

Willingness to reduce travel consumption to support a low-carbon transition beyond COVID-19

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ABSTRACT

This paper explores people's willingness to reduce travel consumption in support of the transition to a low-carbon pathway beyond COVID-19, using new survey data from UK car drivers and air travellers. Evidence from our study indicates that reductions of 24% - 30% to car use and 20% - 26% to air travel could be sustained in the long term. This potentially could lead to annual reductions of 343–529 kgCO₂ per car driver (20% - 29% of pre-COVID-19 car emissions) and 215–359 kgCO₂ per air traveller (10% - 20% of pre-COVID-19 emissions from flying), suggesting that behavioural change may be a major route to emissions reductions. We find that stated voluntary reductions are greater among those who report having 'more time to do creative things' since the start of the COVID-19 lockdowns. Hence, recovery policies promoting low-carbon leisure time may be a key to consumption reductions. We also find that higher-income travellers consume and pollute substantially more than the rest, and yet there is little difference in relative voluntary reductions across the income distribution. We conclude that behaviour associated with affluence represents a major barrier to a low-carbon transition, and that policies must address over-consumption associated with affluence as a priority.

1. Introduction

Over-consumption has been increasingly identified as a major cause of environmental degradation and a key barrier to carbon mitigation (Wiedmann et al., 2020; O'Neill et al., 2018; Røpke, 1999). Despite continued investment in technological solutions aimed at increasing the sustainability of resource use, there is mounting recognition that governments cannot just rely on technological fixes but must find ways to encourage behavioural shifts to reduce excessive consumption (Haberl et al., 2020; Wiedmann et al., 2020; Gough, 2017; Lorek and Fuchs, 2013; Sanne, 2002). Yet the question of how to bring about such shifts without instigating economic recessions and harming consumers and citizens has challenged researchers and policy makers for decades (Nordhaus, 1977, 1991; Arrow et al., 2004; Hausknost, 2020; Wiedmann et al., 2020).¹

Then, in 2020, the world experienced the coronavirus pandemic, which led to major disruptions in consumption worldwide and triggered a global economic downturn. This in turn led to unintended declines in carbon dioxide emissions and other pollutants (Le Quéré et al., 2020). Although a

global pandemic that has caused more than five million deaths (John Hopkins University, 2021) and debilitated the global economy should not be heralded as the means to securing emissions reductions, it does present a unique opportunity to initiate the much-needed behavioural shift towards reduced consumption over the long term (Forster et al., 2020).

One of the key factors determining whether such a shift will be possible at this critical juncture is public willingness to reduce consumption. Habits and structural behaviour can be difficult to change (Kurz et al., 2015); however, by disrupting people's lives and habitual behaviour, COVID-19 has created a 'window of opportunity' for breaking out of old over-consumption habits (Schäfer et al., 2011; Verplanken and Roy, 2016). Evidence shows that when habitual behaviours are disrupted, this can lead to long-term sustainable changes in behaviour (Verplanken and Roy, 2016; Brown et al., 2003), especially among those concerned about the environment (Verplanken et al., 2008). Whether COVID-19 will have a similar effect on long-term consumption is an empirical question.

To shed light on this question, this study aims to document people's willingness to reduce consumption beyond COVID-19 in support of the

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¹ There is a large literature that argues that economic degrowth is an essential component of any transformation to a sustainable world (e.g., Hausknost, 2020; Jackson, 2009; Lorek and Fuchs, 2013).

transition to a low-carbon pathway. To do this, we collect new survey data from UK residents in which respondents are asked about their pre-COVID-19 consumption habits and their willingness to reduce consumption over the longer term “in support of a low-carbon pathway beyond COVID-19”. This will provide a critical insight into the potential for voluntary behavioural change to sustain long-term consumption reductions. As a secondary aim, this paper seeks to identify the extent to which the personal experience of COVID-19 influences people's voluntary consumption reductions. If the experiences associated with COVID-19 are major influences on people's stated reductions, then it is conceivable that consumption levels may bounce back as the pandemic passes and life returns to ‘normality’. Given the rapidly changing context surrounding the pandemic, we repeated the same survey one year later with a new sample to assess whether voluntary consumption reductions have changed in tandem with the changing circumstances.

Crucially, our results and analyses are framed in terms of the differential consumption behaviour and willingness to reduce consumption between rich and poor. The link between affluence and environmental impact has been well-established (Sager, 2019; Oswald et al., 2020; Gössling and Humpe, 2020), and for this reason, we examine behaviour, carbon emissions and voluntary reductions by income quintile.

The analysis in this paper specifically focuses on the consumption of air travel and car use. Our motivation for concentrating on these specific behaviours are threefold: firstly, mobility consumption has been highly affected by the pandemic - at the height of the first lockdown (April 2020) car travel in Britain dropped 78% (DfT, 2021) and flights in the United Kingdom fell 94% (Eurocontrol, 2021) compared with an equivalent day in 2019; secondly, transport accounts for almost half of all household emissions in the UK (ONS, 2020a), so consumption reductions in this sector have the potential to greatly contribute to emissions reductions; thirdly, transport is one of the hardest sectors to decarbonize due to a combination of technical and resource constraints, high infrastructure costs, and persistent uncertainties around the viability of alternative technologies, with consumption reductions identified as a key strategy to achieve emission reductions (de Blas et al., 2020). This last issue is particularly critical with regards to air travel, which has seen demand rising by about 5.9% globally a year since 2010 (ICAO, 2019). In the context of such pronounced growth in demand, behavioural change remains essential to reduce emissions in parallel with the development and commercialisation of technological and fuel improvements (CCC, 2020; de Blas et al., 2020; Kousoulidou and Lonza, 2016).

The UK's Climate Change Committee's Sixth Carbon Budget (CCC, 2020) outlines the necessary travel reductions required to achieve a net zero carbon pathway to 2050. They estimate that at least a 39% reduction in passenger air travel and 17% reduction in car travel will be needed relative to their baseline scenario² by 2050. Thus, major behavioural reductions will be needed to achieve net zero targets, even with ambitious technological and infrastructural developments.³

² The scenarios set out in the CCC's ‘Balanced Net Zero Pathway’ are as follows: (i) for passenger air travel, given that the baseline forecast anticipates an increase of 64% in 2050 compared with the 2018 level, a reduction of 39% in the ‘net zero’ scenario relative to the baseline forecast implies an actual 25% increase in air travel by 2050 compared with the 2018 level; (ii) for passenger car use, given that the baseline scenario anticipates an increase of 15% in 2050 on the 2018 level, a reduction of 17% in the ‘net zero’ scenario relative to the baseline forecast implies an actual 2% fall in car travel by 2050 compared with the 2018 level.

³ For air travel, the estimated reductions needed assume substantial aviation efficiency improvements, sustainable aviation fuels accounting for 25% of the aviation fuels, and carbon capture and storage. These estimates of car travel reductions are based on the assumption of increased tele-working, online shopping, shifting to lower carbon modes of transport and a near-complete dominance of electric vehicles (CCC, 2020). If these technological, infrastructural and behavioural developments do not occur, larger reductions would be required.

Evidence from our study indicates that reductions of 20% - 26% to air travel and 24% - 30% to car driving could be sustained through behavioural changes. Thus, the required reductions to car use outlined by the CCC could potentially be met through voluntary changes in behaviour; aviation however is likely to struggle to meet net zero targets given the large gap between the CCC's (2020) required reductions and the voluntary reductions identified in the present study. This evidence reveals the risk of a ‘reductions gap’ between what people are willing to do and what is needed to achieve a net zero carbon pathway to 2050.

This study also generates insights into the factors that influence ‘willingness to reduce consumption’, focusing on the role of affluence and the impact of personal experiences relating to COVID-19. Our findings confirm that affluence is a major driver of travel consumption and emissions. This is particularly the case for air travel, with individuals in the highest income quintile (i.e., the top 20%) travelling more than twice the distance and generating double the emissions on average compared to the rest of the population. However, income fails to exert any influence on travel reductions. Conversely, the experience of increased time availability ‘to do creative things’ during the pandemic plays a key role in influencing willingness to reduce consumption, an important insight that echoes findings in the literature about the link between time availability and consumption of energy-intensive goods and services (e.g. Chai et al., 2015; Hayden and Shandra, 2009; Knight et al., 2013; Rosnick and Weisbrot, 2007).

This study makes several key contributions to the literature. The first relates to the method used to elicit voluntary travel reductions. Existing studies tend to use statements of intention to reduce consumption using Likert scales and percentage reductions (e.g. Morten et al., 2018; Davison et al., 2014; Nordlund and Garvill, 2003); although useful as a means to identify broad intentions, these approaches cannot generate estimates of the consumption that people are willing to forgo. Our approach – modelled on the ‘contingent valuation’ method in environmental economics (see Methods) – generates estimates of the actual amount of travel (in distance) that people are willing to forgo, and the corresponding carbon emissions reductions these behavioural changes entail.

Secondly, by examining the link between behaviour and income, our paper adds to the literature on the environmental problems of affluence (Sager, 2019; Oswald et al., 2020; Gössling and Humpe, 2020). The link between income and carbon emissions has been well-documented (Sager, 2019; Oswald et al., 2020), and the impacts of mobility-related consumption have been found to increase disproportionately with income (Sager, 2019; Gössling and Humpe, 2020). This study adds to the literature by identifying that, despite affluence being linked to consumption and environmental damage, increasing affluence fails to exert any influence on willingness to address the problem.

Thirdly, the paper adds to our understanding of the factors that influence the willingness to reduce travel behaviour (Morten et al., 2018; Gössling et al., 2019) and to reduce consumption more generally (Haberl et al., 2020; Wiedmann et al., 2020; Gough, 2017; Lorek and Fuchs, 2013).

Finally, the study helps to explore how major disruptions to habits can shift behaviour onto a lower carbon pathway – for instance, through increased ‘discretionary’ time to spend on low-carbon leisure activities (Chai et al., 2015; Druckman et al., 2016). Recent evidence shows that since March 2020, Britons have shifted their behaviour away from travel towards entertainment, creative pastimes and exercise (ONS, 2021). Indeed, the experience of having more time during the lockdowns and partial lockdowns of COVID-19 may be the key to unlocking public willingness to shift behaviour away from high-carbon options towards ‘slow’ low-impact activities in the long run - helping to achieve net zero carbon targets (CCC, 2020).

2. Methods

2.1. Data collection

2.1.1. Wave 1 (June 2020)

We collected data from a total of 2398 UK residents using an online survey in June 2020, which was distributed by a survey company (Qualtrics). During this month, the strict lockdown rules that had been implemented across the UK since March 23rd were being slowly eased. These rules saw the closure of all non-essential high street businesses, universities and schools; people were ordered to stay at home without a “reasonable excuse” (which included shopping for essentials and one hour of exercise a day). Travel abroad was prohibited other than for a small number of permitted reasons, while local travel was highly restricted, and people urged to ‘stay local’. From mid-May, there was an easing of the lockdown restrictions across the UK, with people allowed to spend unlimited time outdoors for recreational purposes while respecting social distancing rules, and from mid-June, non-essential high-street shops were allowed to re-open⁴, while pubs, restaurants, and leisure facilities were allowed to re-open from early July (Wikipedia, 2021a, 2021b; Brown and Kirk-Wade, 2021).

