07)	0.0000 (.)	-0.2011 (-2.86)***	0.4594 (1.70)*	-0.1654 (-0.45)	-0.1178 (-2.64)***	0.0538 (0.84)	-0.1219 (-2.47)**	0.0328 (0.50)

LAeq8hr (control); Insulation Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 1); Insulation Not Eligible; interacted with column header dummy	-0.3063 (-1.07)	0.2665 (0.66)	0.3820 (0.91)	-0.0766 (-0.20)	-0.0628 (-0.21)	-0.1514 (-0.48)	0.3336 (0.87)	-0.6895 (-1.59)	-0.4170 (-1.09)	0.1279 (0.38)	0.0320 (0.11)	0.7471 (1.80)*
LAeq8hr (Quintile 1); Insulation Eligible; interacted with column header dummy	-1.4843 (-1.21)	3.5672 (3.44)***	-1.0374 (-0.78)	0.3210 (0.31)	0.0000 (.)	1.7628 (1.41)	-1.0069 (-0.87)	0.0000 (.)	1.3246 (1.01)	0.0000 (.)	-2.0302 (-1.62)	0.0000 (.)
LAeq8hr (Quintile 2); Insulation Not Eligible; interacted with column header dummy	-0.1040 (-0.48)	-0.0620 (-0.18)	0.2562 (0.74)	-0.4761 (-1.39)	-0.1699 (-0.70)	-0.3798 (-1.40)	0.4566 (1.33)	-0.2665 (-0.56)	0.1329 (0.47)	-0.3396 (-1.38)	0.0317 (0.15)	0.7805 (3.03)***
LAeq8hr (Quintile 2); Insulation Eligible; interacted with column header dummy	0.6392 (1.73)*	1.4103 (4.06)***	1.4400 (4.10)***	-1.0892 (-3.11)***	0.0000 (.)	0.2506 (0.62)	0.4174 (1.09)	0.0000 (.)	-1.1825 (-5.40)***	0.0000 (.)	-0.5256 (-1.32)	0.0000 (.)
LAeq8hr (Quintile 3); Insulation Not Eligible; interacted with column header dummy	-0.2145 (-0.70)	0.2750 (0.64)	0.5514 (1.35)	-0.0517 (-0.12)	-0.5367 (-1.78)*	-0.0737 (-0.25)	1.0252 (2.10)**	-0.5848 (-1.27)	-1.0038 (-2.68)***	-0.8511 (-2.66)***	-0.7096 (-2.34)**	0.7202 (2.14)**
LAeq8hr (Quintile 3); Insulation Eligible; interacted with column header dummy	-0.5556 (-0.61)	1.7246 (3.45)***	-0.0483 (-0.07)	0.0193 (0.03)	1.1463 (1.46)	1.0157 (2.40)**	-0.2198 (-0.34)	-1.2639 (-2.23)**	-1.8119 (-2.52)**	0.0000 (.)	-1.5092 (-3.24)***	0.0000 (.)
LAeq8hr (Quintile 4); Insulation Not Eligible; interacted with column header dummy	-0.1381 (-0.40)	0.7420 (1.74)*	-0.2631 (-0.52)	0.3502 (0.80)	-0.1219 (-0.34)	0.1959 (0.58)	0.7883 (1.86)*	0.0621 (0.12)	0.0894 (0.24)	1.0308 (3.58)***	0.5377 (1.62)	1.0584 (1.94)*
LAeq8hr (Quintile 4); Insulation Eligible; interacted with column header dummy	0.1405 (0.56)	-0.0655 (-0.16)	0.3316 (0.88)	0.4282 (1.15)	0.8232 (2.79)***	0.0068 (0.03)	-0.1243 (-0.35)	-0.7340 (-1.79)*	-0.6745 (-1.22)	-0.7018 (-2.54)**	-0.6030 (-2.24)**	-0.7755 (-1.93)*

LAeq8hr (Quintile 5); Insulation Not Eligible; interacted with column header dummy	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
LAeq8hr (Quintile 5); Insulation Eligible; interacted with column header dummy	-0.1883 (-0.71)	0.0000 (.)	0.0000 (.)	0.0000 (.)	-0.4104 (-1.34)	-0.5532 (-1.80)*	0.0000 (.)	0.0000 (.)	-0.7600 (-1.69)*	-0.5910 (-2.18)**	-0.1125 (-0.44)	0.4061 (2.48)**
Constant	-0.3465 (-0.98)	-0.3355 (-0.95)	-0.3329 (-0.94)	-0.2907 (-0.81)	-0.3367 (-0.95)	-0.3458 (-0.98)	-0.8125 (-1.84)*	-0.1955 (-0.38)	-0.0684 (-0.19)	-0.3083 (-0.85)	-0.4357 (-1.22)	-0.3457 (-0.96)
N	17812	17812	17812	17311	17812	17812	17812	17812	17812	17812	17812	17812
Adjusted R squared	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.321	0.321	0.321	0.320

