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Household Transport Choices: New empirical evidence and policy implications for sustainable behaviour

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Abstract

This paper offers updated insights on the factors that determine households' transport and mobility choices. The analysis uses data from the third OECD Survey on Environmental Policies and Individual Behaviour Change (EPIC), containing responses from over 17 000 households in nine OECD countries. It explores the role of key variables on how households choose the fuel type of their vehicles and the transport modes they use in their trips. The analysis also exploits choice experiment data to estimate the importance of key drivers of electric vehicle purchase decisions and to project future adoption rates of electric vehicles.

The results show that income growth boosts travel demand, car ownership and use, especially at low-income groups. This necessitates transport policies to offset these trends. Geography and location play a pivotal role. Urban residents tend to rely less on personal cars due to better public transport options. In contrast, those in remote areas are 12% more likely to own a car, and rural dwellers are 20-30% more likely to use cars for both commuting and leisure. Residential location also matters for the choice of fuel type, as rural households exhibit a stronger preference for internal combustion engine vehicles than urban households, and especially for diesel cars. Environmental awareness impacts travel behaviours as well, as environmentally concerned individuals are 6-7% less likely to own a car and 5% more likely to purchase a battery electric vehicle.

Specific policies can be critical to accelerate transition to a less carbon-intensive vehicle fleet. For example, the findings highlight the importance of charging infrastructure development in encouraging battery electric vehicle uptake. Results suggest that convenient access to charging at home, work and the usual parking spot could double their adoption rate. In contrast, a typical purchase subsidy of USD 7 000 for a battery electric vehicle is predicted to increase its choice probability by 2.0% to 3.5%. Inertia and status-quo effects favour conventional cars, as their current users are 30% more likely to stick with that choice in future purchases. However, these effects apply to electric vehicles as well, suggesting that policy support can be relaxed once they are widely adopted.

Keywords: household behaviour, car ownership, mode choice, fuel type choice, electric vehicle adoption, electric vehicle subsidies, recharging infrastructure, range anxiety.

JEL Codes: R40, Q54, D12, D91, C25

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The paper has been authored by Ioannis Tikoudis, Rose Mba Mébiame, Nicolina Lamhauge, Katherine Hassett, and Olof Byström (OECD, Environment Directorate), and Andrea Papu Carrone (International Transport Forum). The contributions of the authors are as follows:

Author	Contribution
Ioannis Tikoudis	Conceptualisation, econometric analysis (all parts), forward simulations, primary drafting, editing (all parts)
Andrea Papu Carrone	Econometric analysis of Section 3.2, forward simulations, editing of Sections 3.1 and 3.2.
Rose Mba Mébiame	Econometric analysis of Section 2.5, primary drafting of Section 2.5, editing (all parts)
Nicolina Lamhauge	Project management, editing (all parts)
Katherine Hassett	Conceptualisation, editing (all parts)
Olof Byström	Project management, editing (all parts)

All authors have discussed the results, their practical implications and significance.

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Executive summary

The transport-related choices we make in our everyday lives have important repercussions for the economy and the environment. While they support economic activity and help us access services and social opportunities, they also generate environmental and other externalities. Technological advances will play an important role in curbing these externalities, but the timely transformation of the transport sector necessitates policy-induced behavioural change. Understanding consumer choices and motivations can be pivotal to this end.

To this end, this report provides new insights into the drivers of individual and household transport choices. The analyses build upon the third OECD Survey on Environmental Policies and Individual Behaviour Change (EPIC) from 2022, which collected responses from over 17 000 households in nine OECD countries. The econometric analyses of the report link transport-relevant choices with the socioeconomic characteristics of respondents, as well as their environmental attitudes and beliefs. The data enable an identification of the common drivers that shape transport choices in all countries, as well as of the factors that pertain to specific socioeconomic groups or countries.

The results indicate that income has a strong positive effect on travel demand, car ownership and use, especially at low-income and medium-income levels. Projected income growth is expected to further increase travel demand, car ownership and use, calling for transport policies to offset these trends. Geography and public transport provision also matter a great deal for all transport choices. A respondent located in a remote area, which is typically poorly covered by public transport, is 12% more likely to have regular access to a car, compared to a respondent located within an urban core. Among households with regular access to a car, rural households are 20-30% more likely to use the car for commuting, childcare or leisure-related trips, compared to urban households.

The analyses further suggest that environmental awareness has a significant impact on travel behaviours, notably on less frequent but high-impact choices. Respondents that report a higher level of environmental awareness are at least 6-7% less likely to own a car, and 5% more likely to purchase a battery electric vehicle (BEV) compared to less aware respondents. Individuals residing in low density locations have a higher probability to select an internal combustion engine (ICE) car in their next purchase. Due to the larger distances they face in their daily trips, these respondents find diesel cars substantially more attractive.

The study also provides new insights about the role of policies aiming to accelerate the transition to a less carbon-intensive vehicle fleet. The results show that convenient access to charging infrastructure at home, at the workplace and at household's "usual" parking spot could double the adoption of BEVs relative to not having these options. Furthermore, a BEV purchase subsidy of USD 7000, which is typical in several OECD countries, is shown to increase the probability that a consumer chooses a BEV by 2.0-3.5%. Providing an equivalent amount of support to reduce running costs, for example in the form of subsidised recharging, is estimated to be less cost efficient. Finally, if the aforementioned subsidy is financed by a tax on ICE car sales, the estimated increase in the likelihood of choosing a BEV grows to 3.2-5.5%.

Policies should also factor in the presence of inertia and status-quo effects. The analysis suggests that these favour conventional cars, as individuals that currently use ICE vehicles are 30% more likely to stick to that choice in their next purchase. However, status-quo effects are also strong for BEVs, implying that policy support measures could be relaxed once a tipping point, where a sufficient majority of households own BEVs, is reached. Finally, individuals that fully support stricter fuel standards, environmental labelling in cars, teleworking and EV subsidies are significantly more likely to make greener transport choices. Therefore, boosting support for environmentally relevant transport policies may not be sufficient, but is necessary to generate sustainable change.

In line with findings from the analysis of other areas of the EPIC Survey, the findings herein highlight the importance of policies that provide real incentives to shift long-term behaviour and choices and, in some cases, eliminate environmentally detrimental consumer options with mandatory standards and regulations. The findings also highlight the important role of complementary interventions that seek to overcome behavioural biases, attitudinal rigidities, and lack of information.

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1. Introduction

1.1. Context

The transport sector is crucial for the global economy and well-being. It employs a substantial share of the labour force, facilitates the movement of people and goods, and it provides access to services and social opportunities. As a result, transport services constitute a considerable part of household final expenditure and generate a significant portion of GDP.[1] However, the sector also generates a wide range of environmental, health and other externalities with substantial social costs. It accounts for over a fifth (23%) of global energy-related CO_2 emissions and is characterised by a higher reliance on fossil fuels than any other sector (ITF, 2023[1]). Further, fossil fuel combustion from transport activities generates more than 50% of nitrogen oxides (NO_X), 25% of carbon monoxide (CO), 20% of Volatile Organic Compounds (VOC), 10% of sulphur dioxide (SO_2) and 5% of particulate matter ($PM_{2.5}$). Such air pollutants are known to be harmful for human health (WHO, 2021[2]), as they cause 6.5 million deaths per year (IEA, 2016[3]) and an annual economic cost that exceeds USD 8 trillion (World Bank, 2022[4]). Transport activities also generate other externalities such as noise, accidents and congestion.

Reducing the environmental impact of the transport sector is a challenging task. Current transport systems rely heavily on fossil fuels, and consumers face constraints in redirecting their transport choices towards more environmentally friendly options. Economic growth and demographic changes also put upward pressure on travel demand, which is projected to increase by 65-80% by 2050 (ITF, 2023[1]). With this increase, transport CO_2 emissions can only decrease if the carbon intensity of travel activities is drastically reduced (Riahi, 2022[5]; IEA, 2021[6]). To that end, passenger kilometres must become substantially greener, via a combined proliferation of public transport, electric vehicles, biking, walking and carpooling. Furthermore, urban planning can facilitate more compact cities, where people travel fewer kilometres to work and enjoy the same services (OECD, 2018[7]; OECD, 2020[8]).

Technological developments are required for some, but not all these changes. Improvements to batteries make electric cars more competitive vis-à-vis conventional cars, especially when combined with expanded charging infrastructure. Digital platforms proliferate greener modes of transport (e.g. electric kick-scooters versus traditional motorbikes), or arrangements that increase car occupancy (e.g. ridesharing). The progress in filtering technologies tends to eliminate exhaust emissions of air pollutants, however carbon capture technologies in transport are still at an infant stage, and technological improvements are not expected to deliver the emissions reductions needed to effectively tackle climate change (Sager et al., 2011[9]; Creutzig et al., 2015[10]).

Consequently, policy has a critical role to play in providing supportive infrastructure, accelerating innovation and incentivising sustainable behaviour. Infrastructure investments can increase the availability and accessibility of public transport and facilitate the use of soft mobility. Supply-side policies can increase the efficiency with which public transport is provided and accelerate the electrification of land transport.

[1] For example, between 2002 and 2022 the US transport sector has contributed 7.8-10.2% of the GDP (U.S. Department of Transportation, 2023[131]). This share is considerable smaller in the EU. The transport industry also employs a substantial share of the labour force (e.g. in EU around 10 million people).

Regulations can accelerate the pace at which fuel efficiency improves (Tikoudis, Mba Mebiame and Oueslati, 2022[11]). Regulatory measures can also speed up the introduction and rollout of low-emissions fuels and technologies (ITF, 2023[1]). Independent of the technological context, well-designed policies can limit growth in travel demand and shift mobility choices to more sustainable options. Therefore, interventions that incentivise behavioural change constitute a central component of policy portfolios to decarbonise the transport sector.

Transport-related behaviour can be influenced at various levels and in several ways. For example, fare subsidies can render public transport a more attractive choice compared to car. Road pricing schemes, parking fees, and fuel taxes can curb travel demand and induce a switch from car to greener alternatives. Taxing kerosene, diesel and gasoline may induce similar behavioural changes in long-distance trips. Policy interventions may also influence longer-term consumer choices. Car sales depend on purchase taxes and subsidies, registration taxes, and circulation fees. These taxes can be differentiated across car types depending on their environmental footprint. Subsidies for electric vehicles (EVs), already in use in many OECD countries, can incentivise their uptake, and to some extent dampen demand for conventional cars. Beyond demand-side measures, developing cycling and electric vehicle infrastructure can support desired travel behaviour and provides households the opportunity to alter their travel behaviour.

1.2. Objective and organisation of this report

This report aims to contribute to the development of policies to effectively induce desirable changes in household transport patterns. Developing such policies requires a thorough understanding of the determinants of individual and household behaviour, i.e. the drivers of transport-related choices. In examining this issue, the report builds upon the third round of the OECD Survey on Environmental Policies and Individual Behaviour Change (EPIC) from 2022 (see Box 1.1).

The transport section of the EPIC survey was completed by 8695 respondents in 9 countries.[2] The report explores various consumer choices and behaviours recorded in the survey. First, ***Section 2.2*** examines the factors that influence whether a household has regular access to a car. Second, ***Section 2.3*** takes a closer look at households that would opt for a conventional vehicle that runs on fossil fuels when buying or leasing their next car. Having access to a car is a strong, but not sole predictor of transport mode choice for household travel. To estimate the influence of other factors, such as income and environmental motivation, ***Section 2.4*** examines the primary transport mode respondents report for their commuting, childcare and short-distance leisure trips. Going beyond short distance trips, ***Section 2.5*** explores how often households make long-distance trips for leisure purposes and how they choose to make these trips. ***Section 3.*** exploits the responses from a choice experiment in which respondents were asked to select between an Internal Combustion Engine (ICE) car, a Plug-In Hybrid Electric Vehicle (PHEV), and a Battery Electric Vehicle (BEV) in a hypothetical purchase situation.

A key contribution of the report is that it examines the aforementioned choices in conjunction with the characteristics of the individuals and households that make them, and in a cross-country context. The EPIC dataset contains information on the socioeconomic characteristics of respondents and the households they belong to, as well as their beliefs, attitudes and perceptions about environmental and economic issues. The report obtains new estimates regarding the role of income, household location and other socioeconomic characteristics with respect to a number of reported transport behaviours. It also

[2] The entire sample of the EPIC survey contains 17215 respondents from 9 countries: Belgium, Canada, France, Israel, The Netherlands, Sweden, Switzerland, the United Kingdom and the United States. 8695 respondents were randomly selected to participate in the transport part of the study. As a result, the descriptive statistics of the variables in the full sample and the transport subsample are similar.

provides new insights regarding the role of the most important attributes when it comes to the purchase of an electric vehicle. The results give rise to a number of policy insights, which are presented in ***Section 4.***

Box 1.1. Aim and scope of the EPIC Survey

This report uses data collected in the third round of the OECD Survey on Environmental Policies and Individual Behaviour Change (EPIC). The survey is unique due to its geographic and thematic scope. It explores households' environmental attitudes and actions in the areas of energy, transport, waste and food across nine OECD countries. In addition to collecting information on reported environmental behaviours, the survey records the socioeconomic characteristics of respondents and households, as well as the characteristics of their residential location. As a result, the survey provides information on a wide range of factors that can influence environmentally relevant household decisions. Each round of the EPIC Survey is summarised in Table 1.1. The full questionnaire, as well as further information regarding the implementation of the survey are available in OECD (2023[12]).

Table 1.1. OECD EPIC surveys: coverage, thematic areas and sample sizes

	2008	2011	2022
Countries included	Australia	Australia	Belgium
	Canada	Canada	Canada
	Czech Republic	Chile	France
	France	France	Israel
	Italy	Israel	The Netherlands
	Korea	Japan	Sweden
	The Netherlands	Korea	Switzerland
	Norway	The Netherlands	United Kingdom[1]
	Mexico	Spain	United States
	Sweden	Sweden	
		Switzerland	
Total sample size	10 000	12 303	17 216
Methodology for measuring preferences and behaviour	Self-reporting	Self-reporting	Self-reporting + choice experiments
Number of thematic areas	5	5	4
Possibility to test hypothetical policy interventions	No	No	Yes
Distributional issues addressed	No	No	Yes

[1]The sample from the United Kingdom includes households in England, Northern Ireland, Scotland and Wales.

The third round of the EPIC Survey was implemented in June-July 2022, more than a decade after the second round in 2011. Over this period, a number of changes have taken place with respect to the environmental, political, technological and economic context. These developments contribute to a need to reassess environmental attitudes and behaviours, as well as the effectiveness of environmental policies. At the time of implementation, most significant restrictions related to COVID-19 (lockdowns and international travel bans) had been lifted in the countries sampled. However, the sampling period was characterised by historically high energy prices, overall inflation and geopolitical tensions. The particularities of this context could have several implications for survey responses. Self-reported levels of support for tax instruments, for example, may be lower, while support for policy measures involving financial support (e.g. grant and subsidies) may be higher than they otherwise would be.

1.3. Key findings

The study examines the role of several determinants in shaping the transport choices of households reported in the survey. Among others, determinants include income, residential location, the degree to which respondents are concerned about environmental issues and the extent to which they support a number of transport policies. Other variables of interest, in particular for the choice of vehicle type, include the availability of public charging infrastructure and whether a household has access to the use of a car.

The results are consistent with previous studies regarding the role of income in transport choices and travel behaviour, but they also provide new insights on the magnitude of its impact. Household income has a strong positive effect on car ownership (or car lease). The most affluent households, i.e. those in the 5th income quintile, are 15% more likely to have regular access to at least one car compared to the least affluent ones in the 1st income quintile. Income has a substantial effect on the choice of transport mode as well. With all else equal, individuals from the most affluent households are up to 9% more likely to use a car for their commuting or leisure trips, compared to individuals from the least affluent ones. For childcare trips, this difference exceeds 14%. The study also finds that the income difference between the most and least affluent households may account for a substantial part of the difference in the number of long-distance car trips (35%) and plane trips (6%). Therefore, the results suggest that projected income growth is expected to further increase travel demand, car ownership and use, calling for policy action to offset these trends.

The report suggests that residential location has a profound effect on all transport choices analysed in the study. All else equal, a household located in a remote area is 12% more likely to own a car, compared to a seemingly identical household located within an urban core. If both of these households own a car, an individual from the former is 20-30% more likely to use it in a trip. These findings are consistent with a plethora of studies highlighting the large impact of location on car ownership and use, in particular because low-density areas are difficult to serve by a public transport system in a cost-efficient manner.[3] The findings also emphasise the role residential location and population density play on the choice of fuel type: an individual residing in a remote area is by at least 3% more likely to opt for an ICEV than a seemingly identical individual residing in an urban core. Furthermore, if both decide to buy an ICEV, the resident of a remote area is 10% more likely to opt for a diesel car. This points to the importance of the urban-rural divide in shaping transport choices. In turn, this divide calls for spatially refined measures, i.e. policies in which the burden or the benefit is differentiated by residential location.

There is mixed evidence regarding the role of environmental and climate-change awareness in inducing more sustainable transport choices. In less frequent, hard-to-reverse choices, like the decision to own a car, environmental motivation appears to play a significant role. Environmentally concerned respondents are 6-7% less likely to belong to a household that has regular access to a car, either by owning it or leasing it. The same respondents are more than 5% more likely to prefer a BEV over other more carbon-intensive alternatives, like a PHEV and an ICEV.

In contrast, environmental motivation (i.e. the respondent’s view on the need, urgency and approach to environmental action), has a small, and in some cases adverse effect on regular transport choices. Its effect on the choice of transport mode in long-distance leisure trips is limited, and its impact on their frequency is negligible. Furthermore, its impact on mode choice for short-distance trips is less clear and varies across trip types. While environmental motivation has a positive impact on the propensity to walk or use public transport in commuting trips, it appears to have a strong positive association with the use of car in non-commuting trips. This hampers the assessment of the benefits of campaigns and other policies aiming to increase awareness.

[3] E.g. Savage (2004[66]) shows that urban sprawl has been the main driver of the public transport deficit growth.

Enhanced support for environmentally relevant transport policies is a necessary, but not a sufficient condition to generate sustainable change. Individuals fully supporting stricter fuel standards, environmental labelling for cars, teleworking and EV subsidies are 3-4% less likely to have regular access to a car. Those that express strong support for sustainable transport policies and have regular access to a car are 16% less likely to use it for commuting and 4% less likely to use it for other trips. The experimental data of the survey also suggest that these individuals are 11% more likely to select a BEV in a hypothetical purchase scenario. However, this finding should be interpreted with caution, as ex-ante intention to purchase an EV in the future may also inflate stated support for EV subsidies.

The analysis of responses on the preferred car selected in a series of hypothetical purchase scenarios reveals that less than 20% of the respondents tend to choose a BEV or a Hydrogen Fuel Cell Vehicle (HFCV). While this figure lies close to the current share of sales that these vehicles possess in the market, it implies that their market dominance may be years away, and that achieving a substantially cleaner vehicle stock in the near future is a challenging policy goal.

Strong inertia and status-quo effects also appear to shape household vehicle choices. Those that already use a BEV on a regular basis are almost twice more likely to opt for a BEV in a subsequent purchase. Individuals from households owning or leasing an ICEV are 30% more like to stick to that choice in their next purchase. Given the current prevalence of ICEV cars in the market, these findings suggest that new technologies will likely require more support in order to induce a significant shift to BEV use. Government commitment can signal to consumers and industry that support policies will remain in place in the long run, reducing the transitional risks that are present until the market reaches a tipping point. Purchase costs, and to a lesser extent running costs, of electric vehicles can both affect their market share. The results indicate that a typical subsidy for a BEV purchase of approximately USD 7000 for a BEV increases the likelihood that households choose a BEV by 2.0-3.5%. On the other hand, if the same amount of money is used to subsidise the running costs of BEV use, e.g. by subsidising BEV charging costs, the predicted increase in the BEV share does not exceed 1.8%.

The availability of EV charging infrastructure figures as one of the most important drivers of electric vehicle adoption. Combined, the availability of charging at home and at the workplace is found to increase the likelihood of choosing BEVs by up to 16%. Recharging availability at the usual parking spot has a weaker impact but still important effect, which may reach 8%. The impact of the availability of various types of recharging on the likelihood of choosing a BEV differs across countries.

In line with findings from the analysis of other areas of the EPIC Survey, the findings herein highlight the importance of policies that provide real incentives to shift long-term behaviour and choices. The findings also highlight the important role of complementary interventions that seek to overcome behavioural biases, attitudinal rigidities, and lack of information.

2. Determinants of transport behaviours

2.1. Overview

This section analyses various transport-related behaviours, in particular car ownership (Section 2.2), choice of vehicle type for prospective car purchases or leases of ICE cars (Section 2.3), choice of transport mode for commuting, leisure and childcare trips (Section 2.4) and mode choice for leisure-related long-distance trips (Section 2.5). Each sub-section reports results from econometric models that assess the impact of socioeconomic and attitudinal factors. Socioeconomic variables include income, level of education, level of employment, disability, age, sex, home size, home type, access to open space, location, household situation and household size.[4]

The attitudinal variables considered in the econometric modelling are summarised in Table 2.1. Environmental concern reflects whether a respondent is considered to have a high or low concern about the environment. Environmental motivation reflects the extent to which respondents feel motivated to make sustainable choices. Environmental satisfaction reflects the level of satisfaction with regards to specific environmental aspects. Policy support reflects an aggregated level of support for environmental policies.[5] The construction of these variables is based on work in the literature on environmental psychology (Stern, Dietz and Guagnano, 1995[13]; Dunlap et al., 2000[14]; Gifford, 2011[15]; Sharpe, Perlaviciute and Steg, 2021[16]). The model also controls for economic concern, which reflects the level of concerns with regards to various aspects of the local and global economy.[6]

Table 2.1. Definition of attitudinal variables used in the models

Attitudinal construct	Unit of measure	Survey items	Construction
Environmental concern	Binary	On a scale of 1 to 5, how important is the following to you personally? Climate change (e.g. rising average temperatures, extreme weather events) or other environmental issues (e.g. pollution)	Respondents who answered that these issues were either “important” or “very important” are considered to have a high level of environmentally concern; all others are considered to have a low level of concern.
Environmental motivation	Index (0 to 1)	Please indicate your agreement to the following statements regarding approaches to address environmental issues:	The variable is constructed by summing the responses to each statement, where 1 reflects ‘strongly disagree’ and 5 reflects ‘strongly agree’. The scale is reversed for the first and last two

[4] Inability to work is a dummy variable that equals 1 if the respondent declares that is “unable to work”, and 0 otherwise.

[5] Political opinions are expected to impact pro-environmental action, as it is an expression of pro-environmental motivation (Sharpe, Perlaviciute and Steg, 2021[16]). However, they may be considered endogenous if one’s travelling preferences affect the policy support level for some policies. In order to avoid endogeneity issues, the policy support index is only built on policies that do not translate in direct extra-financial cost (e.g. carbon tax) or restriction (e.g. parking restriction) for the consumer.

[6] The rationale behind including economic concerns is to balance the importance of environmental concerns. While many respondents report to have important environmental concerns, those concerns may translate into lower action if economic concerns are considered as relatively more important. This rationale makes sense when considering the timeline of the survey, which took place during a period of high-energy prices and post-covid recession.

		• Environmental impacts are frequently overstated • Protecting the environment can boost the economy • Environmental issues should be dealt with primarily by future generations • Environmental issues will be resolved primarily through technological progress	statements. The resulting metric is normalised to yield an index ranging from 0 to 1 calculated by dividing the sum of responses by the maximum possible response pattern.
Environmental satisfaction	Index (0 to 1)	How satisfied are you with the following aspects of your local environment? • Outdoor air quality • Level of noise	The variable is constructed by summing the responses to each statement, where 1 reflects 'very dissatisfied' and 5 reflects 'very satisfied'. The resulting metric is normalised to yield an index ranging from 0 to 1 calculated by dividing the sum of responses by the maximum possible response pattern.
Policy support	Index (0 to 1)	What do you think about the following actions governments can take to reduce environmental impacts from cars? • Set stricter fuel efficiency standards for new cars • Provide more detailed labels for cars according to their environmental impacts • Provide a subsidy (or tax credit) for purchasing a low-emissions or energy-efficient car • Promote teleworking	The variable is constructed by summing the responses to each statement, where 1 reflects 'strongly disagree' and 5 reflects 'strongly agree'. The resulting metric is normalised to yield an index ranging from 0 to 1 calculated by dividing the sum of responses by the maximum possible response pattern.
Economic concern	Categorical variable	On a scale of 1 to 5, how important is the following to you personally? Economic concerns (e.g. unemployment, price growth, poverty)	Respondents who answered that these issues were either "important" or "somewhat important" are considered to have a moderate level of economic concern; respondents who answered that these issues were either "important" or "very important" are considered to have a high level of economic concern; all others are considered to have a low level of concern.

2.2. Car ownership and regular access to a car

This section explores why some households chose to own at least one private car, while others do not.[7] While the decision of whether to own a vehicle and what type is an infrequent decision, it is of high environmental importance. This is in part due to the fact that other, more frequent mobility-related decisions, e.g. whether to use a car for a given trip, heavily depend on a household's previous decisions in this regard. The analysis assesses the determinants car ownership using a binary logit model where the dependent variable reflects whether the respondent reports that at least one person in the household has

[7] Whether a household has *regular access to a car* is not directly observed, but evaluated via the survey question: "Do you or does anyone in your household regularly use any of the following (including company-provided equipment)?" Respondents replying positively to any of the options: (a) Gasoline or diesel car, (b) Hybrid electric car (including plug-in hybrid), (c) Fully electric car, and (d) Hydrogen fuel cell or other alternative-fuelled car (e.g. biofuel, biodiesel) are considered to have regular access to a car. Other possible responses include: (e) two-wheel options (scooter, moped, electric motorcycle) and (f) vehicle-sharing programmes and (g) carpooling systems. Respondents replying positively to any of the options (e)-(g) are not recorded as having regular access to car. Therefore, regular use of a car-sharing or car-pooling scheme by someone in the household does not imply "regular access to car" for that household. The survey cannot effectively distinguish ownership from lease, therefore "regular access to car" can be considered as a synonym for "ownership or lease".

access to at least one car.[8] The results are shown in in Table 2.2 and are displayed as differential effects, i.e. how much more or less likely a respondent with the characteristics shown in the table is to have regular access to a car, relative to the indicated benchmark.