The survey samples ($n = 1205$ air travellers, and $n = 1193$ car users) are representative of air traveller and car owner populations in terms of gender, income and region. Summary statistics comparing sample and respective sub-population characteristics can be found in Table S1 in the Supplementary Material, along with details about the sources of population data for each of the variables used to target the sample. Additional summary statistics are found in Supplementary Tables S2(a) and S2 (b). The median time taken to complete the surveys was 15 min (air travel survey) and 16 min (car use survey).

2.1.2. Wave 2 (June 2021)

Exactly one year after the first survey was conducted, we repeated the survey (distributed by Qualtrics) with a new cross-section of 1600 UK residents ($n = 798$ air travellers, and $n = 802$ car drivers). The main purpose of this second survey was to verify whether the voluntary travel reductions elicited during the main Wave 1 survey had changed with the changing circumstances around the pandemic.

At this time, the UK was coming out of its third lockdown. This had been preceded by a short (3–4 week) lockdown imposed throughout the UK during the latter quarter of 2020 to stall the rise in COVID-19 cases (specific dates vary by UK nation). The third lockdown was introduced on Dec 20th in Wales and on Jan 5th in England and Scotland. The restrictions on movement in this third lockdown were similar to those imposed during the first one. From 29th March, the stay-at-home order was lifted throughout most of the UK, followed by a gradual re-opening of non-essential retailers. However, despite the easing of restrictions, travel abroad was still prohibited without a ‘permitted reason’ (as in the first lockdown). Throughout May to June, there was a gradual lifting of lockdown rules, so that by the end of June 2021, most restrictions had been lifted (Wikipedia, 2021a, 2021b; Brown and Kirk-Wade, 2021).

As with Wave 1, the Wave 2 samples are representative of air traveller and car driver populations (Table S1 in the Supplementary Material). Additional summary statistics can be found in Supplementary Tables S2(a) and S2 (b).

2.2. Survey and instruments

Both air and car surveys (Waves 1 and 2) had a common structure, outlined below. Wave 2 included a few additional questions about respondents’ vaccination status and questions to measure levels of ‘pandemic fatigue’, described below. The survey questions are outlined in more detail

in the Supplementary Methods in the Supplementary Material.

2.3. Screeners and socio-economic background

All respondents were first channelled through a series of three screening questions to determine whether they could be classed as ‘air travellers’ (has taken at least one flight in the year 2019 (between Jan 1st and Dec 31st)) or ‘regular car users’ (owns or has access to a car, and uses it at least once a week on average). Responses to these screeners determined whether respondents were redirected to the air travel survey or the car use survey. People that fell under both categories were randomly assigned to either the air travel or car use survey. They were then asked about their gender, income and region of residence. These latter socio-economic questions were used to establish the quotas as per car user and air traveller populations in the UK.

2.4. Personal experience of COVID-19

Respondents were asked to indicate their agreement/disagreement (using a 5-point Likert scale) with two statements designed to capture perceptions about what might be considered a ‘positive’ impact of COVID-19, as well as perceptions of the negative impact of COVID-19 on the respondent:

“Since the COVID-19 lockdown I have had more time to do creative things (e.g. play an instrument, bake, read)” (‘positive’ impact).

“COVID-19 has had a more negative impact on my life compared to most people I know” (negative impact).

Increased time availability may be a consequence of decreased travel during the lockdown - although it may also be a result of lost work opportunities. By framing the item in terms of “time to do creative things” we aimed to isolate the positive experience of increased time, as opposed to the negative experience of losing one’s job. This latter effect is picked up by a separate variable that indicates whether the pandemic had changed the respondent’s job status (binary indicator).

Evidence from past studies indicates that increases in leisure time (or conversely, decreases in work time) may shift consumption towards less energy-intensive goods and services - known as the *composition effect* of time-use changes (e.g. Hayden and Shandra, 2009; Knight et al., 2013; Rosnick and Weisbrot, 2007). Much of this effect is due to reductions in the amount of time spent commuting to work; however, increased time availability may also increase people’s willingness to engage in ‘slower’, less carbon-intensive activities, such as cycling or walking rather than driving. As Chai et al. (2015) argue (and find evidence for), a lack of ‘discretionary’ time hinders individuals’ ability to ensure that their values and concerns are reflected in their consumption patterns. We are interested in examining whether changes in the availability of leisure time due to COVID-19 influences the willingness to reduce travel consumption.

With regards to the perception of negative impact (statement number 2), it has been found that low levels of wellbeing and stress tend to bias decisions towards habitual behaviours (Porcelli and Delgado, 2017). The relationship between voluntary reductions and a negative experience from COVID-19 may thus depend on the level of travel consumption that has become ‘habitual’ at the time of the survey(s). On the other hand, social and personal wellbeing have been found to positively influence pro-environmental behaviour (Prati et al., 2017; Diaz et al., 2020). This suggests that negative experiences of COVID-19 may influence voluntary reductions independent of which behaviours are habitual at the time of the survey.

To explore wellbeing influences, we also included an additional indicator intended to identify subjective wellbeing at the present time (i.e. just after the first lockdown). To do this, we use the Cantril wellbeing scale (Cantril, 1965), as adopted by the Gallup World Poll (Gallup, 2012). This question asks respondents to indicate ‘where you feel you

⁴ Dates vary by UK nation as follows: June 15th in England, June 22nd in Wales and June 29th in Scotland

personally stand, at this time' on a scale ('ladder') of 0 to 10, where 0 = worst possible life, and 10 = best possible life.

2.5. Travel behaviour (air)

The survey elicited detailed information about typical travel behaviour prior to COVID-19. For the air travel survey, we asked about the number of flights taken over a "typical period of 2 years"; our rationale for using this period of time is to allow us to capture less frequent flights (such as long-haul flights) which may take place less than once a year. Air travellers were asked for the average number of flights taken according to flight duration and length: short-haul, (less than 3 h flying time from destination to origin, not including time spent on stop-overs), medium-haul (3–6 h), long-haul (6–12 h) and ultra-long-haul (more than 12 h). They also indicated the purposes of each of their flights (business, holiday, visit friends/family, sporting or leisure events). See Supplementary Methods in the Supplementary Material for the exact questions used.

2.6. Travel behaviour (car)

Car users were asked to indicate the number of round trips made during an average working week for various purposes (go to work/study, shopping, drop-off family members at activities, leisure). Answers were given in intervals ({1–2}, {3–4}, {5–6}, {7+} days per week). They then provided distances for each of these activities. In addition, car users were asked about less-frequent long-distance car journeys (between 50 and 150 miles, and over 150 miles) that they take during a typical 12-month period (using 2019 as the reference). See Supplementary Methods for the exact questions used.

2.7. Willingness to reduce travel consumption

Our approach to eliciting people's willingness to reduce travel consumption is based on the 'contingent valuation' method, used in environmental economics to identify the value people place on a change in the provision of an environmental good or service (Champ et al., 2003). This method generates precise estimates of the amount of reductions that individuals are willing to incur in terms of distance travelled per year.

In the surveys, prior to being asked about their willingness to reduce consumption, respondents were presented with a hypothetical scenario describing a proposed low-carbon pathway beyond COVID-19 and what this would imply for UK air and car travellers (see Supplementary Methods for complete text of hypothetical scenario). Willingness to reduce consumption of travel was elicited using a quasi-open-ended format, in which respondents were asked to indicate how many of their typical trips they wished to reduce; their answers were bounded by their previous responses regarding the number of trips taken during a typical period of time (2 years for air travel, 1 week for regular car use and 12 months for less-frequent long-distance car journeys) so that they couldn't reduce more than they typically travel. These counts were then converted into distances, which differed by type or purpose of journey. Those who were not willing to reduce air or car travel were asked follow-up questions to ascertain the reasons they were not willing to reduce consumption.

2.8. Socio-economic questions and indicators of environmental attitudes

The survey ended with more extensive set of socio-economic questions than those in the screener section, including questions about age, education, and employment. Respondents were also asked whether they were members of environmental organisations, and to indicate their level of agreement on a scale of 1 to 5 (where 1 = 'strongly disagree' and 5 = 'strongly agree') with the statement "In the long term, climate change is at least as serious a crisis as COVID-19".

2.9. Additional questions in Wave 2 survey

The Wave 2 survey also included some additional questions about respondents' vaccination status and their experience of 'pandemic fatigue'. Pandemic fatigue – as a specific form of 'behavioural fatigue' (Harvey, 2020) – refers to a decreased compliance with pandemic-related restrictions, mainly as a function of the amount of time that restrictions are being imposed. Other factors also influence pandemic fatigue, such as the perceived severity of COVID-19 (MacIntyre et al., 2021) and the extent of economic and psychological sacrifices that the restrictions entail (Lilleholt et al., 2020). To identify respondents' levels of pandemic fatigue, we use the 6-item Pandemic Fatigue Scale developed by Lilleholt et al. (2020). The wording of each item in the scale can be found in the Supplementary Methods. With regards to vaccinations, respondents were asked to indicate whether they had had both vaccinations, one vaccination, or no vaccinations.

We have no prior expectations about the influence of these factors on willingness to reduce consumption; however, they may provide critical insights into how preferences for travel and/or the environmental benefits from reduced travel are changing – if at all – over the course of the pandemic.

2.10. Estimating distance travelled

To convert number of trips into distances, we multiplied the number of trips (according to trip type) by the distance. For **air travel**, the number of trips per person in an average year was multiplied by the average distance for each trip type. Distances used (for round trips) were as follows: 1200 miles for short-haul, 3600 miles for medium-haul, 7200 miles for long-haul and 12,000 for ultra-long-haul trips. These distances assume that 1 h of flying is approximately equivalent to 400 miles. All distances per trip type were added together to obtain a total distance flown per person per year. Voluntary reductions in air travel were similarly converted into distances.

For **car use**, distance travelled on weekly car trips was computed as the midpoint of the intervals presented to respondents and multiplied by two to obtain a round trip distance. For those respondents that answered, "don't know", we imputed the distance travelled using the mean of the round-trip distances travelled by other respondents. To convert weekly distances travelled 'during a typical working week' to annual distances, we took the statutory leave of 28 days – equivalent to 5.6 weeks holiday a year – and using rounding, we assumed 46 working weeks a year. We also assume that car use for work or study, dropping off family members and leisure activities only take place during these 46 working weeks. Thus, weekly distances travelled in association with these activities are multiplied by 46 to obtain an annual distance travelled. The only exception is shopping, which we assume occurs all 52 weeks of the year. We acknowledge that foreign travel would impact this assumption; however, given that we do not have information on time spent abroad, we will assume constant shopping behaviour throughout the year.

Regarding less-frequent long-distance travel by car, respondents were asked to indicate the number of trips taken in 2019 (which was used as an indicative year) that were, 1) between 50 and 150 miles long, 2) over 150 miles long. To calculate total annual distance travelled by car on these less frequent journeys, we multiplied the number of trips taken by, 1) 100 miles (the midpoint) times by two (to account for outbound and return journeys), and 2) 400 miles (i.e. 2×200 miles). Total distance travelled by car per year was then calculated by adding the estimates produced above.

