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Who flies but never drives? Highlighting diversity among high emitters for passenger transport in England

Giulio Mattioli[1,2], Milena Büchs[2] & Joachim Scheiner[1]

[1] *Urban Development Research Group, Department of Spatial Planning, TU Dortmund University (Germany)*

[2] *Sustainability Research Institute, School of Earth and Environment, University of Leeds, Woodhouse Lane, LS2 9JT Leeds, United Kingdom*

Abstract

Energy research is paying increasing attention to inequalities in climate emissions and to the disproportionate contribution of 'high emitters' to national emissions, notably from transport. While the individual and household factors associated with high overall emissions are well-known, there is a need for a more nuanced understanding of who 'high emitters' across different domains are and what drives their emissions. This paper highlights diversity within the group of 'high emitters' for transport, based on survey data on English residents' car and air travel. We define groups characterised by high emissions from car travel, air travel, or both. We focus in particular on individuals with 'dissonant' profiles – i.e., combining low emissions for one mode and high emissions for the other. These nuances have been overlooked to date, but they are important from a policy perspective. We describe the identified groups with bivariate and multivariate methods, considering socio-economic attributes, neighbourhood characteristics, social network dispersion, and environmental attitudes. We find that individuals with 'dissonant' emission patterns account for up to 20% of the population, and up to 30% of emissions from car and air travel. Those who combine low car emissions with high emissions from air travel are more likely to be urban residents, higher-income groups, younger adults, females, migrants, and people with dispersed social networks. Individuals with the opposite profile of high car and low air travel emissions tend to be male, middle-aged, and long-distance commuters living in car-dependent areas. We conclude by discussing implications for climate policy in the transport sector.

Keywords: Air travel, Car use, Modality styles, Long-distance travel, Excess travel, Energy Justice

1. Introduction

An emerging topic in energy and climate research is the skewed distribution of energy consumption and related greenhouse gas emissions (GHG), not just at the global level and between countries but also within countries and cities (Baltruszewicz et al., 2023; Büchs & Schnepf, 2013; Chancel, 2022;

Creutzig et al., 2022; Ivanova & Wood, 2020; Leroutier & Quirion, 2022; Millward-Hopkins, 2022; Oswald et al., 2020; Starr et al., 2023). Researchers have highlighted very high levels of inequality, with small groups of 'high emitters' or 'excess consumers' responsible for a disproportionate share of emissions (Brand & Boardman, 2008; Cass et al. 2022; Chatterton et al., 2015; Mattioli & Anable, 2017; Wadud et al., 2022), and have discussed what this implies for the distributional impact of climate policies (Büchs et al., 2021; Garcia & Stronge, 2022; Theine et al., 2022). Given the strong association between emissions and affluence, the energy, travel and consumption practices of the sectors of the population with high socio-economic status are coming under increasing scrutiny as well (Barros & Wilk, 2021; Castano Garcia et al., 2021; Gössling & Humpe, 2022; Nielsen et al., 2021; O'Garra & Fouquet, 2022; Otto et al., 2019; Wiedmann et al., 2020).

Studies typically find that a large share of the emissions of high emitters and/or high-income individuals is from transport, as transport energy consumption is even more unequally distributed, and even more strongly associated with affluence than emissions in other sectors (Baltruszewicz et al., 2022; Feng et al., 2021; Ivanova & Wood, 2020; Oswald et al., 2020). Unlike other sectors, transport has not contributed to emission reductions to date, not even in high-emission countries (Lamb et al., 2021). In these countries, around 90% of passenger transport emissions are from just two modes: car and air travel (Aamaas et al., 2013; Aamaas & Peters, 2017; Brand & Boardman, 2008; UBA, 2020). While car emissions have stagnated or slowed their growth since the 1990s, emissions from aviation have sky-rocketed due to growing travel activity until the COVID-19 pandemic (Lee et al., 2021), and we are already witnessing a rapid recovery with expected record years ahead (EASA & Eurocontrol, 2022; Gössling et al., 2021). Air travel is characterised by extreme inequalities and as such the climate impact of 'frequent flyers' has come under increasing scrutiny as well (Büchs & Mattioli, 2021; 2022; Fouquet & O'Garra, 2022; Gössling & Humpe, 2021; Zheng & Rutherford, 2022).

The individual and household characteristics associated with high levels of emissions overall and for passenger transport specifically are now relatively well understood, including mainly high income, high education and being in employment (see Section 2). However, there is considerable variation in emissions within each of these groups, as attested by the low predictive power of models identifying high emitters (Theine et al., 2022). Meanwhile, contemporary transport research has highlighted several factors that tend to reduce car use in daily life but to increase long-distance and air travel, including urbanity, young adulthood, and migration background. There is also increasing evidence of population groups characterised by 'modality styles' combining low levels of car use and high levels of air travel, which are likely to be high emitters, albeit with a peculiar emission profile.

Taken together, this suggests the need for a more nuanced understanding of who high emitters are, their emission profiles from different travel modes, and what drives their travel patterns. The goal of this article is to highlight diversity within the group of high emitters for passenger transport, based on data on English residents' car and air travel from the UK Household Longitudinal Study (UKHLS) survey. We define groups characterised by high emissions from car travel only, air travel only, or both at the same time. We focus in particular on individuals with 'dissonant' transport emission profiles – i.e., combining low emissions for one mode and high emissions for the other. These nuances have been overlooked to date, but they are important from a policy perspective as they may require more targeted policy responses. Moreover, the richness of the dataset allows us to simultaneously investigate the effect of a wide range of socio-economic, spatial and attitudinal factors, some of which have only rarely been investigated before with a focus on high emissions.

The article is structured as follows: in Section 2 we review research on inequalities in emissions, the determinants of car and air travel use, the relationships and trade-offs between the two, and 'dissonant' modality styles. Section 3 introduces our analysis approach along with the data and the methods. Section 4 presents the results of the analysis which are then discussed in Section 5.

2. Background

2.1 Inequalities in GHG emissions and determinants of high emissions

Previous research has shown that GHG emissions are highly unequally distributed. Globally, the top 10% of emitters are responsible for an estimated 52% of cumulative carbon emissions, while the bottom 50% only contributed 7% (Gore, 2020). In Europe, the top 10% of emitters are responsible for just over a quarter of overall emissions within one year, similar to the share of the bottom 50% of emitters (27% and 26% of the total respectively) (Ivanova & Wood, 2020). Several studies have shown that transport emissions in the EU and within countries are even more unequally distributed than total emissions (e.g., Feng et al. 2021; Ivanova & Wood, 2020, Lévay et al. 2021; Büchs & Schnepf, 2013).

Several socio-economic drivers of high emissions have been identified in the literature, including income, high education and being in employment. Affluence appears to play a very important role. For instance, in the EU, total household emissions and income are positively associated with a correlation coefficient of 0.65 (Ivanova & Wood, 2020). Income and emissions have also shown to be positively associated in a range of country studies, e.g., for the UK (Büchs & Schnepf, 2013, Baiocchi et al. 2010; Druckman & Jackson 2009), Austria (Theine et al., 2022), Belgium, (Lévay et al. 2021), the United States (Feng et al. 2021), or China (Wang & Yuan 2022; Wang et al. 2016), among others. High education also tends to be coupled with higher total emissions, despite higher climate change awareness within this group (e.g., Theine et al., 2022; Lévay et al. 2021; Zhang et al. 2019; Büchs & Schnepf, 2013). Being in employment, as opposed to being unemployed or economically inactive, has been positively linked with overall household emissions in several studies (e.g., Lévay et al. 2021; Büchs & Schnepf, 2013).

Income, high education, and being in employment are also related to higher transport emissions more specifically, further highlighting the key role of affluence (Brand & Preston, 2010; Feng et al. 2021; Leroutier & Quirion, 2022; Lévay et al. 2021; Büchs & Schnepf, 2013). Unlike home energy, which is more evenly distributed across income groups, transport represents a 'luxury good' in many countries, increasing more rapidly with income compared to necessities like home energy or food. While high education and being in employment are associated with higher incomes, these factors have independent positive effects on transport emissions even when controlling for income. Other factors that are related to high overall transport emissions are rural and periurban location, larger household size, belonging to an ethnic minority, being middle aged; being a home owner (compared to renting), and living in a detached house (compared to semi-detached or flats) (Büchs & Schnepf, 2013; Leroutier & Quirion, 2022; Lévay et al. 2021). Relevant to this study, Wadud et al. (2022) find based on English National Travel Survey data that 'excess' emissions from car travel are positively associated with male gender, full-time employment, high income, business travel, company car availability, low population density and rural residence.

2.2 Determinants of car use and air travel

The determinants of travel behaviour can be grouped into resources, competences and constraints at the individual or household level, socio-psychological factors, and factors related to the spatial environment. We discuss these below. Research shows that while car use and air travel have a number of common determinants, some factors have the opposite effect on the two.

Individual- and household-level resources, competences and constraints are mostly measured by sociodemographic variables capturing economic resources (e.g., income), temporal constraints (e.g., weekly work hours), social roles (e.g., gender, household composition), as well as physical and cognitive resources (e.g., health status, education level). Studies typically find that full-time employment, male gender, high education level and high income are associated with both more car use (Chowdhury & Scott, 2020; Duranton & Turner, 2018; Naess, 2009; Naess et al., 2021; Van Acker & Witlox, 2010; Van de Coevering et al., 2021) and more air travel (Alcock et al., 2017; Czepkiewicz et al. 2018a; Falk and Hagsten 2021; Kim & Mokhtarian, 2021; Mattioli & Scheiner, 2022). Interestingly, income effects appear to be stronger for air travel than for car use (Alcock et al., 2017; Dargay & Clark, 2012), although there is also evidence that in certain affluent locations the correlation between frequency of air travel and income might weaken (Czepkiewicz et al. 2019; Árnadóttir et al. 2021). More recent research has found net positive effects of migration background and social network dispersion on air travel (Mattioli & Scheiner, 2022). Social network dispersion, while little explored, also appears to be associated with more car use (Rubin & Bertolini, 2016), while migration and ethnic minority background are associated with less (Hu, 2017; Welsch et al., 2018).