Table 2.2. The effect of key determinants of access to a car

Variable		Differential Effect
Location *Benchmark: Urban area (Major city)*	Suburb	+4%
	Rural	+7%
	Remote area	+5.9%
Age of respondent [a] *Benchmark: Respondent is 18-24 years old*	25-34 years old	-2.9%
	35-44 years old	-4.6%
	45-54 years old	-3.3%
	Older than 54 years	-2.0%
Income *Benchmark: 1st income group*	2nd income group	+3.3%
	3rd income group	+7.5%
	4th income group	+10.3%
	5th income group	+12.2%
Number of adults *Benchmark: One adult in the household*	2 adults	+4.3%
	3 or more adults	+6.1%
Number of children *Benchmark: No children in the household*	1-2 children	+3.5%
	3 or more children	+5.8%
Inability to work [b] *Benchmark: Able to work*	Unable to work	-4.1%
Single Family House *Benchmark: Any type of dwelling other than single family house*	Single-family house	+8.3%

[8] The employed model can be summarised as follows. Respondent n of household h in country c derives utility $U_{n(hcr),1}$ if someone (including respondent n) in the household regularly uses a car (assuming that this car also gives access for respondent n to it):

$$U_{n(hcr),1} = \underbrace{\alpha + A_c + A_r + f(\boldsymbol{x}_{nh};\theta)}_{Q_{nhcr}(\boldsymbol{x}_{nh};A_c,A_r,\theta)} + \varepsilon_{nhc} = Q_{nhcr}(\boldsymbol{x}_{nh};A_c,A_r,\theta) + \varepsilon_{nhc}$$

where A_c and A_r are, respectively, country and region fixed effects, $\boldsymbol{x}_{nc}$ is a set of explanatory variables that vary at the individual level (e.g. education, environmental perceptions) and at the household level (e.g. income category, household composition, household location). Finally, ε_{nhc} is the unobserved utility of having regular access to a car, here assumed to follow an i.i.d. EV type I distribution across respondents, households, countries, and regions. If none in household h uses a car, respondent n has no regular access to any car and utility becomes: $U_{n(hcr),0} = \zeta_{nhc}$, where ζ is drawn from the same distribution as ε. This gives rise to a logit choice probability of having regular access to a car:

$$P_{nhcr,1} = e^{Q_{nhc}r}/(1 + e^{Q_{nhcr}}).$$

The probability of not having access to a car is: $P_{nhcr,0} = 1/(1 + e^{Q_{nhcr}})$. Parameters A_c, A_r and θ are estimated with maximum likelihood, by maximizing the likelihood function:

$$L(A_c, A_r, \theta) = \prod_n \left(P_{nhcr,1}{}^{y(n)} P_{nhcr,0}{}^{1-y(n)}\right) = \prod_n \left(\left(\frac{e^{Q_{nhcr}}}{1 + e^{Q_{nhcr}}}\right)^{y(n)} \left(\frac{1}{1 + e^{Q_{nhcr}}}\right)^{1-y(n)}\right)$$

Private open space *Benchmark: No access*	Access to a private open space	+4.9%
Country and regional fixed effects *Benchmark: Belgium (all regions)*	Canada	+3.1%
	France	+3.6%
	Israel	+3.6%
	The Netherlands	+2.2%
	Sweden	-8.3%
	Switzerland	+4.5%
	United Kingdom	-4.2%
	USA	+5.6%
	Regions (range of impacts from unobserved region-specific variables)	-11.3% to +14.4%
Attitudinal variables	Environmental motivation	-5.5%
	Support for transport policies	-3.5%
	Environmental concerns	-0.5%

Notes: [a] The effect of age on regular access to car declines before increasing again, possibly reflecting -among others- the effect of living with parents. A similar age pattern has been estimated in the analysis of the responses of the second round of the EPIC household survey (Ehreke, Jaeggi and Axhausen, 2014[17]); [b] Disability is proxied via the response: "unable to work, e.g. due to disability" to the survey question: "What is your current employment status? **Technical notes:** All marginal effects reported here are significant and refer to the *absolute change in the probability* of owning/leasing a car in percentage points. For example, a change in the probability of owning/leasing from x % to $(x + d)$ % (due to a change in some explanatory variable) will be reported here as a marginal effect of d %. Estimates are obtained using a logit model that contains regional fixed effects, whose impact on the probability of car ownership/lease. These effects are not reported for reasons of legibility (i.e. 67 regions tested, 14 regions included). A Likelihood Ratio test rejects the hypothesis that regional fixed effects are zero at every convenient level of significance (p-value: 1.655 e-10). Country fixed effects are jointly significant (Likelihood Ratio p-value: 2.2 e-16). Likelihood ratio tests fail to reject the null hypothesis that current economic concern has a statistically significant impact on car ownership or regular use (p-value 0.73). Age effects are jointly significant at 1% (Likelihood ratio p-value: 0.007); Income and locations effects are jointly significant at any conventional level of significance (Likelihood ratio p-value: 2.2 e-16 and 3.528e-15, respectively). Environmental satisfaction (Table 2.1) is statistically insignificant in all tested specifications. The estimated parameters generating the displayed marginal effects are statistically significant at 10% (p-values fall short of 0.10). The Likelihood Ratio tests reject the null hypothesis that effects regarding house type, open space and age are absent, as in Specification 2 (p-value is effectively zero). Additional details on specifications are provided in Section 4. A.1 of the Annex. **Robustness checks:** Excluding the index measuring support for transport policies does not alter the qualitative nature of the findings displayed in the table.

The impact of ***household size*** on the likelihood of having regular access to at least one car is substantial. A household with two adults is 4.3% more likely to have regular access to a car compared to a household with a single adult. This difference exceeds 6% for households with 3 adults and increases even further with the presence of children in the household. For example, the probability that a two-adult household with three or more children has access to at least one car exceeds that of a single-adult household with no children by more than 10%.[9]

In line with existing literature, the effect of ***income*** on car ownership is positive,[10] but this effect diminishes as income increases. For example, compared to households in the 1st income group, households that

[9] This figure is calculated by adding the differential impact of being in a household with two adults (4.3%) and that of having 3+ children (5.8%). Table 2.2 suggests that the combined effect is 10.1%.

[10] For instance, Dargay and Gately (1999[72]) assess the relationship between growth in per capita income and growth in vehicle stocks over the period 1960-1992 in 26 countries, including the largest OECD economies, China, India and Pakistan. They find that the income elasticity of car ownership is high (approximately 2.0) at low-income levels, and that it approaches zero as car ownership becomes more widespread. Chamon, Mauro and Okawa (2008[64]) suggest that the income elasticity of car ownership is low at very low income levels (i.e. because car remains a luxury good

belong to the 2nd income group are 3.3 % more likely to have regular access to a car. The respective difference between the 3rd and 4th income groups falls to 2.8%. However, income effects on regular car access do not fully disappear at higher income levels. A household in the 5th income group is still 1.9% more likely to have regular access to a car compared to a household in the 4th income group. These figures corroborate the relevant findings in the literature.[11] The qualitative pattern of income effects described here does not appear to vary significantly across countries.[12]

Residential location and ***type*** also influence the likelihood of regular access to a car. Location matters, as population density strongly correlates with several aspects of public transport services. The coverage, connectivity and reliability of public transport systems typically decline as population density falls. Lower population density implies longer distances between residences and stops, less frequent services and therefore longer waiting times. These disadvantages contribute to explaining higher car ownership rates observed outside urban areas (Newman and Kenworthy, 1991[18]; Mindali, Raveh and Salomon, 2004[19]; OECD, 2018[7]).[13]

Greater car dependence in low-density areas is also evidenced in the current analysis. Compared to households residing in urban areas, those located in the suburbs are 4% more likely have regular access to a car. This difference increases for households located in villages and small towns (jointly referred to as rural areas) (+7%), as well as in remote areas (+5.9%). Furthermore, a household residing in a single-family house is on average 8.3% more likely to own or lease a car, compared to households living in all other types of dwellings. The impact of having access to a shared or open space is 4.9%. Dwelling type and open space access are considered to indicate access to private parking,[14] which is not directly observed in the data.

Attitudinal variables also influence car ownership. ***Environmental motivation*** is statistically associated with reduced regular access to a car. This index variable, introduced in Table 2.1, ranges between 0 and 1 to reflect how environmentally aware a respondent is. Compared to a demotivated respondent scoring 0, a fully motivated respondent (i.e. someone scoring 1) is 5.5% less likely to report regular access to at least one private vehicle. Support for transport policies is negatively associated with regular access to a car. Respondents were asked to state their support for different transport policy measures, including stricter fuel efficiency standards, subsidies for low emissions cars, environmental labels for cars and the promotion of teleworking. Respondents that strongly agree with all of these policies are 3.5% less likely to live in a household that has regular access to at least one car, compared to those that strongly disagree with all of these policies.

before basic needs are fully covered), but also at high income levels where demand is saturated (i.e. because one or more cars are already owned). The result is a “sigmoid” relationship between income and car ownership, with the steepest positive effect of income on car ownership occurring at medium income levels.

[11] See for example Dargay (2001[70]), Dargay and Gately (1999[72]), and Dargay, Gately and Sommer (2007[120]).

[12] Relevant econometric tests (such as the likelihood ratio test) failed to reject the hypothesis that interactions between income and country dummy variables are statistically significant.

[13] Alternatively, frequent public transport services in areas of low population density will translate into lower occupancy rates in buses and trains. This implies reduced cost efficiency of the public transport system, as the subsidies required to maintain service frequency grow.

[14] Precedent for a similar assumption can be found in Giuliano and Dargay (2006[129]), who use dwelling type as a proxy for the availability of parking space.

The analysis also controls for the inability to work,[15] which is associated with a 4.1% decrease in the likelihood of having regular access to a car.[16]

The econometric model also controls for ***country*** and ***region fixed effects***. Country fixed effects indicate the impact of unobserved factors at the country level. They are strongly positive in countries such as the United States and Canada, where factors contributing to car dependence are more prevalent (e.g. greater urban sprawl). For instance, on-road effective carbon rates display substantial variation across OECD countries, primarily reflecting differences in motor fuel taxes (OECD, 2023[20]). Motor fuel taxes can affect the decision of a household to buy or lease a car insofar as they determine its user costs. In general, these taxes are known to be lower in North America than in Europe. The provision and reliability of public transport alternatives to driving are also more likely to be offered in several European countries.[17] Population density, mixed land use, and the quality of road infrastructure and public transport systems are relevant variables that display substantial spatial variation, often at the level of the urban zone or neighbourhood. In turn, the variation in these factors explains within-city variation in car ownership. To ensure the privacy of households' data, the highest level of spatial resolution available in the data is at a much more aggregate regional level (e.g. South-West in the United States). At this level of spatial resolution, there remain substantial cross-region differences in car ownership that cannot be attributed to the observed factors discussed above (e.g. income, household composition). This is indicated by the impact of regional fixed effects that show considerable variation, ranging from -11.3% to 14.4%.

The findings in this section should be interpreted with caution. As the results suggest, car ownership rates may increase due to the presence of characteristics that are prevalent in areas of low density. Some of the most prominent of these characteristics are the frequency, coverage, and overall quality of the public transport system, which tend to diminish outside urban cores. Here, these characteristics are captured only partially, i.e. by the location in which the household is located (urban, suburban, rural, remote). Therefore, the findings likely overstate the impact of location. Another important limitation in the analysis is that residence type and access to open space, which both serve as proxies for private parking, are not exogenously assigned to respondents. That is, it is likely that unobserved characteristics simultaneously determine both the locational choices and car ownership decisions taken by the household. The Annex presents robustness checks that were conducted to explore the implications of these limitations.

2.3. Choice of future vehicle type for prospective car buyers or renters

Another decision with environmental implications is the choice of engine and fuel type when purchasing a car. The survey asks respondents what fuel type they would be most interested in if they were to purchase or lease a car. The options included in the survey are a series of internal combustion engines (ICE) vehicles fuelled by gasoline, diesel, liquified natural or petroleum gas (LNG, LGP), compressed natural gas (CNG)

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[15] The presence of factors that could possibly impair driving is proxied by a variable recording inability to work. The survey poses the question: "*What is your current employment status?*", with responses including the possibility "*unable to work, e.g. due to disability*". The reported effects here refer to the differential impact of this response.

[16] This estimate may be composed of different, opposing effects. On the one hand, a person that is unable to work due to physical disability is much less likely to regularly use a car than someone that is not unable to work. On the other hand, this negative effect is partially offset by technological advancements that nowadays facilitate driving in the presence of more disabilities. Furthermore, the presence of a disabled person in the household can also increase the probability that another person in the household has regular access to a car, as this facilitates potential caretaking activities. Therefore, the effect of an individual disability on the propensity of a household to own or lease a car is much smaller than what it would likely be if car access were recorded at the individual level.

[17] The findings by Wu et al. (2021[104]) support this hypothesis by examining accessibility (by transport mode) in 117 cities from 16 countries. The study highlights the relatively poor transit and walking access of cities in the United States.

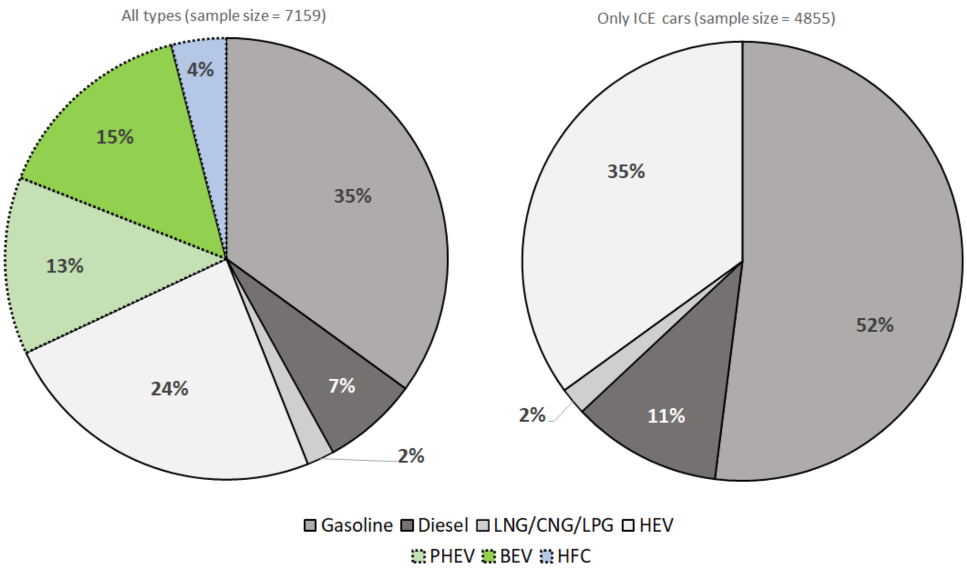
and hybrid electric vehicles (HEV). The survey also includes three lower-emissions alternatives: a battery electric vehicle (BEV), a plug-in hybrid (PHEV) and a fuel cell vehicle powered by hydrogen (HFCV).

This section examines the purchase intentions of those looking to buy an ICE vehicle, namely their choice between gasoline, diesel, LNG/CNG/LPG and HEV alternatives.[18] It uses a subsample of respondents that answered that they intend to purchase one of these types of vehicles in the near future (i.e. right panel of Figure 2.1). An analysis focusing on household choices between ICE cars and greener alternatives (BEV, PHEV) is provided in Section 3.

The choice between different types of ICE vehicles is relevant to environmental policymaking for several reasons. First, ICE vehicles still possess the largest part of the market share. Second, the fuels they consume have different environmental footprints, despite all being fossil-based. For instance, in the absence of carbon capture technologies, the combustion of a litre of gasoline generates approximately 2.3 kilograms of CO_2, while for diesel this number increases to 2.7 (kilograms of CO_2). Finally, fuel economy can vary widely across fossil-fuelled vehicles, where diesel cars are more efficient than gasoline cars, and hybrid vehicles are more efficient than both (Nakata, 2000[21]; Hu et al., 2012[22]).

Figure 2.1. Fuel type of reported purchase intentions

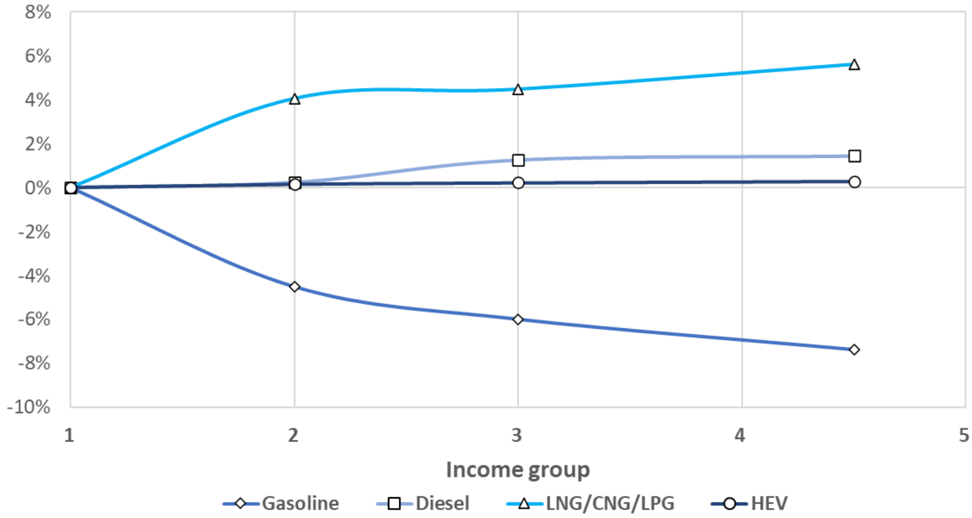
Left panel displays purchase intentions for all vehicle types. Right panel displays purchase intentions among those intending to purchase an ICE vehicle.



Note: The figure is based on the response to the question: "*If you were to purchase or lease a new/used car, which fuel type would you be most interested in?*". The question does not imply a time horizon for the hypothetical horizon (e.g. during the next 5 years). From 8695 respondents in the sample, both pies exclude 1496 respondents that do not know what their next vehicle fuel type is going to be, as well as 40 respondents that fail to state a fuel type that is included in the options. The left pie reflects the 7159 remaining observations. The dotted outer border line in the left panel indicates the subsample that is *not* retained in the analysis of this section. The excluded (from right pie) subsample contains 32% of the 7159 observations, i.e. 2304 respondents, who state that they would opt for a PHEV, a BEV or a HFC vehicle.

The analysis[19] highlights the important role of income in determining vehicle type purchase intentions (Figure 2.2). Compared to a household in the lowest income group (1st), a more affluent household, i.e. one that belongs to the higher two income groups (4th and 5th combined) is 5.6% more likely to select a car powered by natural gas (LNG/CNG/LPG). This impact is considerable in light of the small share that these cars possess in the sample of responses (2%). The probability of choosing other alternatives of higher purchase costs, such as diesel cars and HEVs, increases with income as well. In contrast, income decreases the probability that the respondent expects their next purchase or lease to be a gasoline car by up to 7.4%.

Figure 2.2. The impact of income on ICE vehicle purchase intentions



[19] The results are obtained using a multinomial logit model. Respondent n, who belongs in household h and is sampled in country c derives the following utility from vehicle type v:

$$U_{n(hc),v} = \underbrace{A_v + A_c + f(\boldsymbol{x}_{nh}; \boldsymbol{\theta})}_{Q_{nhcv}(\boldsymbol{x}_{nh}; A_c, A_v, \boldsymbol{\theta})} + \varepsilon_{nhc} = Q_{nhc}(\boldsymbol{x}_{nh}; A_c, A_v, \boldsymbol{\theta}) + \varepsilon_{nhcv}$$

where A_v is an alternative-specific constant, A_c is a country fixed effect, $\boldsymbol{x}_{nh}$ is a vector of explanatory variables that vary at the individual level (e.g. education, environmental perceptions) and at the household level (e.g. income category, household composition, household location). Finally, ε_{nhcv} is the unobserved utility from owning or leasing a vehicle of type v, here assumed to follow an i.i.d. EV type I distribution across vehicles, respondents, households and countries. The probability that the respondent states a preference for a vehicle v is then:

$$P_{n(hc)v} = \frac{e^{Q_{nhcv}(x_{nh}; A_c, A_v, \boldsymbol{\theta})}}{\sum_i \{e^{Q_{nhci}(x_{nh}; A_c, A_i, \boldsymbol{\theta})}\}}.$$

Parameters A_c, A_r and θ are estimated with maximum likelihood, by maximizing the likelihood function:

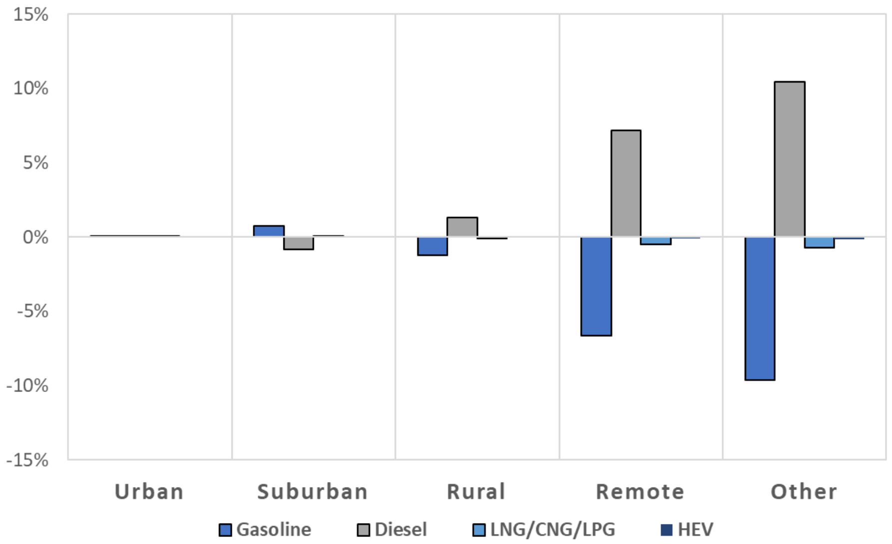
$$L(A_c, A_v, \theta) = \prod_n \left(\prod_i P_{n(hc)i}{}^{y(n,i)} \right)$$

where $y(n, i) = 1$ if respondent n chose vehicle type i, and zero otherwise.

Note: All marginal effects reported in this graph refer to the *absolute change in the probability* of selecting a specific type of ICE car, expressed in *percentage points*. For example, a change in the probability from x % to $x + \delta$ % (due to a change in income) will be reported here as a marginal effect of δ %. The 1st income group serves as a benchmark for the calculation of marginal effects.

The impact of the respondents' residential location, i.e. the ***locational effects***, displayed in Figure 2.3, appear to be particularly strong in remote areas. The main effects pertain to gasoline and diesel cars. While the probability choosing a gasoline car decreases as density falls, that of diesel cars increases. Location has a much smaller effect on the reported intentions to purchase other ICE vehicles. This effect could possibly be attributed to the long distances travelled by households in remote areas. This could lead these households to favour diesel cars, which have a higher purchase cost but lower running costs. Another factor that correlates strongly with the type of settlement is the possibility to use a diesel car without restrictions. That is, while diesel vehicles can be freely used in small towns and rural areas, their use in urban areas can sometimes be restricted (e.g. in Paris, Stockholm). The probability of choosing a diesel car among households in remote areas is 7.1% higher than among those in urban areas. This is mirrored by a lower likelihood of intention to purchase gasoline car (-6.6%) and natural gas cars (-0.5%).

Figure 2.3. Location effects on ICE vehicle purchase intentions



Note: All marginal effects reported in this graph refer to the absolute change in the probability of selecting a specific type of ICE car, expressed in *percentage points*. For example, a change in the probability from x % to $x + \delta$ % (due to a change in location) is reported here as a marginal effect of δ %. Location is recorded based on the question "*How would you best describe the area in which you live?*". Rural areas reflect the responses "*small town" or "village*". "*Other*" refers to areas of undefined density (0.7% of observations). Urban areas serve as a benchmark for the calculation of marginal effects.

Box 2.1. Examples of disincentives for conventional car use

Low-emissions zones in Europe (1996)

A low-emission zone (LEZ) restricts access to an area of high-emissions vehicles (ADEME et al., 2020[23]). Following Sweden's initiatives in 1996, several European countries have implemented similar measures. Italy and Germany amount the most LEZ in Europe (117 and 87 LEZ in 2020, respectively).

Electronic road pricing in Singapore (1998)

This car tracking system allows to charge road fees based on time travelled and congestion levels.[20] While this measure mostly attempts to reduce traffic congestion, it has positive environmental externalities. This measure has resulted in fewer cars on the road and an increase in carpooling and public transport.

"Vehicle Emissions and Energy Economy Label" in New Zealand (2022)

This updated labelling system provides information on performance, estimated costs as well as definition and information on carbon emissions and energy economy of a vehicle. In order to be understandable by consumers, the label design includes key boxes as well as a star-rating system for CO2 emissions and energy economy measures.[21]

The frequency with which respondents make long-distance trips (LDT) has an effect on the type of ICE car they intend to buy or lease in the future.[22] More frequent LDT activity is statistically associated with a stronger preference for diesel cars and a weaker preference for gasoline cars. The estimated effects are reported in Figure 2.4. Compared to a respondent reporting not making any long-distance trips ("no LDT") a respondent that reports making some long-distance trips ("some LDT") is 5.6% more likely to select a diesel car and 5.3% less likely to select a gasoline car. The gap grows (+6.9% for diesel, -6.4% for gasoline) in respondents declaring "Intense LDT", and becomes even larger (+7.4% for diesel, -7.1% for gasoline) for respondents whose frequency of LDT is observed only at its lower bound ("Right tail LDT"). These results enhance further the narrative that follows from Figure 2.3. Trip distances and more frequent long-

[20] More details at https://www.mot.gov.sg/what-we-do/motoring-road-network-and-infrastructure/Electronic-Road-Pricing

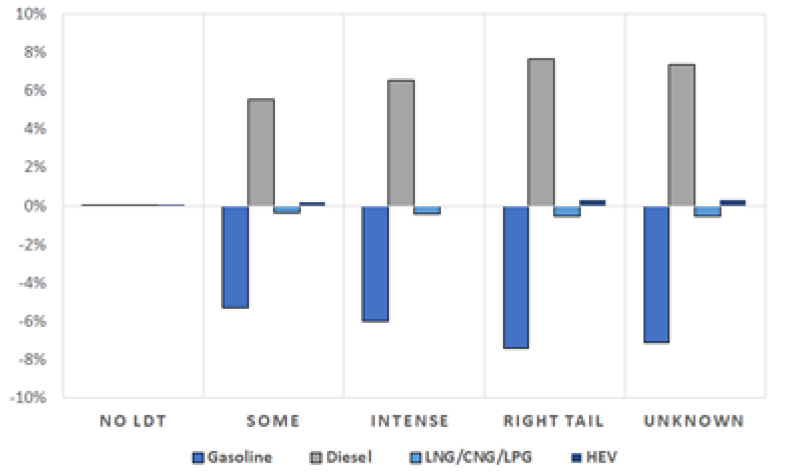
[21] More details at https://www.eeca.govt.nz/regulations/vehicle-emissions-and-energy-economy-labelling-programme/the-vehicle-fuel-economy-label-is-changing/

[22] The survey asked respondents to state the annual number of LDTs they make. These are defined as trips longer than 200 kilometres. They are recorded separately for each mode, with options including car, carpooling, ferry, bus, train and airplane, and by trip purpose (i.e. business and leisure). In each combination of purpose and mode (e.g. business trips by car), the survey recorded the annual number of trips. The factors that affect the demand for long distance trips and the choice of mode in them are examined in Section 2.5. Here, responses are grouped into five categories:

- Respondents who did not make any long-distance trips (labelled "*No LDT*");
- Respondents who make between 1 and 9 long-distance trips for business or leisure ("*Some LDT*");
- Respondents who make between 10 and 18 such trips ("*Intense LDT*");
- Respondents who state that they make more than 9 trips for business or leisure with at least one transport mode, so that only their minimum (but not the exact) number of LDTs is observable ("*Right tail LDT*");
- Respondents who could not recall their total number of trips in any purpose-mode combination, in which case the minimum number of LDTs is not possible to infer either.

distance travel matter for the shares of ICE vehicles, with trade-offs occurring almost exclusively between gasoline and diesel cars.

Figure 2.4. Impact of current long-distance travel (LDT)



Note: All marginal effects reported in this graph refer to the *absolute change in the probability* of selecting a specific type of ICE car, expressed in *percentage points*. For example, a change in the probability from x % to $(x+\delta)$% (here, due to a change in the reported frequency of LDT) will be reported here as a marginal effect of δ %. No LDT serves as a benchmark for the calculation of marginal effects.

Table 2.3 summarises the role of other variables in explaining the choice of vehicle fuel type. Older respondents appear to favour gasoline cars, which are the most traditional option. Those over 55 are 7.3% more likely to select gasoline cars compared to those between 18 and 25 years. Having obtained a higher ***education*** increases the likelihood of favouring the most technologically advanced option in the choice set, i.e. HEVs, although this impact is small (+0.5%). The size of the car that the respondents intend to purchase or lease, the type of car they currently own, and their ***concern*** regarding climate change and other environmental issues are all significant determinants, to different degrees, of the choice between different ICE vehicles.

Diesel cars tend to be more competitive when vehicle size is larger. To control for this effect, respondents were asked to state the vehicle body type they would be most interested in. Response options included: (1) small city cars and subcompact cars; (2) medium-sized cars; (3) large cars; (4) SUVs; (5) pick-up trucks; and (6) vans. The ordinal nature of this variable (i.e. a larger category number always corresponds to a larger vehicle) allows for an approximation of the car size with a single number ranging from 1 to 6. Table 2.3 reports the effect of “moving up” by one category on the probability to choose each of the fuel types considered in the study. The model predicts that each such increase in size category increases the likelihood of selecting a diesel vehicle by 2.4%. This implies, all else equal, that the probability of choosing a diesel car when the choice pertains to a pick-up truck (here, category 5) is 9.6% higher than the probability of choosing a diesel car when the choice pertains to a subcompact car (here, category 1). This increase is almost mirrored by a decrease in the propensity to choose a gasoline car.