2.11. Estimating CO₂ emissions

To generate estimates of carbon dioxide emissions associated with travel and voluntary reductions, respondents were asked about their substitute behaviour and were asked to provide at least one substitute (see Supplementary Methods in the Supplementary Material for details on how substitutes were elicited). Thus, the reduction in travel is generally

Table 1

Assumed proportional changes in air travel emissions for each possible substitute. This shows the percentage change compared with the original journey's emissions (e.g., a train travelling the same distance as a short or medium haul flight emits 55% less emissions); substituting from a plane to a car (with two passengers) leads to an increase of 6% - see text).

AIR	Change (%)	Change (%)
	SH & MH	LH & ULH
Train (same place)	-55%	NA
Car (same place)	6%	NA
Train (closer)	-90%	-92%
Car (closer)	-83%	-86%
Plane (closer)	-50%	-59%
Plane (less frequent)	-50%	-50%
Teleconferencing	-100%	-100%
Eliminate need	-100%	-100%

Notes: SH: Short haul; MH: Medium haul; LH: Long haul; ULH: Ultra long haul. Estimates for substitutes are presented for short and medium haul in column 2, and for long and ultra-long haul in column 3. It is assumed that respondents will not use a train or car as a substitute to reach the same destination for long and ultra-long-haul flights.

associated with a substitute behaviour, some of which may generate emissions. Table 1 and Table 2 show the assumed reductions in emissions for each substitute (presented in terms of 'changes' in emissions).

For air travel reductions, short haul and medium haul flights average 0.132kgCO₂ per mile and long haul and ultra-long-haul flights average 0.162 kgCO₂ per mile travelled (BEIS, 2020). It is worth noting that radiative forcing has not been included for air travel, as there is considerable uncertainty about the exact impact, which adds an estimated 90% to the overall emissions-equivalent CO₂ (BEIS, 2020). Replacing a short or medium haul flight by a train journey of the same distance is assumed to reduce emissions by 55% (see Table 1), since UK train travel has been estimated to emit 0.059 kg CO₂ per passenger mile - although electric continental trains only generate 0.008 kg CO₂ (BEIS, 2020). Substituting a short haul flight for an average single passenger car journey to the same location is assumed to increase emissions to just over two times (212%) the original level - assuming the average (petrol-fuelled) car emits 0.280 kg per vehicle mile (BEIS, 2020). Car journeys to replace air travel imply relatively long trips and here it is assumed that, on average, there will be two people in the car, which reflects average holiday travel car occupancy (DfT, 2020a) - thus, halving emissions per person compared with the vehicle emissions. Thus, replacing a short or medium haul flight by a car journey to the same location is assumed to increase emissions by 6% of the original level (see Table 1). It is assumed that cars and trains are only suitable substitutes for long and ultra-haul flights if the respondent substitutes these flights for closer journeys.

For substitutes in which air travellers selected a closer destination by car or rail, we assume that the traveller is willing to dedicate the same amount of travel time. Given that mainline rail speeds average 80 miles per hour and cars average 60 miles per hour on motorways (DfT, 2020b), and air travel averages 400 miles per hour, it is assumed that rail and car journeys are respectively 0.2 and 0.15 of the air travel distance, leading respectively to a 91% reduction (for train) and 84% (for car, maintaining the assumption of two passengers in the car) compared with short and medium haul flight emissions (see Table 1). Substituting air travel for a closer destination by plane is assumed to reduce the distance by half - this is close to the average of reducing an ultra-long haul to a long haul flight, a long haul to a medium haul and medium haul to a short haul flight.⁵

⁵ A sensitivity analysis undertaken on the impact of changing this distance value to 0.2 and 0.8, instead of 0.5, indicates that the average minimum and maximum values respectively decrease and increase by only 0.3%

Table 2

Assumed proportional changes in car driving emissions for each possible substitute. This shows the percentage of reduction compared with the original journey's emissions (e.g., using public transport instead of a car leads to a range of 58–79% reduction in the respondent's emissions).

CAR	Change (%)
Public Transport	-58% to -79%
Walk /Cycle	-100%
Car Share	-50%
Work/Shop from home	-100%
Eliminate need	-100%

When respondents answered that they would travel by plane less frequently, it was assumed that they would fly half as often.⁶

Turning to the substitution away from cars, we clarify the assumptions underlying our estimation of car emissions. First, without information on car type, it is not possible to take account of the variation in respondents' emissions due their car characteristics, which could range from 0.217 kg per vehicle mile for mini cars to 0.526 kg for luxury saloons (BEIS, 2020). Thus, as explained above, the average emissions of 0.280 kg per vehicle mile is used. Second, while 62% of all car journeys in the UK in 2019 were single occupancy (DfT, 2020a), there is considerable variation depending on the purpose of the journey. Here, it is assumed that respondents' occupancy depends on the purpose of their journey and is equivalent to the average for that purpose, which is 1.14. for work, 1.65 for shopping, 1.01 for drop-offs once the driver is subtracted, 1.82 for leisure and 2.00 for holidays (DfT, 2020a). Thus, vehicle emissions are divided by the car occupancy, implying a range from 0.140–0.277 kg per passenger mile. Based on the carbon emissions per passenger mile data presented above, taking UK rail will reduce emissions by 58% for holidays, 62% for leisure activities, 65% for shopping, 74% for work-related commuting and 79% for drop-offs (see Table 2). Walking, cycling, working from home, teleconferencing, on-line shopping and eliminating the need for the travel are assumed to generate zero emissions. Since working and shopping from home, as well as eliminating the need for travel altogether, may lead to using more heating and electricity in the home, the reductions in emissions presented in Table 2 refer only to travel-related emissions - there is considerable uncertainty about the impact of teleworking on residential energy consumption (Hook et al., 2020). Car-share is assumed to be with one other person - thus, halving emissions (see Table 1).

In the survey, respondents were allowed to select more than one potential substitute per reduced trip. This takes into account that the actual substitute chosen will depend on a number of factors only available at the time of substitution; therefore, forcing a single answer might lead respondents to provide unreliable answers. Thus, there is not a direct one-to-one relationship between a reduction in travel from car driving and flying and a reduction in carbon dioxide emissions. Instead, the study provides a range of emissions reductions for each respondent depending on their lowest-carbon and highest-carbon substitute selected. Figs. S1 and S2 in the Supplementary Material present information about the distribution of emission reductions across the respondents.

2.12. Regression analysis

To analyse determinants of willingness to reduce travel consumption we use Tobit regression models, which are typically used to analyse data involving a high proportion of zero values (which is the case with our data). Tobit models assume that these zeros are indicative of 'censoring',

⁶ A sensitivity analysis undertaken on the impact of changing this frequency value to 25% and 75%, instead of 50%, indicates that the average minimum values change by 0.9% and the maximum values change by 0.8%

by which values of the dependent variable are not observed below zero (Amore and Murtinu, 2019). The implication is that, some of these zeros may in fact represent negative values, which effectively translate to a willingness to *increase* travel consumption. Given that our survey did not ask respondents about their negative willingness to reduce travel (i.e. their willingness to increase travel), we assume that the data is left-censored.

The Tobit model can be written as:

$$WTR_i = \begin{cases} \beta z_i + v_i & \text{if } \beta z_i + v_i > 0 \\ 0 & \text{if } \beta z_i + v_i = 0 \end{cases} \quad (1)$$

where WTR is the “willingness to reduce consumption” for individual i , β is a vector of coefficients associated with our explanatory variables of interest (discussed below), z_i is the vector of explanatory variables of interest, and v_i is the standard normal error term. The functional form of the Tobit model assumes that β is the same in both the participation and quantity models seen above.

The log-likelihood function takes the form:

$$\text{Log}(L) = \sum_{y_i=0} \left[\log \left\{ 1 - \varphi \left(\frac{x_i \beta}{\sigma} \right) \right\} \right] + \sum_{y_i>0} \left[\log \left\{ \varphi \left(\frac{y_i - x_i \beta}{\sigma} \right) \right\} - \log(\sigma) \right] \quad (2)$$

We use the *tobit* command in Stata 15 to run the regressions with robust standard errors. Given that the distribution of WTR was right-skewed for both air and car surveys, we opted to use log-transformed WTR as the dependent variable in our models to reduce the skewness in the data. Link tests confirm that the models were correctly specified; residuals were checked for normality using kernel density graphs, standardized normal probability plots and plots of the residual quantiles against the normal quantiles, and were found to satisfy minimal normality requirements.

Explanatory variables included in the regressions include socioeconomic indicators, membership of an environmental organisation, travel behaviour prior to COVID-19, subjective wellbeing and indicators of personal experience of COVID-19 (see Section 2.2. for descriptions of these variables and Tables S2(a) and S2 (b) in the Supplementary Material for summary statistics associated with all of these characteristics). Some variables were transformed for inclusion in the regression models. These include distance travelled prior to COVID-19, which was log-transformed for the regression analyses in order to moderate the right-skew in this data. We also transformed the indicators of personal experience of COVID-19 (see Section 2.2. for precise wording of these indicator statements) into binary indicators, whereby 1 = ‘agree’ or ‘strongly agree’, 0 = all other responses. Additional models run on the pooled Wave 1 and Wave 2 data with the non-transformed version of these variables (available from the authors upon request) suggest no information was lost by collapsing these Likert scales into binary variables.

Finally, we note that subjective wellbeing is entered into the regressions as a continuous variable. This has the advantage of accounting for the ordinal nature of the variable but assumes equal sized increments in subjective wellbeing along the scale from 0 to 10 (see Section 2.2. for details). As an alternative, wellbeing could be included in the models as a categorical variable, although this approach loses the order information inherent in the scale. Comparison of different models in which subjective wellbeing is treated differently (continuous, categorical, binary), combined with an assessment of the underlying data, allows us to judge inclusion of this variable as continuous in the models as acceptable. These additional analyses are available from the authors upon request.

3. Willingness to reduce consumption

Here we present an overview of overall travel and emission estimates to gain insight into the potential emission reductions from voluntary

travel reductions beyond COVID-19. We focus firstly on results from the Wave 1 (June 2020) survey, and then compare these findings to those from the repeat survey conducted in June 2021 (Wave 2) to assess to what extent WTR has changed over time.

3.1. Wave 1 (June 2020)

Fig. 1 shows the average amount travelled per year (in miles) by air and car prior to COVID-19, and the *reduced* distances in travel that respondents are willing to sustain after COVID-19 has fully passed. Additional statistics for these fig.s are found in the Tables S3-S6 in the Supplementary Material.

We find that, in an average year prior to COVID-19, air travellers flew 15,353 miles per year (including outwards and return journeys) - with most of this distance (42%) associated with long haul flights (i.e. 6–12 h of flight time). Just over a seventh (14%) of the distance travelled was work-related (see Fig. S3 in the Supplementary Material). Car users drove 8567 miles per year - of which 78% comprised shorter trips made on a weekly basis; of this, more than half the distance (54%) was for work or study purposes - indeed work and study trips make up 42% of all annual pre-COVID-19 distance driven (see Fig. S3 in the Supplementary Material).

In terms of voluntary reductions, we find that 56% of the car survey sample are willing to reduce car use, while less than half (45%) of the air survey sample are willing to reduce air travel. The most frequently selected reasons for not being willing to reduce travel consumption were “*I don't fly/use the car that much anyway*” (40% air travellers and 48% of car users selected this reason) and “*I need to travel by plane/car and have no other options*” (38% of air travellers and 52% of car users selected this reason) - see Tables S11 and S12 in the Supplementary Material for full results.