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table C2

12. Appendix D: Mediation Analysis, First Stage

12.1 Physical Health

Dependent Variable: Physical Health	LAeq16hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-0.1530 (-0.29)	0.2664 (0.51)
LAeq16hr (Quintile 5); Insulation Not Eligible	57.9-99	-0.2963 (-0.38)	0.2115 (0.26)
N		28057	28299
Adjusted R squared		0.154	0.158

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table D1: Impact of daytime aviation noise on physical health, compared to a counterfactual of no aviation noise exposure.

Dependent Variable: Physical Health	LAeq8hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	-0.3844 (0.38)	0.5277 (0.52)
N		17677	17830
Adjusted R squared		0.160	0.164

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table D2: Impact of night-time aviation noise on physical health, compared to a counterfactual of no aviation noise exposure.

12.2 Mental Health

Dependent Variable: Mental Health	LAeq16hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq16hr (Quintile 4); Insulation Not Eligible	54.9-57.9	-1.081 (-2.04)**	-0.8604 (-1.61)
LAeq16hr (Quintile 5); Insulation Not Eligible	57.9-99	-1.3269 (-1.75)*	-1.2001 (-1.53)
N		28057	28299
Adjusted R squared		0.307	0.310

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table D3: Impact of daytime aviation noise on mental health, compared to a counterfactual of no aviation noise exposure.

Dependent Variable: Mental Health	LAeq8hr	OLS; Local Authority Fixed Effects	OLS; Shortward Fixed Effects
LAeq8hr (Quintile 3); Insulation Not Eligible	53.4-54.8	-1.5941 (1.23)	-1.7632 (1.35)
N		17677	17830
Adjusted R squared		0.309	0.313

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table D4: Impact of night-time aviation noise on mental health, compared to a counterfactual of no aviation noise exposure.

13. Appendix E: Sleep – Full Tables

Dependent Variable: Sleep Disturbance	Day	Night
SF-12: Physical health	-0.0227 (-0.37)	0.1244 (0.95)
SF-12: Physical health (squared)	-0.0004 (-0.56)	-0.0021 (-1.36)
SF-12: Mental health	-0.1083 (-1.72)*	-0.3580 (-1.60)
SF-12: Mental health (squared)	0.0006 (0.79)	0.0033 (1.39)
Age	0.0691 (2.13)**	0.2370 (3.46)***
Age (squared)	-0.0008 (-2.46)**	-0.0025 (-3.58)***
Male	-0.5469 (-2.52)**	-0.8294 (-1.84)*
Marital Status: With Partner	-0.2724 (-1.20)	-1.1732 (-2.30)**
Education: Degree or higher	-0.5423 (-2.58)***	-1.1973 (-2.64)***
Ethnicity: White	0.6419 (2.74)***	0.8485 (1.73)*
Has dependent children	0.0305 (0.12)	-0.3160 (-0.60)
Carer: Yes	0.1250 (0.27)	1.3389 (1.52)
Urban Area	0.9127 (1.79)*	3.3959 (3.24)***
Wave: 4 (reference)	0.0000 (.)	0.0000 (.)
Wave: 7	-0.1388 (-0.68)	-0.3057 (-0.68)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)
Interview month: 2	-0.6521 (-1.42)	-1.6693 (-1.77)*
Interview month: 3	-0.7019 (-1.28)	-0.2687 (-0.25)
Interview month: 4	-0.0374 (-0.09)	0.9567 (1.08)
Interview month: 5	-0.3835 (-0.91)	-0.4946 (-0.60)
Interview month: 6	-0.7212 (-1.58)	-0.4290 (-0.34)
Interview month: 7	-0.5436 (-1.32)	0.0672 (0.08)
Interview month: 8	-1.8481 (-2.67)***	-2.3401 (-2.02)**
Interview month: 9	-0.7176 (-1.69)*	-0.4621 (-0.57)
Interview month: 10	0.0485 (0.11)	-2.5421 (-1.67)*

Interview month: 11	-0.0744	-0.5713
	(-0.21)	(-0.65)
Interview month: 12	-0.5279	0.0000
	(-0.82)	(.)
LAeq16hr; Insulation Not Eligible	-0.0044	0.0403
	(-0.10)	(0.39)
LAeq16hr; Insulation Eligible	-0.0021	0.0364
	(-0.05)	(0.39)
Log Equivalised Household Income	-0.0027	-0.0556
	(-0.03)	(-0.32)
Constant	3.1553	-1.4019
	(0.95)	(-0.15)
N	904	259
Pseudo R squared	0.154	0.276

Table E1: Impact of an additional decibel of aviation noise on incidence of sleep disturbance.