The analysis also suggests the presence of ***inertia effects***.[23] Respondents from households with regular access to a gasoline or diesel car are 6.5% more likely to report that they intend to purchase one of these

[23] Inertia effects refer to the possibility that past and present experiences shape future choices. In the present model, the inertia effects correspond to the effect of current experience with fuel types on the propensity to opt for various fuel

two types of ICE vehicles, compared to respondents from households that do not have regular access to these cars. If a household has regular access to a hybrid or plug-in hybrid electric vehicle (HEV, PHEV), the probability of selecting a gasoline car falls by 10.6%. In contrast, the probability of stating that they intend to buy or lease a HEV increases by 1.8%.

Table 2.3. Determinants of vehicle type purchase intentions for prospective ICE buyers

	Fuel type	Outcome	Marginal effect
Vehicle size (Continuous variable)	Gasoline	**Effect of "increasing" car volume/size by one category**	-2.1%
	Diesel		+2.4%
	LNG/CNG/LPG		-0.2%
	HEV		-0.1%
Inertia effects	Gasoline or Diesel	**Effect of currently having regular access to a gasoline or diesel car**	+6.5%
	LNG/CNG/LPG		-6.2%
	HEV		-0.3%
	Gasoline	**Effect of currently having regular access to a HEV or PHEV**	-10.6%
	Diesel		+2.0%
	LNG/CNG/LPG		+6.8%
	HEV		+1.8%
	Gasoline	**Effect of currently having regular access to a BEV**	-7.0%
	Diesel		+5.4%
	LNG/CNG/LPG		+2.4%
	HEV		-0.8%
	Gasoline	**Effect of currently having regular access to a HFCV**	-5.0%
	Diesel		+1.1%
	LNG/CNG/LPG		+4.5%
	HEV		-0.6%
Environmental indexes	Gasoline	**Environmental awareness index** *Continuous index in the interval 0 to 1 (reported effects reflect the difference between 0 and 1)*	+18.0%
	Diesel		-22.3%
	LNG/CNG/LPG		+1.3%
	HEV		+3.0%
	Gasoline	**Environmental motivation index** *Continuous index ranging from 0 to 1 (reported effects reflect the difference between 0 and 1)*	-3.4%
	Diesel		-0.6%
	LNG/CNG/LPG		-0.2%
	HEV		+4.2%
Age effects (Baseline = Being under 55 years old)	Gasoline	**Effect of being over 55 years old**	+7.3%
	Diesel		-5.9%
	LNG/CNG/LPG		-1.8%
	HEV		+0.4%
Higher education (Baseline = No Bachelor's degree)	Gasoline	**Effect of higher education**	-0.4%
	Diesel		-0.1%
	LNG/CNG/LPG		0.0%
	HEV		+0.5%

Note: All marginal effects reported here refer to the *absolute change in the probability* of owning/leasing a car in percentage points. For example, a change in the probability of owning/leasing from x% to $(x + d)$% (due to a change in some explanatory variable) will be reported here as a marginal effect of d%.

type. Inertia effects have precedent in the empirical literature, as evidence suggests that they significantly impact the choice of fuel type (Erciş et al., 2012[109]; Jensen, Cherchi and Mabit, 2013[75]; Valeri and Cherchi, 2016[111]).

Assessments of the personal importance and relevance of environmental issues appear to play a prominent role as well. The survey records the degree to which respondents believe that climate change and other environmental issues are important and the extent to which they will affect their own life (e.g. their job security and health) or the lives of future generations (Table 2.1). Respondents who exhibit the highest and lowest degree of environmental concern differ widely in their stated choice of future ICE vehicle. Compared to those least concerned about climate change and other environmental issues[24], those most concerned are 22.3% less likely to opt for a diesel car and, instead, 18.0% more likely to opt for a gasoline car. Overall perceptions regarding the environment also play a significant, albeit less prominent role. Respondents who exhibit the highest and lowest degree of environmental motivation report systematically different choices. Compared to the least motivated, the most motivated respondents are 4.2% more likely to select a HEV and 3.2% less likely to select a gasoline car.

2.4. The choice of transport mode in commuting, leisure and childcare trips

Promoting more sustainable mobility patterns requires a careful analysis of mode choice in commuting and leisure trips, which are among the most frequent and resource-intensive activities that households regularly undertake. While commuting trips typically cover larger distances, trips made for purposes other than commuting tend to be more frequent. For example, in the United States and the United Kingdom commuting trips account for less than 20% of all trips. At the same time, in the United States, 45% of short-distance trips are made for shopping and errands and 27% for recreational purposes (Department of Transport and U.K., 2011[24]; Bureau of Transportation Statistics, 2017[25]). Examining the choice of transport mode for childcare trips is also policy relevant, since these trips may favour private vehicles more than others.[25] Policies should aim to incentivise low-impact and soft transport modes when feasible.

[24] An individual is said to be fully concerned about environmental issues when replying the issues enumerated in Table 2.1 are "very important".

[25] In fact, the literature reports a strong preference for car among households with children, mostly for convenience-related reasons (McCarthy et al., 2017[119]).

Box 2.2. Examples of incentives and regulations for low-impact and soft transport modes

Limited traffic areas in Paris (2024)

The city of Paris defines "limited traffic areas" where transit traffic, i.e. vehicles passing through the area without stopping, is prohibited. This measure aims at reducing pollution and noise in the city centre, and promoting public transportation and soft-mobility such as biking and walking. Paris follows the initiative of other European cities such as Madrid, Milan and Roma.[26]

Developed cycling infrastructure in the Netherlands

The Netherlands have developed a dense cycling network throughout the country over the years.[27] Such infrastructures mostly facilitate short distance trips (i.e. within 15 km). Since the early 2000s, the Dutch government has developed "cycle superhighways" that link cities together in order to facilitate cross-cities and medium- to long-distance trips. In 2023, 23% of all journeys in the Netherlands were made by bicycle.

Klimaticket to promote public transports in Austria (2021)

The Austrian government created a single ticket which allows for almost unlimited public transports use throughout the entire country. Ticket subscription fees are tailored for youth, seniors and families. A survey indicated that 85% of subscribers, most of whom hold a driving license, have replaced car trips by public transport trips.[28]

The car-free city of Pontevedra, Spain (1999)

The city has gradually transformed into a car-free city and favoured soft-mobility modes such as walking and cycling, promoting healthy habits and reducing pollution and car accidents. This transformation was driven by the removal of on-road and off-road parking space (i.e. underground and peripherical parking lots), and the reallocation of road space. The city has received many international prizes – such as the 2014 UN-Habitat award – and became a worldwide reference in terms of sustainable urbanism.

The EPIC survey records the dominant mode a respondent uses to commute, make leisure and childcare trips.[29] The survey allows for 6 options: walking, car, carpooling (driving or riding with at least one other person), public transport, bicycle, and motorcycle. Two additional options comprise an undefined mode (labelled "*Other*")[30] and absence of knowledge (labelled "*Don't know*"). The responses presented in Figure 2.5 reveal that car is the most prevalent mode used for all three trip purposes, with shares that are

[26] More details at https://www.paris.fr/pages/paris-cree-une-zone-apaisee-dans-le-centre-de-la-capitale-20426

[27] More details at https://www.government.nl/topics/bicycles/bicycle-policy-in-the-netherlands

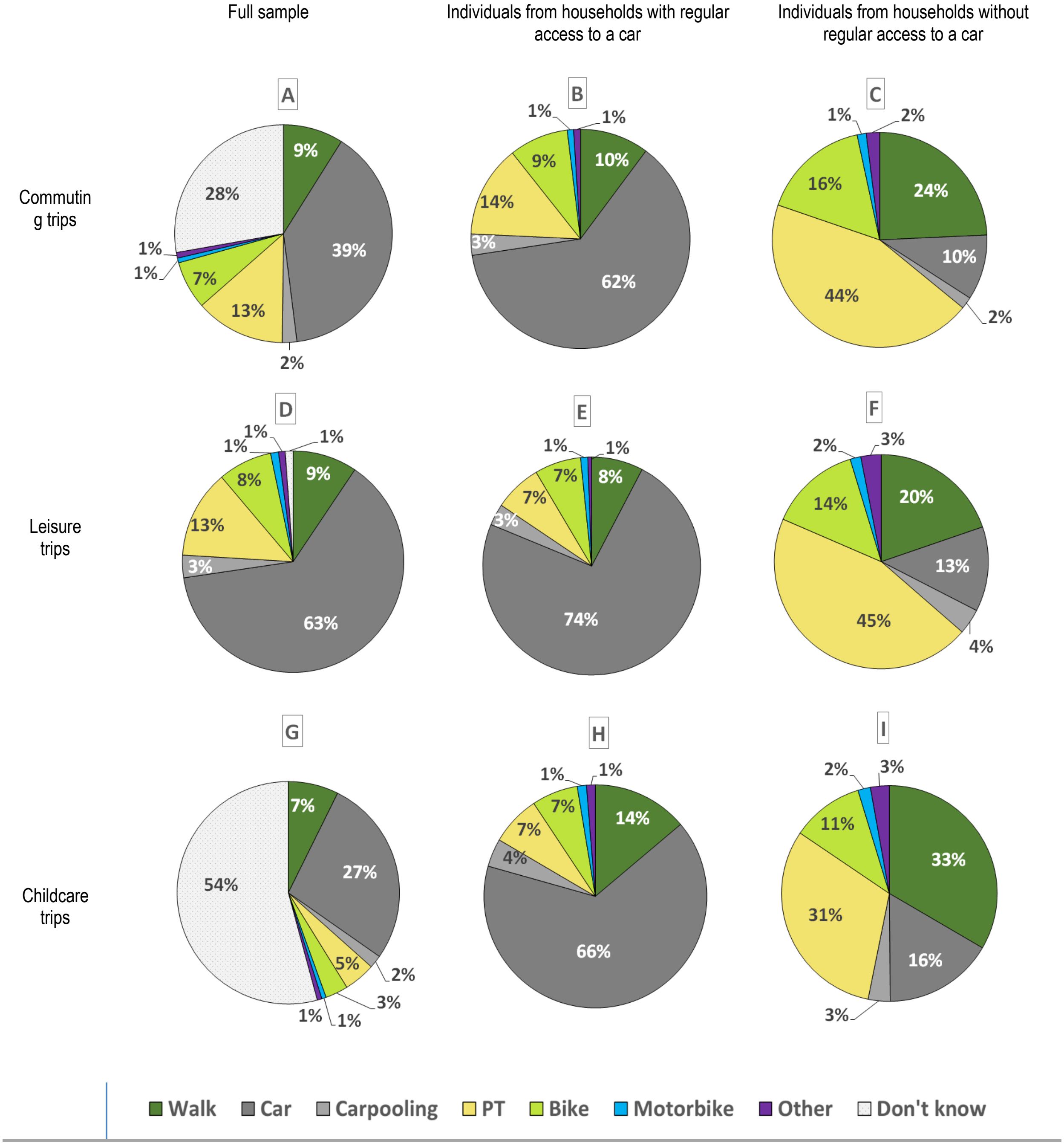
[28] More details at https://www.klimaticket.at.

[29] The analysis in this section is based on the survey question: "Thinking of your personal travel, how do you usually travel to each of the following activities? Please select your primary mode of transport." For each of three trip types, respondents were able to choose from among the six transport modes described above. Leisure trips are defined as "e.g. visiting family and friends, shopping, sports, cultural activities" and childcare trips are defined as "travel to drop off/pick up children at school, childcare or other child related travel, if trip does not include a place of work."

[30] Among others, the undefined mode "*Other*" may comprise taxi and any type of micro-mobility, including e-scooters, e-bikes, and e-skateboards. The survey does not consider *ridesharing services* and carpooling as literal synonyms, therefore the label "*Other*" may also comprise responses referring to the use of such services.

at least three times larger than public transport. The dominance of car is most pronounced for leisure trips.[31]

Figure 2.5. Choice of commuting mode in parts of the sample



[31] A possible explanation is that some leisure trips are likely to be taken for outdoor recreation, and therefore to destinations in more remote areas that are poorly covered by public transport.

Note: The pies show the relative frequency of responses to the question ""Thinking of your personal travel, how do you usually travel to each of the following activities? Please select your primary mode of transport." For each of three trip types, respondents were able to choose one of six transport modes. Panels in the left column represent the entire sample of 8695 respondents. Panels in the middle and the right columns represent, respectively, respondents from households with and without regular access to a car. Upper, middle and lower panels correspond to commuting, leisure and childcare trips. Sample sizes are as follows: Respondents from households with regular access to a car making commuting trips (Sample B): 5267; Respondents from households without regular access to car making commuting trips (Sample C): 947; Respondents from households with regular access to car making leisure trips (sample E): 7222; Respondents from households without regular access to car making leisure trips (sample F): 1297; Respondents from households with regular access to car making childcare trips (sample H): 3509; Respondents from households without regular access to car making leisure trips (sample I): 425.

Regular access to a car (discussed in Section 2.2), is the most important determinant of transport mode choice for short-distance commuting, leisure and childcare trips. In Figure 2.5, this is reflected in the striking differences in the share of transport modes observed between respondents from households *with* (middle column) and *without* (right column) regular access to a car. However, regular access to car cannot fully explain the choice of transport mode. Therefore, effect of the remaining determining factors needs to be isolated. This is possible by comparing the choices of respondents from households that have regular access to a car but differ with respect to other factors explored below.

To this end, the econometric analysis focuses on the mode choice of respondents with regular access to at least one car, in commuting (panel B), leisure (panel E) and childcare (panel H) trips.[32] The study associates these choices with the socioeconomic status of respondents, such as their attitudes and beliefs, as well as the income, location and composition of their household. Country fixed effects are included to capture the impact of unobserved factors on the choice of transport mode across countries.[33] Due to the wide differences in their purpose, as well as in the time and financial constraints associated with the three types of trips, the determinants of mode choice across trip types differ considerably.[34]

[32] A separate estimation is performed for each trip purpose. The utility that respondent n from household h in country c derives from choosing transport mode i is given as:

$$U_{n(hc)m} = \underbrace{A_m + A_c + f(\boldsymbol{x}_{nh}; \boldsymbol{\theta})}_{V_{n(hc)m}(\boldsymbol{x}_{nh}; A_m, A_c, \boldsymbol{\theta})} + \varepsilon_{n(hc)m}$$

where A_c is a country fixed effect, A_m is a mode-specific variable, $\boldsymbol{x}_{nh}$ is a set of explanatory variables that vary across respondents (e.g. age, education, attitudes) and households (e.g. income category, household composition, household location), but *not* across transport modes. Finally, $\varepsilon_{n(hc)m}$ is the unobserved portion of utility, here assumed to follow an extreme value type I distribution across respondents, households, countries and transport modes, giving rise to a multinomial logit choice probability that the respondent chooses mode m:

$$P_{n(hc)m} = \frac{e^{V_{n(hc)m}(\boldsymbol{x}_{nh}; A_m, A_c, \boldsymbol{\theta})}}{\sum_i \left(e^{V_{n(hc)i}(\boldsymbol{x}_{nh}; A_i, A_c, \boldsymbol{\theta})}\right)}$$

where the parameter vectors $\boldsymbol{A}$ and $\boldsymbol{\theta}$ are estimated via maximisation of the likelihood function:

$$L(\boldsymbol{A}, \boldsymbol{\theta}) = \prod_n \left(\prod_i P_{n(hc)i}{}^{y(n,i)} \right)$$

where $y(n, i) = 1$ if respondent n chose transport mode i, and zero otherwise.

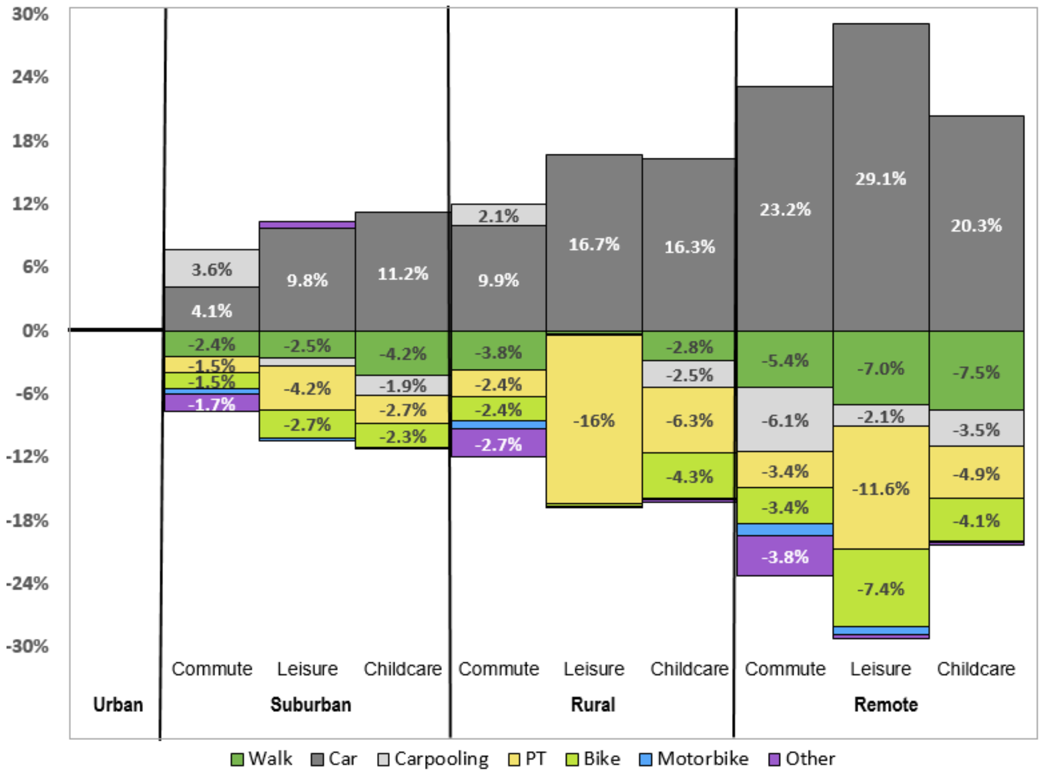
[33] More details can be found in Section 4. A.1 of the Annex.

[34] A differential effect is the change in the probability of choosing a transport mode triggered by a change in the status of an explanatory variable. For example, if being male increases (all else equal) the probability of using motorcycle by

Location effects are found to be particularly strong across all trip purposes.[35] Underlying factors that strongly correlate with population density, such as the quality of public transport services, affect the probability of using a car. This effect is evident from a comparison of descriptive statistics. For example, the probability that a resident of an urban area commutes by car is 46%, a figure that rises to 56% in suburban areas and to 71% in remote areas. At the same time, 23% of respondents in urban areas report that they use public transport for commuting, a figure that falls to 20% in suburban areas, 15% in rural areas and 9% in remote locations. However, locational effects cannot be exclusively attributed to the characteristics of the transport system. Suburban, rural and remote areas may also systematically attract households with different characteristics. For example, families with children are more likely to settle in suburban areas, where car travel is convenient. After controlling for such variables, the impact of location remains substantial but becomes weaker.

Figure 2.6. The impact of location on the choice of transport mode for various trip purposes

Change in the share of each transport mode, compared to urban areas



1% compared to a benchmark category (here, female), the study reports that reporting being male has a differential effect of +1% on the probability of using motorcycle for commuting. All differential effects in the study are expressed in absolute differences in probability (i.e. percentage points), rather than the percentage change in probability. In the context of the above example, the reported 1% differential effect would represent an (absolute) probability change from 2.5% (female) to 3.5% (male). Expressed in terms of percentage change in probability, the same change would correspond to a 40% increase in the likelihood.

[35] This is in line with literature. See, for example, Boarnet and Crane (2001[95]) and Buehler (2011[89]).

Note: The reported numbers display econometric estimates on the *changes* in the shares that walk, car, carpooling, public transport, bike, motorbike, and other transport modes possess, due to a change in the residential location of the commuter. *Changes* refer to switching from an urban location, here used as a reference, to a suburban area, a rural area and remote location. Changes are reported separately for each type of trip (commuting, leisure, childcare). Blocks above the 0% horizontal line designate shares gained by a transport mode, and vice versa. For instance, living in a rural area (see **Rural**) decreases the propensity to select public transport (see PT in yellow) in commuting trips (**see commute**) by 2.4%, compared the propensity of using PT when living in an urban area. The effects on the share of motorbike are displayed in light blue, and the labels are omitted from the graph for reasons of legibility.

Figure 2.6 displays the estimated effect of location on each of the transport modes considered in the study, per trip purpose. The benchmark case pertains to a respondent located in an urban area. With all other factors fixed, an identical respondent in a suburban, rural, and remote area is by 4%, 10% and 23% (respectively) more likely to use car for commuting. In suburban areas, the estimated model predicts that the increase in car use primarily replaces active modes of transport (walking and cycling). This is more pronounced in rural areas, as car travel appears to capture an additional share of active modes. However, the lower density also induces a significant shift from public use to car travel. These effects are amplified in remote areas. Residential location has a similar effect on the propensity to use a car for leisure and childcare trips. However, the increase in car use observed in rural areas is larger for childcare trips. Some differences in substitutional patterns are also evident across trip purposes. For leisure trips, car replaces public transport (i.e. in rural areas compared to urban areas) much more than it does for commuting trips. In all cases, the results show that moving outside urban areas increases the propensity to use a car by 4-29% across trip purposes, with larger changes observed the more remote an area is.

Income is another strong predictor of transport mode choice, with higher income levels associated with a higher propensity to use a car. Figure 2.7 displays the difference in the propensity to choose each transport mode between the 1st income group and all other income groups.[36] At low levels of income, an increase in income is associated with a considerable increase in car use across all trip purposes. Compared to the 1st income category, a seemingly identical individual from the 2nd and 3rd income category is 6 and 8 percentage points more likely to choose a car for commuting, respectively. The effects recorded in the 4th and 5th income category are of similar magnitude, implying that increasing income above the median favours the car use only moderately.[37] Income has also a positive effect on motorcycle use,[38] but this effect is detected in commuting trips only. Across the three trip purposes, income has the strongest impact on mode choice for childcare trips. In general, higher income is associated with less carpooling, use of public transport and active modes of travel. Across the three analyses, the income effect on the propensity to use these modes is negligible at income levels above the median. An exception is the use of bicycles for leisure trips, for which income has a strong positive effect.[39] Comparing two otherwise identical respondents

[36] Details on heterogenous income effects per country can be found in Section 4. A.1 of the Annex.

[37] These results should be interpreted with caution, as high-income households may be able to locate closer to work, and therefore face shorter commuting distances. As commuting distance is not observed in the study, and therefore is not a control variable in the statistical analysis, the income effects for active modes and public transport may be subject to an upward bias. This implies that with commuting distance kept fixed in the analysis, the net impact of an increase in income, e.g. from income level 3 to 4, on the propensity to walk could possibly be negative.

[38] The differential effects of income on motorcycle use reported in Figure 2.7 may appear small, but they become substantial if the share of motorcycle use in the sample of commuters -which is approximately 1%- is taken into consideration. A similar but more pronounced income effect is detected for the unspecified set of transport modes included in the category “Other”. This category could include micro-mobility (e.g. mini scooters), which possess an equally small share in the sample of commuters as motorcycles (1%). The results suggest that increasing income increases the likelihood of choosing such modes by up to 5%.

[39] This finding aligns with existing evidence from the literature suggesting that recreational cycling positively correlates with income. For instance, using data from the Canadian Community Health Survey, Firth et al. (2021[95]) show that

whose income is, respectively, in the 1st and 5th income group, the latter is by 4.5% more probable to make leisure trips by bike. A possible explanation is that higher income increases awareness regarding health issues and the benefits of physical activity, and that recreational bicycling can require some investment in equipment.[40]

The findings regarding income are in line with the literature, which reports a positive relationship between income and car use (Dargay and Hanly, 2002[26]; Dargay, 2007[27]). Public transport is sometimes seen as an inferior service due to the inconvenience it may imply in terms of time, comfort, and reliability, and households with more disposable income tend to prioritise these aspects over cost savings. Other considerations, such as sanitation (especially following the Covid-19 pandemic) or safety can also play a role in decisions to use public transport. For example, the survey results suggest that perceptions around the safety of public transport are a particular concern in the United States. There, over 40% of respondents in households with regular access to a car indicate that safer public transport would induce them to drive less.

The effect of income on mode choice for childcare-related trips is similar, but not identical to those for commuting and leisure. In these trips, income growth contributes to car dependency more than it does in commuting and leisure trips. It also decreases the propensity to choose all other modes, i.e. income growth exclusively favours car use for childcare-related trips, to the detriment of walking and public transport use. This implies that the positive effect of income on recreational cycling observed for leisure trips does not apply to childcare trips. This result likely reflects the practicalities of travelling with children, which can render car use significantly more convenient than other modes relative to travelling without children.

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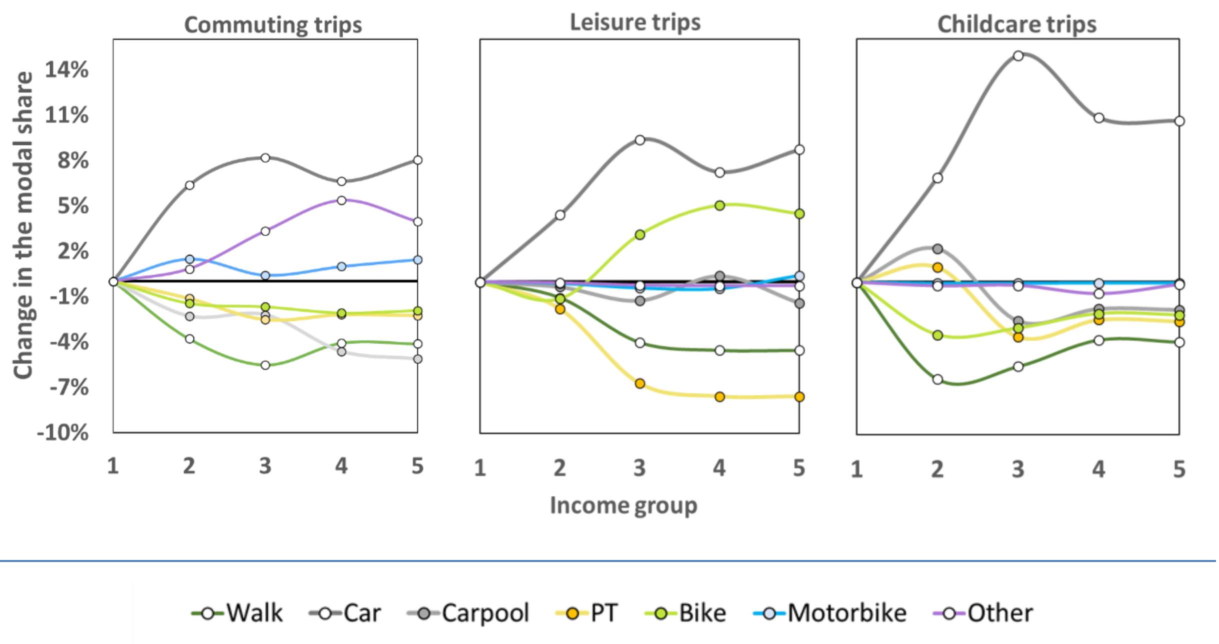
the share of people that bike for leisure purposes is 14.5% for the 1st income quintile and 26.3% for the 5th income quintile. However, the literature also suggests that this relation may not be monotonic. For example, Heesch, Giles-Corti and Turrell (2014[96]) find that the prevalence of recreational cycling increases from 13.5% in low-income levels to over 29% in medium-high income levels but subsides below 25% at annual income levels that exceed AUD 130 000.

[40] In this sense, biking possesses a critical advantage vis-à-vis walking, as it can support physical health while imposing fewer time constraints.

Figure 2.7. Impact of income on transport mode type across trip purposes



Note: Income group 1 serves as a reference. The displayed effects answer the question: "If the average respondent was moved from income group 1 (i.e. i = 1) to another income group i (where i = 2, 3, 4, 5), all else equal, how would their probability of choosing transport mode m (where m = walk, car, carpool, public transport, bike, motorbike, other mode) change?".