Overall, in June 2020, air travellers reported being willing to reduce the amount they fly by 3024 miles per person per year while car users were willing to reduce the amount they drive by 2081 miles per person per year - representing 20% and 24% of the amount travelled by air travellers and car users respectively. In terms of reductions by *trip type*, voluntary reductions are largest (in absolute terms) with respect to long-haul flights (1014 miles per year) and short-distance car journeys to work/study (866 miles per year), as expected given their importance in travel behaviour.

We estimate that voluntary travel reductions could potentially lead to an annual decrease of 451 kgCO₂ per capita for air travel (19.5% of the annual per capita emissions of 2309 kgCO₂) and 432 kgCO₂ per capita for car use (24.4% of the 1770 kgCO₂ emitted per capita per year) (see Table 3), assuming air travel generates 0.132–0.162 kgCO₂ per mile and car travel generates a range from 0.140–0.277 kgCO₂ per passenger, depending on car occupancy as discussed in sub-section 2.4 (BEIS, 2020). However, these estimates assume that people will completely eliminate these journeys; in reality, many of these trips will be substituted for shorter journeys, or alternative forms of transport. Taking into account the range of substitutes selected by survey respondents (see Tables S13(a) and S14(a)) in the Supplementary Material and their carbon-reduction potential (outlined in sub-section 2.4), we estimate that emissions reductions from decreased car use may range between 343 kgCO₂ and 402 kgCO₂ per capita, depending on the substitute selected - equivalent to 19.3%–22.7% of pre-COVID-19 emissions levels - and emissions reductions from voluntary air travel reductions may range between 215 kgCO₂ and 359 kgCO₂ per capita (9.3%–15.6% of pre-COVID-19 emissions). Thus, at most, voluntary travel reductions may reduce emissions from personal car use by just over a fifth, and from air travel by less than one-sixth.

3.2. Wave 2 (June 2021) – One year later

A year later, in the Wave 2 Survey (June 2021), both air travellers and car users express *higher* voluntary reductions in distance travelled

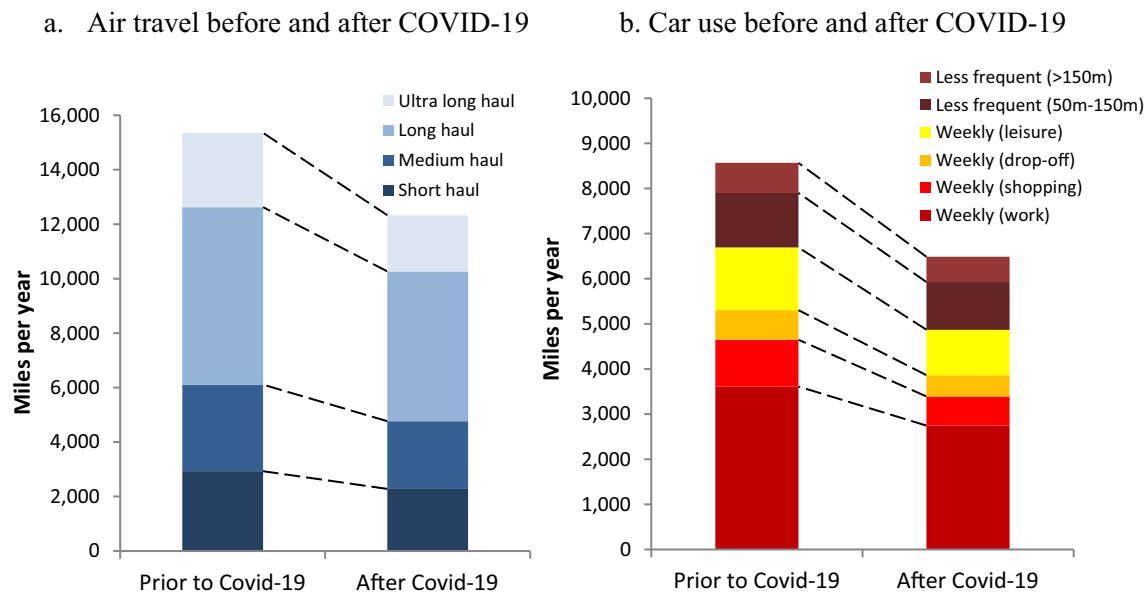


Fig. 1. Travel behaviour (in miles per year) prior to COVID-19 and intended travel after COVID-19. All panels show average distance travelled during a typical year prior to COVID-19, and the reduced amounts that respondents are willing to sustain after COVID-19. The reduced distances are computed by subtracting the stated voluntary travel reductions from the pre-COVID-19 distance travelled elicited in the surveys. Panel a. shows travel behaviour and reductions for air passengers. Flights are divided into short, medium, long and ultra-long haul. Panel b. shows travel behaviour of car users. Car trips are divided into short trips taken on a weekly basis, and less-frequent, long-distance trips (of between 50 and 150 miles, and over 150 miles). Weekly car trips are further subdivided by purpose (get to work/study, shopping, drop off family members at activities, and own leisure activities). See Methods for details of distance calculations.

beyond COVID-19 compared to Wave 1. Results show that the proportion of people saying “yes” to voluntary reductions has increased only marginally over time (from 45% to 47% among air travellers, and from 56% to 60% among car users), suggesting that most of the increase in WTR distance travelled comes from people being willing to forgo *greater distances*. Indeed, hypothesis tests reported in Table A1 in the Appendix shows that air travellers are particularly willing to reduce the longer (long-haul and ultra-long haul) journeys.⁷

The picture among car drivers is less clear. Although WTR appears to have significantly increased over time for almost all types of car journeys, it is also true that Wave 2 car drivers report significantly different amounts of pre-COVID-19 travel compared to Wave 1 drivers. Table A2 in the Appendix shows that Wave 2 car drivers report driving significantly more for weekly non-work activities, and significantly less for long-distance journeys of 50 to 150 miles, prior to COVID-19. Whether this reflects a true difference between samples or reflects poor recall during Wave 2 cannot be ascertained. However, recall is a potential issue, as car users in Wave 2 were being asked about activities conducted almost 18 months earlier. Notably, there is no difference in reported distances travelled for work or in relation to trips of over 150 miles. Arguably, people may have better recall about the longer and less frequent journeys. They may also be expected to have better recall regarding the amount travelled weekly for work, as this tends to be very regular over time.

Given these differences in reported pre-COVID-19 travel distances, we also consider voluntary reductions as a proportion of distance travelled before the pandemic. Results suggest that car drivers in Wave 2 are

willing to reduce greater distances for most activities (work, dropping off family members, and long-distance car trips) compared to Wave 1 drivers.⁸

Overall, we find that voluntary reductions as a proportion of pre-COVID-19 distance travelled have increased between Waves 1 and 2, from 20% to 26% among air travellers, and from 24% to 30% among car drivers. The greatest reductions across both waves come from longer journeys for both air and car travel, as well as from work-related and ‘drop-off’ related car trips.

Estimates of reductions in carbon dioxide emissions are based on combining the WTR values with the respondents’ selection of substitutes (see Tables S13 (b) and S14 (b) in the Supplementary Material). While the WTR values are broadly higher (as discussed above) compared with the Wave 1 survey, there were no noticeable changes in the share of respondents selecting specific substitutes for either car travel or air. We estimate that emissions reductions from decreased car use may range between 463 kgCO₂ and 529 kgCO₂ per capita, depending on the car occupancy (based on the type of journey taken) and the substitute selected – equivalent to 25.1%–28.7% of pre-COVID-19 emissions levels – and emissions reductions from voluntary air travel reductions range between 241 kgCO₂ and 481 kgCO₂ per capita (10.1%–20.1% of pre-COVID-19 emissions) – see Table A5 in the Appendix. Thus, between the Wave 1 and 2 surveys, average voluntary emission reductions associated with personal car use have increased from about one-fifth to one-quarter, and the average reductions related to air travel have risen

⁷ A stacked bar chart (similar to Fig. 1) for Wave 2 can be found in the Supplementary Material (Fig. S4). We do not present it in the main text as it is visually almost indistinguishable from Fig. 1, and as such adds no detail to the discussion here. Additional statistics for this fig. are found in the Tables S7–S10 in the Supplementary Material.

⁸ In terms of *intended* travel after COVID-19, i.e. the reduced amounts that respondents are willing to sustain beyond COVID-19, the last panel in Table A2 shows that Wave 2 car drivers intend to travel significantly less for work and for less frequent journeys of 50 to 150 miles, but intend to drive significantly more for shopping and for leisure compared to car drivers in Wave 1. However, the estimates of intended travel for shopping and leisure are affected by the larger pre-COVID-19 distances reported by car drivers.

Table 3

Travel-related emissions (in kgCO₂) by income quintile prior to COVID-19, and potential changes after COVID-19 (Wave 1 Survey: June 2020).

Air	CO ₂ emissions per capita (kgCO ₂)	Changes in CO ₂ per capita (% change in travel emissions per capita)		
		'Zero carbon potential'	Minimum reduction	Maximum reduction
Overall mean emissions/reductions (kgCO ₂)	2309	-451	-215	-359
		-19.5%	-9.3%	-15.6%
Estimates by Income Quintile				
Q1	1625	-23.2%	-11.3%	-18.3%
Q2	1439	-23.3%	-10.9%	-16.7%
Q3	1610	-20.5%	-9.7%	-16.0%
Q4	2122	-20.9%	-11.7%	-17.8%
Q5	3967	-16.8%	-7.1%	-13.4%
Car	CO ₂ emissions per capita (kgCO ₂)	Changes in CO ₂ per capita (% change in travel emissions per capita)		
		'Zero carbon potential'	Minimum reduction	Maximum reduction
Overall mean emissions/reductions (kgCO ₂)	1770	-432	-343	-402
		-24.4%	-19.3%	-22.7%
Estimates by Income Quintile				
Q1	875	-31.9%	-23.7%	-28.2%
Q2	1187	-18.8%	-15.2%	-16.7%
Q3	1704	-21.6%	-16.1%	-20.0%
Q4	2087	-27.4%	-22.0%	-26.4%
Q5	2454	-24.5%	-20.1%	-22.6%

Notes: This table provides estimates of the potential range of emissions changes resulting from voluntary travel reductions. 'Zero-carbon potential' will be achieved if all travel reductions lead to proportionally equivalent emission reductions (i.e. if all travel reductions are substituted for zero-carbon options or eliminated altogether). The fourth and fifth columns present emissions reductions associated with respondents' selected lowest-carbon substitute ("Maximum reduction") and highest-carbon substitute ("Minimum reduction").

from less than one-sixth to one-fifth.

4. Consumption and emissions across the income distribution

Since the affluent tend to consume and pollute more per capita (Wiedmann et al., 2020), we look at travel behaviour, voluntary reductions and associated carbon dioxide emissions across the income distribution to identify relative differences by income. To do this we present results by income quintile (Fig. 2 and Table 3), focusing first on Wave 1 results.