The spatial environment has opposite effects on car use and air travel. It is well established that residents of large urban areas – particularly compact, inner-city areas with mixed land use – use cars less relative to more car-dependent suburban or rural areas (McIntosh et al., 2014; Buehler et al., 2017; Stevens, 2017; Duranton & Turner, 2018; Ihlanfeldt, 2020; Van de Coevering et al., 2021; Naess et al., 2021). Conversely, several studies in the past two decades have shown that the residents of dense urban areas travel more long-distance and by air, even after socio-economic factors are controlled for (Brand & Preston, 2010; Czepkiewicz et al., 2018b; Holz-Rau et al., 2014). Recent research also shows that living nearer to a large airport is associated with more flights (Bruderer Enzler, 2017; Mattioli et al., 2021), but less car use for long-distance trips (Kim & Mokhtarian, 2021).

With regard to socio-psychological factors, there are notable differences between the two modes. While it is commonly found that there is a weak effect of environmental attitudes on reduced car use (Gärling & Friman, 2012), this 'attitude-behaviour gap' is even more pronounced for flights. Many multivariate studies find no association (Alcock et al., 2017; Árnadóttir et al., 2019; Kim & Mokhtarian, 2021) or even a counterintuitive positive association between environmental attitudes and air travel (Czepkiewicz et al., 2019; Holden & Linnerud, 2011; Schubert et al., 2020).

The effects of socio-psychological factors have also been studied with the broader concept of lifestyles. This term is somewhat opaque in that it may refer to tastes, consumer and activity behaviour, values, norms and perceptions, ways of social networking, and identity (see Scheiner and Holz-Rau, 2007, and Van Acker et al., 2016, for discussion). Some travel behaviour studies define sociodemographic variables such as income and household structure as 'lifestyles' (e.g., Ardeshiri and Vijy, 2019), while others define travel mode orientations per se as lifestyles (e.g., Prato et al., 2017). Consequently, the explanatory value of lifestyles for travel behaviour varies strongly according to their definition and measurement. However, most studies in the field still find significant effects of lifestyles on travel mode use (see Van Acker et al., 2016, for an overview). For instance, Etminani-Ghasrodashti and Ardeshiri (2015) find significant effects of modern and consumer-oriented lifestyles on the frequency of non-work trips made by car. Scheiner and Holz-Rau (2007) report a positive association between the lifestyle dimension 'out-of-home self-realisation' and vehicles kilometres travelled by car. With respect to air travel, Große et al. (2018) find lifestyle to significantly predict long-distance travel for leisure and holidays among Copenhagen residents. Schubert et al. (2020) report for Switzerland that lifestyle significantly predicts personal air travel over short/middle-distances, but not over long distances. In Helsinki and Reykjavik, the geographical clustering of people with cosmopolitan attitudes (which can be interpreted as a lifestyle dimension) in the city centres was found to contribute to a higher frequency of long-distance trips (Czepkiewicz et al., 2020b). However, due to the methodological and definitional issues discussed above it is unclear whether effects of lifestyle on car and air travel point into the same or different directions. We discuss a more field-specific notion of lifestyle in section 2.4 using the term 'modality style'.

2.3. Rebound? Relationships and trade-offs between car use and air travel

Some recent research has explored whether car ownership and use have an impact on air travel or vice versa, i.e., whether there are trade-offs between the two. Ottelin et al.'s (2014) descriptive study found that emissions from flying can offset the gain from reduced driving for middle-income residents in a dense urban area. This can be interpreted as suggestive of a rebound effect of consumption whereby savings on car ownership and use are at least partly spent on air travel. However, most subsequent studies using multivariate analysis have found either a neutral (e.g., Bruderer Enzler, 2017; Czepkiewicz et al., 2020b; Czepkiewicz et al., 2018a) or positive net association (e.g., Czepkiewicz et al., 2019; Czepkiewicz et al., 2020a; Reichert & Holz-Rau, 2015) between car ownership and air travel, even after controlling for income and residential location. Based on consumption data, Andersson & Nässén (2022) found that not owning a car is correlated with slightly more emissions from long-distance travel (mainly by air), while not flying is not associated with more emissions from short-distance travel (mainly by car). Mattioli et al. (2021), using a previous wave of the UKHLS survey, found that both car ownership and car mileage are positively associated with air travel emissions among English residents, even after controlling for intervening factors and stratifying by income groups. Overall, there is weak empirical evidence to support the hypothesis of a rebound effect of consumption between car use and air travel.

As discussed above, socio-psychological research shows that environmental attitudes have less of an effect on air travel than on car use. Accordingly, some studies have found that people who act sustainably in daily life (including by reducing car travel) tend to make an exception for air travel (Barr et al., 2010; 2011; Higham et al., 2016). This can be interpreted as showing how different factors come into play in behavioural decisions "at home" and "away", with e.g., social identity and the need to maintain social networks playing a bigger role for the latter (Hibbert et al., 2013), or as showing how air travel has become embedded into certain social practices (Cass, 2022; Volden & Hansen, 2022; Mattioli, 2020). Another possible explanation is that people tend to underestimate the climate impact of air travel relative to driving (Wynes et al., 2020). However, the discrepancy could also be interpreted as a direct effect of reduced car use on air travel, whereby the adoption of one pro-environmental behaviour decreases the likelihood of other pro-environmental behaviours. In the literature, this phenomenon is referred to with various terms including 'negative spillover effects' (Maki et al., 2019; Nilsson et al., 2017), 'compensatory green beliefs' (Hope et al., 2018; Kaklamanou et al., 2015), and 'moral licensing' (Gholamzadehmir et al., 2019). While there is only limited quantitative empirical evidence overall for negative spillovers (Maki et al., 2019), some studies found that a minority of people believe that driving less compensates for air travel from an environmental and moral viewpoint (Bratt, 1999; Hope et al., 2018; Kaklamanou et al., 2015; McDonald et al., 2015).

2.4 (Dissonant) modality styles

A number of studies in the transport literature have used segmentation methods to identify "mobility styles" (Lanzendorf, 2002; Prillwitz & Barr, 2011) or "modality styles" (Große et al., 2018; Olafsson et al., 2016), defined as groups of individuals with similar use of different travel modes. These concepts can be considered as declinations of the broader notion of 'lifestyle', applied to travel behaviour. Some of these studies have taken into consideration both daily travel and long-distance travel, and both car use and air travel, and have identified (among others) groups characterised by differential use of the two modes.

Prillwitz & Barr's (2011) study was among the first to identify a cluster of "green travellers" characterised by low car use in daily life and pro-environmental attitudes, but relatively high levels of air travel for holidays, in a sample of English respondents. Evidence for the existence of a similar group has been found in subsequent studies from Norway (Julsrud, 2014), Iceland (Czepkiewicz et al., 2019) and Germany (Magdolen et al., 2022). Große et al.'s (2018) study in Denmark found both a group of urban "committed cyclists" – with low car use, green attitudes and high number of flights for weekend trips and holidays – and a group of periurban "die-hard drivers" with high car mileage, low green attitudes and low number of flights. Overall, segmentation studies provide some evidence for the existence of groups with 'dissonant' modality styles with regard to car use and air travel. A limitation though is that with few exceptions (Böhler et al., 2006; Czepkiewicz et al., 2019) they do not estimate the resulting travel-related GHG emissions.

Beyond segmentation studies, other research has found high levels of air travel and low levels of car travel (and related emissions) among certain social groups, including: urban residents (Czepkiewicz et al., 2018b; Ottelin et al., 2014), young adults (Stanes et al., 2015), students (Sippel et al., 2018), environmentalists (McDonald et al., 2015; Volden & Hansen, 2022), as well as migrants and 'temporary transnational residents' (Mattioli & Scheiner, 2022; Monteiro et al., 2021). Some studies have found an association between low car use in daily life and 'cosmopolitan' attitudes and lifestyles (Groth et al., 2021; Sattlegger & Rau, 2016) – which further research suggests are a major determinant of air travel frequency (Czepkiewicz et al., 2019; 2020b).

3. Approach, data and methods

3.1. Approach

As discussed in the previous section, there is evidence of the factors associated with high emissions (as a whole and for transport), of the drivers of car and air travel, and emerging evidence that some sectors of the population combine low car use with frequent air travel. What we do not yet know is how different combinations of air and car travel emissions are distributed among the population, how they result in different profiles of 'high emitters', and the social determinants for each of these groups. This is key because a common recommendation of studies on high and 'excess' emissions is that those who are responsible for a disproportionate share of climate impact ought to be targeted with specific policy measures (e.g., Baltruszewicz et al., 2023; Brand & Boardman, 2008; Cass et al., 2022; Chatterton et al., 2015; Mattioli & Anable, 2017; Wadud et al., 2022). To design such measures, it is essential to identify the key attributes of high emitters. If this group is diverse, both in terms of socioeconomic make-up and in the practices they engage in, this is a key piece of information that should be taken into account in policy design.

Our analysis aims to fill this gap and highlight diversity within the group of 'high emitters' for transport, based on data on individual car and air travel behaviour for England. We define three groups characterised by high emissions from car travel only, air travel only, or both at the same time. We focus in particular on individuals with 'dissonant' transport emission profiles – i.e., combining low emissions for one mode and high emissions for the other – as these have been overlooked to date, and the literature suggests that car and air travel have partly different determinants (Section 2.2). A better understanding of 'dissonant' transport emission profiles is also relevant for research on 'rebound effects' in travel behaviour (due to either economic or psychological factors) and on ‘modality styles’, which have gained attention in recent years (Sections 2.3-2.4). Finally, the amount of emissions resulting from ‘dissonant’ travel behaviour patterns and the individual attributes associated with them can inform the design of policy measures to target high emitters, as discussed above.