Table 2.4 summarises the impact of environmental motivation, environmental concern, and support for transport-related policies. The ***environmental motivation*** index, which ranges between 0 and 1, is statistically associated with higher use of public transport and lower use of all other modes for commuting trips.[41] Compared to a respondent scoring 0, a fully motivated respondent, i.e. someone scoring 1, is 11% more likely to commute by public transport, and less likely to choose any other mode, in particular car (-5%). However, results differ for leisure and childcare trips. Here, environmental motivation is associated with a significant increase in car use for leisure trips (+20%) and childcare trips (+27%). This could result in part from a rebound effect: making an effort to reduce car use for regular commuting trips may lead individuals to feel morally licensed to use a car for occasional leisure or childcare trips.[42] Another reason could be that an environmentally motivated individuals may be more likely to pursue outdoor activities in remote areas that are accessible primarily by car. Simultaneously, environmental motivation has a strong positive effect on the propensity to walk for childcare trips (+17%). ***Environmental concern*** has a minimal effect on transport mode choices across trip purposes.

Support for ***transport policies*** is significantly associated with transport mode choices, in particular for commuting trips. A commuter that fully agrees with all of the policy measures included in the index (see Table 2.1) is 15.9% more likely to cycle, 5.5% more likely to walk and 5% more likely to take public transport, compared to one that fully disagrees with these policies. The difference in the propensity to use a car between those who support transport policies and those who don't is 16.6%. Policy support has similar effects on transport mode choice, albeit of varying magnitudes, for leisure and childcare trips.

[41] Details regarding the construction of this index are provided in Table 2.1.

[42] For more on moral licensing, see for example Dütschke et al. (2018[136]) and Simbrunner and Schlegelmilch (2017[137]).

Table 2.4. Impact of environmental attitudes on the choice of transport mode

		Commuting trips	Leisure trips	Childcare trips
Support for Transport Policies (Index ranging from 0 to 1)	Walk	+5.5%	+0.7%	+0.6%
	Car	-16.6%	-3.8%	-3.3%
	Carpool	-5.0%	+1.1%	-0.3%
	PT	+5%	-0.3%	+1.5%
	Bike	+15.9%	+4.7%	+2.1%
	Motorbike	-1.7%	-0.6%	+0.2%
	Other	-3.2%	-1.8%	-0.7%
Environmental motivation (Index ranging from 0 to 1)	Walk	-1.6%	-2.8%	+17.1%
	Car	-4.8%	+20%	+27%
	Carpool	-1.4%	-6.5%	-15.9%
	PT	+11.1%	+5.7%	-19.4%
	Bike	-2%	-9.7%	-8.0%
	Motorbike	-0.4%	-5.2%	-1.0%
	Other	-0.9%	-1.5%	0.2%
Environmental concern (Index ranging from 0 to 1)	Walk		-0.2%	-1.0%
	Car		-0.5%	+1.1%
	Carpool		-0.6%	-0.3%
	PT		+1.2%	+0.5%
	Bike		+0.2%	0%
	Motorbike		- 0.1%	-0.1%
	Other		0%	-0.1%

Note: This table displays marginal effects of environment-related attitudinal variables on the choice of transport mode for commuting, leisure and childcare trips. All displayed numbers represent the difference in the choice probability of a transport mode due to a switch of the explanatory index variable from 0 to 1. Only variables with significant effects are displayed.

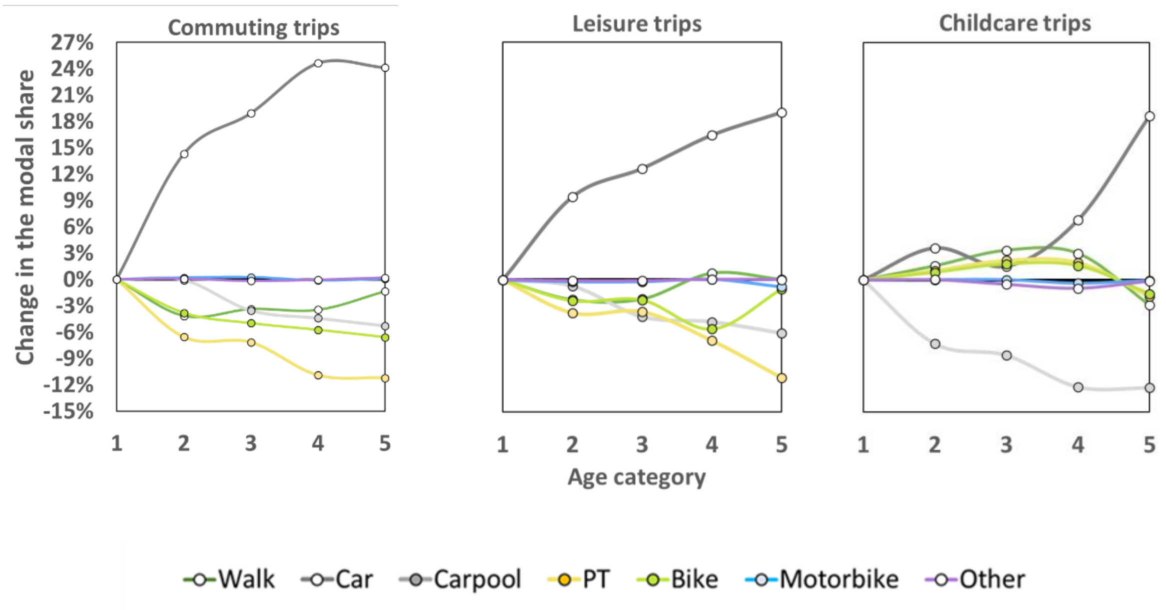
Table 2.5 reports effects of ***economic concerns***, which also impact the choice of commuting transport mode. Controlling for economic concerns is essential, as user costs can vary widely and economic concerns can be correlated with environmental concerns. Particularly notable is the switch away from car use to walking as economic concerns grow, which occurs especially for commuting and leisure trips. For commuting, the latter effect intensifies as concerns grow from low to high, with respondents expressing high economic concerns being 5% more likely to walk to work. For the same change in level of economic concerns, respondents are 1.2% less likely to use car.

Table 2.5. Impact of economic concerns on the choice of transport mode

	Displayed effect	Walk	Car	Carpool	PT	Bike	Motorbike	Other modes
Commuting trips	Switch from “low” to “moderate” economic concerns	+2.9%	-2.0%	-0.4%	+0.1%	-0.5%	0%	-0.1%
	Switch from “low” to “high” economic concerns	+5.0%	-1.2%	+1.0%	-0.7%	-4.7%	+0.3%	+0.2%
Leisure trips	Switch from “low” or “medium” to “high” economic concerns	+4.3%	-1.2%	+0.9%	+1.1%	-4.9%	0%	-0.2%
Childcare trips		-3.7%	-2.4%	+6.5%	-0.7%	-0.1%	+0.1%	+0.3%

Age has a positive effect on the probability that a respondent will use a car for all trip purposes (Figure 2.8). Compared to a respondent 18-24 years old, a respondent 35-44 years old is 14.3% more likely to use a car for commuting. This difference grows to 26.4% for those 45-54, after which it appears to stabilise among those over 55. The impact of age on the likelihood of biking, walking, carpooling, and especially public transport are also displayed in Figure 2.8. Being over 55 years old decreases the choice probability of commuting by public transport by 11.2%. For childcare trips, the switch from carpool to car is much stronger at ages above 55 years old. This could be attributed to the fact that respondents in this category are more likely to have undertaken these trips only because they own a car in the first place, taking into account income, living situation, and other variables that correlate with age and are factored in the analysis as separate controls.

Figure 2.8. Effect of age on the choice of transport mode for commuting trips



Note: Age category 1 serves as a reference. The displayed effects respond to the question: "If two seemingly identical (average) respondents belonged to age group $\mathbf{a}$ = 1 (i.e. 18-24 years) and age category $\mathbf{a}$ (where $\mathbf{a}$ = 2 (25-34 years), 3 (35-44 years), 4 (45-54 years), 5 (55+ years)), by how much would their probabilities of choosing transport mode $\boldsymbol{m}$ (where $\boldsymbol{m}$ = walk, car, carpool, public transport, bike, motorbike, other mode) would differ?"

Other controls included in the econometric analysis that also have statistically significant effects on commuting mode choice are displayed in Table 2.6. First, there are systematic differences in the way ***men*** and ***women*** choose their transport mode. Second, the ***number of children*** plays a statistically significant role for the mode choice of childcare trips, reducing the probability that these trips are made by car. Despite appearing counterintuitive, this effect could be explained by a negative correlation between the number of children and the distance between the points of interest (e.g. schools). Since the distance of these trips is not directly factored in the analysis, the results should be interpreted with caution.

Table 2.6. Marginal effects of socioeconomic variables

Variable	Value	Transport mode	Effects		
			Commuting trips	Leisure trips	Childcare trips
Sex (Benchmark: Female)	**Male**	Walk	-0.2%	-0.9%	-6.7%
		Car	-0.3%	-1.3%	+2.2%
		Carpool	-0.1%	-0.3%	+2.2%
		PT	-0.2%	-1.5%	+2.2%
		Bike	-0.3%	+3.4%	-0.5%
		Motorbike	+1.1%	+0.7%	+0.3%

		Other	0%	-0.1%	+0.3%
Number of adults in the household (Benchmark: Less than 3 adults)	**3 or 4 adults**	Walk		-1.2%	-3.5%
		Car		-1.7%	+5.4%
		Carpool		+2.0%	+2.3%
		PT		-2.0%	-2.3%
		Bike		+3.0%	-1.9%
		Motorbike		-0.1%	0%
		Other		-0.1%	-0.1%
	5 or more adults	Walk		+8.2%	
		Car		-7.5%	
		Carpool		+5.1%	
		PT		-15.7%	
		Bike		+8.8%	
		Motorbike		+0.8%	
		Other		+0.5%	
Number of children in the household (Benchmark: No children)	**1 or 2 children**	Walk	1.7%		+2.6%
		Car	2%		-1.5%
		Carpool	3.8%		-0.6%
		PT	-3.7%		-2%
		Bike	-3.4%		+1.4%
		Motorbike	0.6%		0%
		Other	-1%		+0.1%
	3 or more children	Walk	2.9%		+2.6%
		Car	-7.6%		-10.7%
		Carpool	10.8%		+3.8%
		PT	-3.6%		+1%
		Bike	-2.9%		+2.9%
		Motorbike	1.2%		+0.1%
		Other	-0.9%		+0.2%
Living with relatives (Benchmark: No)		Walk		-3.9%	-1.4%
		Car		-5.4%	-3.2%
		Carpool		-1.2%	-0.7%
		PT		+15.1%	6.1%
		Bike		-4.1%	-0.8%
		Motorbike		+0.4%	0.1%
		Other		-0.2%	-0.1%
Living alone (Benchmark: No)		Walk	3.2%		
		Car	6.0%		
		Carpool	0.3%		
		PT	-2.8%		
		Bike	-5.4%		
		Motorbike	1.6%		
		Other	-1.5%		
Student (Benchmark: No)		Walk		-2.6%	
		Car		-3.6%	
		Carpool		-0.8%	
		PT		+10.1%	
		Bike		-2.8%	
		Motorbike		+0.3%	
		Other		-0.1%	

Note: This table displays marginal effects of various variables related to household situation on the choice of transport mode for commuting, leisure and childcare trips. Only variables with significant effects are displayed.

2.5. Leisure-related long-distance trips

Travelling long distances for leisure poses an environmental challenge despite the economic, social and cultural benefits it provides. Compared to short-distance trips, long-distance travel can entail other modes of transport, including rail, boat and plane. Moreover, while long-distance trips comprise a smaller share of total trips compared to short-distance trips, the frequency with which households make these trips for leisure has increased over time. For example, air traffic has increased by 5% per year since the 1990s and is expected to continue to grow (ITF, 2021[28]), and younger generations travel abroad more frequently than older generations (Frändberg and Vilhelmson, 2011[29]; UNWTO and WYSE Travel Confederation, 2011[30]). Policies should address this by incentivising fewer long-distance trips by high-polluting modes.

Box 2.3. Examples of incentives to use low-impact transport modes for long-distance trips

Ban of short-distance flights in France (2023)

Domestic short-distance flights are eliminated if a rail alternative of less than 2 hours and 30 minutes exists. This rail alternative has to be direct, available several times a day and should connect the same departure location and destination as the flight (Service Public, 2023[31]).

Increasing high-speed railway network through the "Hour model", Denmark (2008)

This initiative aims to reduce travel time between the four main cities of Denmark to one hour in order to promote a shift to rail travel for long-distance trips. This measure has contributed to the development of a high-speed railway network. The first new high-speed line with a one hour travel time opened in 2019 (ITF, 2023[32]).

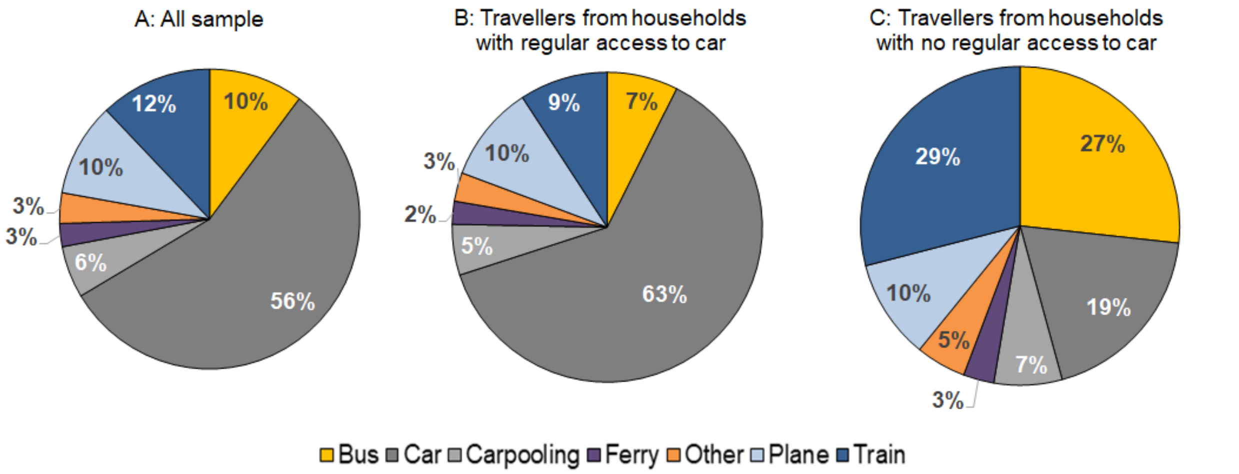
The EPIC survey records information on long-distance travel for leisure. It asks respondents to indicate the number of trips they usually make in a typical year by the following modes: bus, car, carpooling, plane, rail, ferry, and other modes. For each mode, respondents can indicate one of the following ranges: No trips, 1-3 trips, 4-6 trips, 7-9 trips, and over 9 trips. Because the upper range is open-ended, the analysis computed the *minimum* number of trips made by respondents per mode, i.e. the lowest value of each range.[43]

This section analyses dominant mode choice of respondents for long-distance trips.[44] Figure 2.9 displays the distribution of dominant mode across several sub-samples of respondents. Panel A shows that car is the dominant mode choice overall (56%), followed by train (12%), bus (10%) and plane (10%). This pattern is particularly observed among households that report having regular access to a car (Panel B), while those reporting no regular access to a car (Panel C) opt most often for public transport such as bus (27%) and train (29%). Plane travel varies little across the sub-samples and does not appear to be correlated with regular access to a car. It is possible that plane travel may be perceived as a complementary mode to a car, as it can cover much longer distances.

[43] Each respondent and mode combination is attributed a value among 0, 1, 4, 7 and 10, depending on the reported range.

[44] Dominant mode refers to the transport mode that is most often used for long-distance travel. For further results on the frequency of long-distance trips per mode, please refer to section A.1. of the Annex.

Figure 2.9. Dominant transport modes for long-distance leisure travel among subsamples



Note: This panel of pie charts displays the distribution of dominant modes across various sub-samples. Sub-samples are defined based on respondents' answers to the question: "Do you or does anyone in your household regularly use any of the following?" Response options included bus, car, carpooling, ferry, plan, train and other. Panel A reflects the whole sample. Panel B reflects households with regular access to car. Panel C reflects households with no regular access to car.

Figure 2.10 displays the transport modes used for long-distance leisure trips in Canada and Sweden, which exhibit the largest differences in mode distribution. Overall, respondents from Sweden are less reliant on cars (45%), and report more frequent use of trains (15%), buses (13%) and carpooling (9%) for long distance leisure-related trips compared to respondents from Canada. Respondents from Sweden also report that they fly less often (9%) compared to respondents from Canada (15%). Although Canada and Sweden have similar landscapes, their sizes differ as does the transport infrastructure available.

Besides structural barriers, some socio-demographic characteristics and attitudes appear to be strong determinants of the choice of transport mode for long-distance leisure trips. In this section, a multinomial logit regression is used to model the mode choice for long-distance leisure trips.[45] The sample is restricted to respondents from households that have regular access to a car (see discussion in Section 2.4). The model controls for age, sex, level of education, employment, income, household size, household situation and residential location. It also controls for whether the respondent is environmentally motivated. Finally, the model includes country and regional fixed effects.

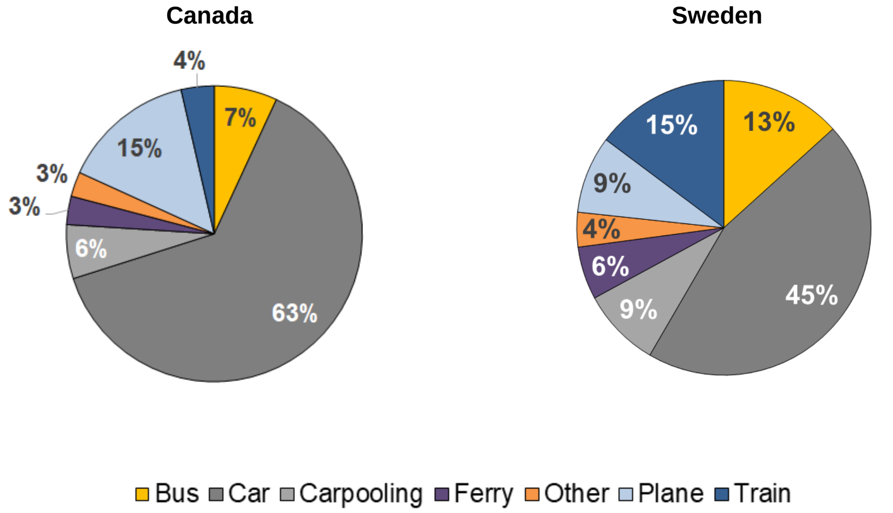
[45] The employed model uses a random utility that respondent n in country c derives from choosing dominant transport mode i:

$$U_{nci} = \underbrace{A_c + f(\boldsymbol{x}_n)}_{V_{nci}} + \varepsilon_{nci}$$

where A_c is a country fixed effect, $\boldsymbol{x}_{nc}$ is a set of explanatory variables that vary across countries and respondents (e.g. income category, household composition, household location). Finally, ε_{nci} is the unobserved portion of utility, here assumed to follow an extreme value type I distribution across respondents and transport modes, giving rise to a multinomial logit choice probability of choosing mode i:

$$P_{nci} = e^{V_{nci}} \Big/ \sum_j (e^{V_{ncj}})$$

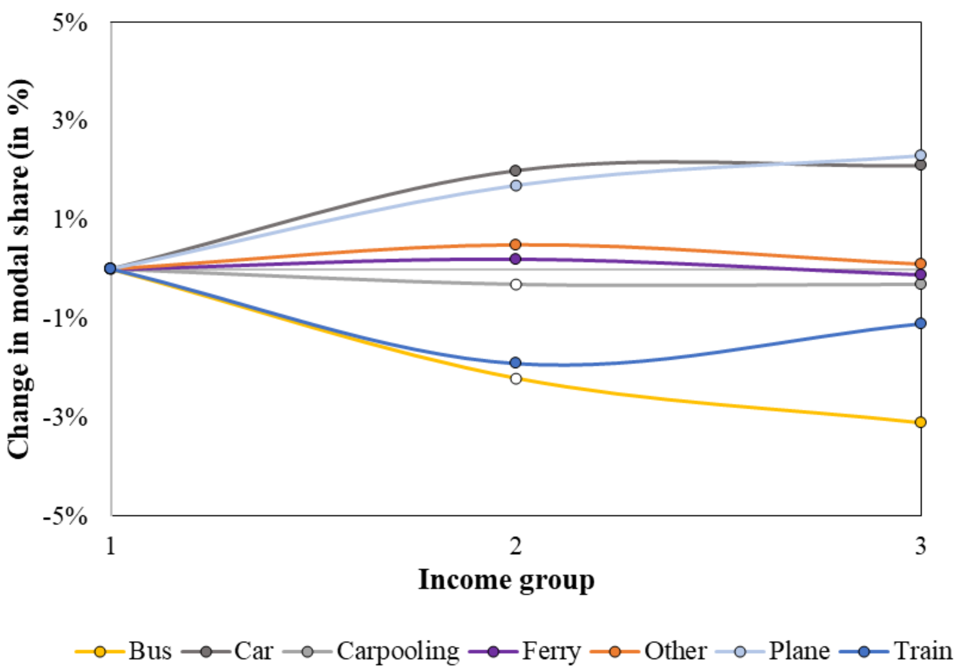
Figure 2.10. Dominant modes in parts of the sample in Canada and Sweden



Note: This figure displays the shares of dominant modes for Canada and Sweden. Households that report having regular access to car and those that don't are both included in the sample.

Conditional on having regular access to a car, ***income*** has a positive effect on the propensity to fly and drive a private car, and a negative effect on the propensity to carpool or taking the bus for long distance leisure trips (Figure 2.11). This is aligned with the literature, as numerous studies have observed that high income households tend to favour private transport modes or flying (Mallett, 2001[33]; Georggi and Pendyala, 2001[34]; Limtanakool, Dijst and Schwanen, 2006[35]; Dargay and Clark, 2012[36]; Reichert and Holz-Rau, 2015[37]). Income also negatively affects the propensity to travel long distances by train or bus.

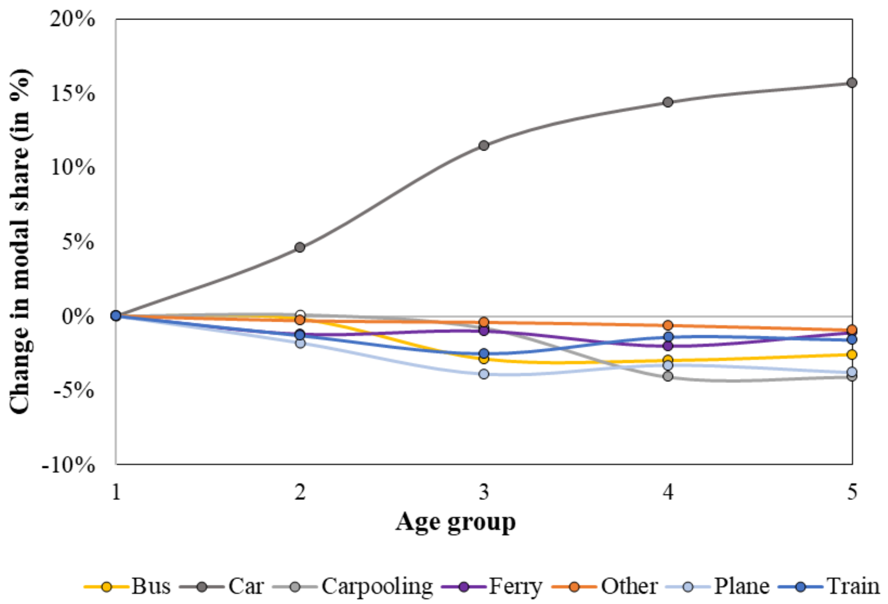
Figure 2.11. The impact of income on transport mode choice for leisure-related long-distance trips



Note: In the survey, income groups range from lowest-income households (1) to highest-income households (5). Income group "1" serves as the benchmark. Income groups are comparable across surveyed countries. In the present model, income groups 1-3 are grouped together as they do not significantly differ from each other. Income group "1" mentioned in this figure therefore refers to income groups 1-3 in the survey. Filled dots indicate that the marginal effect is significant at least at the 10% level. White dots indicate that the marginal effect is not significant at the 10% level.

Age increases the propensity to use a car for long-distance leisure trips (Figure 2.12). It also decreases the probability of using all other travel modes. This is generally supported in the literature; although some work has found that age increases the likelihood of travelling by bus for long-distance trips (Georggi and Pendyala, 2001[34]; Dargay and Clark, 2012[36]), other studies identify a preference for cars (Schwanen, Dijst and Dieleman, 2001[38]). The elderly are more likely to have physical constraints and to be more sensitive to comfort, which would favour the use of a private vehicle over public transport. A stronger preference for car travel may also arise from habits and past experience: older generations have travelled locally and closer to home in their youth more than recent generations, and may find car travel more convenient for doing so (Frändberg and Vilhelmson, 2011[29]). Habits have indeed been shown to be a key determinant of mode choice (Verplanken and Knippenberg, 1996[39]). The impact of additional factors are presented in Table 2.7.

Figure 2.12. The impact of age on transport mode choice for leisure-related long-distance trips



Note: Age category 1 serves as a reference. Age categories are: 18-24 years (1), 25-34 years (2), 35-44 years (3), 45-54 years (4), 55+ years (5).

Table 2.7. Impact of socioeconomic and attitudinal factors on transport mode choice for leisure-related long-distance trips

Variable	Value	Bus	Car	Carpooling	Ferry	Other	Plane	Rail
Environmental motivation	//	-1.3%	-1.1%	+0.1%	+1.1%	-1.3%	-0.1%	+2.6%
Education (Benchmark: No higher education)	Higher education	-0.6%	-4.7%	-0.4%	+0.3%	+0.2%	+2.4%	+1.9%
Household situation (Benchmark: Living alone)	Couple with children	-0.3%	+5.5%	-3%	+0.9%	-0%	-0.6%	-2.5%
	Couple without children	-2.9%	+6.9%	-2.8%	+0.3%	-0.4%	+2.1%	-3.3%
	Single parent	-0.6%	+6.9%	-3.8%	+0%	-0.2%	-0.3%	-2%
Household size	//	+0.6%	-2.7%	+0.7%	+0.5%	+0.3%	+0.5%	+0.1%
Location (Benchmark: Rural)	Urban	+2.8%	-8.3%	+1.1%	+1.2%	-0.2%	+2.5%	+0.8%
Sex (Benchmark: Woman)	Man	+0%	-4.4%	-0.2%	+0.8%	+0.7%	+1.4%	+1.7%
Student	Yes	+3.2%	-1.3%	-0.15%	-2.5%	-0.7%	+1.3%	1.5%
Young children in the household	Yes	-2.6%	+8.3%	-0.4%	-1%	-0.9%	-3.1%	-0.2%

Note: "Rural" refers to small towns/villages as well as remote areas. "Urban" refers to urban and suburban areas. Household size and environmental motivation are continuous variables, while the other variables are categorical variables.

Higher ***education*** increases the likelihood of travelling by plane (+2.4%) and by rail (+1.9%), but decreases the likelihood of travelling by car (-4.7%). One explanation is that being educated increases the number and the spatial distribution of an individual's social network (Ohnmacht, Maksim and Bergman, 2016[40]), making long-distance trips more numerous and potentially longer (Reichert and Holz-Rau, 2015[37]).

Mode choice varies little across ***employment*** status. There is no observed difference in mode choice between those who are employed, unemployed and retirees, conditional on being a car user. In comparison, students travel significantly more by bus (+3.2%) and rail (+1.5%) but less by car (-1.3%). A higher preference among students for bus travel may be related to cost: while household income is controlled for, information on individual-level income is not available in the survey. Household income may not be distributed evenly among household members, especially for commuting purposes.

Sex appears to significantly impact the choice of transport mode for long-distance leisure trips. Men are less likely to opt for travelling by car than women. This finding most probably arises from the model being restricted to car users, which evicts the sex gap in driving license effect.[46]

Household composition also impacts mode choice in various ways. Living with children, whether as a couple or as a single parent, increases the propensity to opt for car but decreases the propensity to carpool. Living as a couple with children decreases the propensity to travel by rail. These tendencies are particularly evident among households with young children. Overall, living with a relative increases the likelihood of traveling by car compared to living alone. This is likely due in part to the fact that the costs of car travel can be shared (Reichert and Holz-Rau, 2015[37]). A larger household size is associated with a lower likelihood of travelling by car and a slightly higher likelihood of traveling by more economical modes, i.e. bus and carpooling.