4.1. Wave 1 (June 2020)

Fig. 2 shows that as income rises, consumption also rises, as expected. What is notable is the contrast between the amount of air travel by the highest income quintile (Q5) and all other income quintiles (panel a, Fig. 2). Prior to COVID-19, the average respondent in Q5 flew almost twice as much as the average in Q4 and about three times as much as all other quintiles. This is in line with recent findings regarding the disproportionate amount of air travel by the rich (Banister, 2019) and the 'super-rich' (Otto et al., 2019).

Relative to the amount travelled, voluntary travel reductions are broadly comparable across the income distribution (although marginally lower among more affluent air travellers), with most income quintiles willing to reduce travel by an average of about 20–25% of pre-

COVID-19 levels. Thus, there is no notable difference in willingness to reduce travel (relative to pre-COVID-19 levels) across the income distribution.

From the point of view of achieving significant emissions reductions and embarking on a low-carbon pathway, however, affluent travellers would have to reduce the amount they travel by a much larger extent in order to counter the excessive emissions they cause (see Table 3). This is especially salient for air travel, where the most affluent (Q5) emit on average two and half times more than travellers in all other income quintiles. Even after accounting for voluntary reductions in air travel beyond COVID-19, those in the highest income quintile still expect to fly on average 21,679 miles per year (leading to roughly 3200 kgCO₂ emissions from these flights alone).

This is problematic not just because of the excessive contribution of this income group to overall emissions, but also because of the aspirations they create for the rest of society (Otto et al., 2019; Gössling, 2019). If other air travellers were to emulate the flying behaviour of those in the highest income quintile, then emissions from air travel would be more than three times greater than current levels. Much larger reductions would be required; indeed, an approximately 50% reduction would be needed to bring air travel down to similar levels as other quintiles.

4.2. Wave 2 (June 2021) – One year later

One year later, Wave 2 survey responses indicate that the pre-Covid difference in air travel and emissions between rich (Q5) and the rest (Q1–Q4) is less wide (from 250% to 209% larger) but the pre-Covid difference in car driving and related emissions is greater (164% to 182% larger).⁹ However, there is little evidence that voluntary reductions in air travel have changed by income quintile compared to reductions one year earlier. Results in Table A3 in the Appendix show that, although voluntary air travel reductions are modestly higher in Wave 2 for most income quintiles (Q2 to Q5), these differences are only (weakly) significant for those in Q3. However, proportional air travel reductions are significantly higher in Wave 2 for the highest income quintile (Q5), whose relative WTR has increased from 17% in Wave 1 to 26% in Wave 2 ($p = 0.0013$).

As for car users, results show that voluntary travel reductions are higher among drivers in Q2–Q5 in Wave 1 compared to those in Wave 2 – although the difference is not statistically significant for Q4. Relative to total pre-COVID-19 distance travelled, voluntary reductions are 12% larger in Wave 2 compared to Wave 1 for drivers in Q2 and Q3, and 8% larger for drivers in Q5. On the other hand, we observe a decreased relative willingness to reduce travel among car drivers in the lowest income quintile (weakly significant).

In terms of carbon dioxide emission reductions, potential emissions reductions due to voluntary air travel reductions range between 9% and 23% in Wave 2, depending on the income quintile and the substitute chosen (see Table A5 in the Appendix). The maximum emission reductions are greater than in the Wave 1 survey – especially for the top income quintile (Q5). For car driving, the change differs across quintiles – the emissions reductions associated with the poorest quintile (Q1) fell from 24%–28% in Wave 1 to a narrow range of 18%–19% in Wave 2, while emissions reductions have increased among other quintiles – from the 15% to 26% range in the first survey to 24%–31% in Wave 2.

In sum, although higher-income travellers are willing to reduce their travel consumption (and hence emissions) by a larger amount compared to one year earlier, it still remains the case that larger reductions would be required by the more affluent travellers – as before, an

⁹ A stacked bar chart (similar to Fig. 2) for Wave 2 can be found in the Supplementary Material (Fig. S5). We do not present it in the main text as it is visually almost indistinguishable from Fig. 2, and as such adds no detail to the discussion here.

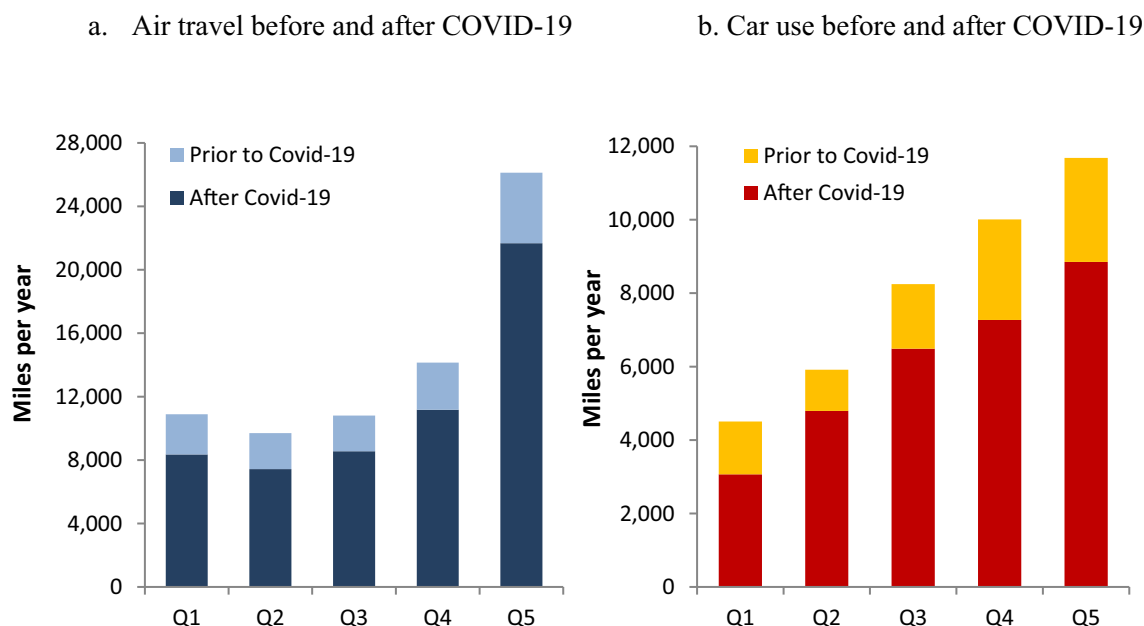


Fig. 2. Travel behaviour (in miles per year) by income quintile prior to COVID-19 and intended travel after COVID-19. Both panels show average amount travelled during a typical year prior to COVID-19, and the reduced amounts that respondents are willing to sustain after COVID-19. Panel a shows travel behaviour and reductions for air passengers for each income quintile. Panels b shows travel behaviour and reductions of car users by income quintile.

approximately 52% and 45% reduction would be needed to bring top income air travel and car driving respectively down to similar levels as other quintiles. The question is: how to motivate greater reductions, particularly among the high-income earners?

5. Influences on 'willingness to reduce' travel

Determining how greater travel reductions can be motivated among car and air travellers – particularly among the affluent – requires insight into which factors influence willingness to reduce consumption. We address this using Tobit regression models, as outlined in Section 2.5. Explanatory variables include socio-economic indicators, membership of an environmental organisation, travel behaviour prior to COVID-19, subjective wellbeing and indicators of personal experience of COVID-19 (see Section 2.2. for descriptions of these variables and Tables S2(a) and S2 (b) in the Supplementary Material for summary statistics associated with all of these characteristics). We also include a binary variable indicating agreement with the statement '*In the long-term, climate change is at least as serious as COVID-19*', which aims to capture the extent to which respondents consider climate change a critical issue for the future.

We are particularly interested in examining whether voluntary reductions are mostly motivated by (relatively) stable personal factors, such as income, gender and education, or whether the personal experience of COVID-19 has had any effect. If COVID-19 is a major source of motivation, this effect may be temporary as the pandemic passes and life returns to 'normality'. Both of the attitude statements used to capture positive (more time to do creative things) and negative (more negative impact compared to others) experiences of COVID-19 (see Section 2.2 for specific wording used) were entered into the regression as binary indicators (outlined in Section 2.5). We note that these variables, inasmuch as they intend to measure perceptions and subjective experiences, are simply indicators of these, and should not be interpreted as direct measures. Interpretation of these indicators is limited because we have no information about their measurement error, and hence we cannot be completely certain that they represent the intended construct. This also applies to the measures of subjective wellbeing and attitude towards climate change.

We are also interested in identifying heterogeneous influences by income quintile. To examine such influences, we ran regressions with

interactions between income and the independent variables; however, the interactions were not significant in the models, suggesting that influences on voluntary consumption reductions do not vary by income. For this reason, we do not present these interactions here; however, this *lack* of interaction between income and other explanatory factors is noteworthy because it suggests there are no factors within income quintiles that might distinguish respondents' 'willingness to reduce' (WTR) consumption responses. Income does not appear to interact with, or moderate, our indicators of COVID-19 experience; it does not appear to affect membership of environmental organisations; in sum, income does not appear to influence the antecedents of consumption, or voluntary consumption reductions (and this is true for both survey waves). We discuss this issue in more detail in the next section. We also anticipated that income might moderate the experience of COVID-19 - with higher-income respondents suffering less from changes in work status and benefitting more from increased time-availability for leisure purposes, such as gardening (as found in ONS, 2020b). We find no effect of these interactions on willingness to reduce travel.

Results of the regressions for the air travel survey are found in Table 4 while results for the car user survey are found in Table 5. In both tables, we report results from regressions on Wave 1 and Wave 2 individually, as well as results from a pooled regression model. The latter model includes a control for survey wave (where 1 = Wave 2). This variable will help identify if there are additional factors not included in the models that influence WTR in Wave 2. Log-normal distributions of WTR consumption were used for all estimations, therefore all coefficients indicate changes in the (natural) log of WTR. Any reporting of coefficients in the text will refer to the exponentiated coefficient, which will allow for interpretation in terms of WTR. Notably, we interpret these exponentiated coefficients in terms of percentage changes rather than in terms of the ratio change.¹⁰

Overall, if we compare results across both the air travel (Table 4) and

¹⁰ Exponentiated coefficients provide the ratio between values of the dependent variable for one-unit increases in the independent variable; for example, an exponentiated coefficient with a value of 1.1 implies that a one-unit increase in the independent variable will lead to 1.1 times the increase in the dependent variable. This is equivalent to a 10% increase in the dependent variable.