In the remainder of this section, we provide information on the data basis (3.2) and the bivariate and multivariate methods used to describe the groups (3.3). Given the large number of dependent and independent variables considered, we do not list specific hypotheses about their relationships here. We comment in Section 5 on the extent to which the results confirm the expectations derived from the literature reviewed in Section 2.

3.2. Data

3.2.1 Dataset

Our analysis is based on data from the general-purpose, nationally representative survey UKHLS (UK Household Longitudinal Study) (University of Essex, Institute for Social and Economic Research, 2020). We conduct a cross-sectional analysis of data from Wave 10 (2018-2019), though we integrate two variables about social network dispersion from Wave 9 (2017-2018), collected for the same respondents, as discussed below. The full sample size for Wave 10 is 34,318 individuals. We use weighting factors provided by the UKHLS as appropriate to take into account differences in sample selection probability and other aspects of UKHLS’ complex survey design (sampling clusters and strata) (Knies, 2018).

In order to include spatial variables, we restrict our analysis to respondents living in England (accounting for 84.3% of the UK population – ONS, 2019), as comparable information is not available for the other ‘constituent nations’ of the UK (Wales, Scotland and Northern Ireland). We use geographic identifiers of respondent residence at the LSOA level (University of Essex & Institute for Social and Economic Research, 2021) to link respondents to geographical information, as described in Table 7, Supplementary Material[1].

3.2.2. Dependent variables

The dependent variables in our bivariate and multivariate analysis refer to the membership of groups defined by their (high or low) level of GHG emissions from car travel and air travel, as described in Section 4.1. We derive GHG emission estimates from questions included in the ‘environmental behaviour’ module in Wave 10 on car mileage (as driver) and the number of personal flights over the last 12 months. Estimating emissions from these variables requires a number of assumptions and entails some limitations, as we discuss below in this section, as well as in the Supplementary Material (Table 6), and in the discussion section.

For car travel, we multiply reported mileage by GHG conversion factors, obtaining approximate estimates of each respondent’s GHG emissions from car travel as driver in the 12 months prior to the interview (as kgCO2e for GWP100). For air travel, we multiply the number of flights for private reasons (for three destination categories) by representative flight distance values, and then by the appropriate GHG conversion factors[2]. We obtain approximate estimates of each respondent’s GHG emissions from

[1] LSOAs (Lower Layer Super Output Areas) are small, homogeneous census units, including on average 1,500 inhabitants.

[2] The partial imputation of travel distances is relatively common in studies on long-distance travel and air travel (e.g., Alcock et al., 2017; Bruderer Enzler, 2017; Czepkiewicz et al., 2018a; Holz-Rau et al., 2014; Loy et al., 2021; Mattioli et al., 2021; Reichert & Holz-Rau, 2015).

private air travel in the 12 months prior to the interview (in kgCO2e). The GHG conversion factors for car and air travel include both direct and indirect (well-to-tank) emissions and (for air travel) radiative forcing, as discussed in Table 6 in the Supplementary Material, where we describe the original UKHLS variables, the estimation procedure and the data sources in detail.

We add the two GHG variables together to obtain an estimate of annual emissions from car and air travel, which we use to describe the groups in our analysis. We are unable to include emissions from travel with other modes (e.g., bus and rail) as the UKHLS dataset does not include information that would allow us to estimate them. Nevertheless, we argue that the sum of emissions from car and air travel is a good proxy for individual total annual transport-related emissions. Emissions from the use of other modes typically account for less than 10% of passenger transport GHG in European countries (Aamaas et al., 2013; Aamaas & Peters, 2017; Brand & Boardman, 2008; UBA, 2020). As such, we refer to this variable as 'total' transport emissions in the following.

Our emission estimates are limited in four ways. First, the car emission estimate includes all travel, regardless of purpose, while the air travel emission estimate excludes business travel, which implies a degree of imbalance between the car and air travel data. We believe that the exclusion of business flights affects our findings only to a limited extent, as business travel accounts for a small share of flights, and a large share of these are domestic, hence generating fewer emissions[3]. Second, UKHLS only collects information on car mileage as driver, and does not include any equivalent information on car passenger use or vehicle occupancy. Therefore we assign the entirety of car emissions to vehicle drivers. This means that, for example, people who travel exclusively as car passengers have zero emissions from car travel in our analysis. In that sense, our analysis entails an underestimation of the emissions of individuals who travel often as car passengers, and an overestimation of the emissions of those who often drive cars for trips with high occupancy rates. Note, however, that previous research in a UK context (Heinen & Mattioli, 2019) has found that allocating all emissions to the drivers or dividing them equally between drivers and passengers tend to give very similar results[4]. Third, our car emission estimates differentiate between vehicles with different propulsion (where such information is available), but do not consider other vehicle characteristics (e.g., age, engine power) which affect emissions per km. Finally, UKHLS provides no information on the type of seat (e.g. economy, business class or first class) for the plane trips. As such we use average emission factors based on the average seating configuration of aircraft in each distance segment (as we discuss in footnote 5 to Table 6 in the Supplementary Material). This tends to overestimate the emissions of those who travel economy, and underestimate of those who choose other types of seats. We comment on how these limitations might affect our findings in Section 5.

[3] Only 10% of international air travel by UK residents in 2018 was for business reasons (own elaboration based on DfT, 2020b). Business travel accounted for 48% of domestic flights in Great Britain in the period 2002-2016 (DfT, 2020a), but domestic flights accounted for just 14% of passenger traffic at UK airports in 2018 (own elaboration based on DfT & CAA, 2019). O'Garra and Fouquet (2022) estimate that in an average year prior to COVID only 14% of the distance flown by UK residents was work-related (p.6). On the other hand, business travellers are more likely to travel business class, which would tend to increase emissions per km.

[4] As a sensitivity test, we have repeated our analysis dividing the car driver emissions of all respondents by the average occupancy rate for car trips in England in 2018-2019, i.e., 1.6 passenger per vehicles (DfT, 2022). We find minor differences for some of the values reported in Sections 4.1 and 4.2, which would only marginally affect our interpretation of the findings. The rest of our findings (reported in sections 4.3 and 4.4) is identical, as the allocation of individuals to the high-emitter groups is based on their rank within the distribution of car emissions, which is unchanged when the car emissions of all respondents are divided by a constant value. These additional analyses are available from the authors upon request.

3.2.3. Independent variables

Our analysis includes several independent variables, organised into a theoretical framework as depicted in Table 1. Both the definition of the theoretical dimensions and the selection of the variables were guided by the literature review in Section 2. We are able to cover five dimensions: i) affluence; ii) other basic socio-economic characteristics; iii) spatial attributes of the respondent's area of residence; iv) migration background, ethnicity and personal social networks; v) environmental attitudes and behaviours. The specific independent variables are briefly listed in the table. The reader is referred to Table 7 in the Supplementary Material for a detailed description of each variable. We comment below on the dimensions that we are able to include in our analysis, and on the extent to which we were able to cover each of them.

Table 1 – List of independent variables, organised by theoretical dimension

Theoretical dimension		Variables
i)	Affluence	• Household income (after housing costs)
ii)	Other basic socio-economic characteristics	• Tertiary education qualification • Employment status • Age • Household size • In a cohabiting relationship • Sex • Responsibility for children • Long-standing illness or disability
iii)	Spatial attributes of the area of residence	• type of area (rural-urban classification) • population density • 'car dependence' indicator • travel time to the nearest rail station • travel time to the nearest airport • number of airports within 60 minutes travel time • number of annual passengers at the nearest airport
iv)	Migration background, ethnicity and personal social networks	• 'migration generation' • ethnic group • share of friends living outside of the local area • the presence of close family abroad[5]
v)	Environmental attitudes and behaviours	• green self-image • climate change concern (scale) • climate change engagement (scale) • climate change detachment (scale) • pro-environmental behaviour (at home and for purchasing) (scale)

[5] Note that both social network variables were collected from the same respondents in Wave 9 (2017-18), i.e., one year earlier than the other variables that we use in the analysis. As such, they assess the dispersion of the respondent's social networks *at the start of the reporting period* for car and air travel (since respondents were asked in the following Wave, 12 months later, to report on their car and travel behaviour for the previous 12 months).

With regard to affluence, we have detailed information on household income but not on private wealth (e.g., savings, home ownership), although we are able to consider this indirectly to some extent by calculating disposable income after housing costs. We include a range of predictors related to other basic socio-economic characteristics and spatial attributes of the area of residence, as these are typically seen as important determinants of transport emissions. We further include variables related to the migration background and spatial dispersion of social networks, due to recent research showing their impact on travel behaviour.

We are able to include a wealth of information on attitudes related to the environment and climate change, as well as on pro-environmental behaviour in daily life, as UKHLS includes 25 questions on this. We summarised these variables into five constructs, based on a review of previous quantitative studies that have used them (Binder & Blankenberg 2017; Busic-Sontic et al., 2017; Chng et al., 2019; Clark et al., 2016; Hand 2020; Longhi 2013; Lynn, 2014; Lynn & Longhi, 2011; Melo et al., 2018; Netuveli & Watts, 2020; Powdthavee, 2020; Roberts et al., 2018; Thomas et al., 2018; Welsch et al., 2021; Wu et al., 2019). For a detailed description of these socio-psychological constructs and the items that measured them, see Table 7 in the Supplementary Material. Note that we include a scale assessing pro-environmental behaviour at home and for purchasing. A positive association between these forms of pro-environmental behaviour and high transport emissions could be interpreted as evidence of negative spillover or 'moral licensing' effects (Gholamzadehmir et al., 2019).

Despite its importance for travel behaviour (see Section 2.2), we are unable to include predictors related to the 'lifestyle' dimension, due to lack of data of this within the dataset. It is possible however that some of the environmental attitude constructs included in our analysis indirectly capture (or are correlated with) lifestyle dimensions.

3.3. Methods

Our analysis is organised in four steps. We start by generating two categorical variables reporting the decile of the emission distribution that the respondent belongs to, for both air travel and car travel emissions (Section 4.1). We cross-tabulate these variables and describe the resulting 'bidimensional space' in terms of sample distribution, average transport emissions per capita and share of total transport emissions.