Compared to living in a ***rural*** environment, living in an ***urban*** area decreases the likelihood of travelling long-distance trips by car (-7.4%) compared to other transport modes. Living in an urban area provides a wider set of alternatives due to the closer proximity to transport infrastructures such as airports and train stations. Therefore, what appears to be an "urban" effect can also be interpreted as a mode availability

46 For example, in Great Britain in February 2023, 76% of men have a driving license, while only 64% of women have one (Data Europa, 2021[138]).

effect. The latter effect appears to be significant for bus (+3.3%), plane (+1.8%) and ferry (+1.1%), but insignificant for rail. The insignificant impact for rail may result from large train station networks covering both large cities and small towns, as well as the model restriction on households with regular access to a car.

Those who are ***environmentally motivated*** are slightly less likely to travel by car (-1.1%), more likely to opt for trains (+2.9%) and equally likely to opt for planes compared to those who are not. Environmental concern creates a significant – though moderate – shift among modes that are substitutable, i.e. car and rail, in favour of the least polluting option. However, it does not affect the propensity to travel by plane, which may be considered a complement to ground transport rather than a substitute. This would imply that environmental concerns impact relatively low-cost choices, i.e. shift between easily substitutable modes, but not necessarily the distance travelled or the destination. Diekmann and Preisendörfer (2003[41]) define the *low-cost hypothesis*, according to which the effect of environmental concerns on environmental-related behaviour decreases with behavioural cost. Cognitive dissonance has also been highlighted in the literature in explaining the gap between beliefs, statements and environmentally relevant behaviours (Gifford, 2011[42]; Bosone, Chevrier and Zenasni, 2022[43]).

3. Willingness to pay for electric vehicle attributes

3.1. Presentation of experiment

Understanding consumer motivations and choices in more detail is important for the formulation of policy that yields results. To support such analyses, the transport section of the EPIC survey includes a discrete choice experiment (DCE) that explores preferences for low emission vehicles. In response to the urgent need and high policy priority to decarbonise the transport sector, numerous studies explore how a transition to electromobility can be accelerated. As that transition requires a boost in the market share of electric vehicles, many of these studies use DCEs to shed light on what induces consumers to choose an electric vehicle and how much they are willing to pay for improvements in various vehicle attributes. An overview of recent research using DCEs is provided in Table A.2.1 in the Annex. The experiment in the EPIC survey, however, provides unique insights given the experimental design and the uniform format across the nine survey countries.

In the experiment, respondents are asked to imagine that they will buy or lease a new car, defined by a bundle of characteristics, here referred to as *attributes*. Attributes include the drivetrain type, purchase price, running cost, driving range, refuelling and charging time, as well as the availability of home charging. Every combination of attributes constitutes an *alternative*. The DCE presents to respondents 6 choice situations (games), and in each of them respondents are asked to choose between 3 alternatives, to which the report refers collectively as the *choice set*.

An example of such a choice set is displayed in Table 3.1. The experiment is organised as follows. The attributes are combined to create 24 distinct choice sets, each giving rise to a different choice situation involving an ICE car, a PHEV and a BEV (hereafter, a *game*). In turn, the choice sets are grouped into 4 blocks, with each of them containing 6 games. Each respondent is randomly assigned one of the blocks. While respondents may receive the same block of games, the nominal values on the purchase and running costs may differ, since these values reflect previous answers respondents have provided on the purchase price range of the vehicles they are interested in. The values for the running costs depend on the country respondents come from. Further details on the construction of the DCE is provided in the Annex. The model is estimated with the standard logit model. The model specification and estimation are outlined in the Annex.

Box 3.1. Using discrete choice experiments to better understand decision-making

In discrete choice experiments (DCEs), subjects are asked to make hypothetical choices by selecting a preferred alternative from a menu of options (Bateman and et. al, 2002[44]; OECD, 2018[45]). Stated preference data generated by DCEs enable an estimation of how much respondents value the various characteristics (attributes) of the options presented. Some attributes, such as purchase price and user costs, can be directly affected by policy (e.g. a tax or a subsidy), while others are exclusively determined by the current state of technology (e.g. battery autonomy, recharging time).

Stated preference approaches offer significant advantages over revealed preference approaches when it comes to policy evaluation (OECD, 2018[45]). One of the greatest advantages of a DCE is that it can incorporate ex-ante scenarios that exceed the limits of current technological possibilities and the actual policy framework. Therefore, they allow to explore consumer responses in fully hypothetical contexts.

Discrete choice experiments also generate data that provide a richer picture of preferences than simpler stated preference elicitation methods. The data generated by choice experiments allow for an estimation of how much respondents value the characteristics of the options being considered, also known as willingness-to-pay. Examples include travel time, travel cost, and comfort for transport mode options. The data can also provide insights into how respondents make trade-offs between these characteristics and how sensitive their choices are to changes in the characteristics of the options presented. The EPIC Survey data allow for disaggregation at the household level to understand how these values and sensitivities vary across the population according to location or socioeconomic variables such as age, income and gender.

Table 3.1. Example of a choice set in the discrete choice experiment

Alternative	1	2	3
Attribute			
Drivetrain (vehicle engine and fuel type)	Battery electric	Plug – in hybrid	Gasoline$^{(a)}$
Monthly ownership cost	$M_1^{(b,d)}$	$M_2^{(b,d)}$	$M_3^{(b,d)}$
Running cost	C_1 per 100 km$^{(b,c,d,e)}$	C_2 per 100 km$^{(b,c,d,e)}$	C_3 per 100 km$^{(b,c,d)}$
Driving range	R_1 km$^{(e)}$	R_2 km$^{(e)}$	R_3 km$^{(e)}$
Highway recharging/refueling time	T_1 = 20 minutes to 80% charge	T_2 = 5 minutes (refuel)	T_3 = 5 minutes (refuel)
Can be charged at home	Yes/No	Yes/No	No$^{(a)}$

Notes: (a) Respondent specific; (b) Country specific; (c) Expressed in local currency units; (d) Expressed in miles for the US; (e) Provided in levels. The upfront purchase cost is converted to monthly cost by assuming a payment period of 5 years (i.e. 60 months). The choice set is unlabelled: the labels used (i.e. vehicle 1, 2, 3) provide no distinguishing information about the vehicles and so are not considered as attributes.
Source: Table generated by the authors for illustrative purposes.

3.2. Findings

Perceptions over environmental issues explain many of the findings emerging from the choice experiment. Table 2.1 presented three index variables designed to measure these perceptions: (a) satisfaction with environmental quality, (b) environmental motivation, (c) environmental concern. Respondents reporting maximum levels of satisfaction with the ***environmental quality*** of their local environment, in particular with outdoor air quality and level of noise, are 8.6% more likely to select the ICE alternative in the choice experiment, compared to respondents reporting minimum levels of satisfaction. At the same time, they are 5.5% and 3.1% less likely to opt for the BEV and PHEV alternatives, respectively. ***Environmental motivation*** has also a positive impact on the probability of choosing a BEV. Maximum levels of awareness are associated with a 4.8% additional probability to select a BEV, mirrored by a decrease in the probability of choosing an ICE alternative (-4.8%). Finally, the impact of ***environmental concern*** on the propensity to choose a BEV in the DCE is positive but small (+1.2%). In total, the estimates associated with the three environmentally relevant indexes indicate that environmental perceptions are a substantial driver of the choices made in the DCEs. A respondent that is *not* environmentally satisfied and displays the maximum level of concern for all environmental issues (Table 2.1) is almost 15% more likely to opt for the BEV alternative. The corresponding figure for the PHEV alternative, considered less "green" than its BEV counterpart, is still positive but substantially smaller (3.7%). To the extent that these estimates represent causal relationships, the results imply that cultivating environmental motivation could possibly boost the actual market share of BEVs.

Support for transport policies is statistically associated with a higher probability to reject the option of a conventional car. Respondents who fully support transport policies are 16.5% less likely to opt for an ICE alternative, compared to respondents that do not support these policies at all. This is accompanied by 10.5% and 6% increases in the probability to opt for BEVs and PHEVs, respectively.

The ***purchase cost*** of a BEV affects its choice probability in the DCE, indicating the role that purchase subsidies and battery costs may play in determining the actual[47] market shares of BEVs. A monthly subsidy of USD 1.00 increases the probability to choose BEV by 0.017-0.030%, depending on the income group. Therefore, a typical purchase subsidy[48] of USD 7000, which with a 60-month repayment period corresponds to a monthly subsidy of approximately USD 117, raises the share of BEVs by 2.0-3.5%.[49] This impact is non-negligible,[50] but the results indicate that subsidies may not be the main driver behind the booming growth of BEV sales observed in recent years.[51] The findings also have implications for the

[47] *Actual* BEV market share refers to the share of car sales that corresponds to BEVs in reality, i.e. outside the choice experiment.

[48] See Harvey (2020[101]) for estimates of BEV and PHEV purchase subsidies in various countries.

[49] The number is obtained by multiplying the estimate for the differential effect of purchase cost, β with the price change, Δp. For example, with an average $\beta = -0.0235\%$ and the price change implied by the USD 7000 subsidy, i.e. $\Delta p = \left(\frac{7000}{60}\right) \approx -117$ USD/month, one obtains a percentage change of $\beta \cdot \Delta p = 2.75\%$. The current study does not analyse the cost effectiveness of BEV purchase subsidies. Recent work that focuses on this matter includes the study by Sheldon and Dua (2019[99]) for the US.

[50] In the DCE environment, the estimates suggest the likelihood of BEVs can be increased by 5-7% if the BEV purchase price is reduced by 10%. A price elasticity of -0.50 on a 20% likelihood to choose a BEV means that a 20% price increase will decrease that likelihood by 10% (-0.50 · 0.20 = 0.10), i.e. two percentage points, from 20% to 18%.

[51] Sierzchula et al. (2014[100]) study the determinants of electric vehicle adoption using a 2012 sample of PHEV market rates in 30 countries. They find that financial incentives of USD 1000 are statistically associated with 0.6% increase in the market share of these vehicles. Ma, Xu and Fan (2019[102]) find that the willingness to pay for a combined (i) 50 km increase in BEV range, and (ii) the presence of a recharging station every 3 km is almost USD 7000 (approximately 50 000 Yuan).

impact of declining battery costs, which make up a considerable part of the cost of a BEV. A 50% decline in the cost of a USD 10 000 battery pack may boost the share of BEVs by 1.4%-2.5%.

Falling purchase costs in BEVs can also affect the share of the other alternatives. The estimates suggest that the same price drop considered above, i.e. USD 117 per month, will decrease the share of PHEVs by 0.9%-1.6% and that of ICEVs by 1.1% to 2.0%.[52]

Box 3.2. Examples of measures to ease the cost burden of alternative-fuel vehicles

Tax incentives to promote EVs in Norway (1990-today)

In this policy package, Norway implemented various tax incentives to decrease ownership and running costs. These include exempting BEVs from registration tax and VAT, as well as offering their owners a 50% reduction in road taxes, ferry and parking fees. As a result of such policies, Norwegian authorities expect to reach a nearly 45% EV share in the vehicle fleet by 2030.[53]

"Green bonus" purchase subsidies for hybrid, electric and hydrogen vehicles in France (2008)

This policy provides financial assistance for the purchase of a hybrid, electric or hydrogen private vehicle, whether new or secondhand. Subsidies amounts from 900 to 7000 euros in 2023. Subsidies include a price and a weight limit.[54]

Table 3.2 summarises the impacts that purchase costs have on the probability of choosing the three types of vehicles. A tax of USD 6000 on the purchase of an ICE vehicle, here translating into a monthly cost of USD 100 during the first 5 years of its lifetime, decreases the probability of choosing an ICE vehicle by 2.4 - 4.1%. The same tax on PHEVs would decrease their probability to be selected by 2.2 - 3.7%.

Table 3.2. The impact of purchase costs on the choice of fuel type

	Impact of a USD 100 increase in the purchase cost (per month[a]) on likelihood of selecting a vehicle type		
	BEV	PHEV	ICE
BEV purchase cost	-1.7% to -3.0%	+0.7% to +1.3%	+1.0% to +1.7%
PHEV purchase cost	+0.8% to +1.3%	-2.2% to -3.7%	+1.4% to +2.4%
ICEV purchase cost	+1.0% to +1.7%	+1.4% to +2.2%	-2.4% to -4.1%
	Own- and cross purchase cost elasticities		
	BEV share	PHEV share	ICE share
BEV purchase cost	-0.51 to -0.71	0.15 to 0.23	0.15 to 0.23
PHEV purchase cost	0.20 to 0.28	-0.47 to -0.66	0.20 to 0.28
ICEV purchase cost	0.26 to 0.35	0.26 to 0.35	-0.30 to -0.43

Note: All marginal effects reported here refer to the absolute change in the probability of choosing a specific fuel type in the choice experiment. A change in the probability of selecting a fuel type, e.g. from x% to $(x + d)$%, due to a USD 1.00 change in purchase cost will be reported

[52] Cross elasticity estimates range between 0.15 and 0.23 across income groups and do not differ between PHEVs and ICEVs due to modelling assumptions. The changes reported here are proportional to the "*stated share*" of PHEVs and ICEVs in the sample. This is an artifact of the *Independence of Irrelevant Alternatives* (IIA) assumption embedded in the logit model.

[53] More details at https://elbil.no/english/norwegian-ev-policy/

[54] More details at https://www.service-public.fr/particuliers/actualites/A14391?lang=en

here as a marginal effect of d%. All variation in the reported results stems from differences across income groups. Typically, the largest magnitudes correspond to income group 1 and the smallest magnitudes to income group 5; [a] The repayment period is set to 60 months. Assuming no inflation, the differential effect pertains to a USD 6000 increase in the purchase cost of a car.

Running costs have a significant impact on the choice of vehicle type. Table 3.3 reports the change in the choice probabilities resulting from an increase of USD 1.00 per 100 km in running costs.[55] If this change pertains to the running costs of ICEVs, it reduces the probability that they are chosen by 0.37%. The shares of PHEVs and BEVs absorb this change, with 60% of the shift being directed to PHEVs and 40% to BEVs.

Table 3.3. The impact of running costs on the choice of fuel type

	Differential effect of a USD 1.00 increase in running cost (per 100 km)		
	On BEV share	On PHEV share	On ICE share
BEV running cost	-0.27%	0.12%	0.15%
PHEV running cost	0.12%	-0.34%	0.22%
ICEV running cost	0.15%	0.22%	-0.37%
	Own- and cross-running cost elasticities		
	BEV share	PHEV share	ICE share
BEV running cost	-0.08	0.03	0.03
PHEV running cost	0.05	-0.11	0.05
ICEV running cost	0.08	0.08	-0.10

Note: All marginal effects reported here refer to the *absolute change in the probability* of choosing a specific fuel type in the choice experiment. A change in the probability from x% to $(x + d)$%, i.e. a change of d percentage points will be reported here as a marginal effect of d%.

A policy-relevant question is whether purchase and running costs have a similar impact on behaviour. To compare the two impacts, the benchmark purchase subsidy of USD 7000 needs to be converted to a kilometric subsidy (expressed in USD per 100 kilometres) over the lifetime of a car. Assuming a lifetime of 280000 kilometres, the subsidy of USD 7000 translates to a running cost subsidy of USD 2.5 per 100 kilometres. The estimates of Table 3.3 suggest that such a decrease in the running cost of a BEV will increase the probability that it will be chosen by 0.68%. In contrast, Table 3.2 predicts that USD 7000 financing a purchase rebate of USD 117 per month over a 60-month period increases that probability by 2.0 to 3.5%. Therefore, the efficiency of running cost subsidies in inducing the choice of BEV relative to purchase rebates ranges between 19.0% to 34.0%, although alternative calculations may suggest higher values.[56]

[55] An alternative conversion can use the expected kilometric car use during the first five years of the car's lifetime. For a car owner that travels an average distance of 37 miles (59.5 kilometres) per day, as reported in the National Household Travel Survey by the US Department of Transportation, i.e. 1785 kilometres per month (30 days), the subsidy of USD 117 corresponds to USD 6.55 per 100 kilometres. Using again the estimate in Table 3.3 for the effect of a BEV running cost subsidy of USD 1.00 per 100 km, a cost decrease of USD 6.55 per 100 kilometres is estimated to increase the likelihood of choosing a BEV by 1.77%. Thus, the efficiency of the running cost subsidy relative to the purchase rebate (defined as the ratio of the changes in the likelihood to choose a BEV) ranges between 50.6% and 88.5%.

[56] For the same driver (i.e. the one who travels the average distance reported), an increase in the vehicle running costs that amounts to USD 5.60 per 100 km generates an additional monthly cost of USD 100 per month. This is the equivalent of a USD 6000 increase in purchase cost with a repayment period of 60 months, whose effect was explored in Table 3.2.

The ***availability of EV charging infrastructure*** figures as one of the most important drivers of electric vehicle adoption (Table 3.4).[57] In general, combined charging availability at home and at the workplace decreases the probability of choosing an ICE car by almost 15%. The demand shift is directed towards BEVs (+16%) while PHEVs lose share (-1%). Recharging availability at the usual parking spot has a weaker, but still substantial impact, i.e. over 6% increase in the probability of choosing a BEV. Stating that charging infrastructure is available within 3 kilometres from a respondent's residential location could be correlated with actual ownership of an electric vehicle, or an interest in acquiring one in reality.[58] Availability of charging infrastructure within 3 kilometres from residence has a small positive association with the probability of selecting a PHEV. The implication is that, isolated from the availability to charge at home, work and at the usual parking spot, charging infrastructure within 3 kilometres does not offer a substantial amount of additional convenience to potential BEV buyers. However, the additional convenience it brings is sufficient to render a PHEV substantially more attractive, primarily vis-à-vis ICE cars, but also BEVs. Charging infrastructure does not affect the probability of choosing electric vehicles the same way in each country.

[57] Availability of charging infrastructure at work, at the usual parking spot and within 3 kilometres from a respondent's residence is recorded via the survey question: "*Please select which statements best describe the availability of charging stations for electric cars near you*". Respondents may declare that (a) they don't know, (b) there are no vehicle charging stations in their area or (c) select one or more of the four following options: (1) I can charge in my driveway or in my garage; (2) I can charge at work; (3) I can charge on the street or in the parking lot where I park my car; (4) I can charge within 3 kilometres of my home or workplace. The estimates shown are obtained from a model specification using one dummy for each of the elements (2), (3) and (4), letting it equal one if the respondent has indicated that the statement is true (otherwise zero). These dummies remain constant across the games (i.e. hypothetical choice situations) a respondent faces in a choice experiment. In contrast, a dummy variable indicating whether charging at the driveway or garage is available is (i.e. element 1) is replaced by a dummy indicating whether the respondent has been asked to hypothesize that home charging is available (see Table 3.1). The latter dummy does not only vary across respondents, but also across the games they play in their choice experiment.

[58] Therefore, the estimated effect of this variable on the propensity to select a BEV or a PHEV in the DCE should not be interpreted as a causal effect, as it may also reflect the effect of actual ownership of an electric vehicle on that propensity. This bias is mitigated by controlling for the fuel type of the vehicle currently owned by the respondent (if any).

Box 3.3. Examples of infrastructure improvements for alternative-fuel vehicles

Improving the charging station network through the “San Jose Clean Energy Program” in California, United States (2019)

This program provides various incentives to opt for electric vehicles, including grants and assistance to install at-home vehicle chargers. Households can pretend to a free at-home charging station or a $1000 pre-paid charging card if they recently purchased an EV through the Californian Clean Vehicle Assistance Program. Households can also benefit from up to $1000 federal tax credit, and up to $2500 financial incentives from PG&E (local electricity and gas company) for installing an at-home vehicle charger. The program also includes time-of-use electricity consumption tariffs for EV drivers, as well as preferential tariffs. The city of San Jose has also expanded its public charging station network, with a target of 25% of charging stations being located in low-income and disadvantaged communities.[59]

Electric vehicle “Charging right” in Norway (2017)

In order to fulfill its 2025 Zero emission goal, the Norwegian government introduced a “charging right” for people living in apartments. This implies that landlords must install and share the cost of charging infrastructure in the building.[60]

Table 3.4. The impact of recharging availability at home, workplace and public spaces

	On BEV share	On PHEV share	On ICE share
	Differential effect of recharging availability at home		
Switzerland	+8.9%	-3.8%	-5.1%
Canada	+11.7%	-4.9%	-6.8%
Rest of the countries	+12.7%	-5.3%	-7.4%
	Differential effect of recharging availability at workplace		
USA	+6.5%	+2.2%	-8.7%
The Netherlands	-2.6%	+1.7%	+0.9%
Switzerland	+8.0%	-6.4%	-1.6%
Canada	+7.6%	-4.4%	-3.2%
Rest of the countries	+3.1%	+4.1%	-7.2%
	Differential effect of recharging availability at the usual public parking spot		
USA	+8.2%	+4.3%	-12.5%
UK	+3.2%	+5.6%	-8.8%
Sweden, Israel	+5.7%	-2.3%	-3.4%
Switzerland	-1.2%	+5.3%	-4.1%
Canada	+6.1%	+5.3%	-11.4%
Rest of the countries	+6.4%	-2.2%	-4.2%
	Differential effect of recharging availability at a public spot within 3 km from residential location		
USA	+0.2%	+1.3%	-1.5%
UK	+0.1%	+1.9%	-2.0%

59 More details at https://sanjosecleanenergy.org/ev/

60 More details at https://elbil.no/english/norwegian-ev-policy/

Sweden, Israel	+1.3%	+3.1%	-4.4%
Switzerland	+5.1%	-0.8%	-4.3%
Canada	+1.7%	+0.3%	-2.0%
Rest of the countries	-1.6%	-0.4%	+2.0%

Note: Share refers to the predicted choice probability of a given vehicle type in the experiment. All marginal effects reported here refer to the absolute change in the probability of choosing a specific fuel type in the choice experiment. A change in the probability from $x\%$ to $x + \delta\%$, i.e. a change of δ percentage points will be reported here as a marginal effect of $\delta\%$.

The ***battery autonomy*** of BEVs is another important barrier to their more widespread proliferation. In the DCE, increasing the driving range of a BEV by 100 kilometres is associated with a 1.1% increase in the probability of choosing a BEV. A 20% increase in the BEV driving range is estimated to increase a hypothetical market share of 20% to 20.8%. However, BEV driving range may not have the same effect in every country. In the case of the United States, the estimated impact is essentially zero, reflecting the possibility that driving range is only a single factor among others that currently hamper the more widespread uptake of BEVs. In the United Kingdom and Israel, the effect of battery autonomy is positive, but substantially smaller than the rest of the countries (Table 3.5).

Table 3.5 also reports the predicted impact of a 10-minute reduction in BEV highway recharging time. The estimates imply that the time savings increase the probability of choosing a BEV by almost 0.5 percentage points, drawing almost equally from the propensity to choose PHEVs and ICEVs. As is the case with driving range, the impact of highway recharging time on the likelihood of choosing a BEV differs across countries. Country-specific effects are significant for France, where the findings suggest that the time savings have a larger impact on the BEV share (+1.5 percentage points) compared to the United States and Sweden, where time savings have no statistically significant impact on the choice of fuel type.

Table 3.5. The impact of driving range and highway recharging speed

	On BEV share	On PHEV share	On ICE share
	Impact of a 100-kilometre increase in BEV driving range		
USA	0.1 %	-0.1 %	0.0 %
UK, Israel	0.22%	-0.07%	-0.15%
Rest of the countries	+1.1%	-0.5%	-0.6%
	Impact of a 10-minute saving in highway recharging time		
USA, Sweden	0.0%	0.0%	0.0%
France	+1.48%	-0.66%	-0.82%
Rest of the countries	+0.48%	-0.21%	-0.26%

Note: Share refers to the predicted choice probability of a given vehicle type in the experiment. All marginal effects reported here refer to the absolute change in the probability of choosing a specific fuel type in the choice experiment. A change in the probability from $x\%$ to $x + \delta\%$, i.e. a change of δ percentage points will be reported here as a marginal effect of $\delta\%$.

Some effects that were shown to be significant for other choices explored in Section 2. are also significant in the present analysis. After controlling for the key attributes (such as the availability of EV rechargers) residential location still has a role to play in explaining vehicle choice. A respondent that lives in a rural area is 1.5% more likely to choose an ICEV, and this number increases to 3.6% for a respondent living in a remote area. Living in a single-family home increases the probability of choosing a BEV by 1%. Finally, frequent long-distance travellers are 3% more likely to select a PHEV, which can currently combine the range and refuelling time of an ICEV with the cost-saving features of an ICEV.

Beyond the effect of different attributes on choice probabilities, the estimates from the discrete choice experiment can also be used to calculate the willingness-to-pay (WTP) for various vehicle attributes. This is the amount of money that the average respondent is willing to pay in order to improve a certain attribute of a vehicle. Table 3.6 shows the WTP of the average respondent from each of the five income groups for additional BEV range, faster BEV charging in highways, and full charging availability for a BEV and a PHEV.

In most countries, respondents in the first four quintiles of the income distribution are willing to pay approximately USD 2400 to add 100 kilometres in the battery autonomy of a BEV. Exceptions include the United Kingdom and Israel, where this WTP is estimated to be USD 550, and the US, where it is even lower, at USD 120. The willingness to pay for an additional range of 100 kilometres increases considerably in the fifth quintile of the income distribution.

Table 3.6. Willingness-to-pay for vehicles attributes

			Income group				
Variable	Country	Unit	1	2	3	4	5
Range of BEV [b]	FRA, NDL, SWE, CHE, CAN, BEL	USD / 100 km	2565	2403	2221	2359	3831
	USA	USD / 100 km	130	122	113	120	194
	UK, ISR	USD / 100 km	594	556	514	546	886
Highway refueling time savings of BEV [c]	NDL, CHE, CAN, BEL, UK, ISR	USD / min	107	100	93	98	160
	USA, SWE	USD / min	18	17	16	16	27
	FRA	USD / min	340	318	294	313	508
Charging availability of BEV	FRA, NDL, SWE, BEL, USA, UK, ISR	USD	23,743	22,241	20,564	21,840	35,465
	CHE	USD	16,625	15,573	14,398	15,292	24,832
	CAN	USD	21,811	20,431	18,890	20,063	32,579
Charging availability of PHEV	FRA, NDL, SWE, BEL, USA, UK, ISR	USD	14,592	13,668	12,637	13,422	21,795
	CHE	USD	15,723	14,728	13,617	14,463	23,485
	CAN	USD	19,338	18,114	16,748	17,788	28,885

Notes: [b] Hidrue et al. (2011[46]) estimate a WTP of 2900-6200 USD_{2022}/100 km.