Table 4
Factors affecting logWTR air travel in support of a low-carbon pathway

AIR TRAVEL MODELS	Wave 1 (Jun 2020)		Wave 2 (Jun 2021)		Pooled Wave 1 + 2	
	Mean	Std err	Mean	Std err	Mean	Std err
Socio-economic characteristics						
Female	0.208	(0.533)	0.992	(0.621)	0.562	(0.404)
Age (divided by 10)	−0.929***	(0.188)	−0.306	(0.231)	−0.653***	(0.144)
University or college degree	−0.201	(0.551)	−0.302	(0.633)	−0.247	(0.417)
Owns a car	−0.245	(0.669)	−1.007	(0.803)	−0.550	(0.514)
Income quintile 2	−0.350	(0.948)	0.509	(1.126)	−0.045	(0.727)
Income quintile 3	−0.649	(0.907)	0.301	(1.097)	−0.244	(0.700)
Income quintile 4	−0.171	(0.894)	0.444	(1.101)	0.065	(0.696)
Income quintile 5	−1.264	(0.942)	−0.635	(1.142)	−0.956	(0.728)
Member of environmental organisation	1.845***	(0.606)	1.002	(0.710)	1.452***	(0.460)
Pre-Covid-19 travel behaviour						
Log of total annual distance flown	−0.304	(0.270)	−0.347	(0.292)	−0.291	(0.197)
Percent total distance travelled for work	−0.172*	(0.088)	−0.110	(0.101)	−0.141**	(0.065)
Log total distance x percent work travel	0.023**	(0.009)	0.017*	(0.010)	0.020***	(0.007)
Personal experience of COVID-19						
Since Covid-19, I've had more time	2.119***	(0.557)	1.651***	(0.621)	1.901***	(0.413)
Covid-19, more negative impact on me	0.452	(0.636)	0.440	(0.788)	0.379	(0.490)
Work status change since Covid-19	−0.602	(0.842)	0.745	(1.373)	−0.307	(0.708)
Other						
Subjective wellbeing (scale 0–10)	0.456***	(0.155)	−0.043	(0.164)	0.229**	(0.113)
Climate change at least as serious as Covid-19	3.124***	(0.529)	3.726***	(0.653)	3.384***	(0.409)
Wave 2					0.806**	(0.400)
Constant	1.839	(2.811)	2.580	(3.243)	1.655	(2.120)
N	1205		798		2003	
Log likelihood	−2297.305		−1576.360		−3880.725	
F-statistic	10.679 (17 df)***		7.607 (17 df)***		16.635 (18 df)***	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$. Fig.s in parentheses are standard errors.

Table 5
Factors affecting logWTR car use in support of a low-carbon pathway

CAR USE MODELS	Wave 1 (Jun 2020)		Wave 2 (Jun 2021)		Pooled Wave 1 + 2	
	Mean	Std err	Mean	Std err	Mean	Std err
Socio-economic characteristics						
Female	0.197	(0.390)	0.997**	(0.426)	0.538*	(0.289)
Age (divided by 10)	−0.785***	(0.149)	−0.395**	(0.162)	−0.625***	(0.110)
University or college degree	0.354	(0.409)	0.372	(0.434)	0.362	(0.300)
Took at least one flight in 2019	0.795*	(0.412)	0.147	(0.423)	0.501*	(0.297)
Income quintile 2	−0.684	(0.708)	0.162	(0.812)	−0.311	(0.539)
Income quintile 3	−1.219*	(0.702)	1.110	(0.748)	−0.187	(0.516)
Income quintile 4	−0.956	(0.717)	0.654	(0.779)	−0.255	(0.533)
Income quintile 5	−1.748**	(0.754)	1.164	(0.842)	−0.534	(0.566)
Member of environmental organisation	1.924***	(0.442)	2.209***	(0.450)	2.043***	(0.317)
Pre-Covid-19 travel behaviour						
Log of total annual distance driven	0.566*	(0.297)	0.558*	(0.294)	0.591***	(0.207)
Percent total distance travelled for work	0.046	(0.058)	0.070	(0.055)	0.064	(0.040)
Log total distance x percent work travel	−0.005	(0.007)	−0.006	(0.006)	−0.006	(0.005)
Well-served by public transport	0.762**	(0.378)	0.476	(0.413)	0.674**	(0.281)
Personal experience of COVID-19						
Since Covid-19, I've had more time	2.048***	(0.407)	2.052***	(0.424)	2.094***	(0.296)
Covid-19, more negative impact on me	0.069	(0.525)	1.087**	(0.489)	0.475	(0.362)
Work status change since Covid-19	−0.349	(0.562)	−0.135	(1.104)	−0.332	(0.496)
Car not used during lockdown	0.389	(0.497)	0.253	(0.595)	0.421	(0.381)
Other						
Subjective wellbeing (scale 0–10)	0.024	(0.117)	0.089	(0.119)	0.063	(0.084)
Climate change at least as serious as Covid-19	2.341***	(0.391)	3.006***	(0.424)	2.634***	(0.288)
Wave 2					1.027***	(0.288)
Constant	−1.296	(2.771)	−5.220*	(2.876)	−3.695*	(1.959)
N	1193		802		1995	
Log likelihood	−2555.284		−1741.077		−4309.420	
F-statistic	10.539 (19 df) ***		13.634 (19 df) ***		21.670 (20 df)***	

Notes: The car use regressions include a dummy for the 18.5% of respondents that did not use their car at all during the lockdown; a similar variable was not included in the air travel regressions as only 2% of respondents had used a plane since the lockdown. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$. Fig.s in parentheses are standard errors.

car user (Table 5) samples, we observe that many of the same factors influence voluntary reductions in both air travel and car use. For example, membership of an environmental organisation (about 20% of air travellers and car users in both waves) has a very large and positive effect on WTR in both Wave 1 air and car samples, as well as in the pooled models for both samples. Exponentiated coefficients from the pooled model show that – *ceteris paribus* – members of environmental organisations are willing to reduce air travel 3.27 times more and car travel 6.71 times more compared to those who are not members of environmental organisations. Similarly, agreement that ‘*climate change is as serious as COVID-19*’ also significantly increases WTR across both Wave 1 and 2 air and car travel samples. These results reflect a correlation between pre-existing environmental values, and willingness to act on those values, as found in other studies (Gössling et al., 2019; Morten et al., 2018).

We also find that older air travellers and car users are generally less willing to reduce the amount travelled (this effect is not significant in the Wave 2 air traveller sample). This may reflect the fact that older respondents consider themselves more dependent and less flexible with regards to car use or air travel (e.g. Davison et al., 2014); this is partly supported by reasons given by a number of older respondents for not reducing their travel, such as: ‘*I’m older so need to travel more before I can’t*’ (air travel survey, Wave 1) and ‘*I am 82, live alone with no bus service*’ (car survey, Wave 1). Alternatively, the negative impact of age may reflect a perception among older respondents that there is nothing much they can do about climate change (Haq et al., 2010); unfortunately, we cannot ascertain whether this is the case as the survey did not elicit perceptions of behavioural control.

Notably, willingness to reduce air travel is not influenced by the income of air travellers (Table 4), whereas among car travellers (Table 5), WTR is significantly lower among those in the highest income quintile (Q5) in Wave 1 compared to those in Q1 (the exponentiated coefficient indicates that it is 83% lower) – this despite the fact that Q5 car users in wave 1 drive two-and-half times the distance that Q1 drivers drive in a year. One year later, however, there is no evidence of a negative relationship between Q5 and voluntary reductions.

Interestingly, willingness to reduce air travel is not influenced by the distance flown, although the significant (positive) interaction term between distance flown and workshare shows that, as the share of work travel increases, distance flown has an increasing positive effect on WTR (Fig. S6 in the Supplementary Material illustrates the relationship for Wave 1 respondents). Among car users, WTR distance is positively associated with pre-COVID-19 distance driven; however, there is no evidence of a relationship with the amount of travel for work. Car users are also more willing to reduce the amount they drive when they are well-served by public transport (in Wave 1 and the pooled model), highlighting the importance of investments in extending the public transport network as a means to reducing carbon emissions.

Turning to the key question of whether COVID-19 influences voluntary reductions, we find respondents who agree that they have had ‘*more time to do creative things*’ since COVID-19 have a greater WTR in all models, suggesting that time availability is a key factor influencing consumption. Related findings have been reported in other studies (Knight et al., 2013; Hayden and Shandra, 2009; Rosnick and Weisbrot, 2007), in which longer working hours were found to be associated with increased energy consumption and carbon emissions, and larger ecological footprints, even after accounting for the contribution of work time to productivity. The implication is that increased leisure time (or conversely, decreased work time) may contribute significantly to emissions reductions (Druckman et al., 2012; King and van den Bergh, 2017; Sanne, 2002). This may occur because time scarcity encourages more convenient yet less environmental choices, such as driving rather than

walking or cycling (Hayden and Shandra, 2009). Increased leisure time thus appears to be a key mechanism by which COVID-19 may motivate consumption reductions in the longer-term.

This is particularly important in the context of the COVID-19 pandemic, in which people’s living circumstances – including time-availability – are rapidly changing. Results in Table S2(a) and S2(b) in the Supplementary Material show that the proportions of respondents agreeing that they have more time for creative things has declined significantly between Waves 1 and 2: specifically, we observe that 63% and 60% of air and car travellers respectively agreed with this statement in Wave 1, while only 45% and 47% of air and car travellers respectively agreed with this in Wave 2. Thus, the window of opportunity to motivate reduced consumption may already be narrowing as people return to their busy lives.

On the other hand, negative impacts of COVID-19 – whether in terms of changes in work status or a perceived relative disadvantage compared to others – appear to have no effect on voluntary air and car travel reductions in Wave 1. However, results for the Wave 2 car user sample show that a negative perceived experience of COVID-19 is associated with higher levels of WTR consumption. There is ample evidence in neuroscience that chronic stress induces habitual decision-making and behaviour (Porcelli and Delgado, 2017; Schwabe and Wolf, 2009). Although we did not elicit details about respondents’ stress levels, it is conceivable that individuals who perceive themselves at a relative disadvantage with regards to COVID-19 are also suffering from chronic stress, which in turn may bias decisions towards habitual behaviours. Given the reduced levels of car use during the COVID-19 period, with 17% and 14% of Wave 1 and Wave 2 car users respectively not using their car at all during the lockdowns (and see Table S17 for official statistics), it is possible that the increased WTR among those with a negative experience of COVID-19 reflects a bias towards habitual behaviours, rather than any particular increase in environmental concern.

Finally, the coefficient on the ‘Wave 2’ variable is positive and significant in both pooled air travel and car use models, suggesting that there is a factor – or set of factors – influencing WTR in Wave 2 that are not otherwise captured by the model. This will be discussed in more detail in the following section. Overall, these results provide some insight into the type of mechanism that may encourage consumption reductions over the long term.

As a final note, we conducted additional analyses on Wave 2 data to examine the influence of vaccination status and pandemic fatigue on people’s WTR responses. Regressions (Supplementary Table S15) show that vaccination status (see Supplementary Fig. S7 for distribution of results) has no effect on voluntary reductions in either model, while pandemic fatigue has a negative influence on WTR among air travellers, but no effect on car users. As we did not measure pandemic fatigue in Wave 1, we cannot say much about how changing levels of pandemic fatigue have impacted voluntary reductions. However, it is likely that pandemic fatigue has increased since the Wave 1 survey, suggesting that voluntary reductions will have been negatively affected. However, even accounting for (potentially increased levels of) pandemic fatigue, people in Wave 2 are willing to reduce their travel consumption even more than those in Wave 1.

6. Discussion

Almost half of all greenhouse gas emissions from households in the UK relate to travel behaviour (ONS, 2020a). Reducing emissions from road and air transport remains a significant challenge as the UK looks to reach net zero emissions by 2050. Part of the problem is that individuals are generally resistant to changing habitual behaviour (Gärling and Axhausen, 2003). Yet COVID-19 has disrupted habitual travel behaviour

and in doing so, has presented a unique opportunity to encourage more permanent shifts in behaviour towards sustainable travel patterns. Indeed, a central question of this paper is 'how much of the reduction in travel due to Covid-19 restrictions can be sustained through voluntary reductions?'