We then define the three groups of 'high-emitters' that we are interested in (Section 4.2): individuals with 'Low Car travel emissions and High Air travel emissions' (LCHA); with 'High Car travel emissions and High Air travel emissions' (HCHA); and those with 'High Car travel emissions and Low Air travel emissions' (HCLA). These correspond to the upper-right, bottom-right and bottom-left corners of the bidimensional space, as illustrated in Fig. 4 in Section 4.2[6]. Given that the definition of what constitutes 'high' and 'low' levels of emissions is to some extent arbitrary (see e.g., Cass et al., 2022; Wadud et al., 2022), for each of the groups we use three different (and progressively more stringent) sets of thresholds, as described in Section 4.2 (Fig. 4). This allows us to sensitivity-test our result, and to identify which variables are robust predictors of belonging to one of the groups (regardless of definition). For each of the nine group definitions (three different definitions for each of the three

[6] As our interest in this paper is on high emitters, we do not focus on the fourth corner of the bidimensional space, namely respondents with low emissions from both car and air travel. This might be interesting to explore in future research.

groups of 'high-emitters'), we report the share of the population that they account for, as well as the share of emissions and average emissions per capita (for car travel, air travel, and both combined). The analysis in the first two steps is based on the full UKHLS Wave 10 sample for England, minus cases with missing information on the emission variables or no cross-sectional weight (n=17,501).

In a third step (Section 4.3), we present an analysis of the bivariate association between the independent variables and group membership. This is followed by multivariate analysis with a logistic regression model, where each group is compared to the rest of the sample, i.e., all respondents that do not belong that group[7] (Section 4.4). In both steps, the sample is restricted to respondents who provided full information for all dependent and independent variables (listwise deletion[8], n=14,035). We present three sets of models, one for each of group of 'high emitters'. The models included in the main text are based on the full sample for Wave 10 post listwise deletion, and include all independent variables described in Table 7 (Supplementary Material), except the two predictors assessing the spatial dispersion of social networks[9] (as these are taken from Wave 9). To explore the impact of social network dispersion on group membership, we repeat the same analysis on the subsample of respondents that provided sufficient information in both Wave 9 and 10, counting 10,854 individuals (weighted as appropriate using UKHLS 'longitudinal sample weights'). We include these models in the Supplementary Material (Tables 10 to 12). For all models we tested for multicollinearity obtaining no VIF value higher than 5. All regression tables show odds ratios, which have a multiplicative interpretation, with coefficients higher than 1 indicating a net positive association between predictor and dependent variable, and coefficients lower than 1 indicating a negative association.

Further to the analysis reported here, we have re-run the regression models excluding from the sample respondents with driver's licence and household car who reported zero annual car mileage (as this might be the result of reporting errors), obtaining very similar results.

4. Results

4.1. Describing the joint distribution of car and air travel emissions

Fig. 1 shows the distribution of the UKHLS sample over the bidimensional space defined by deciles of the car emission and air travel emission distributions, with darker shading indicating higher values. Note that due to a high share of respondents with zero emissions (30.2% for car travel, 51.9% for air travel), several deciles are tied together in a single category (deciles 1-3 for car travel, 1-5 for air travel), which is why the first row and first column are depicted wider than the others in Figs 1 to 4. There is a relatively high share of households (21.1%) reporting no emissions from either mode of transport. The rest of the sample is relatively evenly distributed across the bidimensional space, reflecting the low correlation between car and air travel emissions in the sample (R=0.1).

In our analysis, we are particularly interested in the 'dissonant corners' of the joint distribution, i.e., those combining very low levels of emissions from one mode with very high levels of emissions from

[7] As a sensitivity test, we tried alternative modelling approaches (multinomial logistic regression and probit regression models). We obtained very similar results, which would not change our interpretation of the findings. This additional analysis is available from the authors upon request.

[8] While listwise deletion is common practice in this kind of analysis, this might reduce the representativeness of our findings if the missing data are not random, i.e., if those that did not respond to all questions had specific characteristics.

[9] Note that the predictors included in the models vary slightly by high-emitter group as we had to summarise some of their categories to make sure that there was outcome variation within the categories of the independent variables (some of which have rather small sample size).

the other mode (upper right and bottom left in the bidimensional space), as well as in individuals who can be considered as ‘high emitters’ for both modes (bottom right).

Car travel \ Air travel	1st-5th (0 KgCO2e)	6th (283-636 KgCO2e)	7th (850-1271 KgCO2e)	8th (1418-2541 KgCO2e)	9th (2688-4773 KgCO2e)	10th (4810+)
1st-3rd (0 KgCO2e)	21,1%	3,4%	1,6%	0,8%	1,9%	1,5%
4th (0.4-365 KgCO2e)	5,0%	1,4%	0,9%	0,6%	1,1%	0,9%
5th (368-1094 KgCO2e)	5,3%	1,6%	1,1%	0,7%	1,2%	1,0%
6th (1127-1824 KgCO2e)	5,4%	1,7%	1,2%	0,8%	1,2%	1,2%
7th (1836- 2553 KgCO2e)	3,9%	1,6%	0,9%	0,6%	1,1%	1,0%
8th (2560- 3533 KgCO2e)	3,5%	1,5%	1,0%	0,6%	1,1%	1,2%
9th (3540- 4376 KgCO2e)	4,2%	1,8%	1,2%	0,7%	1,3%	1,3%
10th (4448+ KgCO2e)	3,4%	1,3%	1,1%	0,7%	1,2%	1,3%

Figure 1 – Distribution of the sample by annual emissions for car travel and air travel (deciles) (n=17,501). Darker shading indicates higher values.

While relatively few respondents belong to the high-emission margins and ‘corners’ of the joint distribution, their levels of transport emissions are disproportionately high, as shown in Fig. 2, showing levels over 7.5tCO_2e per year for respondents in the top decile of car emissions, over 10t for respondents in the top decile of the distribution for air travel emissions, and over 20t for those that belong to the top of the distribution for both. Interestingly, respondents with zero car emissions but in the top decile of the air travel emission distribution have higher total transport emissions than those with the opposite profile (zero emissions from air travel, but top decile of car travel emissions).

Car travel \ Air travel	1st-5th (0 KgCO2e)	6th (283-636 KgCO2e)	7th (850-1271 KgCO2e)	8th (1418-2541 KgCO2e)	9th (2688-4773 KgCO2e)	10th (4810+)
1st-3rd (0 KgCO2e)	0	607	1260	2201	3722	11046
4th (0.4-365 KgCO2e)	181	791	1434	2299	3995	10303
5th (368-1094 KgCO2e)	827	1439	2070	2971	4593	10420
6th (1127-1824 KgCO2e)	1611	2215	2870	3802	5453	12942
7th (1836- 2553 KgCO2e)	2253	2847	3516	4424	6109	12636
8th (2560- 3533 KgCO2e)	3023	3661	4299	5188	6864	12986
9th (3540- 4376 KgCO2e)	3913	4535	5138	6082	7795	14233
10th (4448+ KgCO2e)	7819	8390	8378	9368	10674	20498

Figure 2 – Total annual transport emissions per capita (KgCO2), by annual emissions for car travel and air travel (deciles) (n=17,501). Darker shading indicates higher values.

Fig. 3 shows, for each cell of the joint distribution, the share of total transport emissions that it is responsible for. This can be thought of as the product between the share of the sample it accounts for and the average emissions per capita value (reported in the previous two figures). The high-emission margins and 'corners' of the distribution account for a disproportionate and non-negligible share of total transport emissions. In the next few sections, we will focus on these groups of 'high-emitters'.

Car travel \ Air travel	1st-5th (0 KgCO2e)	6th (283-636 KgCO2e)	7th (850-1271 KgCO2e)	8th (1418-2541 KgCO2e)	9th (2688-4773 KgCO2e)	10th (4810+)
1st-3rd (0 KgCO2e)	0,0%	0,6%	0,5%	0,5%	1,9%	4,7%
4th (0.4-365 KgCO2e)	0,3%	0,3%	0,4%	0,4%	1,2%	2,5%
5th (368-1094 KgCO2e)	1,2%	0,6%	0,6%	0,6%	1,5%	2,9%
6th (1127-1824 KgCO2e)	2,5%	1,0%	1,0%	0,8%	1,8%	4,5%
7th (1836- 2553 KgCO2e)	2,5%	1,3%	0,9%	0,7%	1,9%	3,6%
8th (2560- 3533 KgCO2e)	2,9%	1,6%	1,3%	0,9%	2,1%	4,5%
9th (3540- 4376 KgCO2e)	4,6%	2,3%	1,7%	1,3%	2,8%	5,2%
10th (4448+ KgCO2e)	7,5%	3,1%	2,5%	1,8%	3,5%	7,2%

Figure 3 – Share of total transport emissions from transport, by annual emissions for car travel and air travel (deciles) (n=17,501). Darker shading indicates higher values.

4.2 Defining and describing 'high-emitter' groups

Fig. 4 illustrates how we defined the groups of 'high-emitters' that we focus on in the remainder of our analysis. As discussed in Section 3.3, we focus on three high emissions 'corners' of the joint distribution, i.e., respondents with: i) 'Low Car and High Air travel emissions' (LCHA); ii) 'High Car and Low Air travel emissions' (HCLA); iii) 'High Car and High Air travel emissions' (HCHA). Given the arbitrariness of defining what 'low' and 'high' is, for each of these groups we use three different sets of thresholds, as illustrated in Fig. 4. Notably we define 'low' levels of emissions in a range between zero and the median of the distribution (5th quintile). We define 'high' levels of emissions as in or higher than the 8th quintile, i.e., in the top 30% of the distribution.