14. Appendix F: APS Results

Dependent Variable: Life Satisfaction	Day; Local Authority Fixed Effects	Day; Shortward Fixed Effects	Night; Local Authority Fixed Effects	Night; Shortward Fixed Effects
Leq16hr; Insulation Not Eligible	-0.0317 (-0.13)	-0.0601 (-0.25)		
Leq16hr; Insulation Eligible	-0.0806 (-0.37)	-0.1055 (-0.48)		
Leq16hr (squared); Insulation Not Eligible	0.0002 (0.09)	0.0004 (0.20)		
Leq16hr (squared); Insulation Eligible	0.0010 (0.56)	0.0012 (0.67)		
Leq8hr; Insulation Not Eligible			-0.5015 (-1.00)	-0.5076 (-1.02)
Leq8hr; Insulation Eligible			-0.4441 (-0.98)	-0.4467 (-0.99)
Leq8hr (squared); Insulation Not Eligible			0.0050 (1.02)	0.0051 (1.05)
Leq8hr (squared); Insulation Eligible			0.0039 (0.98)	0.0039 (0.99)
General Health: Category 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
General Health: Category 2	1.0418 (3.23)***	1.0439 (3.24)***	1.2751 (1.68)*	1.2703 (1.69)*
General Health: Category 3	1.8991 (6.17)***	1.8931 (6.15)***	2.0700 (2.66)***	2.0653 (2.68)***
General Health: Category 4	2.4732 (8.05)***	2.4663 (8.04)***	2.5958 (3.35)***	2.5929 (3.37)***
General Health: Category 5	2.8466 (9.23)***	2.8394 (9.22)***	3.0275 (3.90)***	3.0240 (3.92)***
House Prices	-0.0000 (-0.28)	-0.0000 (-0.23)	-0.0000 (-0.52)	-0.0000 (-0.51)
NO2	0.0275 (0.59)	0.0244 (0.52)	0.0825 (0.87)	0.0483 (0.51)
NOx	-0.0276 (-1.50)	-0.0266 (-1.44)	-0.0479 (-1.18)	-0.0340 (-0.85)
PM10	0.0506 (0.68)	0.0461 (0.61)	0.0735 (0.42)	0.0744 (0.41)

PM25	0.0645 (0.58)	0.0704 (0.63)	-0.0380 (-0.14)	-0.0061 (-0.02)
Male (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Female	0.1161 (2.74)***	0.1129 (2.67)***	0.0515 (0.69)	0.0475 (0.64)
Age	-0.0794 (-8.33)***	-0.0797 (-8.38)***	-0.0516 (-3.47)***	-0.0517 (-3.47)***
Age (squared)	0.0008 (8.12)***	0.0008 (8.18)***	0.0005 (3.17)***	0.0005 (3.17)***
Marital Status: Category 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Marital Status: Category 2	0.5366 (9.95)***	0.5354 (9.94)***	0.5600 (5.27)***	0.5538 (5.23)***
Marital Status: Category 3	-0.1274 (-0.85)	-0.1444 (-0.96)	0.0152 (0.06)	0.0105 (0.04)
Marital Status: Category 4	0.1777 (2.13)**	0.1758 (2.10)**	0.3763 (2.54)**	0.3781 (2.57)**
Marital Status: Category 5	-0.0233 (-0.19)	-0.0123 (-0.10)	0.3824 (1.76)*	0.3778 (1.74)*
Marital Status: Category 6	0.7576 (5.08)***	0.7529 (5.04)***	-0.1335 (-0.28)	-0.1430 (-0.30)
Education Level: Category 1	0.2312 (1.70)*	0.2428 (1.79)*	-0.0609 (-0.25)	-0.0428 (-0.18)
Education Level: Category 2	0.3277 (2.20)**	0.3352 (2.26)**	0.0298 (0.10)	0.0652 (0.21)
Education Level: Category 3	0.2464 (1.70)*	0.2635 (1.82)*	-0.4395 (-1.59)	-0.4119 (-1.49)
Education Level: Category 4	0.3830 (2.59)***	0.3878 (2.63)***	-0.0543 (-0.21)	-0.0483 (-0.18)
Education Level: Category 5	0.2446 (1.53)	0.2492 (1.56)	-0.0744 (-0.24)	-0.0667 (-0.22)
Education Level: Category 6 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Education Level: Category 7	0.0400 (0.18)	0.0446 (0.20)	-0.0603 (-0.17)	-0.0700 (-0.20)
Education Level: Category 8	0.4159 (0.80)	0.4338 (0.83)	1.4290 (3.67)***	1.4363 (3.71)***