Evidence from the present study indicates that reductions in car use of 24% - 30% and reduction in air travel of 20% - 26% could be sustained over the longer term through behavioural changes.¹¹ This suggests that, if the net zero pathway for car emissions reductions as specified by the CCC (2020) were to be embarked upon now,¹² its objectives could be met through voluntary changes in behaviour, when combined with the potential to substitute towards electric vehicles powered from low carbon sources. In contrast, aviation is likely to struggle to meet net zero targets through voluntary travel reductions, given the large gap between CCC's (2020) required and voluntary reductions, as well as the limited potential for sustainable aviation fuels.

Nonetheless, these results show that a significant fraction of required emissions reductions can be achieved through behavioural changes. The question of how to motivate even greater reductions can be identified through regression analysis, which allows us to identify the key factors influencing people's voluntary travel reductions. We find that willingness to reduce air and car travel is positively affected by the increased availability of time experienced as a result of COVID-19. This resonates with findings from other studies about the link between time scarcity and consumption of resource-intensive 'convenience' goods and services - known as the 'composition effect' of time-use changes (Knight et al., 2013; Hayden and Shandra, 2009; Rosnick and Weisbrot, 2007). Much of this effect is due to reductions in the amount of time spent commuting to work; however, increased time availability may also increase people's willingness to engage in 'slower', less carbon-intensive activities, such as cycling or walking rather than driving.

An ONS study conducted during the first lockdown found that, between March and April 2020, there was a 16% increase in the amount of time spent on entertainment (e.g., watching TV, playing games, socialising online), a 24% increase in time spent keeping fit, and a 147% increase in time spent gardening and doing DIY compared to the same time five years earlier (ONS, 2020b). These changes in behaviour reflect increases in non-travel-related leisure that have continued in subsequent lockdowns and in less restricted periods - for instance, in September–October 2020 (ONS, 2021), when many of the restrictions were lifted, entertainment remained 6% above 2014–2015 levels, while keeping fit and gardening and DIY remained 33% and 78% above 2014–2015 levels respectively (see Table S16 in the Supplementary Material). In March 2021, during the third lockdown, time spent on non-work activities was lower compared to the same time last year, but was still greater than the amount of time spent on leisure in 2014–2015 (ONS, 2021).

These changes in time-use towards more leisure activities may potentially lead to reduced levels of travel consumption and associated emissions if sustained over the longer term. As discussed by Chai et al. (2015), the availability of 'discretionary' time may be the key to unlocking public willingness to shift behaviour away from high-carbon options (e.g., driving, flying) towards 'slow' low-impact activities (e.g., walking, cycling, taking the train).

Given that 14% of air travel and 45% - 46% of car travel in our two surveys was associated with work and/or commuting, there is an

opportunity for government to support long-term reductions in work-related travel by facilitating tele-working (such as ensuring high-speed broadband infrastructure in the whole country), and investing in more and better public transport and sustainable commuting options (e.g., mobility as a service (Mulley, 2017)). Indeed, we found that (in both Wave 1 and 2) over a quarter of all car commuters are willing to walk or cycle to work and almost one-fifth are willing to work from home to reduce carbon dioxide emissions. Similarly, about one-eighth of air travellers are willing to use teleconferencing services instead of flying and almost four-tenths would consider eliminating the need of certain flights. Support for these reductions in work-travel may contribute towards what Sanne (2002) refers to as 'living lightly'.

Another area which could benefit from government support regards interventions to encourage travellers to 'stay local' and/or explore destinations closer to home. Our findings show that voluntary reductions in travel appear to have increased over time (from June 2020 to June 2021) with most of this increase relating to longer journeys, both for air travel (long-haul and ultra-long-haul flights) and car travel (trips over 50 miles). This may reflect increasing environmental concern, although we note that neither membership of environmental organisations nor levels of agreement that '*climate change is as important as COVID-19*' have changed between the study waves. It is also possible that this finding reflects other factors, such as a renewed interest in exploring closer destinations after prolonged travel restrictions (and conversely, less interest in travelling further afield), or alternatively, increased caution about engaging in long-distance journeys soon after a global pandemic - especially relevant to air travel, in which passengers have to spend the entire journey in enclosed spaces with others. What is clear however, is that - even accounting for pandemic fatigue and increased vaccination rates - people are not showing any inclination to increase their travel after COVID-19, but rather, are willing to reduce their travel consumption even more beyond COVID-19, especially with regards to long-distance journeys. This might be capitalised on, with government encouraging local travel, use of trains instead of cars where possible, and discouraging longer journeys by plane or by car.

Another critical policy issue government must address is the environmental impact of affluence. The affluent within countries and across countries are responsible for a disproportionate share of emissions (Oswald et al., 2020; Sager, 2018; Wiedmann et al., 2020). Our results indicate that individuals in the highest income quintile (i.e., the top 20%) are responsible for 29% in Wave 1 and 31% in Wave 2 of car travel emissions and 37% in Wave 1 and 34% in Wave 2 of air travel emissions. If the current levels of consumption among these wealthy were to be emulated by all existing air travellers and car drivers (Gössling, 2019), carbon dioxide emissions would increase two-and-a-half times from car use and more than three-fold from air travel.

Yet although affluence positively influences consumption, and hence emissions, our results suggest that it fails to exert any particular influence on how people think or intend to behave with regards to consumption reductions. Given the disproportionate contribution of high-income travellers to carbon emissions, and the role of the affluent in creating consumption aspirations for others, it is essential that affluence should be accompanied by some form of "progressive responsibility". There are discussions about replacing income tax with "progressive consumption taxes" (e.g., Rogoff, 2019), and more specifically, 'frequent flier levies' (Fouquet and O'Garra, 2020) to target excessive air travel.

Ultimately, given the lack of self-regulation among the rich, broader personal carbon accountability and responsibility is needed. This could involve every citizen declaring their annual carbon dioxide emissions and eventually being taxed on personal emissions generated (which, as a double dividend, would help reduce income tax), or alternatively, being allocated a personal carbon allowance (Burgess, 2016). It is worth noting that most of the global population emits less than the per capita average of 2100 kg CO₂e emissions required to limit global heating to 1.5C by 2030, while the top 10% richest emit on average 10 times more and the top 1% richest emit 35 times more per capita than this amount

¹¹ Potential reductions are presented here as ranges to account for the different levels of reductions estimated from the two survey waves. The higher end of each range reflects Wave 2 responses for both air and car surveys.

¹² It is important to note that while the voluntary reductions presented in this paper relate to the early 2020s and the reductions required by the CCC's (2020) net zero pathway discussed in this paper relate to 2050. Thus, the difference between the voluntary and required reductions can only alert us to a potential 'reductions gap' in the future rather actually identify one for the present.

(Gore, 2020). Thus, personal carbon allowances could focus on capping high emitters, thus minimizing political or public resistance to personal emission responsibility, as occurred in France over the carbon tax (Carattini et al., 2019).

7. Conclusion

Opportunities to transform economies and societies occur only a few times per century – for instance, following major wars, economic depressions or natural cataclysms. COVID-19 is a once-in-a-generation opportunity, which has forced drastic behavioural changes that could potentially be sustained beyond the pandemic. To shed light on the potential for sustaining these changes, this paper documents people's willingness to reduce consumption in support of the transition to a low-carbon pathway.

We find that people's willingness to reduce travel consumption in the longer term is substantial, with voluntary reductions in the range of 20% - 26% of air travel and 24% - 30% of car use. To put these figures in perspective, during the first lockdown (from late March to late May 2020), average week-day flights in the United Kingdom fell by 89% and car travel in Britain declined 58% compared with the equivalent period in 2019 (see Table S17 in the Supplementary Material). Based on these figures and the survey results, there is the potential to sustain roughly one-third of car use reductions and one-quarter of air travel reductions that occurred during the first Covid-19 lockdown. These percentage reductions in distance travelled are similar to those used by Costa et al. (2021) to model the most 'ambitious' target in their analysis of decarbonisation options in Europe. We note however that their 'ambition' levels account for multiple other factors, such as modal shifts and occupancy, that we do not explicitly model in our study. Nonetheless, our results confirm that voluntary behavioural shifts have the potential to deliver significant emissions reductions.

In terms of reaching net zero by 2050, this paper concludes that around 20% to 29% of car travel emissions and 10% to 20% of air travel emissions may be reduced long-term due to behavioural change. If we compare these figures to the required reductions of 17% of car travel and 39% of air travel needed to achieve a net zero carbon pathway to 2050, as outlined in the UK's Climate Change Committee's Sixth Carbon Budget (CCC, 2020), then results of the present study offer a glimmer of hope.

The evidence suggests that the net zero requirements associated with car use could be met through voluntary changes in behaviour (provided electric vehicles radically overhaul the car fleet), but aviation is likely to struggle to meet net zero targets given the large gap between the CCC's (2020) required reductions and voluntary reductions identified in the present study. Thus, for air travel there is evidence of a substantial 'reductions gap' between what people are willing to do in the long run and what is needed to achieve a net zero carbon pathway to 2050.

We also note that, despite contributing disproportionately to emissions through excessive amounts of travel, affluent travellers are no more inclined to reduce emissions than the less affluent – this is an important addition and challenge to the literature on the environmental problems of affluence (Sager, 2019; Oswald et al., 2020; Gössling et al., 2020; Haberl et al., 2020; Wiedmann et al., 2020). It shows that greater income, consumption and environmental damage fails to generate additional responsibility or self-restraint. This is concerning since rising income over the next thirty years is likely to drive up consumption and emissions but not responsibility to address climate change, despite the fact that behavioural shifts are essential to stabilising global climate to a 1.5 °C rise above pre-industrial levels (CCC, 2020).

Inevitably, a margin of uncertainty exists around the estimates. As discussed in Section 2, a number of assumptions had to be made to convert responses into reductions in travel and emissions. Sensitivity analyses were undertaken, and the impact on the final results was small. In addition, the study depended on respondents reporting their willingness to change truthfully – this is a common issue with survey studies

eliciting intentions. As a result, there is uncertainty about how much of the stated reductions in travel will be acted upon in support of the transition to a low-carbon pathway. To guard against this 'hypothetical bias', the study used a robust design, including a cheap talk script, as suggested in the stated preference literature (Champ et al., 2003) – nonetheless, the only way of verifying whether people actually implemented their 'willingness to reduce consumption' is to conduct a follow-up study of respondents once COVID-19 has fully passed.

Another issue is the timing of the surveys, which could affect the responses. The two surveys were arranged at the same time of year (i.e., June) and both coincided with a post-lockdown period. During the first survey in June 2020 and second survey in June 2021, average week-day British car travel was down 29% and 7% respectively, and flights in the United Kingdom had declined by 83% and 70% respectively compared with the equivalent period in 2019 (see Table S17 in the Supplementary Material). The evidence indicates that the week-day average at the time of the survey is not positively correlated with the willingness to reduce travel stated in the survey.

Finally, since the study was initiated during the first COVID-19 wave, there is no pre-COVID-19 data to confirm the role of the pandemic in changing behaviour. Our use of indicators of COVID-19 impact on people's real and felt experiences was intended to address this limitation. Ultimately, the estimates provide a useful indicator of car drivers' and air travellers' willingness to reduce travel to aid the transition to a low-carbon pathway.