Our focus on the high emission 'corners' of the distribution leaves out of the analysis individuals with 'high' emissions from one mode and intermediate levels of emissions from the other, as e.g., those in the top three deciles of the distribution for air travel emissions and car emissions in the 6th or 7th decile, or vice-versa. We assume that these respondents have characteristics that are intermediate between those of the groups considered in our analysis. In that sense, our focus on the high emission 'corners' of the joint distribution is a heuristic to highlight diversity among 'high emitters' in a parsimonious way.

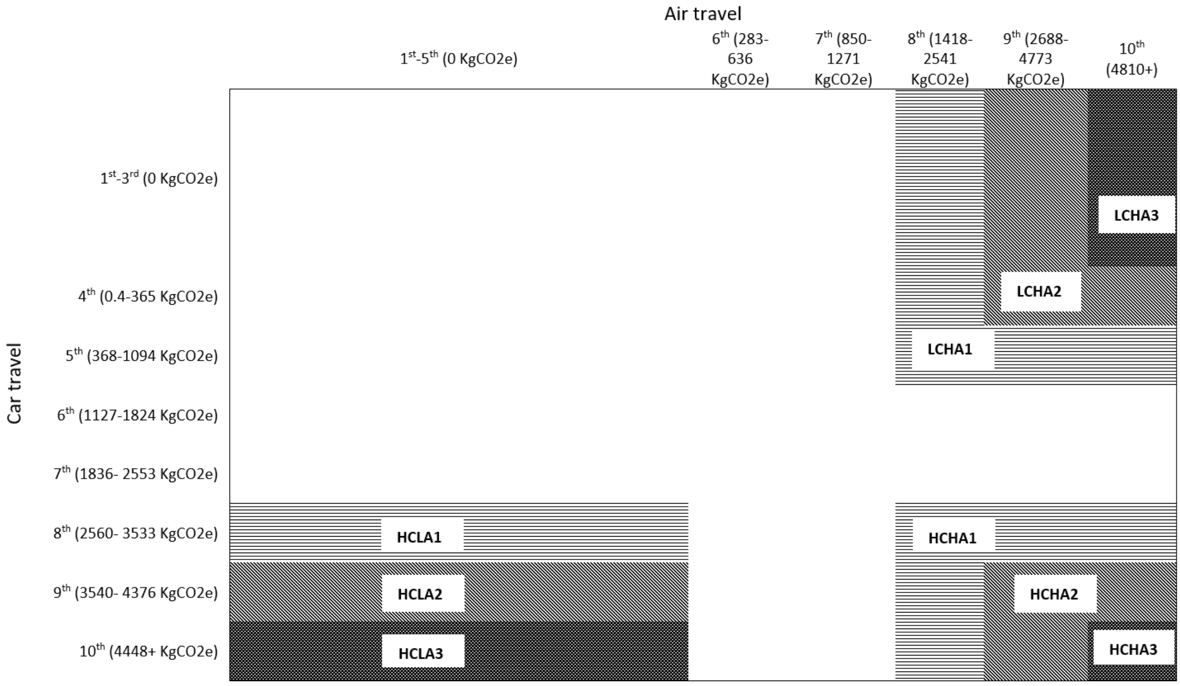

Figure 4 – Diagrammatical representation of the groups of 'high-emitters' considered in the analysis

Table 2 - Descriptive statistics for the various definitions of 'high-emitters' groups (n=17,501 for full sample). Note: for each group (e.g., LCHA), the percentage values for the different definitions (1-3) cannot be added up as groups with a higher number are subset of groups with a lower number (with e.g., LCHA2 being a subset of LCHA1 – see Fig.4).

	Car emission deciles	Air travel emission deciles	Sample share	Original variables		Average GHG emissions per capita (TCO_2e)			Share of total GHG emissions		
				Average car mileage	Average no. of flights	Car	Air	Total (car+air)	Car	Air	Total (car + air)
LCHA1	1-5	8-10	9.6%	822	3,40	0.286	5.755	6.041	1.5%	32.2%	16.2%
LCHA2	1-4	9-10	5.3%	223	3,34	0.065	6.879	6.944	0.2%	21.4%	10.4%
LCHA3	1-3	10	1.5%	0	4,95	0.000	11.046	11.046	0.0%	9.8%	4.7%
HCLA1	8-10	1-5	11.1%	13,255	0,00	4.838	0.000	4.838	28.9%	0.0%	15.0%
HCLA2	9-10	1-5	7.6%	15,521	0,00	5.669	0.000	5.669	23.2%	0.0%	12.1%
HCLA3	10	1-5	3.4%	21,397	0,00	7.819	0.000	7.819	14.4%	0.0%	7.5%
HCHA1	8-10	8-10	9.3%	12,997	4,23	4.739	6.409	11.147	23.9%	35.0%	29.2%
HCHA2	9-10	9-10	5.0%	15,181	4,60	5.537	7.812	13.349	14.9%	22.7%	18.6%
HCHA3	10	10	1.3%	21,013	7,13	7.662	12.836	20.498	5.2%	9.4%	7.2%

As illustrated in Table 2, depending on the definition, individuals with low emissions from car travel but high emissions from air travel (LCHA) account for 1.5%-9.6%% of the population, but for a disproportionate share of transport emissions (4.7%-16.2%) and notably emissions from air travel (9.8%-32.2%). We estimate the average total annual transport emissions from individuals in this group to be between 6.0 and 11.0 tonnes CO_2e, virtually all of which due to air travel.

Individuals with high emissions from car travel but low (zero) emissions from air travel (HCLA) account for a similar share of the population (3.4%-11.1%), and for a disproportionate share of transport emissions (7.5%-15.0%), notably from cars (14.4%-28.9%). Average emissions per capita are slightly lower than for LCHA at 4.8-7.8 tonnes CO_2e per year, depending on the definition.

Taken together, the groups with 'dissonant' emission profiles (LCHA and HCLA) account for a non-negligible share of the population (4.9%-20.7%%) and transport emissions (12.2%-31.2%).

Individuals combining high emissions for both modes (HCHA) account for a smaller share of the population (1.3%-9.3%) than the other groups but for a disproportionate share of transport emissions (7.2%-29.2%), due to higher emissions per capita (11.1-20.5tCO_2e). In the broadest definition (HCHA1), this group is responsible for an estimated 23.9% of all emissions from car travel and 35.0% of all emissions from air travel, despite accounting for just 9.3% of the population.

Taken together, the three groups considered in our analysis account for 6.2%-30.0% of the population, and for 19-60% of total transport emissions, depending on the definition adopted.

4.3 Bivariate analysis

In this section, we comment on the bivariate associations between group membership and independent variables, based Tables 8 and 9 (included in the Supplementary Material).

Of all the predictors included in Table 8 only one is consistently and significantly associated with all three groups in the same direction: tertiary education. The HCLA and HCHA groups show similar associations with several variables, being overrepresented among the employed (particularly those with longer commutes), middle-aged adults, males, and people living in couples and/or larger households (which are more likely to include children). There is also a positive association with living in small towns and rural areas, and in areas characterised by low population density and high levels of car dependence. Both groups are also associated with a low 'green self-image' and a lower score on the scale measuring 'pro-environmental behaviour' in the home and when purchasing.

Yet the bivariate analysis also suggests that HCLA groups, combining high car use and low levels of air travel, are distinct from HCHA (high emitters on both) in several ways. Notably, they are not clearly concentrated among (very) high income groups and are more likely to live far away from airports and rail stations. While there is no consistent association between HCHA and migration and ethnic background, HCLA groups are clearly overrepresented among White British. While respondents in the HCHA groups are characterised by higher levels of climate engagement and lower levels of climate detachment (which contrasts with their travel behaviour, their self-assessed environmental behaviour, and with their poor 'green self-image'), this is not the case for the HCLA groups, which show no statistically significant association with these variables.

The profile of the LCHA groups – which combine low car use with high levels of air travel – is distinct from other 'high emitters' in many respects. LCHA individuals are overrepresented among higher-income and tertiary-educated individuals, students and pupils, young adults, as well as among people who do not have children and/or are not in a cohabiting relationship. Unlike HCLA and HCHA, which are overrepresented among males, LCHA are overrepresented among females. LCHA is also positively associated with residence in urban areas and notably London, as well as in areas characterized by high population density, low car dependence, and good access to both large airports and rail stations. The share of LCHA is higher among individuals with migration and/or ethnic minority background (notably 'first-generation' migrants, i.e., those born abroad). LCHA individuals are more likely to have higher levels of 'climate engagement' and pro-environmental behaviour in other areas of life, and lower levels of ‘climate detachment’ – though not necessarily higher levels of ‘climate change concern’ or ‘green self-image’.

Bivariate associations between group membership and social network variables are reported separately in Table 9 (Supplementary Material). This shows that all ‘high emitters’ groups are overrepresented among people with some or most of their friends outside of the local area. However, having close family abroad is positively associated with HCHA and LCHA, but negatively associated with HCLA.

In the next section, we explore whether these bivariate findings hold in a multivariate setting.

4.4 Multivariate analysis

In this section, we present the results of logistic regression models comparing each group with the rest of the sample (reference category). Starting with the LCHA group, several factors are positively associated with group membership in most models in Table 3 (i.e., with odds ratio value higher than 1), providing robust evidence of association. These include higher income, young adulthood, being in education, being female, London residence and population density, as well as first migration generation and Asian and Black background. Factors showing a consistent negative association with LCHA (i.e., with odds ratio value lower than 1) include having to commute over 10km to work, disability, and responsibility for children.

Factors positively associated with LCHA in only some of the models provide weaker evidence for association. These include smaller household size, living in an area of low car dependence, and the number of passengers at the nearest airport. While ‘climate detachment’ is negatively associated, and pro-environmental behaviour positively associated with LCHA in some models, most coefficients associated with environmental attitudes and behaviours are not statistically significant.

Table 10 (Supplementary Material) shows the models including social network dispersion variables. Both having family abroad and having friends outside of the local area are positively associated with LCHA, though the coefficients for the latter are statistically significant only for the broadest definition of the group (LCHA1).

Further to the analysis reported here, we estimated models including household car and driver’s licence availability, to control for possible mediation effects. We obtained results very similar to those reported here.