Education Level: Category 9	0.0733 (0.45)	0.0825 (0.51)	-0.0687 (-0.22)	-0.0765 (-0.24)
Employment: Category 1	0.5082 (4.11)***	0.5173 (4.20)***	0.9139 (3.34)***	0.8979 (3.27)***
Employment: Category 2	0.7113 (6.15)***	0.7138 (6.20)***	1.0910 (4.17)***	1.0748 (4.11)***
Employment: Category 3	0.2483 (0.43)	0.2616 (0.45)	-0.2243 (-0.42)	-0.2350 (-0.44)
Employment: Category 4	0.6729 (1.60)	0.6823 (1.61)	2.1957 (5.36)***	2.1991 (5.24)***
Employment: Category 5 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Employment: Category 6	0.7487 (4.98)***	0.7619 (5.11)***	1.0676 (3.36)***	1.0709 (3.34)***
Employment: Category 7	0.4927 (3.44)***	0.5033 (3.53)***	1.1463 (3.85)***	1.1411 (3.83)***
Employment: Category 8	-0.7185 (-1.42)	-0.7162 (-1.42)	0.9236 (1.84)*	0.9090 (1.78)*
Employment: Category 9	0.0381 (0.19)	0.0452 (0.22)	0.6999 (1.53)	0.6964 (1.53)
Employment: Category 10	0.7945 (1.47)	0.8113 (1.50)	0.0862 (0.13)	0.0828 (0.13)
Employment: Category 11	0.9977 (7.38)***	1.0083 (7.48)***	1.3295 (4.72)***	1.3347 (4.73)***
Employment: Category 12	1.1188 (5.90)***	1.1247 (5.90)***	1.1477 (2.83)***	1.1477 (2.81)***
Employment: Category 13	-0.4435 (-1.06)	-0.4289 (-1.02)	1.2958 (1.82)*	1.2980 (1.83)*
Employment: Category 14	0.5305 (2.63)***	0.5447 (2.72)***	0.5213 (1.30)	0.5077 (1.27)
Income: Category 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Income: Category 2	0.1303 (1.28)	0.1326 (1.30)	-0.0419 (-0.26)	-0.0416 (-0.26)
Income: Category 3	0.2686 (3.19)***	0.2643 (3.14)***	0.1259 (0.90)	0.1295 (0.93)
Income: Category 4	0.5322 (5.85)***	0.5291 (5.80)***	0.3013 (1.99)**	0.3036 (2.00)**

Income: Category 101	0.2361 (2.33)**	0.2323 (2.29)**	-0.0560 (-0.35)	-0.0525 (-0.33)
Ethnicity: Category 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Ethnicity: Category 2	0.1741 (1.43)	0.1771 (1.44)	0.0125 (0.05)	0.0115 (0.05)
Ethnicity: Category 3	-0.0386 (-0.54)	-0.0334 (-0.47)	0.2310 (2.01)**	0.2347 (2.03)**
Ethnicity: Category 4	-0.3299 (-3.17)***	-0.3255 (-3.13)***	-0.0127 (-0.07)	-0.0127 (-0.07)
Ethnicity: Category 5	-0.0242 (-0.22)	-0.0233 (-0.21)	-0.3806 (-1.55)	-0.3823 (-1.55)
Ethnicity: Category 11	-1.3595 (-3.52)***	-1.3451 (-3.42)***	-2.3994 (-8.95)***	-2.3964 (-8.86)***
Number of dependent children	-0.0215 (-1.06)	-0.0221 (-1.09)	-0.0237 (-0.73)	-0.0228 (-0.71)
Religious: No (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Religious: Yes	0.1084 (2.27)**	0.1032 (2.16)**	0.1166 (1.34)	0.1154 (1.32)
Interview month: 1 (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Interview month: 2	-0.0134 (-0.14)	0.0010 (0.01)	-0.3575 (-1.97)**	-0.3674 (-1.96)*
Interview month: 3	0.0604 (0.65)	0.0770 (0.82)	-0.2407 (-1.39)	-0.2442 (-1.36)
Interview month: 4	-0.0476 (-0.51)	-0.0498 (-0.53)	-0.0294 (-0.17)	-0.0447 (-0.26)
Interview month: 5	-0.1619 (-1.57)	-0.1412 (-1.37)	-0.1400 (-0.73)	-0.1403 (-0.71)
Interview month: 6	-0.0189 (-0.19)	-0.0024 (-0.02)	-0.3458 (-1.74)*	-0.3474 (-1.70)*
Interview month: 7	-0.0299 (-0.32)	-0.0253 (-0.27)	-0.4518 (-2.51)**	-0.4454 (-2.46)**
Interview month: 8	-0.0030 (-0.03)	0.0135 (0.13)	-0.4239 (-2.15)**	-0.4420 (-2.17)**
Interview month: 9	0.0546 (0.52)	0.0708 (0.66)	-0.3350 (-1.61)	-0.3430 (-1.61)