The WTP for increasing the range of an EV by 100 kilometres shown in Table 3.6 can be translated into a value of time (VOT). To obtain this value, the additional BEV range (expressed in kilometres between two charging cycles), needs to be converted to recharging time savings (hours). Assuming an initial range of 400 kilometres implies 875 charging cycles from an empty battery to 80% over a lifetime of 280000 kilometres. A range increase to 500 kilometres would imply a reduction of these cycles to 700, i.e. a saving of 175 cycles.[61] With additional assumptions regarding the charging location and charging speed, these saved cycles can be converted into time savings. For instance, if all saved cycles occur at home, i.e. under

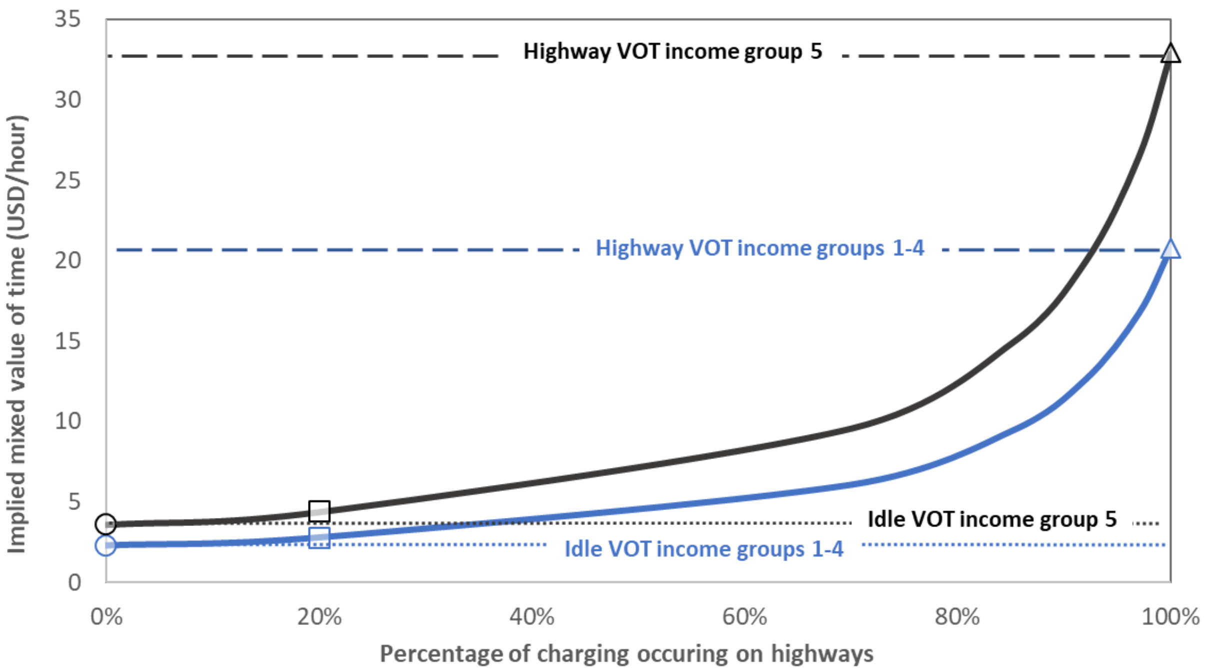
[61] More generally, if the kilometric lifetime of the vehicle is L kilometres, charging cycles occur to x%, and the initial and improved battery ranges are R_0 and R_1 kilometres, the *number* of saved charging cycles is given by:

$$C = \frac{L}{(x/100)} \cdot \left(\frac{1}{R_0} - \frac{1}{R_1}\right) = \frac{100 \cdot L \cdot (R_1 - R_0)}{x \cdot R_0 \cdot R_1}.$$

Replacing L with 280000, x with 80, R_0 with 400 and R_1 with 500 yields $C = 175$ saved cycles.

"idle" conditions, it can be argued that they would correspond to 1050 saved hours.[62] Then, a WTP of USD 2400, such as that reported in Table 3.6, implies an "*idle VOT*" of USD 2.29 per hour.[63] On the other hand, if all of the saved charging cycles occurred on the highway, the 175 saved cycles would correspond to 116 hours and the WTP of USD 2400 would imply a "*highway-specific"* VOT of USD 20.78 per hour.[64]

Figure 3.1. Implied value of time from the WTP for BEV range



Notes: Assumptions include a BEV lifetime of 280000 kilometres, charging cycles occur exclusively from an empty battery to 80%, a reference battery autonomy (range) of 400 km, Level 2 charging lasts for 6 hours (occurring exclusively under idle conditions, e.g. at home or work), and Level 3 charging lasts for 40 minutes (occurring exclusively on the highway). Circles indicate the value of time (VOT) corresponding to idle conditions; triangles correspond to the VOT on the highway; and squares correspond to a "mixed VOT" that is derived under the assumption that 20% of recharging cycles occur on the highway and 80% at home. Other points on the curves correspond to a mixed VOT derived under a different allocation of charging cycles between highway and home.

Figure 3.1 displays the *average* VOT savings implied by the WTP for a longer BEV range under any combination of charging at home or on a highway. The circles and the triangles mark the idle VOT and the highway-specific VOT, derived earlier for the two polar cases in which charging occurs exclusively at home or in the highway. The average VOT of someone who combines both charging modes lies between these polar values. For example, the average VOT of someone who belongs to income groups 1-4 and recharges

[62] Here, it is assumed that charging at home occurs exclusively with Level 2 chargers that require 6 hours to fill an empty battery to 80%.

[63] The reported number is the outcome of dividing USD 2400 by 1050 hours, i.e. $\frac{2400\ USD}{1500\ hours}$ where both the numerator and the denominator are expressed per 100 kilometres of additional BEV range during the vehicle lifetime.

[64] Here, it is assumed that charging at the highway occurs exclusively with Level 3 chargers that require 40 minutes to fill an empty battery to 80%. The 175 saved cycles would then imply 115.5 saved hours. Dividing USD 2400 by 115.5 yields the reported VOT.

20% of the times on a highway (therefore 80% of the times at home) is USD 2.78 per hour.[65] The time valuations for the high-income group, shown in the black curve of Figure 3.1 are approximately 60% higher than these of the lower four income groups, shown on the blue curve.

In most of the countries included in the study, respondents in income groups 1-4 are willing to pay approximately USD 1000 (during the lifetime of the vehicle) to reduce the highway charging time of a BEV by 10 minutes. This WTP can also be translated to a value of time savings on highway recharging, which under plausible conditions is aligned with the highway-specific VOT estimated from the WTP for additional BEV range.[66] The WTP for faster highway recharging increases by approximately 60% in the highest income group, which roughly corresponds to the top 20% of the income distribution.

The figures in Table 3.6 indicate that the WTP for full accessibility to charging infrastructure is higher than the WTP for BEV range and highway charging time savings. For respondents in income groups 1-4, the willingness to pay for combined accessibility to chargers at home, work and at the usual parking spot ranges between USD 15000 and USD 24000. These respondents would be willing to pay less, i.e. USD 12500-19500, if the same accessibility pertained to a PHEV, rather than a BEV. This systematic difference is explained by the fact that PHEVs are not subject to the same range anxiety issues BEVs are subject to. The systematically higher WTP of the 5th income group for relevant vehicle attributes, already highlighted for BEV range and charging speed, is also evident with respect to accessibility to charging infrastructure.

The findings of this section can inform analyses assessing the social costs and benefits of the provision of denser and faster EV charging networks. As such analyses would require extensive information of the local conditions across countries, they extend beyond the scope of the current report. The preference estimates exhibited in this section can also be used together with assumptions regarding how EV attributes will develop in the future. This projection exercise, pursued in the next section, can yield insights regarding the distance between the observed trends and current ambition in EV adoption.

3.3. Forward simulations

The projections assessed in this section extend to 2035. The benchmark year is 2022, i.e. the year in which the data were collected. The year 2030 serves as an intermediate year. For each of the future points of assessment (2030 and 2035) the exercise in this Section predicts the share of BEVs using the estimated

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65 More generally, the average VOT following from the WTP for additional BEV range is:

$$VOT(i,\alpha) = \frac{WTP(i) \cdot x\% \cdot R_0 \cdot R_1}{L \cdot (t_R \cdot \alpha\% + t_H \cdot (100-\alpha)\%) \cdot (R_1 - R_0)}.$$

where $WTP(i)$ is the willingness to pay of income group i to increase the range between two recharging cycles, from R_0 to R_1 kilometres; L is the kilometric lifetime of the vehicle; charging cycles occur to $x\%$; $\alpha\%$ of charging cycles occur in a highway; $100-\alpha\%$ of charging cycles occur at home; one charging cycle at home requires t_H hours; and one charging cycle at the highway requires t_R hours. Setting $L = 280000$, $x = 80$, $\alpha = 20$, $R_0 = 400$, $R_1 = 500$, $t_R = 0.66$, $t_H = 6.0$, and $WTP(i) = 2400$ yields the reported VOT of 2.78 USD per hour. The derivative of the above expression with respect to α depends on α itself, therefore the VOT is a non-linear function of the relative frequency with which the vehicle is recharged on the highway.

66 Assuming, as before, that 875 charging cycles (from empty to 80%) during the lifetime of the BEV, and that 33% of charging activity (i.e. 289 cycles) will occur on highways, implies a highway value of recharging time of USD 20.78. This equals the value of recharging time on highways implied by the WTP for additional BEV range. The relative frequency with which a vehicle an average vehicle will recharge on the highway on the highway is currently unknown, but it will likely depend on the share of long-distance trips in the total number of trips. Aultman-Hall and Ullman (2020[132]) report that long-distance travel comprises approximately 30% of the passenger miles in the United States.

preference parameters giving rise to the results discussed in the previous section, and the expected future state of the key explanatory variables. These evolving variables include the BEV range and recharging time of EVs on the highway, vehicle purchase prices, running costs, and the availability of charging at home, work and the usual parking spot.

The purchase price of vehicles evolves over time. BEVs become cheaper as battery production costs decrease (Nykvist and Nilsson, 2015[47]). This occurs because the impact of accumulated knowledge offsets the potential impact of rising raw materials prices (Mauler et al., 2022[48]). In the explored scenario, the pre-tax price of a compact BEV in 2030, i.e. without taxes and subsidies, is assumed to be 23-30% lower than in 2022. For larger cars, such as Sport Utility Vehicles (SUVs), the fall in price ranges between 20% and 28%. The price of BEVs is assumed to continue falling between 2030 and 2035. In 2035, a compact BEV (respectively, a larger car) is up to 34% (respectively 31%) less expensive than it was in 2022. The drop in production costs is smaller for PHEVs, i.e. up to 10% in 2030, with no further decreases after that year. This reflects the substantial difference in the size of the battery in PHEVs compared to BEVs. ICEVs are assumed to be 3-5% more expensive in 2030 and 5-7% more expensive in 2035. BEV purchase subsidies remain fixed over the entire time horizon of the simulation.

In addition to becoming cheaper, batteries are also assumed to become more efficient over time. A forward projection of the battery autonomy of BEVs and PHEVs in historical data is provided in the 2022 Global EV Outlook (IEA, 2022[49]).[67] A projection of the linear trend in these data suggests a BEV range that is 50% higher in 2030 and more than 80% higher in 2035, compared to its benchmark level in 2022.[68] The battery range of PHEVs grows more slowly, by 12% in the period 2022-2030 and by 6% in the period 2030-2035.

1. In contrast to the purchase prices of electric vehicles, the running costs of the three vehicle types are kept fixed in the time window of the simulation. This reflects the substantial amount of uncertainty that characterises oil prices. This uncertainty, which has considerably increased since 2022 in light of geopolitical turmoil, offsets the positive effects of technological progress on fuel economy[69] or in any other cost component of pre-tax gasoline prices (e.g. transportation, storage and distribution). Importantly, the simulation assumes that no tax on the carbon content of gasoline is implemented. Similar assumptions are made regarding the running costs of electric vehicles. While their energy efficiency is projected to increase by more than 30% by 2035, the extensive uncertainty that underlies future electricity prices does not support an assumption of considerable decreases in running costs for BEVs and PHEVs.

The recharging times of electric vehicles are assumed to decline considerably. Three separate effects contribute to the evolution of recharging times. First, the extended range (approximately +80% in 2035) for BEVs, requires a larger battery pack. Second, the increase in the battery pack size is much smaller (approximately +40%) than the increase in the range. This occurs due to concurrent improvements in the energy efficiency of BEVs (approximately +33%). Finally, the charging time of a kilowatt-hour is projected

67 See also: https://www.iea.org/data-and-statistics/charts/evolution-of-average-range-of-electric-vehicles-by-powertrain-2010-2021.

68 These projected ranges align with those used in the study by Paradies et al. (2023[134])

69 See, for example, the study by Tikoudis, Mba Mebiame and Oueslati (2022[135]).

to decrease by 130% in 2035. These assumptions, which are in line with those made by the ICCT,[70] yield charging times that are approximately 40% shorter than those in 2022.[71]

Table 3.7. Summary of simulation assumptions

Variable	Evolution
BEV purchase prices [a]	Fall by 20-30% until 2030 and by up to 34% cheaper in 2035
PHEV purchase prices [a]	Fall by up to 10% until 2035, with most of the decrease having taken affect by 2030
ICE purchase prices [a]	Increase up to 7% until 2035
BEV purchase rebates	Remain constant in the period 2022-2035
Battery autonomy (range) [b]	BEVs: +50% by 2030, +80% by 2035 PHEVs: +12% by 2030, +19% by 2035
Running costs	Kept fixed throughout 2022-2035 for all three vehicle types
EV recharging times (highway)	-40% by 2035
Number of publicly available EV chargers	Increases 8-fold until 2030 and by more than 13 times until 2035.
Likelihood of access to EV charging	
At home [c]	22-58% in 2022; 42-75% in 2030; 52-96% in 2035. EV charging is *feasible* in all single-family dwellings by 2035. Likelihood of access (to EV charging) in a multi-family dwelling *with* open space doubles every 5 years in the period 2022-2030 and every 7.3 years in the period 2030-2035. Likelihood of access in a multi-family dwelling *without* open space doubles every 14 years in the period 2022-2035. Likelihood of residing in the three dwelling types is kept fixed.
At work [c]	Likelihood of access (to EV charging) doubles every 5 years in the period 2022-2030 and every 7.3 years in the period 2030-2035.
Within 3 kilometres from home [c]	Likelihood approaches 100% in 2030 and is equal to 100% in all countries in 2035.
Within 300 metres from home [c]	41-86% in 2030; 48-100% in 2035.

Note: [a] Prices before tax or subsidy; [b] Expressed in kilometres; [c] Values vary by country.

The likelihood of having access to an electric vehicle charger at home, work, at the usual parking spot, or within 3 kilometres from the residential location evolve with time. For 2022, the simulation uses the average

[70] For more information: https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf

[71] Letting "*min*" denote minutes, "*b.pack*" to denote battery pack, and "kWh" to denote kilowatt-hours, the charging time of a battery pack can formally be expressed as:

$$\underbrace{\frac{\mathbf{min}}{\mathbf{b.pack}}}_{\substack{charging\ time \\ (per\ charging\ cycle)}} = \underbrace{\frac{\mathbf{kWh}}{\mathbf{b.pack}}}_{battery\ size} \times \underbrace{\frac{\mathbf{min}}{\mathbf{kWh}}}_{\substack{charging \\ speed \\ (per\ unit\ of\ energy)}} = \underbrace{\underbrace{\frac{\mathbf{km}}{\mathbf{b.pack}}}_{\substack{range \\ (A)}} \times \underbrace{\frac{\mathbf{kWh}}{\mathbf{km}}}_{\substack{energy \\ efficiency \\ (B)}}}_{battery\ size} \times \underbrace{\frac{\mathbf{min}}{\mathbf{kWh}}}_{\substack{charging\ speed \\ (per\ unit\ of\ energy) \\ (C)}}$$

Taking logs and differentiating yields the annual growth rate of the charging time (per cycle) as a sum of the annual growth rates of range (component A), (inverse) energy efficiency (component B) and charging speed per unit of energy (component C). The percentage changes for the 2022-2035 period reported within the text correspond to annual growth rates of approximately +4.71% (range), -2.18% (inverse energy efficiency) and -6.24% (charging speed per unit of energy). Adding up these figures yields a negative annual growth rate of -3.71% for the charging time of a battery pack. In turn, this implies that the charging time of a battery pack is approximately 40% shorter in 2035.

level of access to home chargers reported in the survey. For 2030 and 2035, it is assumed that (respectively) 85% and 100% of those living in single-family homes will be able have access to a charger in case they decide to purchase an electric vehicle. For those not living in single-family homes but have access to open space, accessibility to chargers is assumed to grow at an annual rate of 15% in the period 2022-2030 and 10% in the period 2030-2035.[72] A household residing in a multi-family building with no access to open space is also assumed to be more likely to have access to home charging. That probability grows at an annual rate of 5%.[73] The likelihood of having access to an EV charger at work is assumed to increase with the same annual rate as that in multi-family buildings with access to open space.[74] Therefore, compared to 2022, the probability of having access to an EV charger at work is more than 3 times higher in 2030 and almost 5 times higher in 2035. The likelihood of having access to an EV charger within 3 kilometres from the residential location is calculated using a series of additional assumptions, with the most important being that the number of publicly available EV chargers increases with annual rates of 30% between 2022 and 2030, and 10% between 2030 and 2035. These rates imply that the number of these chargers will have grown by more than 8 times in 2030 and 13 times in 2035, compared to 2022. With these number of chargers, the probability that the average respondent has access to a publicly available EV charger within 3 kilometres from 2030 onwards is estimated to be 100%.[75] With the same number of chargers, the probability that an EV charger is available at the usual parking spot increases as well. Depending on the country, it lies in the range 5-11% in 2022, in the range 41-86% in 2030, and 48-100% in 2035.[76]

The predicted share of a vehicle type (ICE, PHEV, BEV) at any year *t* is referred to as the *experimental share of that* vehicle type *at t*. The exercise computes the growth rate of the experimental share of BEVs in the periods 2022-2030 and 2030-2035 and uses it to project forward the *actual* market shares of BEVs in the 9 countries of the experiment.

Figure 3.2 displays the results of the forward simulation for the 9 countries of the study. By construction, the predicted market shares of BEVs (left panel) and PHEVs (right panel) in 2022 is aligned with actual observed market shares in 2022. Box 3.4 provides the technical details of the projection.

[72] An annual growth rate of 15% (respectively 10%) of a likelihood implies that this likelihood doubles every 4.96 years (respectively 7.28 years).

[73] The implication of this assumption is that the likelihood of having home access to an EV charger in a multifamily building without open space increases by 1.9 times its current value (i.e. 2-9%, depending on the country).

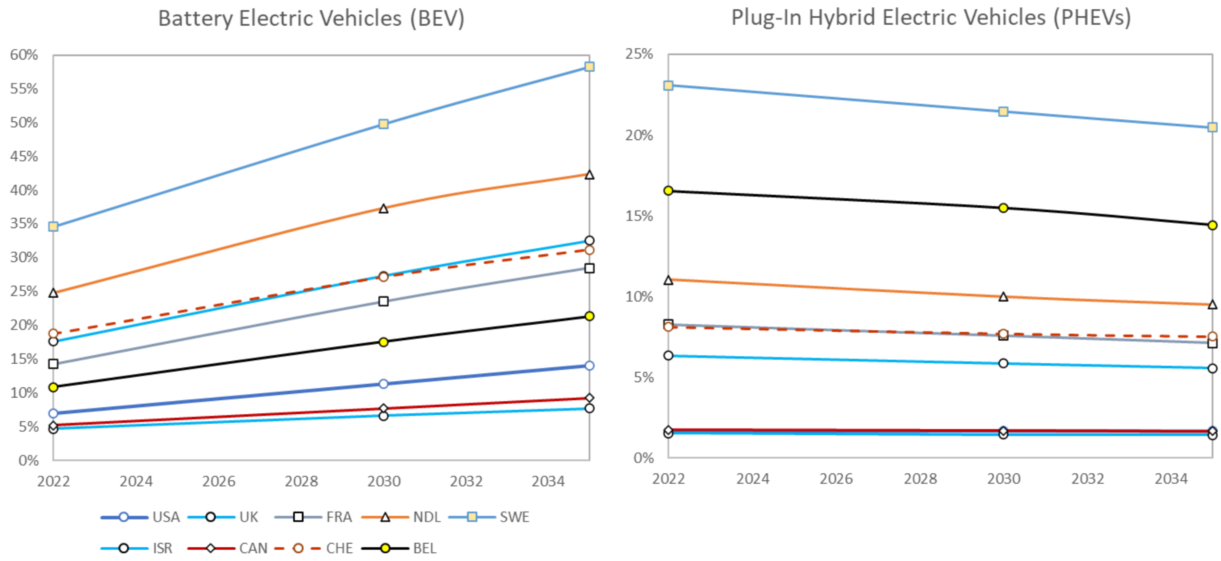
[74] See previous calculations regarding the implications of this probability growth rate. Throughout the study, access to open space is used as a proxy to access to parking space, which is not directly observed.

[75] Here, it is assumed that public chargers and population are uniformly distributed over space. It is also assumed that the built area (A) in which respondents of country c reside, as well as the population within it remain the same. These imply that a number of $N_{c,t}$ EV chargers will cover a maximum of $K_{c,t} = 100 \times \left(\frac{N_{c,t} \cdot \pi \cdot r^2}{A}\right)$% of the population in a distance less than r kilometres. Deviating from these assumptions requires more complex calculations to approximate the coverage percentages $K_{c,2030}$ and $K_{c,2035}$.

[76] Here, an additional assumption is that the “usual parking spot” lies within a radius of 0.3 kilometres from the residence of the average respondent.

Figure 3.2. Implications for the mid-term adoption of electric vehicles

Simulated evolution of the sales market share of BEVs and PHEVs



The results yield a series of new policy-relevant insights. First, based on the potential trajectories of BEV market shares over the next ten years, there appears to be a significant risk that market-based growth of BEV falls short of policy ambitions in many countries. In most cases, projected market shares of BEVs fall short of 35%, and in some cases these shares remain low even in the long run. Therefore, the perpetuation of current policies and the technological progress assumed in the simulation may not suffice to obtain market shares dominated by zero tailpipe emission vehicles. To that end, directly phasing out fossil fuel vehicle sales in the medium run may be necessary.

Furthermore, the simulations suggest that this finding cannot be attributed to the competitive effect PHEVs may exert to BEVs since the share of PHEVs in sales is expected to decline over time. Moreover, results from the experiment in Section 3.2 indicate that households are relatively unresponsive to subsidies (and by consequence, also taxes) which also suggests that incremental changes in financial support for electric transportation may not induce a level of uptake sufficient to result in a tipping point. Rather, despite the rapid progress witnessed so far in electric transportation, the improvements in costs, range and charging time may need to further accelerate to reach policy goals without resorting to the ban of combustion engines.

The results reported in Figure 3.2 should be interpreted with caution for a series of reasons. While the simulations indicate that a vehicle market dominated by BEVs may not be highly likely in 2035, they also demonstrate a steady increase in the BEV market share. In addition, there is no evidence of a plateau in the process of transiting from a market dominated by ICEVs to one dominated by BEVs. Rather, the simulations suggest that the rate of this transition is slower than that required to obtain more ambitious policy goals. Another limitation is that the current simulation does not allow for diffusion effects to materialise in the period 2022-2035. These effects describe the overcoming of factors that hamper the maturity of the electric vehicle market but are not modelled explicitly, as they are not directly observed. As most of these barriers[77] are expected to gradually subside, it can be argued that the omitted diffusion effects could have a positive and significant effect on BEV proliferation.

Box 3.4. Projecting experimental and actual shares of BEVs

The probability that respondent n from country c chooses a BEV in year t (i.e. $2022, 2030$ or 2035) is given by the logit choice probability formula:

$$P_{\mathrm{n,BEV,c,t}} = exp\left(A_{BEV} + \boldsymbol{x}'_{BEV,c,t}\,\widehat{\boldsymbol{\beta}}_{BEV,c,g(n)}\right) \Big/ \left(\sum_{j} exp\left(A_j + \boldsymbol{x}'_{j,c,t}\,\widehat{\boldsymbol{\beta}}_{j,c,g(n)}\right)\right) \qquad (4.1.\mathrm{a})$$

where j denotes the vehicle type in the discrete choice experiment (BEV, PHEV or ICE), $\mathbf{x}'_{j,\mathrm{c,t}}$ denotes the vector of attributes of vehicle type j, $\mathbf{x}'_{\mathrm{BEV,c,t}}$ is the vector of attributes characterising BEVs (see below), $\widehat{\boldsymbol{\beta}}_{j,\mathrm{c,g}(n)}$ denotes the estimated parameters of the econometric model used to produce the findings of **Section 3**.

The average share of BEVs in country c, at year *t* in the DCE experiment is:

$$\mathrm{S}_{\mathrm{BEV,c,t}} = \frac{1}{N_c}\sum_{n}\left(D_{\mathrm{nc}}\,P_{\mathrm{n,BEV,c,t}}\right)$$

where $D_{\mathrm{nc}} = 1$ if respondent *n* is from country *c*, and N_c is the number of respondents from country *c*. The growth in the experimental share of BEVs between 2022 and 2030 in country c is given by: $\mathrm{g}_{\mathrm{c,2022-30}} = (\mathrm{S}_{\mathrm{BEV,c,2030}} - \mathrm{S}_{\mathrm{BEV,c,2022}})/\mathrm{S}_{\mathrm{BEV,c,2022}}$. The respective growth between 2030 and 2035 is: $\mathrm{g}_{\mathrm{c,B}} = (\mathrm{S}_{\mathrm{BEV,c,2035}} - \mathrm{S}_{\mathrm{BEV,c,2030}})/\mathrm{S}_{\mathrm{BEV,c,2030}}$. The projected share of BEVs in the actual market is given by: $\mathrm{M}_{\mathrm{BEV,c,2030}} = \mathrm{M}_{\mathrm{BEV,c,2022}} \times \left(1 + \mathrm{g}_{\mathrm{c,2022-30}}\right)$, where $\mathrm{M}_{\mathrm{BEV,c,2022}}$ is the *actual* market share of BEVs observed in country *c* in 2022. For 2035, the projected market share is: $\mathrm{M}_{\mathrm{BEV,c,2035}} = \mathrm{M}_{\mathrm{BEV,c,2030}} \times \left(1 + \mathrm{g}_{\mathrm{c,2030-35}}\right)$.

[77] For instance, while the DCE controls for the speed of recharging in highways, it does not do so for the density of EV rechargers. It is known that the distance between charging points in the highway can be an important barrier in the decision to purchase a BEV. Diffusion effects may also refer to overcoming issues in the supply chain of spare parts or vehicle maintenance. Finally, they could also refer to market maturity (i.e. BEV sales reinforce themselves as consumers become more familiar with a new technology and overcome misperceptions about it).

Box 3.5. Gender and transport-related behaviours

The report provides insights in cross-gender trends in transport-related behaviour, both in the choice of transport mode and the type of car. In particular:

- **Women appear to be less likely to use motorised vehicles than men for childcare trips** (-2.2% for car, carpooling and public transports), and **are significantly more likely to report walking as their main transport mode for these trips** (+6.7%). While this may be interpreted as a higher level of sustainability among women, it may also reflect differences in the types of childcare trips undertaken across genders. Studies have shown that women – especially mothers – tend to have shorter home-to-work trips, which would favour short and daily childcare trips such as bringing and picking children to/from school (MacDonald, 1999[50]; Le Barbanchon, Rathelot and Roulet, 2020[51]). Such dynamics are mostly driven by lower-wages, spatial disparity in job offers as well as persisting traditional gender norms related to parenting (Schwanen, 2007[52]; Le Barbanchon, Rathelot and Roulet, 2020[51]; Kwon and Akar, 2022[53]). Ensuring that green alternatives such as public transport suit women's preferences (i.e. safe, convenient and comfortable) would serve to pursue both the policy objective of greater gender equality in transport accessibility as well as greater sustainability.
- For short-distance leisure trips, **men are more likely to report bicycling as their main transport mode compared to women** (+3.4%). This result could reflect differences in preferences for spending leisure time or differences in the extent to which current cycling infrastructure supports men's and women's needs. To the extent that it reflects the latter, this result could suggest greater scope for policies to consider the needs and preferences of underrepresented groups such as women when building cycling infrastructure. Some evidence suggests that expanding cycling infrastructure may not induce more diversity among cyclists (Aldred, Woodcock and Goodman, 2016[54]). Good quality routes and awareness campaign for responsible driving and cycling behaviour could incentivise women to cycle more, as safety concerns are among the top reasons for not cycling more (Aldred, Woodcock and Goodman, 2016[54]; Grudgings et al., 2018[55]).
- As regards long-distance leisure trips, the results indicate that **men travel more often than women**, in particular by car (+6.4%), plane (+6.6%) and rail (+13.9%). This result aligns with the literature showing gender to be a significant predictor of all-purpose long-distance trips, with men travelling more than women (Brand and Preston, 2010[56]; Dargay and Clark, 2012[36]; Reichert and Holz-Rau, 2015[37]), including for recreational purposes (Mallett, 1999[57]). Similar to childcare trips, this apparently more sustainable behaviour among women may reflect gender differences in household-related tasks. As women have on average lower wages, perform more child-related tasks and are more likely to be single parents than men, they consequently tend to be less likely to afford long-distance leisure trips than men (Taylor, Ralph and Smart, 2015[58]; Craig and van Tienoven, 2019[59]).
- **Men are much more likely to opt for a BEV over an ICEV compared to women** (+23.7%). This finding confirms recent studies which assessed the significant gender gap in EV uptake (Sovacool et al., 2019[60]). This difference may originate from a difference preferences related to technology. Anfinsen, Lagesen and Ryghaug (2019[61]) outline differences in EV perception across gender, with men reporting greater interest in technological characteristics such as speed, and women reporting greater interest in environmentalism. In the EPIC household survey, 37% of women agree that environmental issues will be primarily resolved through technological progress, versus 52% of men. Policy focus could be placed on emphasizing the environmental benefits of EVs, which could increase uptake among segments of the population beyond early-adopter tech-optimists.