Table 3 – Parameter estimates (odds ratios) for the logistic regression of the probability of belonging to the LCHA ('Low Car emissions, High Air emissions') groups. Significance levels: * p<0.05; ** p<0.01; *** p<0.001.

Model	2A	2B	2C
Group definition	LCHA1	LCHA2	LCHA3
Household income (ref. cat.: 1st income quintile / bottom)			
2nd	1.28	1.46*	1.21
3rd	1.60***	1.78***	0.89
4th	1.82***	1.90***	2.17**
5th – top	2.62***	2.36***	1.62
Tertiary education qualification (dummy)	1.07	0.96	1.03
Employment status (ref. cat.: In employment, other)			
In employment, 5-10 miles from workplace	0.74*	0.74	0.67
In employment 10+ miles from workplace	0.46***	0.43***	0.24**
Retired	1.04	0.89	1.34
In education	1.61**	1.45*	0.89
Other	0.98	1.15	1.00
Age (ref.cat. 16-29 years old)			
30-59 years old	0.52***	0.42***	0.46***
60-74 years old	0.49***	0.37***	0.17***
75+ years old	0.36***	0.27***	0.12***
Household size	0.93*	0.94	0.94
In a cohabiting relationship (dummy)	1.16	0.89	0.63*
Female (dummy)	2.16***	2.26***	2.56***
Responsible for children (dummy)	0.53***	0.54***	0.37**
Long-standing illness or disability (dummy)	0.74***	0.83	0.91
Type of area (Ref.cat: C – Urban: City and Town)			
A1 – Urban: Major conurbation: London	2.09***	1.90***	1.52
A1 – Urban: Major conurbation: Other	1.12	1.13	1.04
B1 – Minor conurbation	1.01	1.22	0.55
D – Rural: Town and fringe	0.90	0.85	0.83
E- F – Rural: Village, Hamlets and isolated dwellings	0.79	0.86	0.73
Population density in LSOA (1000s persons per hectare)	1.02*	1.04***	1.05***
Total travel time to reach 8 essential services by public transport or walking (z-score) (car dependence indicator)	0.90	0.89	0.59**
Travel time to nearest rail station (hours)	0.94	0.87	0.97
Travel time to nearest large airport (hours)	1.00	1.18	1.15
Number of airports within 60 minutes travel time	0.99	1.00	0.80
Annual passengers at nearest large airport (millions)	1.00	1.00	1.01*
Migration generation (ref. cat.: 4th+)			
3rd	0.98	0.94	0.96
2nd	1.15	1.23	0.94
1st	1.95***	2.38***	1.90**
Ethnic group (ref. cat.: White British)			
Other White	1.44	0.96	1.52
Asian or Asian British	1.79***	2.03***	1.89*
Black or Black British	1.62*	2.14**	1.65
Other + Mixed	1.45	2.09***	2.01

'Green self image' (ref. cat.: "don't really do anything / 1-2 things that are environmentally-friendly"			
A few things	1.06	1.01	1.15
Most / everything	1.19	1.12	1.14
Climate change concern (score)	1.04	1.09	0.82
Climate engagement (z-scores)	1.05	1.06	1.18
Climate detachment (z-scores)	0.93	0.94	0.88
Pro-environmental behaviour (z-scores)	1.03	1.11*	1.06
Constant	0.06***	0.03***	0.02***
N	14035	14035	14035
Log-likelihood	-4333.19	-2773.41	-1062.32
Wald χ2	855.04	759.63	493.38
Prob. > χ2	(p<0.001)	(p<0.001)	(p<0.001)
McFadden's R^2	0.13	0.15	0.18
McKelvey & Zavoina's R^2	0.21	0.25	0.39
AIC	8752.37	5632.82	2210.63
BIC	9076.99	5957.44	2535.25

Turning now to the HCLA groups (combining high levels of car emissions and low emissions from air travel), we find robust associations with several factors, including employment (particularly when commuting distance is long), middle-adulthood and early older age, being male, disability, as well as the degree of car dependence of the residential area (Table 4). Note that while responsibility for children is positively correlated with HCLA, being female is negatively correlated, which can be interpreted as follows: women are less likely to belong to the HCLA group, but this is offset to some extent if they have children.

In most models, high income is negatively correlated with the probability of belonging to HCLA groups. Some of the models also show a negative coefficient for the second income quintile (relative to the first). This contrasts with the bivariate analysis showing a slightly higher share of HCLA among mid-to-higher income groups. This can be interpreted as follows: when holding other factors equal – including employment and commute distance, which tend to be associated with higher incomes – lower income households are more likely to belong to the HCLA group[10].

Other predictors show a negative, statistically significant association with HCLA membership, but only in some of the models. This is the case for being in a cohabiting relationship, as well as for population density, living in London and other major conurbations, and within 60 minutes travel time from several airports. While some models show a negative association between 'climate detachment', 'pro-environmental behaviour' and HCLA membership, most coefficients related to environmental attitudes are not statistically significant in a multivariate setting.

The models including social network variables (Table 11 in Supplementary Material) show that having close family abroad tends to reduce the probability of belonging to HCLA in most models, while having more than half of friends outside of the local area tends to increase it.

[10] Further analysis, not reported here for the sake of brevity, shows virtually no statistically significant differences between income quintiles when employment status and commuting distance are not controlled for.

Table 4 – Parameter estimates (odds ratios) for the logistic regression of the probability of belonging to the HCLA ('High Car emissions, Low Air travel emissions') groups. Significance levels: * p<0.05; ** p<0.01; *** p<0.001.

Model	3A	3B	3C
Group definition	HCLA1	HCLA2	HCLA3
Household income (ref. cat.: 1st income quintile / bottom)			
2nd	0.81	0.81	0.70
3rd	1.00	0.98	0.81
4th	0.87	0.79	0.60*
5th – top	0.66**	0.64**	0.61*
Tertiary education qualification (dummy)	1.11	1.06	0.98
Employment status (ref. cat.: In employment, other)			
In employment, 5-10 miles from workplace	1.55***	1.45**	1.53*
In employment 10+ miles from workplace	2.31***	2.91***	3.53***
Retired	0.53***	0.42***	0.22***
Other (including in education)	0.50***	0.46***	0.41***
Age (ref.cat. 16-29 years old)			
30-59 years old	2.29***	2.50***	1.71**
60-74 years old	2.14***	2.24***	1.80*
75+ years old	1.40	1.27	1.30
Household size	1.03	1.00	0.98
In a cohabiting relationship (dummy)	0.99	0.90	1.07
Female (dummy)	0.43***	0.42***	0.32***
Responsible for children (dummy)	1.54***	1.36*	1.18
Long-standing illness or disability (dummy)	1.21**	1.26**	1.26*
Type of area (Ref.cat: C – Urban: City and Town)			
A1 – Urban: Major conurbation: London	0.53***	0.56**	0.60
A1 – Urban: Major conurbation: Other	0.75**	0.78*	0.88
B1 – Minor conurbation	0.72	0.76	1.11
D – Rural: Town and fringe	1.06	1.11	1.03
E-F – Rural: Villages, Hamlets and isolated dwellings	1.07	1.28	1.36
Population density in LSOA (1000s persons per hectare)	0.96**	0.96*	0.96
Total travel time to reach 8 essential services by public transport or walking (z-score) (car dependence indicator)	1.16***	1.14**	1.08
Travel time to nearest rail station (hours)	1.13	1.08	1.27
Travel time to nearest large airport (hours)	0.84*	0.85	0.87
Number of airports within 60 minutes travel time	0.88*	0.89	0.88
Annual passengers at nearest large airport (millions)	1.00	1.00	1.00
Migration generation (ref. cat.: 4th+)			
3rd	1.18	1.25	1.07
2nd	0.91	0.92	0.87
1st	0.89	0.96	1.12
Ethnic group (ref. cat.: White British)			
Other White	0.65	0.76	0.73
Asian or Asian British	0.72	0.78	0.83
Black or Black British	0.83	0.89	0.53
Other + Mixed	0.89	0.62	0.68

'Green self image' (ref. cat.: "don't really do anything / 1-2 things that are environmentally-friendly"			
A few things	0.96	1.05	1.04
Most / everything	0.88	0.92	0.92
Climate change concern (score)	1.05	1.05	0.97
Climate engagement (z-scores)	0.91*	0.93	0.98
Climate detachment (z-scores)	0.97	1.00	0.95
Pro-environmental behaviour (z-scores)	0.99	0.94	0.85**
Constant	0.13***	0.08***	0.05***
N	14035	14035	14035
Log-likelihood	-4722.61	-3618.83	-2000.59
Wald χ2	962.86	907.26	642.93
Prob. > χ2	(p<0.001)	(p<0.001)	(p<0.001)
McFadden's R^2	0.12	0.14	0.15
McKelvey & Zavoina's R^2	0.24	0.26	0.32
AIC	9529.21	7321.66	4085.17
BIC	9846.28	7638.73	4402.24

Table 5 shows the results for the regression models predicting membership in the HCHA groups, which combine high levels of emissions from both modes. Factors consistently positively associated with HCHA include high income, tertiary education, employment (particularly with long commutes) and first migration generation. We also find a consistent negative association between HCHA membership and retirement, household size, being female, being in a cohabiting relationship, disability, and London residence. 'Green self-image' and 'pro-environmental behaviour' are negatively associated with HCHA in most models, although most other coefficients related to environmental attitudes are non-significant. There are other factors for which there is less robust evidence of negative association with HCHA, including population density, travel time to the nearest airport, and 'Other' or 'Mixed' ethnic background. Models including social network predictors (Table 12 in Supplementary Material) show a significant positive association between HCHA and having friends outside of the local area.

Table 5 – Parameter estimates (odds ratios) for the logistic regression of the probability of belonging to the HCHA ('High Car emissions, High Air travel emissions') groups. Significance levels: * p<0.05; ** p<0.01; *** p<0.001.