Interview month: 10	-0.0607 (-0.62)	-0.0628 (-0.64)	-0.0416 (-0.22)	-0.0227 (-0.12)
Interview month: 11	0.0001 (0.00)	0.0173 (0.19)	-0.2680 (-1.34)	-0.2877 (-1.39)
Interview month: 12	-0.1071 (-0.99)	-0.0872 (-0.80)	-0.5843 (-2.54)**	-0.5881 (-2.54)**
Year: 2011 (day-time reference)	0.0000 (.)	0.0000 (.)	no data	no data
Year: 2012	0.4267 (2.88)***	0.4168 (2.74)***	no data	no data
Year: 2013 (night-time reference)	0.3924 (2.47)**	0.3871 (2.36)**	0.0000 (.)	0.0000 (.)
Year: 2014	0.5981 (3.18)***	0.5934 (3.07)***	0.1650 (1.37)	0.1822 (1.52)
Year: 2015	0.9888 (3.11)***	0.9886 (3.06)***	0.1994 (0.37)	0.2945 (0.56)
Year: 2016	1.0777 (4.05)***	1.0730 (4.00)***	0.5257 (1.17)	0.5171 (1.20)
Year: 2017	0.9814 (3.29)***	0.9832 (3.26)***	0.4791 (1.17)	0.5104 (1.26)
Aviation related occupation: No	-0.5332 (-2.42)**	-0.5521 (-2.53)**	-0.4889 (-1.28)	-0.4904 (-1.28)
Aviation related occupation: Yes (reference)	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Dwelling Type: Category 1	0.0000 (.)	0.0000 (.)	0.0000 (.)	0.0000 (.)
Dwelling Type: Category 2	0.0528 (0.32)	0.0610 (0.37)	-0.0429 (-0.14)	-0.0626 (-0.20)
Dwelling Type: Category 3	0.0357 (0.23)	0.0546 (0.34)	0.2254 (0.79)	0.2229 (0.77)
Dwelling Type: Category 4	-0.0951 (-0.60)	-0.0745 (-0.47)	0.0282 (0.10)	0.0253 (0.09)
Dwelling Type: Category 5	-0.1557 (-0.78)	-0.1537 (-0.78)	-0.0724 (-0.19)	-0.0842 (-0.21)
Dwelling Type: Category 6	-0.3923 (-0.78)	-0.3508 (-0.69)		
Dwelling Type: Category 7	0.9205 (2.05)**	0.9351 (2.09)**	2.1586 (4.65)***	2.1386 (4.53)***

Dwelling Type:	0.0311	0.0477	0.1421	0.1323
Category 99	(0.21)	(0.32)	(0.52)	(0.48)
Constant	4.9643	6.0983	16.1081	16.7505
	(0.73)	(0.90)	(1.23)	(1.28)
N	12801	12801	3164	3164
Adjusted R squared	0.180	0.181	0.166	0.166

Robust t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table F1.

15. Appendix G: Identification Strategy (technical)

We employ regression analysis to assess the statistical association between various levels of noise exposure on Life Satisfaction, health, and sleep. First, a continuous specification is estimated to establish the marginal impact of an additional decibel of noise exposure on wellbeing. We then employ a semiparametric specification to compare those who are exposed to different levels of aviation noise to a counterfactual group of close by residents who are not exposed to aviation noise. Using these counterfactual specifications, we additionally employ mediation analysis to establish the proportion of the effect on life satisfaction that occurs through physical and mental health as mediators. Finally, we use logistic regression to test for a statistical relationship between aviation noise and sleep.

In all the analysis presented below, models are estimated separately for day and night noise, (a) to capture differential impacts of aviation noise exposure, and (b) due to the differing spatial distribution of aviation noise between day and night.

In each specification we exclude treated observations (in all years) for which road or rail noise exposure is higher than aviation noise exposure in either of the years for which road and rail noise data is available, to avoid potential for double-counting. In the counterfactual analyses we additionally exclude control observations which are exposed to road or rail noise at or above the minimum observed threshold of 50dB and 48dB for day and night models respectively.