4. Policy implications

Decarbonising the transport sector requires a simultaneous focus on reducing travel demand and the fuel intensity of the travel modes used. This report uses data from the OECD EPIC Survey to shed light on the drivers of individual and household transport choices and to inform policy efforts toward these aims. This includes an assessment of what factors play a role in the decision to purchase a car and what transport mode to use for commuting, childcare and leisure-related trips. Table 4.1 and Table 4.2 provide a qualitative summary of the results of these analyses.

Table 4.1. Determinants of car ownership and vehicle type

		Purchase cost	Running cost	Charging availability	Driving range	Income	Location	Environmental concern	Environ-mental motiva-tion	Support for trans-port policies
Car ownership	Yes	a	a	a	a	+++	++	-	-	-
Desired fuel type (DCE)	ICEV	-	-	- - -	- -	i	+	-	- -	- - -
	PHEV	-	-	+ +	+	i	-	-	+ +	+ +
	BEV	-	-	+ + +	+ +	i	-	+	+	+ + +

Note: This table synthetises the findings from various analyses presented in this report. Signs "+" and "-" indicate the how the covariates (presented in the top row) affect the variables of interest (presented in the first two columns). The number of "+" and "-" reflects the magnitude of the effect: "+" or "-" indicate a small effect magnitude, "+ +" or "- -" indicate a medium magnitude, and "+ + +" or "- - -" indicate a large effect magnitude; "a" indicates that the effect is either absent from the analysis for data-related reasons (e.g. purchase cost and running cost are available in the DCE but not for the actual vehicle reported) or econometric constraints (e.g. statistically insignificant); "i" indicates that the impact is modelled as an indirect effect realised exclusively via interactions with other variables.

Table 4.2. Determinants of transport mode choice by trip purpose

		Age	Income	Density	Environmental concern	Environmental motivation	Support for transport policies
Car	Commuting trips	+ + +	+ +	- - -	a	-	- - -
	Leisure trips	+ + +	+ +	- - -	-	+ + +	-
	Childcare trips	+ + +	+ + +	- - -	+	+ + +	-
	Long-distance trips	+ + +	+	- - -	a	-	a
Public transport	Commuting trips	- - -	-	-	a	+ + +	+ +
	Leisure trips	- - -	- -	- - -	+	+ +	-
	Childcare trips		-	-	+	- - -	+
	Long-distance trips	-	-	+	a	+	a
Plane	Long-distance trips	-	+	+	a	-	a

Note: This table synthetises the findings from various analyses presented in this report. Signs "+" and "-" indicate the how the covariates (presented in the top row) affect the variables of interest (presented in the first two columns). The number of "+" and "-" reflects the magnitude of the effect: "+" or "-" indicate a small effect magnitude, "+ +" or "- -" indicate a medium magnitude, and "+ + +" or "- - -" indicate a large effect magnitude; "a" indicates that the effect is either absent from the analysis for data-related reasons (e.g. purchase cost and running cost are available in the DCE but not for the actual vehicle reported) or econometric constraints (e.g. statistically insignificant); "i" indicates that the impact is modelled as an indirect effect realised exclusively via interactions with other variables.

Historically, many countries have invested heavily in road and other infrastructure that facilitates car usage. Consequently, in many high-income countries private car ownership is approaching a saturation point, a trend that is difficult to reverse (ITF, 2013[62]; Goodwin, 2020[63]). However, the results of the present study suggest that policies aiming to provide meaningful alternatives to car ownership are still relevant, especially in countries with older vehicle fleets. Furthermore, such policies can also help middle-income countries, where a large part of the population may be considering a car purchase for the first time (Chamon, Mauro and Okawa, 2008[64]), to avoid locking in a car-dependent future.[78]

Vehicle electrification should be a priority when alternatives to car may not be feasible. The market penetration of BEVs is on an upward trend, and their stock in 2023 is estimated to be 5 times higher than in 2018 (IEA, 2023[65]). However, the market shares of BEVs and alternative-fuel vehicles still fall far short of the share of ICEVs, representing an estimated 2.1% of the market in 2022 (IEA, 2023[65]). In the OECD EPIC survey, less than 20% of the respondents state that they would intend to purchase a BEV or a HFCV. This figure is not far above the current market share of these vehicles. Although vehicle fleets dominated by BEVs and HFCVs may therefore be years away, reducing the emissions intensity of the vehicle fleet in the near term is a requisite and feasible policy objective.

While preferences for electric vehicles (BEVs, PHEVs) appear to be strongly driven by non-pecuniary characteristics, these characteristics can be addressed through policies. The results suggest that providing access to EV charging at homes, workplaces and parking locations could double the market share of BEVs. However, coverage by public charging infrastructure is currently insufficient: one third of households report not having access to a charging station within 3 kilometres from their residence (OECD, 2023[12]). The results indicate that recharging time of an electric car continues being an important factor for vehicle choice. In most countries, respondents are willing to pay USD 900-1600 to decrease the charging time needed for BEVs at highway stations by 10 minutes.

While the uptake of electric vehicles continues to depend on the provision of BEV purchase subsidies, this dependence may be weaker than what previous research has suggested. Results suggest that removing a typical purchase subsidy of USD 7000 could be expected to decrease the share of BEVs by 2.0-3.5 percentage points.[79] To the extent that this number will be corroborated by future studies, it would imply that the fiscal cost of inducing a BEV sale via a purchase subsidy is increasing, and that it may lie over the full cost of acquiring a new BEV acquired with private means. Nevertheless, a purchase subsidy remains significantly more effective than an equivalent reduction in user costs. If USD 7000 is provided in the form of subsidised electricity to recharge a BEV, the boost in the BEV share will not exceed 1.8 percentage

[78] These policies need to overcome structural barriers, as cars are often considered more comfortable and more convenient than alternative modes of transport. A cultural and social barrier also exists in the form of ingrained beliefs that strongly associate cars with status and independence (Paulssen et al., 2014[105]; Mattioli et al., 2020[106]; Moody and Zhao, 2020[107]).

[79] The estimate implies an elasticity between -0.5 and -0.7. Studies using DCEs suggest a larger elasticity of BEV shares with respect to BEV purchase prices (Cirillo, Liu and Maness, 2017[84]; Jensen et al., 2021[79]; Muehlegger and Rapson, 2021[130]; Fridstrøm and Østli, 2021[121]; Xing, Leard and Li, 2019[122]), which in most cases range between -1.0 and -3.0.

points. Moreover, a subsidy could also reduce the environmental benefits of BEV use if it leads households to drive more.

This analysis also suggests that policy design needs to account for strong inertia and status-quo effects. Households owning ICEVs are 30% more likely to report intending to choose an ICEV for their next purchase. This suggests that new technologies will likely require more support to tip the economic benefit in favour of cleaner fuel choices. Governments should send a strong signal to consumers and industry that policy support is not transitory. On the other hand, households owning a BEV are twice as likely to opt for a BEV again in a subsequent purchase. Therefore, sustainable choices are also self-reinforcing, and the required policy support they need to receive in the long run is expected to be substantially smaller. Another policy implication of the findings related to inertia pertains to the role that leasing options may potentially play in escaping dependence on current conventional transport options. While the data do not allow to estimate the *per se* effect of the presence of a short-lease option[80] on the propensity to opt for an electric vehicle, the estimated status-quo effects indicate that the role of this availability may be important.

Policies promoting more sustainable transport alternatives will ideally be differentiated by location. The findings emerging from this report imply that 4-11% of the car trips that originate from suburban areas could possibly be eliminated if the public transport system delivered a level of service that is comparable to that in urban areas. This number grows even more in rural and remote areas (i.e. up to 30%). However, investing in public transport systems in these areas is less feasible, as budget deficits of operators providing competitive levels of public transport services in low density environments typically climb (Savage, 2004[66]).

The rural-urban divide has policy implications that go beyond car ownership and the choice of transport mode. If two otherwise identical households that are located in an urban and a remote area, respectively, decide to purchase a new car, the latter is 19% more likely to select an ICEV than the former. If both households decide to buy an ICEV, the household in a remote area is at least 10% more likely to opt for a diesel car. Given that car ownership and use has been found to be less elastic with respect to price changes in low-density areas (Dargay, 2002[67]; Matas and Raymond, 2008[68]), a tax to discourage these options could be expected to be less effective in rural or remote areas.

Given correlations between income and transport choices, distributional considerations need to be carefully considered when designing and implementing the transport policies discussed herein. Income is found to be a strong driver of car ownership and use, the demand for long-distance leisure travel, as well as of the choice of fuel type, in line with the literature (Dargay and Gately, 1999[69]; Dargay, 2001[70]; Matas and Raymond, 2008[68]; Nolan, 2010[71]).

Purely behavioural interventions are cost effective and complement tax-based policies and regulations. Individuals that fully support stricter fuel standards, environmental labelling in cars, teleworking-facilitating policies and EV subsidies are 3-4% less likely to belong to a household that has regular access to a car, 16% less likely to use a car to commute and 11% more likely to select a BEV in a subsequent car purchase. Environmentally concerned respondents are also 6-7% less likely to belong to a household that uses car on a regular basis and 5% more likely to prefer a battery electric vehicle (BEV). Such results suggest that cultivating environmental awareness can generally be expected to foster more sustainable transport choices, especially with respect to less frequent and more consequential choices such as the decision to own a car.

[80] To estimate such an effect, respondents need to be put in various hypothetical situations in which the length of the lease contract for a BEV varies. The obtained data will then allow to explore the extent to which inertia effects depend on the duration of the lease contract.

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Annex A. Survey methodology

A.1 Supplementary material for Section 2

Section 2.1. Robustness checks for the estimates of regular access to a car

Robustness checks of the basic specification reported in

Table 2.2 are justified as monitoring mechanisms for the stability of the econometric estimates in the complete absence of variables that are potentially endogenous. **Robustness check A** excludes the explanatory variable indicating the agreement of the respondent with transport policies (see Table 2.1). The rationale for this exclusion is that respondents form households not owning a car may tend to favour policies such as teleworking. Similarly, households owning a car may be more likely make a car purchase in the future and, consequently, they may tend to be more supportive of policies promoting electric vehicles (e.g. subsidies). **Robustness check B** excludes also both proxies for parking, as these variables may correlate with unobserved characteristics (of the individual and the household) favouring the regular use of car. **Robustness check C** excludes the four dummy variables characterising the age of the respondent.

Variable		Reported (Table 2.2)	Robustness check A	Robustness check B	Robustness check C
Location *Benchmark: Urban area (Major city)*	Suburb	+4%	+4.2%	+5.5%	+5.6%
	Rural	+7%	+7.0%	+9.5%	9.6%
	Remote area	+5.9%	+6.2%	+12.3%	12.3%
Age of respondent [a] *Benchmark: Respondent is 18-24 years old*	25-34 years old	-2.9%	-3.3%	-3.7%	Excluded
	35-44 years old	-4.6%	-5.1%	-5.2%	
	45-54 years old	-3.3%	-4.1%	-4.4%	
	Older than 54 years	-2.0%	-2.5%	-1.8%	
Income *Benchmark: 1st income group*	2nd income group	+3.3%	+3.7%	+4.7%	+4.2%
	3rd income group	+7.5%	+8.1%	+10.0%	+9.5%
	4th income group	+10.3%	+10.9%	+13.2%	+12.5%
	5th income group	+12.2%	+12.8%	+15.5%	+15.6%
Number of adults *Benchmark: One adult in the household*	2 adults	+4.3%	+4.5%	+5.8%	+6.1%
	3 or more adults	+6.1%	+6.3%	+8.5%	+9.2%
Number of children *Benchmark: No children in the household*	1-2 children	+3.5%	+3.1%	+4.1%	+3.0%
	3 or more children	+5.8%	+5.6%	+6.5%	+5.4%
Inability to work [b] *Benchmark: Able to work*	Unable to work	-4.1%	-4.3%	-5.1%	-5.8%
Single Family House *Benchmark: Any type of dwelling other than single family house*	Single-family house	+8.3%	+8.5%	Excluded	Excluded
Private open space *Benchmark: No access*	Access to a private open space	+4.9%	+4.9%		
	Canada	+3.1%	+3.2%	+6.4%	+6.7%

Country and regional fixed effects *Benchmark: Belgium (all regions)*	France	+3.6%	+4.0%	+4.4%	+4.6%
	Israel	+3.6%	+3.9%	+4.3%	+4.7%
	The Netherlands	+2.2%	+2.3%	+2.2%	+2.2%
	Sweden	-8.3%	-8.5%	-9.7%	-9.6%
	Switzerland	+4.5%	+4.1%	+2.6%	+2.5%
	United Kingdom	-4.2%	-4.6%	-4.1%	-3.9%
	USA	+5.6%	+6.1%	+10.4%	+10.7%
	Regions (range of impacts from unobserved region-specific variables)	-11.3% to +14.4%	-10.6% to 10.5%	-10.4% to +12.3%	-10.3% to +12%
Attitudinal variables	Environmental motivation	-5.5%	-6.3%	-6.7%	-8.0%
	Support for transport policies	-3.5%	Excluded	Excluded	Excluded
	Environmental concerns	-0.5%	-0.4%	-0.5%	-0.5%

Section 2.2. Car ownership and regular access to a car

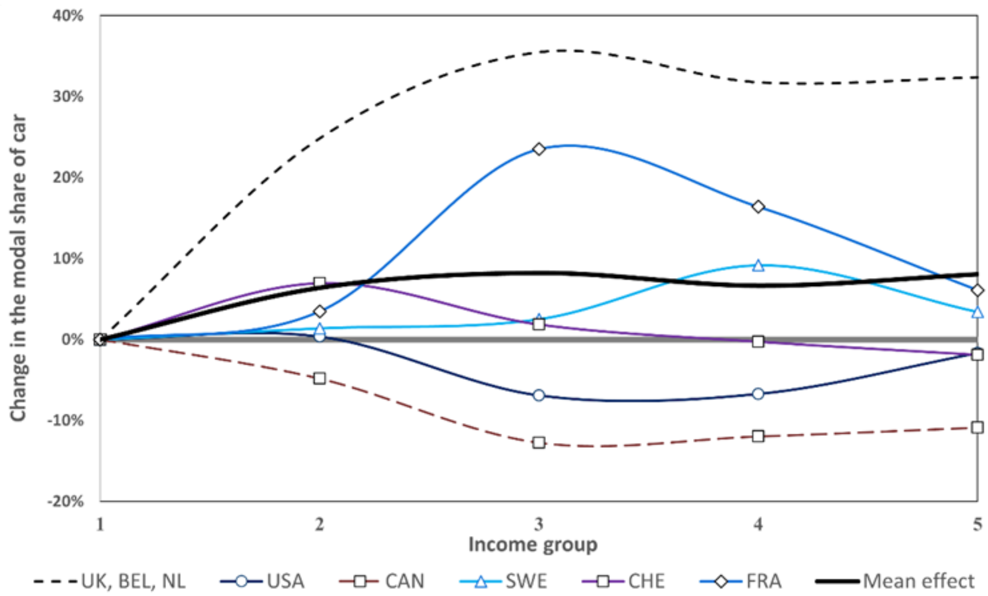
	Fuel type	Outcome	Marginal effect
Vehicle size (Continuous variable)	Gasoline	**Effect of "increasing" car volume/size by one category**	-2.1%
	Diesel		+2.4%
	LNG/CNG/LPG		-0.2%
	HEV		-0.1%
Inertia effects	Gasoline or Diesel	**Effect of currently having regular access to a gasoline or diesel car**	+6.9%
	LNG/CNG/LPG		-6.6%
	HEV		-0.3%
	Gasoline	**Effect of currently having regular access to a HEV or PHEV**	-10.7%
	Diesel		+1.6%
	LNG/CNG/LPG		+6.7%
	HEV		+2.4%
	Gasoline	**Effect of currently having regular access to a BEV**	-6.1%
	Diesel		+5.1%
	LNG/CNG/LPG		+2.2%
	HEV		-1.2%
	Gasoline	**Effect of currently having regular access to a HFCV**	-4.6%
	Diesel		+0.5%
	LNG/CNG/LPG		+5.1%
	HEV		-1.0%
Environmental indexes	Gasoline	**Environmental awareness index** *Continuous index in the interval 0 to 1 (reported effects reflect the difference between 0 and 1)*	+17.3%
	Diesel		-22.7%
	LNG/CNG/LPG		+1.3%
	HEV		+4.1%
	Gasoline	**Environmental motivation index** *Continuous index ranging from 0 to 1 (reported effects reflect the*	-4.0%
	Diesel		-0.8%
	LNG/CNG/LPG		-0.3%
	HEV		+5.1%

		difference between 0 and 1)	
Age effects (Baseline = Being under 55 years old)	Gasoline	**Effect of being over 55 years old**	+7.0%
	Diesel		-5.7%
	LNG/CNG/LPG		-1.9%
	HEV		+0.6%
Higher education (Baseline = No Bachelor's degree)	Gasoline	**Effect of higher education**	-0.4%
	Diesel		-0.1%
	LNG/CNG/LPG		0.0%
	HEV		+0.5%

Section 2.3. Choice of transport mode for commuting, leisure and childcare trips

Income effects can be substantial and vary widely by country. Figure A.1.1 illustrates cross-country differences for commuting trips. The mean, cross-country effect is represented by the solid black line. At low levels of income, an increase in income contributes to a substantial switch to car. Compared to the 1st income group, a seemingly identical individual from the 2nd and 3rd income group is more likely to choose a car for commuting by 6 and 8 percentage points, respectively. At higher income categories the effect of income is moderate. One explanation can be that higher-income households can better afford to live closer to workplace(s) and other facilities including public transport. Allowing for country-specific income effects reveals that the magnitude, sign and pattern of the income effect varies considerably. For example, in the United Kingdom, the Netherlands and Belgium, income effects are strong, but their deviation from the mean effects is not statistically significant. For the United States and Canada, income effects are negative. This may be explained by the widespread use of cars in all income groups in these countries (Dargay and Gately, 1999[72]), and as a result income is not a good predictor of it.

Figure A.1.1. The effect of income on choosing car for commuting trips, per country

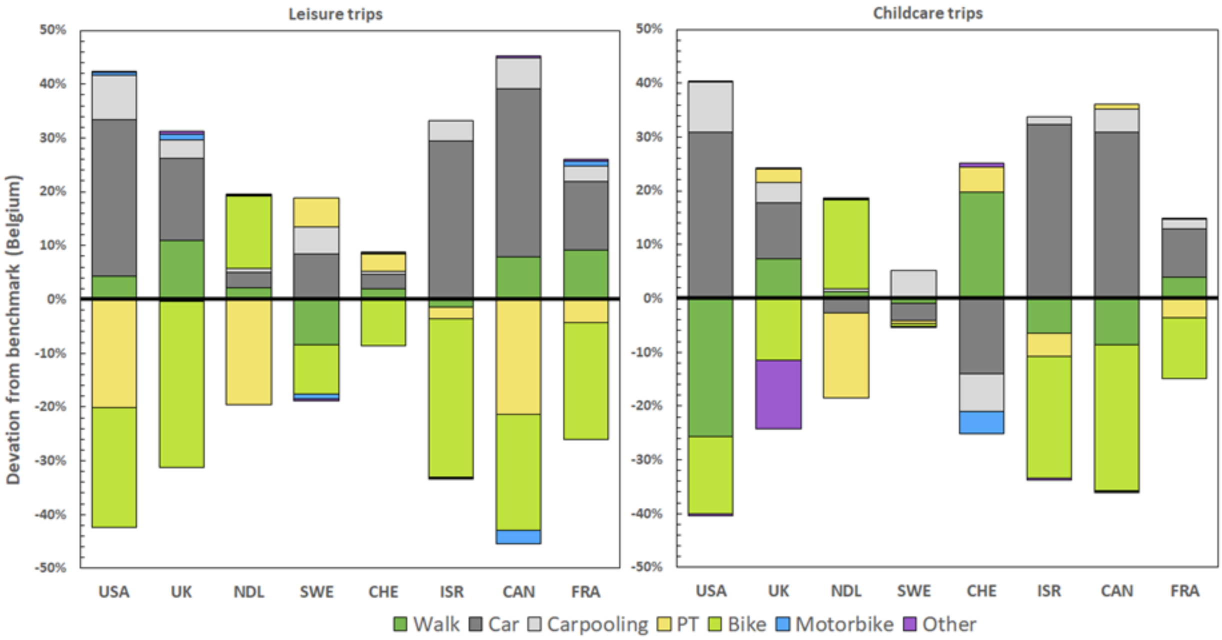


Note: The estimations focus exclusively on households that own or have regular access to a car. Therefore, the reported income effects are direct, i.e. they are net of indirect effects income may have on mode choice via car ownership. Income is recorded in a categorical manner, taking values from 1 to 5. Each category represents a country-specific income range. Points above (under) the 0% horizontal line signify that the probability of choosing car for commuting trips when income is at the corresponding levels (2, 3, 4 or 5) is higher (lower) than the same probability when income is at level 1. The "*mean effect*" is obtained from a model that excludes country-specific income effects. Country-specific income curves are obtained from a model that allows the income effect to be differentiated by country. Compared to Israel (the baseline), the Netherlands, Belgium, and the UK possess income effects that do not statistically differ from each other, and therefore have a common income effect curve. Income does not have a positive effect in countries where car is the dominant commuting mode, such as the United States and Canada.

Country fixed effects are included in the estimations to capture the impact of unobserved factors on the transport mode across countries, and their corresponding estimates encapsulate substantial information. Figure A.1.2 displays the impact of unobserved factors varying across 8 countries of the survey on each transport mode for leisure and childcare trips. Belgium serves as the comparison benchmark. Transport modes that lie above the horizontal line (i.e. at 0%) are favoured by the unobserved factors in that country, relative to Belgium. The opposite is true for the transport modes that lie below the horizontal line.[81] For instance, unobserved factors (e.g. the spatial density of biking infrastructure) contribute to recreational cycling being 13.6% more likely in the Netherlands than it is in Belgium. The corresponding impact in the United States is -22.3%. This implies that the aforementioned factors render biking in the United States 22.3% less likely than it is in Belgium, and therefore 35.9% less likely than it is in the Netherlands. The length of the bar reflects the scale of the unobserved heterogeneity of that country, compared to the benchmark (here, Belgium). As such, the United States, Canada, Israel and the United Kingdom differ more widely from Belgium than other countries, such as the Netherlands and Switzerland. Furthermore, a visual inspection of Figure A.1.2 reveals that the large differences in the former set of countries are driven by factors that systematically favour the use of cars. For example, in the United States and Canada, these factors render the choice of car use for leisure and childcare trips 28% to 31% more likely than in Belgium. In contrast, for countries where unobserved factors are expected to be similar to those in Belgium, e.g. the Netherlands, the estimates of car fixed effects fluctuate around zero (i.e. +2.5% for leisure trips, -2.6% for childcare trips).

[81] The latter line lies always in the middle of the bar, as the effects represent changes in the share of mutually exclusive alternatives which, by definition, add up to 100%. Therefore, the changes in these shares sum up to 0%.

Figure A.1.2. Country fixed effects per transport mode

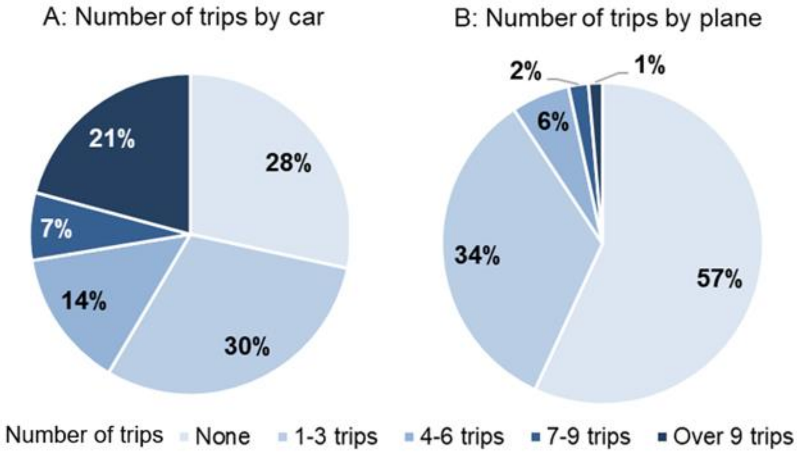


Note: Benchmark country is Belgium.

Section 2.5 Leisure-related long-distance trips

While section 2.5 examined the role of socio-demographic and attitudinal variables in explaining choice of transport mode for long-distance leisure trips, this section analyses patterns in the annual number of long-distance leisure trips travelled by either car, plane (Figure A.1.3) and other modes. The analysis includes both car users and non-car users.

Figure A.1.3. Number of annual long-distance leisure trips

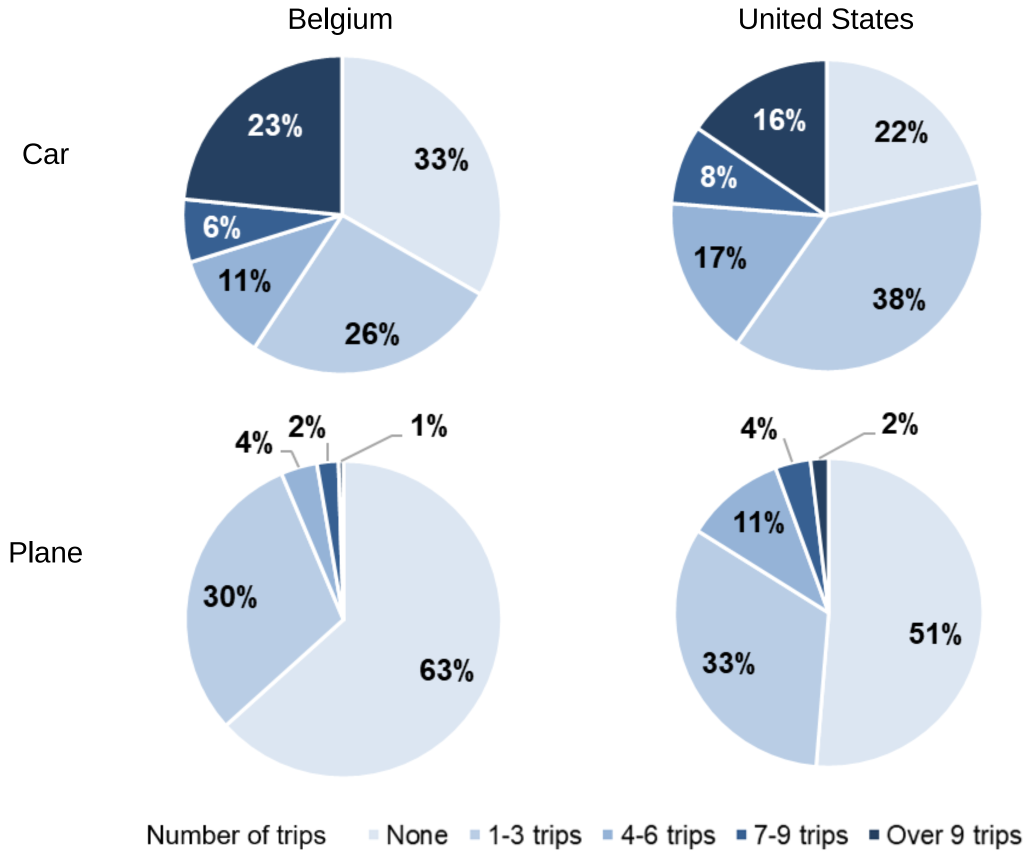


Note: This panel of pie chart displays the distribution of the minimum number of long-distance trips by car and plane related to leisure per respondent. The figure reads as follows: 28.4% of the sample reported not to do any trips by car per year, while 30.1% of the sample reported to do one trip by car per year.

Car appears to be a common mode for long-distance trips, while plane is a less common but still a prominent mode. Less than a third (28%) of respondents report to never use car for long-distance trips, and over 40% report to do at least four long-distance trips per year. A fifth report to do over nine long-distance trips by car per year. In comparison, nearly half of respondents report that they take long-distance flights for leisure at least once a year, and a minority (9%) fly at least four times a year. Considering the environmental impact of flights, this is a high number. Travelling long-distance for leisure by other modes (i.e. bus, carpooling, ferry, train or other) has a relatively similar distribution to that observed for plane, in that many respondents report to do very few or no trips, and a only few respondents report to do many trips. However, the share of respondents indicating not doing any trip by other mode is lower (41%) than by plane. A third (35%) do 1-5 long-distances trips per year, and a quarter (25%) 6 trips or more per year by other modes.