Model	4A	4B	4C
Group definition	HCHA1	HCHA2	HCHA3
Household income (ref. cat.: 1st income quintile / bottom)			
2nd	0.97	0.73	0.32*
3rd	1.34*	1.03	0.81
4th	1.73***	1.52*	1.96
5th – top	2.75***	2.01***	3.15**
Tertiary education qualification (dummy)	1.55***	1.46***	0.96
Employment status (ref. cat.: In employment, other)			
In employment, 5-10 miles from workplace	1.34**	1.25	0.64
In employment, more than 10 miles from workplace	2.00***	2.59***	2.84***
Retired	0.43***	0.34***	0.29**
Other (including in education)	0.88	1.01	0.65
Age (ref.cat. 16-29 years old)			
30-59 years old	1.06	1.24	1.00
60+	1.04	1.22	0.87
Household size	0.92**	0.92	0.91
In a cohabiting relationship (dummy)	1.42***	1.49**	1.42
Female (dummy)	0.63***	0.64***	0.39***
Responsible for children (dummy)	0.95	0.87	0.44
Long-standing illness or disability (dummy)	0.64***	0.53***	0.45***
Type of area (Ref.cat: C – Urban: City and Town)			
A1 – Urban: Major conurbation: London	0.58***	0.60**	0.45*
A1 – Urban: Major conurbation: Other	0.83	0.78	0.67
B1 – Minor conurbation	0.76	0.76	0.69
D – Rural: Town and fringe	1.21	1.33	1.46
E-F – Rural: Villages, Hamlets and isolated dwellings	1.13	1.25	1.48
Population density in LSOA (1000s persons per hectare)	0.94***	0.95**	0.95
Total travel time to reach 8 essential services by public transport or walking (z-score) (car dependence indicator)	1.04	1.00	0.98
Travel time to nearest rail station (hours)	1.07	0.98	1.10
Travel time to nearest large airport (hours)	0.73**	0.78	0.65
Number of airports within 60 minutes travel time	1.03	1.01	0.84
Annual passengers at nearest large airport (millions)	1.00	1.00	1.01
Migration generation (ref. cat.: 4th+)			
3rd	0.85	1.09	1.93*
2nd	1.30*	1.32	1.41
1st	1.18	1.64**	2.43**
Ethnic group (ref. cat.: White British)			
Other White	1.31	0.96	0.72
Asian or Asian British	0.98	0.78	0.57
Black or Black British	0.86	0.94	0.54
Other + Mixed	0.51*	0.44*	0.79
'Green self image' (ref. cat.: "don't really do anything / 1-2 things that are environmentally-friendly"			

A few things	1.12	1.12	1.28
Most / everything	0.79*	0.72*	0.36**
Climate change concern (score)	0.95	0.98	0.88
Climate engagement (z-scores)	1.01	1.03	0.98
Climate detachment (z-scores)	0.99	1.02	0.88
Pro-environmental behaviour (z-scores)	0.85***	0.89*	0.73**
Constant	0.12***	0.05***	0.03***
N	14035	14035	14035
Log-likelihood	-4239.45	-2692.16	-826.94
Wald χ2	1086.38	726.26	386.22
Prob. > χ2	(p<0.001)	(p<0.001)	(p<0.001)
McFadden's R^2	0.14	0.14	0.21
McKelvey & Zavoina's R^2	0.27	0.29	0.48
AIC	8560.90	5466.33	1735.89
BIC	8870.42	5775.85	2045.41

5. Discussion

Four key learnings can be drawn from our findings: i) there is a high degree of heterogeneity among high emitters for passenger transport; ii) while most high emitters are characterised by high levels of affluence, certain subgroups show some association with factors of social disadvantage; iii) there is little evidence that holding environmental attitudes is associated with being a high emitter in one way or another, which contrasts with the attention that this nexus has received to date; iv) conversely, hitherto overlooked factors such as social network dispersion, migration background and long-distance commuting appear to play a bigger role. We discuss these key learnings in the remainder of this section.

The main finding of this study is that high emitters for passenger transport are a heterogeneous group. Considering both the bivariate and multivariate analysis, only three socio-economic predictors show a more or less consistent, significant association with all groups of high emitters in the same direction, namely tertiary education (positive association) and retirement and old age (negative association). There is no consistent pattern of association with either spatial or attitudinal predictors. The share of friends living outside of the local area – a factor not typically considered in this kind of analysis – is the only other variable that increases the probability of group membership for each of the three groups of high emitters.

Notwithstanding this heterogeneity, we clearly identify a group of respondents with high emissions from both car and air travel (HCHA), and with very high levels of transport emissions per capita. The factors associated with this group are closely in line with the findings of previous research on high emitters and include high income, employment, middle adulthood, being male and residence in lower-density areas. However, we also identify two groups with 'dissonant' emission profiles, combining low or zero emissions from one mode and high emissions from the other. These two groups have high levels of transport emissions per capita, and account for a non-negligible share of the population (up to 20%) and of emissions from car and air travel (up to 30%). This means that individuals with high emissions from one mode but low emissions from the other account for a similar share of transport emissions as those with high emissions from both (up to 29%). They thus deserve more attention than they have received to date. Moreover, the factors associated with membership of the two 'dissonant' groups deviate to some extent from the conventional wisdom on high emitters, as we discuss below. It is possible that previous research on high emitters, by lumping together air and car travel emissions in a single metric, has tended to overlook this. Previous studies have often provided indirect evidence of heterogeneity among high emitters, e.g., in terms of high variance of certain predictors, and low share of explained variance in linear predictive models (see, e.g., Theine et al., 2022). Our study provides more direct and intuitive evidence of such heterogeneity, by contrasting the profiles of three subgroups of high emitters with different travel behaviour patterns.

In detail, respondents with high emissions from car travel but low emissions from air travel (HCLA) are similar in many respects to those with high emissions from both modes (HCHA). However, they are more equally represented in all income groups and, when other factors such as employment and commuting distance are controlled for, a net association with lower income and disability appears. These are factors of social disadvantage which are not usually found to be associated with high emissions. While there is limited research on the energy use of disabled people (Ivanova & Middlemiss, 2021), existing studies show that poor health tends to reduce energy consumption for both car use and air travel (Büchs et al., 2018), although some individuals with disability can be quite reliant on cars for their mobility (Verlinghieri et al., 2021). Respondents with low emissions from car travel but high emissions from air travel (LCHA) have a profile that is distinct from the other two groups. Here we see an association with factors that, to date, have been considered as conducive to lower transport emissions such as: residence in urban areas with good public transport, being female, young adulthood, as well as migration background.

Our findings regarding the 'dissonant' groups are consistent with research showing that daily travel and long-distance travel have partly different determinants (Czepkiewicz et al., 2018; Reichert & Holz-Rau, 2016), as do car and air travel (Kim & Mokthtarian, 2021; Mattioli & Scheiner, 2022). They also dovetail with the findings of segmentation studies on 'modality styles' (Czepkiewicz et al., 2019; Große et al., 2018; Julsrud, 2014; Magdolen et al., 2022; Prillwitz & Barr, 2011), although we go beyond them by estimating transport emissions, classifying respondents on that basis, and considering a wider range of social, spatial and attitudinal predictors from a large, representative national survey. Our findings are particularly consistent with Große et al. (2018) who found evidence of both frequent-flyer cyclists in urban areas and of frequent drivers who fly little in periurban areas in Denmark. This suggests that our findings may be generalizable beyond England, although one must keep in mind that the UK is characterized by higher levels of air travel (Graver et al., 2020; Hopkinson & Cairns, 2021) and lower levels of car ownership (European Commission, 2021) relative to other comparable countries, which might influence our results. As such, the group characterised by high emissions from air travel but low car use may account for a smaller share of the population in other countries.

With regard to the role of affluence and related inequalities, two of the high-emitter groups considered in our analysis (HCHA and LCHA) are disproportionately concentrated among higher-income groups. Yet we also find that respondents with high emissions from car travel, but no flights (HCLA) are more evenly represented across the income spectrum, and are particularly overrepresented among those with long commutes. This is consistent with previous research showing that income is more strongly associated with car use than air travel (Alcock et al., 2017; Dargay & Clark, 2012; Mattioli & Adeel, 2021), and confirms that affluence plays a bigger role in increasing emissions from air travel as compared to driving. This implies that the sectors of the population who drive high mileage but never (or seldom) fly are not on average particularly affluent, as our analysis shows.

Mattioli et al. (2018) found that 9% of UK households are in 'car-related economic stress' combining low income, high motoring costs and low price elasticity of fuel demand (likely due to commuting), and as such are particularly vulnerable to fuel price increases. It is possible that some of those households are included as high emitters in the HCLA group – although we cannot ascertain this due to the lack of transport expenditure data in the UKHLS survey. We note however that many factors associated with the HCLA group in our analysis correspond to the social profile of participants to the French Yellow Vest movement against fuel tax increases of 2018-2019, including: being male, middle adulthood, employment, middle-lower income, and residence in periurban and rural areas (Bedock et al., 2019; Bélard, 2018; Guerra et al., 2021; Maligorne, 2019).

Our analysis has also investigated whether high emitters differ from the rest of the population in terms of environmental attitudes and behaviours (in areas other than transport). The main conclusion here is that these factors do not seem to play an important role. While there is some association between these constructs and high-emitter group membership in the bivariate analysis, these tend to become insignificant in the multivariate analysis. This suggests that while some groups of high emitters have for example higher levels of 'climate engagement' relative to the average of the population, this is mainly because of underlying differences in the socio-economic make-up (i.e., a higher level of education). We do find, however, some indication that individuals with low car emissions and high air travel emissions (LCHA) have higher levels of pro-environmental attitudes (including a 'green self-image') relative to other high emitter groups (at the bivariate level). Conversely, individuals with high emissions from both travel modes (HCHA) are less likely than the rest of the population to have a ‘green self-image’, which is consistent with their very high emissions. Yet the lack of a negative association between belonging to the ‘dissonant’ groups (LCHA and HCLA) and green self-image in the multivariate models suggests a lack of awareness of how much car and air travel contribute to environmental damage (Wynes & Nicholas, 2017).