15.1 Life Satisfaction

15.1.1 Marginal Impact of Aviation Noise

We utilise the pooled cross-sectional Understanding Society data to calculate the marginal impact of exposure to an additional decibel of aviation noise on Life Satisfaction, denoted SWB_{it}. Both day and night samples are restricted to the sample for which we have measurements of noise exposure (>51dB and >48dB respectively). In Equation 1, $LAeq_{it}$ represents individual i's aviation noise exposure in LAeq during year t; this is specified as a quadratic to maximise model fit. The quadratic specification was chosen by fitting a variety of polynomial functions and selecting the model with the highest adjusted R^2. I_i is a dummy variable equal to one if individual i lives in a postcode that is entitled to subsidised insulation, and $\bar{I}_i$ is a dummy variable equal to one if they do not; it is important to note that noise exposure and subsidised insulation entitlement are strongly but imperfectly correlated, as entitlement to each scheme depends on noise exposure in a particular reference year (which differs for each airport – see Table 3.1 in the previous section). β_{1Q} and β_{2Q} are therefore the coefficients on the linear and square $LAeq_{it}$ terms for those that do not qualify for subsidised insulation, and γ_{1Q} and γ_{2Q} are the respective coefficients for those that do. The first order partial differentials of SWB_{it} with respect to β_{gQ} and γ_{gQ} respectively therefore identify the marginal impact of aviation noise on Life Satisfaction for those who do not, and do, qualify for subsidised insulation.

$\ln M_i$ is the natural log of equivalised household income, Wave_t is a vector of year dummies, and SU_i is a spatial unit fixed effect, defined as local authority, and alternatively as pooled CAS Wards (for robustness). CAS Wards are pooled by the first five digits of ward code; within-ward sample sizes were insufficient to include full wards. The resulting number of pooled CAS Wards in our regression sample is 121, whereas the number of local authorities is 70, hence this measure is more spatially disaggregated. $H_{1\boldsymbol{it}}$ and $H_{2\boldsymbol{it}}$ represent SF-12 Health Survey measures of physical and mental health respectively, specified as quadratics. $\mathbf{X}$ is a $(N \times k)$ matrix of covariates constructed in line with current best-practice in the subjective wellbeing literature (see Fujiwara and Campbell (2011) for a more substantive discussion on selection of covariates in wellbeing regressions); the full list of covariates are listed in the full regression output tables in Appendix A. We additionally control for house prices to account for any compensation for aviation noise captured in the housing market through a hedonic pricing mechanism, as well as Nitrous Dioxide, Nitrous Oxide, PM_{10} and $\text{PM}_{2.5}$ measures of air pollution, to net out aviation impacts on wellbeing that occur through channels other than noise. u_i is the error term, subject to the usual Gauss-Markov assumptions.

$$SWB_{it} = \alpha + \sum_{g=1}^{G=2}\left[\beta_{gQ}\left(\bar{I}_{it} \cdot LAeq_{it}^{g}\right)\right] + \sum_{g=1}^{G=2}\left[\gamma_{gQ}\left(I_{it} \cdot LAeq_{it}^{g}\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\mu_{gh}H_{hit}^{g} + \mathbf{X\beta} + u_{it} \quad (1)$$

The pooled cross-sectional regression sample is weighted to ensure that the results can be generalised to the UK population. We use a range of cross-sectional weights provided in the USoc dataset for different waves (variables: *indscus*_xw for wave 1, *indscub*_xw for waves 2-5 and *indinue*_xw for waves 6-8). These weights adjust for unequal selection probabilities (for example, ethnic minority respondents are over-represented in the raw dataset that includes a booster sample targeting that group), differential nonresponse (when different respondent groups drop out of the sample with different probability), and potential sampling error. Finally, we scale the weights within each survey wave so that that they sum up to a constant number – this ensures that our analysis does not rely on some survey waves more heavily than others.

For robustness, we repeat the estimation of Equation 1 using Instrumental Variables (IV). There is potential for the existence of simultaneity between SWB and both physical and mental health: general wellbeing is known to affect both physical and mental health (Siahpush et al., 2008). This is partially addressed by controlling for objective SF-12 measures of health as opposed to self-reported subjective health, which has potential to be more highly correlated with self-reported subjective wellbeing. It is important to stress that the theoretical bias of simultaneity between Life Satisfaction and health would be confined to the vector of μ_{gh} coefficients, so this is unproblematic for the estimation of impacts on Life Satisfaction, and subsequent valuation. However, to more fully address the potential for simultaneity, we re-estimate Equation (1) using single-wave lagged measures of physical and mental health as instruments for current physical and mental health.