Future research is needed to better understand how to ensure potential reductions are fully achieved. As economists, the obvious solution is to internalise the external costs via a pricing mechanism. However, this raises the issue of whether it is politically acceptable to allow the wealthy to maintain their polluting lifestyle, while others are driven to reduce their emissions for financial reasons. While economically efficient, carbon taxation may exacerbate inequalities of consumption and, ultimately, opportunity – and this has been reflected in public demonstrations exemplified by the 'gilet jaune' in France (Carattini et al., 2019). Thus, in the interest of minimizing inequality and associated social tensions, carbon mitigation strategies need to explore ensuring that all (and especially the affluent) reduce their high-carbon behaviour (Fouquet and O'Garra, 2020).

The current paper suggests that there is a window of opportunity to sustain a proportion of the reductions that occurred in 2020, and furthermore, the COVID-19 experience may offer a clue to how such behavioural changes may be encouraged without using price mechanisms. The evidence shows that those with more time (in particular, for creative leisure activities) were more open to reducing their travel consumption. Over the last 30 to 40 years, travel has increasingly become locked-in as a way to spend one's leisure time, whether due to habit (Cohen et al., 2011) or structural factors (Young et al., 2014). COVID-19 has forced individuals to substitute travel for creative activities in (or near) the home. The existence of this substitution and the possibility of enhancing it remains to be explored in more detail in future research, but could offer a way to improve wellbeing through a more diverse range of leisure pursuits and ultimately, stimulate the shift to a low-carbon pathway.

Ethics declaration

This study was approved by the London School of Economics' Research Ethics Committee on 13th May 2020.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Appendix

Table A1

Comparing Wave 1 and Wave 2 by trip type – AIR TRAVEL.

Hypotheses – AIR	Wave 1	Wave 2	difference (W2-W1)	p-value	
Mean distance travelled prior to C19: wave1 = wave2					
SH	2930.29	2640.60	–289.69	0.016	**
MH	3178.76	3135.34	–43.42	0.829	
LH	6515.85	6996.99	481.14	0.304	
ULH	2728.63	3000.00	271.37	0.498	
Total	15,353.53	15,772.93	419.40	0.660	
Mean WTR: wave1 = wave2					
SH	649.29	611.28	–38.02	0.482	
MH	691.62	753.38	61.77	0.439	
LH	1015.77	1569.93	554.16	0.001	***
ULH	667.22	1112.78	445.56	0.025	**
Total	3023.90	4047.37	1023.47	0.012	**
Mean intended distance after Covid-19: wave1 = wave2					
SH	2281.00	2029.32	251.67	0.019	*
MH	2487.14	2381.96	105.18	0.540	
LH	5500.08	5427.07	73.02	0.861	
ULH	2061.41	1887.22	174.19	0.565	
Total	12,329.63	11,725.56	604.07	0.443	
WTR as % of pre-Covid-19 distance travelled: wave1 = wave2					
SH	0.222	0.231	0.006	0.753	
MH	0.218	0.240	0.022	0.272	
LH	0.156	0.224	0.068	0.001	***
ULH	0.245	0.371	0.126	0.000	***
Total	0.197	0.256	0.059	0.002	***

NOTES: *p*-values reported for i) two-tailed *t*-tests on continuous data (mean distances and WTR), ii) test of two proportions, for proportions data. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

Table A2

Comparing Wave 1 and Wave 2 by trip type – CAR USE.

Hypotheses - CAR	Wave 1	Wave 2	difference (W2-W1)	p-value	
Mean distance travelled prior to C19: wave1 = wave2					
WORK	3611.09	3356.24	–254.85	0.329	
SHOP	1036.60	1279.82	243.23	0.003	**
DROPOFF	656.28	818.06	161.79	0.054	*
LEISURE	1389.31	1786.99	397.69	0.001	***
LD (50–150)	1207.88	897.01	–310.87	0.000	***
LD (>150)	665.88	710.72	44.84	0.470	
Total	8567.03	8848.85	281.82	0.487	
Mean WTR: wave1 = wave2					
WORK	865.69	1137.50	271.81	0.015	**
SHOP	390.95	464.78	73.83	0.116	
DROPOFF	184.72	271.20	86.47	0.019	**
LEISURE	383.08	498.32	115.23	0.019	**
LD (50–150)	150.88	186.03	35.15	0.051	*
LD (>150)	105.62	159.10	53.49	0.004	***
Total	2080.94	2716.93	635.98	0.001	***
Mean intended distance after Covid-19: wave1 = wave2					
WORK	2745.40	2218.74	–526.66	0.020	**
SHOP	645.65	815.04	169.40	0.004	***
DROPOFF	471.55	546.87	75.31	0.260	
LEISURE	1006.22	1288.68	282.46	0.006	***
LD (50–150)	1057.00	710.97	–346.03	0.000	***
LD (>150)	560.27	551.62	–8.65	0.877	
Total	6486.09	6131.92	–354.16	0.289	
WTR as % of pre-Covid-19 distance travelled: wave1 = wave2					
WORK	0.240	0.339	0.099	0.000	***
SHOP	0.377	0.363	–0.014	0.526	
DROPOFF	0.281	0.332	0.050	0.015	**

(continued on next page)

Table A2 (continued)

Hypotheses - CAR	Wave 1	Wave 2	difference (W2-W1)	p-value	
LEISURE	0.276	0.279	0.003	0.883	
LD (50–150)	0.125	0.207	0.082	0.000	***
LD (>150)	0.159	0.224	0.065	0.000	***
Total	0.243	0.307	0.064	0.002	***

NOTES: p-values reported for i) two-tailed t-tests on continuous data (mean distances and WTR), ii) test of two proportions, for proportions data. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

Table A3

Comparing Wave 1 and Wave 2 by income quintile – AIR TRAVEL.

Hypotheses - AIR	Wave 1	Wave 2	difference (W2-W1)	p-value	
<i>Mean distance travelled prior to C19: wave1 = wave2</i>					
Q1	10,890.00	7839.56	−3050.44	0.113	
Q2	9699.50	10,424.43	724.93	0.563	
Q3	10,809.34	13,027.06	2217.72	0.051	*
Q4	14,147.37	16,209.00	2061.63	0.151	
Q5	26,122.62	24,521.36	−1601.26	0.582	
<i>Mean WTR: wave1 = wave2</i>					
Q1	2537.14	2103.30	−433.85	0.542	
Q2	2264.32	2967.94	703.62	0.236	
Q3	2252.92	3338.82	1085.91	0.084	*
Q4	2972.37	3819.00	846.63	0.209	
Q5	4443.93	6399.03	1955.10	0.118	
<i>Mean intended distance after Covid-19: wave1 = wave2</i>					
Q1	8352.86	5736.26	−2616.59	0.093	*
Q2	7435.18	7456.49	21.32	0.984	
Q3	8556.42	9688.24	1131.81	0.268	
Q4	11,175.00	12,390.00	1215.00	0.324	
Q5	21,678.69	18,122.33	−3556.36	0.131	
<i>WTR as % of pre-Covid-19 distance travelled: wave1 = wave2</i>					
Q1	0.233	0.268	0.035	0.543	
Q2	0.233	0.285	0.051	0.295	
Q3	0.208	0.256	0.048	0.248	
Q4	0.210	0.236	0.026	0.169	
Q5	0.170	0.261	0.091	0.013	**

NOTES: p-values reported for i) two-tailed t-tests on continuous data (mean distances and WTR), ii) test of two proportions, for proportions data. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

Table A4

Comparing Wave 1 and Wave 2 by income quintile – CAR TRAVEL.

Hypotheses - CAR	Wave 1	Wave 2	difference (W2-W1)	p-value	
<i>Mean distance travelled prior to C19: wave1 = wave2</i>					
Q1	4505.27	5414.51	909.24	0.193	
Q2	5917.03	7093.24	1176.21	0.093	*
Q3	8247.33	7327.10	−920.23	0.182	
Q4	10,010.78	9835.54	−175.24	0.844	
Q5	11,681.18	13,473.05	1791.87	0.106	
<i>Mean WTR: wave1 = wave2</i>					
Q1	1436.16	1203.93	−232.23	0.416	
Q2	1124.85	2186.06	1061.21	0.002	***
Q3	1759.13	2431.00	671.87	0.044	**
Q4	2741.61	2879.27	137.66	0.748	
Q5	2831.45	4339.01	1507.56	0.011	**
<i>Mean intended distance after Covid – 19: wave1 = wave2</i>					
Q1	3069.11	4210.58	1141.47	0.057	*
Q2	4792.18	4907.18	115.00	0.839	
Q3	6488.20	4896.10	−1592.10	0.006	***
Q4	7269.17	6956.26	−312.90	0.676	
Q5	8849.73	913,403.00	904,553.27	0.755	
<i>WTR as % of pre-Covid-19 distance travelled: wave1 = wave2</i>					
Q1	0.319	0.222	−0.096	0.094	*
Q2	0.190	0.308	0.118	0.009	***
Q3	0.213	0.332	0.118	0.003	***
Q4	0.274	0.293	0.019	0.658	
Q5	0.242	0.322	0.080	0.069	*

NOTES: p-values reported for i) two-tailed t-tests on continuous data (mean distances and WTR), ii) test of two proportions, for proportions data. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

Table A5Travel-related emissions (in kgCO₂) by income quintile prior to COVID-19, and potential changes after COVID-19 (Wave 2 Survey in June 2021).

Air	CO ₂ emissions per capita (kgCO ₂)	Change in CO ₂ per capita (% change in travel emissions per capita)		
		'Zero carbon potential'	Minimum reduction	Maximum reduction
Overall mean emissions/ reductions (kgCO ₂)	2441	−616 −25.8%	−241 −10.1%	−481 −20.1%
Estimates by Income Quintile				
Q1	1160	−27.0%	−12.8%	−19.1%
Q2	1547	−28.7%	−12.9%	−21.7%
Q3	1972	−25.7%	−9.1%	−19.5%
Q4	2462	−29.0%	−10.2%	−23.2%
Q5	3733	−26.3%	−9.8%	−22.2%
Car	CO ₂ emissions per capita (kgCO ₂)	Change in CO ₂ per capital (% change in travel emissions per capita)		
		'Zero carbon potential'	Minimum reduction	Maximum reduction
Overall mean emissions/ reductions (kgCO ₂)	1844	−574 −31.1%	−463 −25.1%	−529 −28.7%
Estimates by Income Quintile				
Q1	1078	−21.0%	−18.0%	−19.2%
Q2	1412	−32.3%	−26.3%	−30.5%
Q3	1508	−33.9%	−27%	−29.6%
Q4	2075	−29.5%	−24.1%	−27.1%
Q5	2897	−32.4%	−25.4%	−30.7%

Notes: This table provides estimates of the potential range of emissions changes resulting from voluntary travel reductions. 'Zero-carbon potential' will be achieved if all travel reductions lead to proportionally equivalent emission reductions (i.e. if all travel reductions are substituted for zero-carbon options or eliminated altogether). The fourth and fifth columns present emissions reductions associated with respondents' selected lowest-carbon substitute ("Maximum reduction") and highest-carbon substitute ("Minimum reduction").

Appendix B. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecolecon.2021.107297>.

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