There is weak evidence of a positive net association between pro-environmental behaviour (at home and for purchasing) and the LCHA group. This could be interpreted as suggestive of a ‘moral licensing’ effect (Gholamzadehmira et al., 2019) whereby individuals in this group think they ‘did their bit’ for the environment by, e.g., buying recycled paper products and that that allows them to fly frequently. The same interpretation cannot be applied to the other two high emitter groups though, as they exhibit a negative association with the pro-environmental behaviour scale. There could be another possible ‘moral licensing’ effect for the two ‘dissonant’ groups, whereby low levels of car use are seen as justifying high levels of air travel (or vice versa) from a moral viewpoint. Since the dataset does not include direct questions about how respondents trade-off environmentally-relevant behaviour, we are unable to corroborate or disprove any hypothesis related to ‘moral licensing’ effects. It must be noted, however, that previous studies using the same dataset (Mattioli et al., 2021) have found a positive net association between car use and air travel, which is inconsistent with the hypothesis of a negative spillover between the two modes.

Taken together, our findings broadly confirm existing research with regard to the weak link between environmental attitudes and long-distance travel behaviour. It must be noted however that other studies found evidence of a strong association of long-distance and air travel with other socio-psychological constructs such as cosmopolitan attitudes (Czepkiewicz et al., 2019; 2020b; Oswald & Ernst, 2020), the perceived fun, freedom, and comfort of air travel (Dütschke, et al., 2022) or tech-savviness and polychronicity (Kim & Mokhtarian, 2021). While we are unable to include these factors in our analysis, this is a promising area for future research, along with the nexus between lifestyles and high transport emissions.

Our analysis highlights the role of some factors that have received little attention in research on high emitters to date. First, the geographical dispersion of social networks. This is one of few factors with a net association with all high emitter groups in our analysis. While having close family abroad reduces the likelihood of having high emissions from car use and low emissions from air travel (HCLA), this is probably because flights abroad substitute for car trips for family visits in the UK among people who have family abroad. Mattioli & Scheiner (2022) find that this results in higher total transport emissions for them. Second (and relatedly), we find a positive association between migration background and both groups with high emissions from air travel, even after controlling for other factors. In much previous research, migration background was either not considered or argued to be conducive to more sustainable transport, because of its negative association with car use (Hu, 2017; Klocker et al., 2015; Welsch et al., 2018). Third, we find strong evidence of an association between longer-distance commuting and high emissions from car use. While long-distance commuting has drawn some attention from within transport studies, this has mostly been in relation to the resulting time poverty and negative consequences on the commuter’s wellbeing (e.g., Pucci et al., 2022; Morris et al., 2020). Research making the link between long-distance commuting and high emissions is still underdeveloped (Conti, 2017; Lovelace, 2014). Besides commuting, it is of course possible that people with high emissions from car use but no flights (HCLA) also generate emissions with long-distance leisure trips by car that might be substitutes for flights, as discussed by Raudsepp et al. (2021). Overall, we argue that these three factors (social network dispersion, migration background and long-distance commuting) deserve more attention in future research on high emitters and ‘excess’ travel.

There are some limitations to the data basis which might influence our results and should be kept in mind for their interpretation. First, business air travel is not included in our analysis, which might explain to some extent why some groups that tend to fly less for work (young adults, students and pupils, females) are overrepresented in the LCHA group (Aguilera & Proulhac, 2015; Dargay, 2012; Reichert & Holz-Rau, 2015). Second, there is no information on vehicle occupancy and car use as passenger, meaning that all emissions from car travel had to be assigned to drivers. This might explain some of the differences between high emitter groups, e.g., the overrepresentation of females in the LCHA group, as women are more likely to travel by car as passengers (Scheiner & Holz-Rau, 2012). It is possible that these and other associations would be less pronounced if the emissions of car use were equally allocated to all vehicle occupants. Third, while our estimation of car emissions considers vehicle propulsion, it does not take into account other vehicle characteristics (e.g., engine capacity) with a bearing on GHG emissions per kilometre. Since certain socio-economic variables tend to be associated with vehicle characteristics (e.g., car size), this might result in the underrepresentation of those who tend to own more powerful and high-carbon vehicles (e.g., higher income groups) in the groups that we identify as having high emissions from car use. Fourth, due to the lack of information on the type of seat, we used "average passenger" emission factors for plane trips, which tend to overestimate the emissions of economy passengers and to underestimate those of business and first class passengers. If these differences were taken into account, it is possible that we would find, e.g., an even greater association between higher income and the groups characterised by high emissions from air travel. Finally, our analysis does not include emissions from modes other than car and plane. While we cannot rule out that some people achieve high transport emissions simply through e.g., frequent train use, we expect these cases to be relatively rare, as car and air travel account for the overwhelming majority of aggregate passenger transport emissions.

6. Conclusions

Recent research shows that since the early 2000s, carbon emission inequalities within countries outstrip inequalities between countries, reversing the previous pattern (Chancel, 2022). Against this background, there has been a surge in interest for carbon inequalities, high emitters and excess consumption. Our study contributes to this burgeoning field by highlighting heterogeneity among high emitters for passenger transport, depending on which mode (car or air travel) dominates their emission profile. The findings have implications for future research and policy making, which we discuss below.

In terms of future research directions, the heterogeneity of high emitters seems to warrant further investigation, possibly using segmentation methods. Our analysis shows a remarkable degree of diversity even within a single emission sector (passenger transport), depending on the transport mode. This would likely be even more pronounced if the other main sectors of household emissions (domestic energy, food, purchases, etc.) were taken into account. The characteristics of people with low emissions from car travel but high emissions from air travel deviate notably from the conventional wisdom on high emitters, and more research on this group is needed. Our study also points to several drivers of high transport emissions which have been overlooked to date, including disability, young adulthood, long-distance commuting, migration background and the geographical dispersion of social networks. All these factors (and particularly the last one) warrant further investigation. Our findings suggest that different types of high emitters are overrepresented in different age groups. Future research may explore to what extent these differences are due to age rather than cohort effects, and how and whether individuals transition from one type of high emitter to another over the life course. Incidentally, our findings here may also inform public debates on how and to what extent different generations and age groups contribute to and bear responsibility for climate change. The extent to which some high emitters might suffer from forms of 'transport poverty' (Lucas et al., 2016), whether because of excessive time or money invested in commuting by car is an interesting direction for future research as well. With regard to the role of socio-psychological factors, our findings support the conclusion that there is a weak link between pro-environmental attitudes and high levels of transport emissions. Perhaps more research effort should go into investigating the role of other types of attitudes (e.g., cosmopolitan attitudes, sensation or adventure seeking) and related lifestyles in motivating long-distance travel and related emissions, particularly when it comes to leisure trips.

With regard to policy implications, the typology of high emitters identified here could inform travel demand forecasting, as well as the development of measures targeting the few who emit the most. Yet the degree of heterogeneity that we find suggests that high emitters cannot easily be identified based on few socio-economic predictors. It also suggests that different policies might be needed to target different subgroups of high emitters. At first sight, one might conclude that high emitters with high car use and low air travel are more 'locked-in' to their behaviour by their residential location and their work patterns relative to the other 'dissonant' group, where frequent air travel may be more 'discretionary', more linked to lifestyle and thus more open to change. At a closer look, however, this is far from certain, as we find a strong impact of social network dispersion and migration background on air travel emissions. This suggests that a substantial share of high emitters' air travel is for 'visiting friends and relatives', and previous research has found very low willingness to forego these trips (Gössling et al., 2019; Randles and Mander, 2009) suggesting that they are to some extent 'locked-in' as well (Cass, 2022; Frändberg & Vilhelmson, 2010; Mattioli, 2016). Indeed, recent research (O'Garra & Fouquet, 2022) found that willingness to reduce air travel was not higher than willingness to reduce car travel among UK residents, with a high share of respondents reporting that they needed to travel by plane and had no other options. Overall, the travel behaviour of high emitters is likely to be due to a mix of structure and agency, which the analysis presented in this paper can only partially shed light on.

Overall, policy strategies to reduce the emissions of high emitters will have to include a mix of: i) technological solutions; ii) measures aimed at reducing travel demand in the short term (whether through pricing or otherwise) and; iii) measures to avoid 'locking-in' the need for high levels of travel activity by car and plane on the longer term. The exact mix will depend on the characteristics of the high emitter group. For example, prioritizing technological solutions such as vehicle electrification might make more sense for groups characterised by high levels of car use and car dependence but who are not particularly affluent (as one of the 'dissonant' groups identified by our analysis). For groups characterised by high levels of air travel, there is little alternative to travel demand management measures, as there are no technological solutions that are viable at scale in the short-to-medium term. These might include both carbon taxes and 'frequent flyer levies', which are designed to target high emitters (Büchs & Mattioli, 2021; 2022; Fouquet & O'Garra, 2022; Zheng & Rutherford, 2022).

In this context, our findings are relevant for debates on the fairness of travel demand management measures, particularly financial ones. When faced with the task of reducing carbon emissions in the transport sector, policymakers may consider whether e.g., to tax motor fuel, or aviation fuel, or both. Our analysis suggests that depending on which mode is targeted, rather different social groups will be impacted. As we have noted, the social profile of the group with high emissions from car travel but low emissions from air travel in our analysis is rather similar to that of the participants to the French Yellow Vest movement of 2018/2019. While the original demand of the Yellow Vests was a motor fuel tax cut, the movement subsequently proposed increasing aviation taxes as an alternative (Atkin, 2018;

Leclerc, 2019). As our findings suggest, that would have impacted first and foremost other social groups (younger, more female and urban), which we can speculate may have been a motivation behind the proposal. In that sense, our study highlights how different climate policy packages in the transport sector would impact different groups of high emitters to a different extent. These groups have different social profiles, corresponding to different political constituencies, which might be relevant for policymakers to consider, notwithstanding the urgency of reducing emissions from both modes.

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