Substituting the simple linear equation $H^g_{hit} = \alpha_{gh} + \omega_{gh} H^g_{hit-1} + \varepsilon_{ghit}; g \in \mathbb{N}\{1,2\};\ h \in \mathbb{N}\{1,2\}$ into Equation 1:

$$SWB_{it} = \alpha + \sum_{g=1}^{G=2}\left[\beta_{gQ}\left(\bar{I}_{it} \cdot LAeq^g_{it}\right)\right] + \sum_{g=1}^{G=2}\left[\gamma_{gQ}\left(I_{it} \cdot LAeq^g_{it}\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\left[\mu_{gh}\left(\alpha_{gh} + \omega_{gh}H^g_{hit-1} + \varepsilon_{ghit}\right)\right] + \mathbf{X\beta} + u_{it} \qquad (2)$$

Subject to the normal Two Stage Least Squares proof, it can be shown that $\exists\ \omega_{gh} :\ \omega_{gh} = \frac{\gamma_{gh}}{\mu_{gh}}$. This yields Equation 3.

$$SWB_{it} = \alpha + \sum_{g=1}^{G=2}\left[\beta_{gQ}\left(\bar{I}_{it} \cdot LAeq^g_{it}\right)\right] + \sum_{g=1}^{G=2}\left[\gamma_{gQ}\left(I_{it} \cdot LAeq^g_{it}\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\omega_{gh}H^g_{hit} + \mathbf{X\beta} + e_{it} \qquad (3)$$

15.1.2 Counterfactual Analysis

We adopt a semi-parametric specification to determine the impact on Life Satisfaction on individuals living in households exposed to various levels of aviation noise, comparative to a control group of individuals living in nearby households who are not exposed to any significant aviation noise (as identified by the CAA in the noise exposure dataset through a binary variable indicating postcodes that are exposed to a level of aviation noise sufficiently below the 51 dB daytime / 48 dB night time threshold, such that exposure to aviation noise can be treated as non-existent).

Observations are categorised by level of noise exposure for the purpose of calculating conditional wellbeing differentials between individuals exposed to various levels of aviation noise and the counterfactual. Noise exposure is left-skewed, and there are insufficient observations at very high levels of exposure to categorise observations at the decibel level; we therefore group treated observations by quintile of noise exposure in order to (a) ensure there are sufficient observations in each treated category for meaningful analysis, and (b) avoid the possibility of specification searching. The Quintile dB ranges are reported in all results tables.

Equation 4 is largely equivalent to Equation 1, however $LAeq^j_i\ j \in \mathbb{N}[1,5]$ is now specified as a vector of dummy variables equal to one if individual i falls within quintile j of aviation noise exposure. It must be stressed that coefficients derived in this part of the analysis therefore have a different interpretation to the marginal impacts derived in the section above: β^j_Q and γ^j_Q report the statistical relationship between quintile j aviation noise exposure on Life Satisfaction for individuals who do and do not qualify for subsidised insulation respectively, comparative to those who are not exposed to aviation noise, net of confounding factors. This approach significantly increases the sample size due to the inclusion of control observations; this in turn increases the statistical power of regression covariates, which is particularly helpful for Section 4.2 of this report, in which we establish the extent of the wellbeing impacts that are transmitted through physical and mental health. Just as in Section 4.1.1, Equation 4 is alternatively estimated using single-wave lags of SF-12 measures of physical and mental health, H_{1it} and H_{2it}, to mitigate the potential for simultaneity between health and wellbeing (see Equations 2 and 3; the generic terms $f(\cdot)$ and $g(\cdot)$ can be applied to the specific functional forms of Equations 1 and 5).

$$SWB_{it} = \alpha + \sum_{j=1}^{J=5}\left[\beta^j_Q\left(LAeq^j_{it} \cdot I_i\right)\right] + \sum_{j=1}^{J=5}\left[\gamma^j_Q\left(LAeq^j_{it} \cdot \bar{I}_i\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\left[\mu_{gh}\left(\alpha_{gh} + \omega_{gh}H^g_{hit-1} + \varepsilon_{ghit}\right)\right] + \mathbf{X\beta} + u_{it} \qquad (4)$$

Once again, using the fact that $\exists\ \omega_{gh} :\ \omega_{gh} = \frac{\gamma_{gh}}{\mu_{gh}}$ yields Equation 5.

$$SWB_{it} = \alpha + \sum_{j=1}^{J=5}\left[\beta^j_Q\left(LAeq^j_{it} \cdot I_i\right)\right] + \sum_{j=1}^{J=5}\left[\gamma^j_Q\left(LAeq^j_{it} \cdot \bar{I}_i\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\omega_{gh}H^g_{hit} + \mathbf{X\beta} + e_{it} \qquad (5)$$

Finally, in Equation 6 we test for heterogeneous treatment effects by individually interacting treatment quintile dummies for those with and without subsidised insulation, $LAeq_{it}^{j} \cdot I_i$ and $LAeq_{it}^{j} \cdot \bar{I}_i$, with sociodemographic characteristics $x \in \mathbf{X}$. This allows us to establish whether people from different sociodemographic groups are differently affected by aviation noise; this also offers suggestive evidence of the external validity of the base specifications (1) and (4).

$$SWB_{it} = \alpha + \sum_{j=1}^{J=5}\left[\beta_Q^j\left(LAeq_{it}^j \cdot I_i\right)\right] + \sum_{j=1}^{J=5}\left[\gamma_Q^j\left(LAeq_{it}^j \cdot \bar{I}_i\right)\right] + \sum_{j=1}^{J=5}\left[\vartheta_Q^{xj}\left(LAeq_{it}^j \cdot I_i \cdot x\right)\right] + \sum_{j=1}^{J=5}\left[\varphi_Q^{xj}\left(LAeq_{it}^j \cdot \bar{I}_i \cdot x\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\sum_{h=1}^{H=2}\mu_{gh}H_{hit}^g + \mathbf{X\beta} + u_{it} \quad (6)$$

Just as with the marginal impact analysis in the previous subsection, Equations 4-6 are estimated separately for day and night noise to capture differential impacts of noise that occurs at different times of the day.

15.2 Health Mediation Analysis

The impact of noise on wellbeing has potential to be transmitted through a number of channels; one important channel to consider, as identified in Section 2.3.3 of this report, is health. In our estimations so far, we controlled for both physical and mental health as important determinants of wellbeing; with such controls in place, the coefficients on noise reflect the total impact of noise on wellbeing, and are not therefore informative in respect to the channels through which that effect is transmitted.

We use Mediation Analysis to test the extent to which wellbeing impacts are transmitted through both physical and mental health (the mediator variables). For mediation analysis to be robust, both physical and mental health coefficients in Equation 4 must be unbiased. As discussed in Section 4.1, the potential for simultaneity between health and wellbeing may cause bias to health coefficients. In response, we alternatively estimate all specifications using single-wave lags of both physical and mental health as instrumental variables in Equation 5. We utilise the IV estimates of the counterfactual analyses to conduct mediation analysis, to assess the proportion of the total wellbeing impact that is respectively transmitted through both physical and mental health.

We employ the Sobel (1982) Product of Coefficients approach to quantifying mediation. We first consider equation (6); the set of coefficients β^j_Q and γ^j_Q represent the total effect of aviation noise on subjective wellbeing, controlling for a full set of covariates including physical and mental health. We re-estimate Equation 7, dropping SWB_{it} and specifying physical and mental health variables, H_{1it} and H_{2it} on the left-hand side in Equations 7 and 8 respectively.

$$H_{1it} = \alpha + \sum_{j=1}^{J=5}\left[\sigma_Q^j\left(LAeq_{it}^j \cdot I_i\right)\right] + \sum_{j=1}^{J=5}\left[\delta_Q^j\left(LAeq_{it}^j \cdot \bar{I}_i\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\omega_{g2}H_{2it}^g + \mathbf{X\beta} + e_{it} \quad (7)$$

$$H_{2it} = \alpha + \sum_{j=1}^{J=5}\left[\sigma_Q^j\left(LAeq_{it}^j \cdot I_i\right)\right] + \sum_{j=1}^{J=5}\left[\delta_Q^j\left(LAeq_{it}^j \cdot \bar{I}_i\right)\right] + \beta_M \ln M_{it} + \text{Wave}_t\kappa + \text{SU}_i\rho + \sum_{g=1}^{G=2}\omega_{g1}H_{1it}^g + \mathbf{X\beta} + e_{it} \quad (8)$$

We then define the mediator coefficient $\mathcal{M}_{hit}$: $(\mathcal{M}_{hit}|I_i) = \omega_{gh} \cdot \sigma_Q^j$ and $(\mathcal{M}_{hit}|\bar{I}_i) = \omega_{gh} \cdot \delta_Q^j$.

Significance of mediation effects are determined by z-statistics, defined by:

$$(z|I_i) = \frac{\omega_{gh} \cdot \sigma_Q^j}{\sqrt{\omega_{gh}^2 \cdot \left[\text{s.d.}\left(\delta_Q^j\right)\right]^2 + \sigma_Q^j \cdot \left[\text{s.d.}\left(\omega_{gh}\right)\right]^2}} \text{ and } (z|\bar{I}_i) = \frac{\omega_{gh} \cdot \delta_Q^j}{\sqrt{\omega_{gh}^2 \cdot \left[\text{s.d.}\left(\delta_Q^j\right)\right]^2 + \delta_Q^j \cdot \left[\text{s.d.}\left(\omega_{gh}\right)\right]^2}}$$

Subject to the sequential ignorability assumption (that is, assignment to noisy areas is independent of health), and no-interaction assumption (mediator and direct effects do not vary as functions of treatment status), mediation analysis separates the wellbeing impacts of aviation noise that occur through health from those that occur directly (Imai, Keele & Tingley, 2010).