The frequency of travel by car and plane varies across countries. Figure A.1.4. displays statistics for Belgium and the United States that display relatively large differences. Although both countries have similar average number of long-distance trips per respondent, the distribution of the trips differ.[82] In Belgium, the majority of respondents (57%) either no or over 9 long-distance trips by car per year, compared to the United States where the majority of respondents (63%) report to do between 1 and 7 trips per year by car. Nearly half of respondents from the United States (49%) report to do at least one long-distance trip by plane compared to 37% of respondents from Belgium. These differences may be explained by various factors such as country size and nature of the transport infrastructure available. However, differences in lifestyle, attitudes and socio-demographics may also be strong determinants of travel demand.

Figure A.1.4 Number of long-distance trips related to leisure per respondent per country



[82] Respondents from Belgium and the United States report to do on average 3.5 and 3.2 long-distance trips related to leisure in a typical year, respectively.

Note: This panel of pie chart displays the distribution of the minimum number of long-distance trips by car and plane related to leisure per respondent in Belgium and the United States. The figure reads as follows: 33% of the sample reported not to do any trips by car per year in Belgium, while 22% of the sample reported not to do any trip by car per year in the United States.

To assess the impact of attitudes and socio-demographic factors, an Ordinary-Least-Square regression is performed. The dependent variable refers to the minimum total number of trips per respondent per mode over a typical year. Explanatory variables include age, sex, level of education, employment level, whether the respondent cannot work due to a disability, teleworking frequency, income level, household size, household situation, whether there are children in the respondent's household, home type and location. The model also controls for the respondent's motivation to take personal action for the environment, as well as for country and regional fixed effects. The results are summarised in Table A.1.1.

Table A.1.1. The effect of key determinants on the number of leisure-related long-distance trips per

Variable	**Value**	**Car**		**Plane**	**Other modes**
		All sample	Only those with regular access to car	All sample	All sample
Age (Benchmark = 18-24 y.o.)	25-34	-13.7%	-11.1%	-9.4%	-29%
	35-44.	-28.2%	-22.7%	-18.4%	-57.7%
	45-54.	-34.6%	-28.9%	-25.7%	-80.4%
	55+	-36.4%	-36.6%	-24.1%	-83.6%
Country (Benchmark = BEL)	CA		-27.7%	-6.9%	-48%
	CH	+15.4%			+46%
	FR	+18.9%			
	IL	+25.1%			-10.9%
	NL	+12.9%			
	SE				+34.8%
	UK		-15.8%	+5.9%	
	US		-23%	+8.4%	-30.6%
Education	Higher education	+5.6%	+5.2%	+6.4%	+13%
Employment (Benchmark = Active)	Retired				+13%
	Student			-5.3%	
Environmental motivation	Yes			-3.7%	
Household situation (Benchmark = Living alone)	Couple with children	+14.6%			
	Couple without children	+13.4%	+6.6%	-3.3%	-11.5%
	Flat share	+17.9%	+16.8%		
	Living with relatives & children				
	Living with relatives but no children	-8.6%	-15.7%	-14.8%	-14.5%
	Other				+25.6%
	Single parent	+12.1%		-6.7%	
Household size	//	0.037	0.038	+2.2%	+9.6%
Income group (Benchmark = 1st group)	2nd	+17.2%	+13.4%		
	3rd	+27.9%	+23%		
	4th	+35.2%	+27.7%		
	5th	+42.6%	+34.8%	+6.5%	-6.7%
Location (Benchmark	Urban	-12.5%	-5.1%	+4.2%	+22.8

= Rural)					
Sex (Benchmark = Woman)	Man	+4.6%	+6.4%	+6.6%	+13.9%
Telework frequency (Benchmark = Never)	1-3 days per week	+17.8%	+19.3%	+30.8%	+56.1%
	Less than 4 days per month	+5.6%	+7.3%		
	More than 3 days per week	+9.1%	11.4%	+19.4%	+38.2%
Unable to work	Yes	-13.5%			
Young children in the household	Yes				-12.7%

Note: "Rural" refers to small towns/villages as well as remote areas. "Urban" refers to urban and suburban areas. The total sample size for this exercise is 8632.

The **income** effects on the number of long-distance leisure trips are among the largest in magnitude. Belonging to a higher income quintile increases car travel demand by 17.2 to 42.6% compared to belonging to the 1st income group. When controlling for car ownership, income effects on car travel demand are still significant and positive, though not as high in magnitude (+13.4 to +34.8%). On the other hand, belonging to the highest income group increases travel demand for plane by 6.5% and decreases travel demand by other modes by 6.7% compared to belonging to lower quintiles, respectively. Although the effect is heterogenous across modes, income increases travel demand overall, consistent with existing literature (Georggi and Pendyala, 2001[34]; Mallett, 2001[33]; Dargay and Clark, 2012[36]; Reichert and Holz-Rau, 2015[37]) and as discussed in Section 2.5. Travelling and the choice of travel destination is also a way to signal class membership to peers (Correia, Kozak and Reis, 2016[73]; Liu and Li, 2020[74]) Overall, income effects on car travel demand appear to be large in magnitude up to the 3rd income groups (+17.2% for the 2nd income group, +27.9% for the 3rd income group), and smaller for the 4th (+35.2%) and 5th (+42.6%) income groups.

Age reduces the number of long-distance leisure trips, consistent with observations made in the literature (Schwanen, Dijst and Dieleman, 2001[38]; Mallett, 2001[33]; Limtanakool, Dijst and Schwanen, 2006[35]) Reasons for this decline may include physical constraints or generational effects. That is, new generations have assimilated more frequent travel patterns from a young age. Both reasons can also explain why the decline in travel demand with age is sharper for other modes than for car and plane that may be less comfortable, and compared to cars, also less flexible.

Being **unable to work** because of, for example, a disability, reduces the number of long-distance leisure trips by car (-13.5%). However, when controlling for car ownership, disability does not have a significant effect on car travel demand anymore. Disability seems to play a role on car travel demand only through car ownership, but not in the frequency of use.

Higher **education** induces more leisure-related long-distance trips, in particular by modes other than car and plane (+13%). A rationale is that higher education is likely to augment the geographic spread of someone's acquaintances. In fact, obtaining higher education may imply more flexible location patterns, increasing the probability that someone is located away from home when acquiring higher education and when finding a job (Frei et al., 2009). Being educated is also associated with better language skills, which renders international travel easier and favours modes such as rail and plane (Reichert & Holz-Rau, 2015).

Teleworking increases long-distance travel for leisure purposes in all modes, though the impact of teleworking frequency is not linear. People who telework, most of whom work in service companies located in urban area, have more flexibility to combine work and leisure, for example by teleworking in a travel destination. Some studies also found a rebound effect of the decreasing number of work-related trips being compensated by an increase in recreational trips (Moeckel, 2017[75]; Ravalet and Rérat, 2019[76]). The impact of teleworking 1-3 days per week (+18 to +56.1%) is greater than the impact of teleworking more than 3 days per week (+9 to +38.2%). Those which would explain the non-linear effect of teleworking frequency. Teleworking effects are particularly strong for modes other than car and plane.

Household composition and size (here referred to as **living situation**), appear to have significant effects on the demand for long-distance trips. The presence of young children in the household negatively impacts the number of leisure-related long-distance trips by modes other than car and plane (-12.7%). However, when isolating the effect on car use from the effect on car ownership, living as a couple with children or as a single parent does not significantly impact car travel demand. Living as a couple without children also does not significantly impact travel demand after accounting for the effect of car ownership. Living in a flat share positively impacts the number of leisure-related long-distance trips by car (+16.8-17.9-%). Sharing a residence with non-relatives may increase visits to family and relatives. Living with adult relatives negatively impacts the number of leisure-related long-distance trips in all modes. Sharing the residence with older relatives increases the likelihood that they will be in need of assistance, e.g. due to physical constraints. This hampers long distance travel, an effect that is reflected upon the corresponding estimates (-15.7 to -8.9%). Finally, an additional household member increases long-distance travel demand by 2.2 to 9.6%. However, larger households tend to travel more often by economical modes such as bus and train (included in Table A.1.1 as “other modes”, +9.6%), than in more expensive modes such as plane (+2.2%).

Being a man increases travel demand in all modes compared to being a woman. The literature has reported that **sex** was a significant predictor of all-purpose long-distance trips, with men travelling more than woman (Brand and Preston, 2010[56]; Dargay and Clark, 2012[36]; Reichert and Holz-Rau, 2015[37]). Some studies have found sex to mostly impact business-related travel and to have little to no effect on leisure-related long-distance travel (Limtanakool, Dijst and Schwanen, 2006[35]; Reichert and Holz-Rau, 2015[37]). However, other studies show that men do more recreational travel than women (Mallett, 1999[57]).

Location is a strong determinant of travel demand. Living in urban area is statistically associated with a decrease in leisure travel by car (-12.5% overall, -5.1% among regular car users), and an increase in leisure travel by plane (+4.2%) and other modes (+22.8%). Urban areas encompass a diversity of travelling infrastructures such as train stations, airports or carpooling networks, which facilitates alternatives to car. It also reduces the generalized cost of long-distance travel and contributes to increasing travel demand (Limtanakool, Dijst and Schwanen, 2006[35]; Reichert and Holz-Rau, 2015[37]; Czepkiewicz, Heinonen and Ottelin, 2018[77]). Living in an urban area also increases the number of social interactions and social connections, creating more occasions to travel. People living in urban areas may also more frequently look for opportunities to disconnect from the stress and intensity of an urban lifestyle (Heinonen et al., 2013[78]).

Being **environmentally motivated** decreases moderately travelling frequency by plane (-3.7%), but does not impact travel demand by car. This may be due to difficulties in changing habits, and limited behaviour, i.e. focusing on low-cost behaviour at the expense of efficiency (Diekmann and Preisendörfer, 2003[41]; Gifford, 2011[42]; Bosone, Chevrier and Zenasni, 2022[43]). Limiting the use of car and plane for long-distance leisure trips also reduces the possible destinations available.

A.2 Supplementary material for Section 3

Overview of the literature on Discrete Choice Experiments on car types

Table A.2.1.Overview of the literature on Discrete Choice Experiments on car types

Paper	Geographic and time scope	Sample size	Choice alternatives	Attributes	Explanatory factors	Modelling strategy
(Jensen et al., 2021[79])	Denmark, 2020	2961	ICEV PHEV BEV	Purchase price, Operational costs, Driving Range , Acceleration, Booth size, Charging station location, Refuelling / Charging speed, Range gained from 10mn fast, charging, Emissions	Age, Income, Sex, Own a conventional car, Desired car type	Multinomial logit model
(Danielis et al., 2020[80])	Italy, 2018	996	ICEV EV	Purchase price, Driving range, Fuel economy, Fast charging time, Charging station location, Policy incentive (Free parking)	Age, Education, Environmental concerns, EV knowledge, Part of an environmental association, Number of driving licenses in household, Owned garage, Do long-distance trips	Multinomial logit, Random parameter logit models
(Noel et al., 2019[81])	Denmark Finland, Iceland, Norway, Sweden, 2016-2017	5494	ICEV EV	Purchase price, Driving range, Acceleration, Vehicle-to-grid capability, Refuelling / Charging speed, Electricity source	Age Children in the household Number of cars owned Intensity of car use Experience driving EV Previous knowledge of Vehicle-to-grid	Mixed logit model
(Huang and Qian, 2018[82])	China, 2015	348	ICEV PHEV BEV	Purchase price, Operational costs, Driving range, Brand origin, Recharging distance, Possibility of home charging, Emissions, Policy incentives (Purchase subsidies, Policy of vehicle licensing, Driving restriction, Congestion charge, Access to bus lanes)	Age, Sex, Household size, Number of children in household, Location size, Normative influence, Face influence, Risk aversion, Perceived symbols of car ownership, Intended vehicle price Car use experience	Nested logit model
(Cherchi, 2017[83])	Denmark, 2014-2015	2363	ICEV EV	Purchase price, Operational costs, Driving range, Car size, Parking-related policies	Age, Sex, Employment-related characteristics, Number of cars owned	Hybrid choice model (Mixed logit model, Latent variable model)
(Cirillo, Liu and Maness, 2017[84])	Maryland, US, 2014 Survey data	456	ICEV HEV BEV Opt-out (no purchase)	Purchasing price, Fuel cost, Driving range, Fuel economy, Car size	Age, Education, Sex Number of workers in the household, Number of vehicles owned	Mixed multinomial logit model
(Axsen, Goldberg and Bailey, 2016[85])	Canada, 2013	2449	ICEV PHEV BEV	Purchase price, Fuel cost, Driving range, Possibility of home charging, Refuelling / Charging speed	Age, Education, Income, Residence type, Number of vehicles owned, Desired car size	Hybrid choice model (Multinomial logit model, Latent class model)
(Helveston	US, China	384 &	ICEV	Purchase price, Operational	Age, Education, Income,	Multinomial

et al., 2015[86])	2012-2013	572	HEV PHEV BEV	costs, Acceleration, Brand origin, Fast charging capability	Sex, Household size Number of children in the household, Intensity of car use, Number of vehicles owned	logit model Mixed logit model
(Valeri and Danielis, 2015[87])	Italy, 2013	121	ICEV CNGV LPGV HEV BEV	Purchase price, Operational costs, Driving range, Refuelling distance, Acceleration	Age, Income, Sex, Do long-distance trips, Being a car expert	Multinomial logit model Mixed error component logit model
(Hackbarth and Madlener, 2013[88])	Germany, 2011	711	LNG Biofuel HEV PHEV BEV HFCV	Purchase price, Fuel cost, Driving range, Refuelling / Charging speed, Emissions, Policy incentives (free parking, bus lane access, vehicle tax exemption), Car size	Age, Education, Environmental concerns, Parking lot equipped with socket, Intensity of car use	Mixed logit model
(Jensen, Cherchi and Mabit, 2013[89])	Danemark, 2012	369	ICEV EV	Purchase price, Fuel cost, Driving range, Top speed, Battery life, Refuelling distance, Emissions	Age, Environmental concerns, Technological interest, Perception of car as social symbol, Number of car owned, Desired vehicle size	Multinomial logit model
(Hess et al., 2012[90])	US, 2008-2009	3274	ICEV CNGV HEV PHEV BEV Flexifuel	Purchase price, Operational costs, Driving range, Acceleration, Fuel economy, Refuelling /Charging speed, Car size, Age of vehicle, Policy incentives (Free parking, tax credit, subsidies)	Income	Nested logit model
(Hidrue et al., 2011[91])	US, 2008-2009	3029	ICEV EV	Purchase price, Fuel cost, Driving range, Refuelling / Charging speed, Acceleration, Emissions	Age, Education, Income, Sex, Environmental concerns, Tech optimism, Desired car size, Desire a hybrid, Do long-distance trips, Own more than one car, Possibility of home charging	Hybrid choice model (Multinomial logit model, Latent class model)
(Mabit and Fosgerau, 2011[92])	Denmark, 2007	2146	ICEV Biofuel HEV BEV HFCV	Purchase price, Operational costs, Driving range, Top speed, Refuelling / Charging speed, Service	Age, Sex, Income, Household situation Children in household	Mixed logit model with random effects
(Bolduc, Boucher and Alvarez-Daziano, 2008[93])	Canada, 2002-2003	1500	ICEV AFV HEV HFCV	Purchase cost, Operational costs Fuel availability (% of stations that are available to fuel car tech x), Power, Emissions, Policy incentive (Express lane access)	Age, Education, Income, Sex, Transit user, Car pool user, Driving alone	Hybrid choice model (Multinomial logit model, Latent class model)
(Batley, Toner and Knight, 2004[94])	UK, 2001	179	ICEV AFV	Purchase price, Operating costs, Driving range , Top speed, Fuel availability (% of stations that are available to fuel car tech x), Refuelling distance, Emissions	Age, Income, Sex, Children in the household, Environmental concerns, Tech optimism, Number of vehicles owned, Intensity of car use, Mode choice for commuting	Mixed logit choice model

Note: This table provides a non-exhaustive overview of the literature on Discrete Choice Experiments for car types. Acronyms in the choice alternatives columns refer to: Internal Combustion Engine Vehicle (ICEV), Liquefied Petroleum Gas Vehicle (LPGV), Compressed Natural Gas Vehicle (CNGV), Alternative-Fuel Vehicle (AFV), Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), Battery Electric Vehicle (BEV) and Hydrogen Fuel Cell Vehicle (HFCV).

Details on the construction of the DCE

The *drivetrain* determines the engine and fuel type of the vehicle. Alternative 1 is a Battery Electric Vehicle (BEV) and alternative 2 is a Plug-in Hybrid Electric Vehicle (PHEV). Alternative 3 is an Internal Combustion Engine vehicle (ICEV). Its exact type depends on the reply of the respondent to the question: "*If you were to purchase or lease a new/used car, which fuel type would you be most interested in?*". Here, this question is referred to as **Question A**. Responses to question A were visualised earlier, in Figure 2.1. In Alternative 3, respondents are offered the exact same option as their response to question A, if that response was in ICE vehicle (gasoline, diesel, natural gas, HEV). However, if the response was a "greener" alternative (PHEV, BEV, HFCV), respondents are offered the HEV option. Finally, if the response to question A was indefinite ("*I do not know*", "*Other*"), the drivetrain in Alternative 3 is set to gasoline.

The purchase costs refer to the monetary cost of acquiring a vehicle. They are expressed in annual terms, assuming a payment period of 60 months (i.e. 5 years). To obtain purchase cost values, the survey asks the respondents the following question: "*If you were to purchase or lease a new/used car, what do you expect the price range of the vehicle to be?*". This question is referred to as **Question B**. The respondent (r) selects a price range among a set of 12 consecutive price ranges that differ by country. This range is denoted by $P_{c,r,L} - P_{c,r,U}$, where the subscripts L and U denote the lower and the upper bound of the range. For example, a potential price range for the US respondents is USD 25000 to 30000, thus for a respondent r that declares this as the price range of the next vehicle purchase, it holds that $P_{US,r,L} = 25000$ and $P_{US,r,L} = 25000$ USD. The purchase cost of an ICE alternative, i.e. alternative 3, is always set to the lower bound purchase price of a respondent r from country c. Assuming away interest payments, and dividing by 60 monthly payments of equal value, the monthly purchase cost of an ICE vehicle in Table 3.1 is: $\mathrm{M}_3 = P_{c,r,L}/60$, and it is fixed in each choice situation (game) x faced by respondent r. For the BEV and PHEV alternatives, the corresponding costs (i.e. M_1 and M_2 in Table 3.1) are given by $(a_x \cdot P_{c,r,L})/60$, where a_x is a price multiplier taking values between 1.10 and 1.50. Therefore, the hypothetical choice situations that a respondent faces in the different games involve a choice among a conventional vehicle in the lowest bound of the declared price range and two alternative choices, whose prices are 10% to 50% higher.

The *running costs* mainly refer to the monetary value of fuel consumption that each alternative requires. For the PHEV and BEV alternatives, these costs vary by country to reflect cross-country differences in electricity and gasoline prices. The monthly running costs for BEV and PHEV in Table 3.1 are given respectively by $\mathrm{C}_1 = \beta_{1x} \cdot C_c$ and $\mathrm{C}_2 = \beta_{2x} \cdot C_c$, where C_c is a monthly, country-specific reference cost of using BEVs and PHEVs (common for both types of vehicles), and β_{1x}, β_{2x} are multipliers that range between 0.5 and 1.5, creating variation of the BEV and PHEV running costs across games. Furthermore, they may differ from each other in any given game, i.e. it can be that $\beta_{1x} \neq \beta_{2x}$. This generates differences in the monthly cost of BEV and PHEV use in the same game. For ICE vehicles, the corresponding value of C_3 differs by drivetrain type (gasoline, diesel, natural gas, HEV) and by country, but otherwise it remains fixed across games played by the same respondent.

A number of other attributes come into play in the experiment. *Refuelling* refers to the replenishment of the final fuel of a vehicle and *driving range* is the distance driven between two stops for refuelling. The driving range of PHEVs and ICEVs, respectively R_2 and R_3, is fixed to 800 km (500 miles for US respondents) and their refuelling time is set to 5 minutes. For BEVs, the driving range, R_1, varies across games played by the same respondent, taking values of 200, 400 and 600 kilometres (respectively 125, 250, 375 miles). Refuelling time in BEVs refers to the time needed to obtain 80% battery capacity on a highway, an attribute that alternates between 20 and 60 minutes. In the DCE, the availability for home charging, refers to the possibility of recharging a BEV or PHEV at home. This possibility is fully hypothetical, and it alternates between "Yes" and "No" values across games, and between BEVs and PHEVs in the same game. The variable is irrelevant for ICEVs.

Model specification and estimation

The specification of the discrete choice model is as follows. Using the convention introduced by Table 3.1, subscript i = 1, 2, 3 is used to denote the BEV, PHEV and ICE alternative, respectively. Index n denotes the respondent and c denotes a country out of the 9 countries in the survey. The utility from choosing one of three drivetrain types is:

$$U_{ncik} = \mathrm{A}_i + \underbrace{S_{nci} + P_{nci} + X_{ncik} + M_{ncik}}_{\textbf{systematic utility } (V_{ncik})} + \varepsilon_{ncik}$$

where ICE serves as the reference (benchmark alternative), therefore its systematic utility V_{ncik} is set to zero and $\mathrm{A}_3 = S_{nc3} = P_{nc3} = X_{nc3k} = M_{nc3k} = 0$ for each respondent n, country c and game k; A_1 is the difference in utility from selecting a BEV instead of an ICE car that can be attributed to unobserved factors; S_{nc1} is the difference in utility from selecting a BEV (instead of an ICE car) that can be attributed to socioeconomic factors that do vary across respondents and countries, but are unrelated to alternatives; P_{nc1} is similar to S_{nc1}, but refers to differences in utility between a BEV and an ICEV that are caused by certain beliefs and perceptions (such as environmental motivation, agreement with transport-related policies) rather than socioeconomic factors; X_{nc1k} is the difference in utility from selecting a BEV instead of an ICE car in game k of the DCE offered to respondent i that is attributed to differences in the characteristics of the BEV and ICE alternatives; M_{nc1k} is an additional utility difference from selecting a BEV instead of an ICE car that is generated because the differences in the attributes of the vehicles may have a different impact in different socioeconomic groups; $\mathrm{A}_2, S_{nc2}, X_{nc2k}, M_{nc2k}$ are the respective utility differences between a PHEV and an ICE car.

2. The utility differences caused by socioeconomic factors are specified as follows:

$$S_{nci} = \underbrace{\sum_c (\mathrm{A}_{i,c} D_{nc})}_{\text{country effects}} + \underbrace{\sum_{\mathrm{a}} (\mathrm{A}_{i,\mathrm{a}} D_{n\mathrm{a}})}_{\text{age effects}} + \underbrace{\sum_s (\mathrm{A}_{i,s} D_{ns})}_{\text{settlement type effects}} + \underbrace{\mathrm{A}_{i,\mathrm{H}} D_{n\mathrm{H}}}_{\text{single family house effect}} + \underbrace{\mathrm{A}_{i,\mathrm{F}} D_{n\mathrm{F}}}_{\text{sex effects } (female)} + \underbrace{\mathrm{A}_{i,\mathrm{C}} D_{n\mathrm{C}}}_{\text{effect from car access}} + \underbrace{\mathrm{A}_{i,\mathrm{C}} D_{n\mathrm{C}}}_{\text{effect from car access}} + \underbrace{\mathrm{A}_{i,\mathrm{L}} D_{n\mathrm{L}}}_{\text{intension to lease}}$$
$$+ \underbrace{\mathrm{A}_{i,\mathrm{W}} D_{n\mathrm{W}}}_{\text{charge at work effect}} + \underbrace{\sum_c (\mathrm{A}_{i,\mathrm{W},c} D_{n\mathrm{W}} D_{nc})}_{\text{charge at work effect (country-specific deviation)}} + \underbrace{\mathrm{A}_{i,\mathrm{P}} D_{n\mathrm{P}}}_{\text{charge at public effect}} + \underbrace{\sum_c (\mathrm{A}_{i,\mathrm{W},c} D_{n\mathrm{W}} D_{nc})}_{\text{charge at work effect (country-specific deviation)}} + \underbrace{\sum_l (\mathrm{A}_{i,l} D_{nl})}_{\text{LDT effects}}$$

where the A- and D-terms are, respectively, fixed effects and dummy variables whose interpretation is offered in Table A.2.2. The second component of the systematic utility is:

$$P_{nci} = \sum_j (\beta_{I,i,j}\, X_{nj})$$

where X_{ncj} is the value of index variable $j = (1, 2, 3, 4)$ taking the value between 0 and 1. The four indices considered here are: i) environmental satisfaction, ii) environmental motivation, iii) climate-change awareness, and iv) support for transport policies. These index variables have been described in **Section 2.** , together with the survey questions that enter their construction. As it is the case with socioeconomic variables, the four indices vary across respondents, but not across the three alternatives provided to a respondent in a given game (i.e. BEV, PHEV, ICEV). In order to be identified, the discrete choice model needs to generate differences in the utility of using a BEV, PHEV, ICEV that can be attributed to the four indices, whose values are fixed across the three alternatives. This is achieved by allowing the marginal utility of a given index to be different in a BEV, PHEV and ICEV, i.e. with the use of alternative-specific coefficients $\beta_{i,j}$.

The X_{ncik} is the portion of systematic utility that stems from the variation of the attributes of the three alternatives. The corresponding specification is as follows:

$$X_{nc,k,\mathrm{BEV}} = \beta_C \cdot (C_{nk,\mathrm{BEV}} - C_{nk,\mathrm{ICE}}) + \beta_R \cdot (R_{nk,\mathrm{BEV}} - R_{nk,\mathrm{ICE}}) + \beta_T \cdot (T_{nk,\mathrm{BEV}} - T_{nk,\mathrm{ICE}}) + \beta_H \cdot (H_{nk,\mathrm{BEV}})$$

$$X_{nc,k,\mathrm{PHEV}} = \beta_C \cdot (C_{nk,\mathrm{PHEV}} - C_{nk,\mathrm{ICE}}) + \beta_T \cdot (T_{nk,\mathrm{PHEV}} - T_{nk,\mathrm{ICE}}) + \beta_H \cdot (H_{nk,\mathrm{PHEV}})$$

$$X_{nc,k,\mathrm{ICE}} = 0$$

where $C_{n,k,\mathrm{BEV}}, R_{n,k,\mathrm{BEV}}, T_{n,k,\mathrm{BEV}}$ is the running cost, driving range, and recharging time, as they appear in the BEV alternative in the k-th game of the DCE presented to respondent n from country c; variables $C_{n,k,\mathrm{PHEV}}, R_{n,k,\mathrm{PHEV}}, T_{n,k,\mathrm{PHEV}}$ are the corresponding values that appear in the PHEV alternative in the very same game; $H_{n,k,\mathrm{BEV}}$ and $H_{n,k,\mathrm{PHEV}}$ are dummy variable that indicate whether charging a BEV or PHEV at home is possible at the k-th game of the DCE offered to respondent n.

The final term, i.e. M_{ncik}, contains interactions between attributes and other variables that are fixed across the three alternatives. Using subscript i to denote BEV or PHEV, the specification is:

$$M_{nc,k,i} = \underbrace{\textstyle\sum_h \left(\beta_{Ph} D_{nh} (M_{nk,i} - M_{nk,\mathrm{ICE}})\right)}_{\substack{\textbf{income group-specific} \\ \textbf{purchase cost effects}}} + \underbrace{\textstyle\sum_c \left(\beta_{Rc} D_{nc} (R_{n,k,i} - R_{n,k,\mathrm{ICE}})\right)}_{\textbf{country-specific BEV range effects}} + \underbrace{\textstyle\sum_c \left(\beta_{Tc} D_{nc} (T_{nk,i} - T_{nk,\mathrm{ICE}})\right)}_{\substack{\textbf{country-specific refueling} \\ \textbf{time effects}}} + \underbrace{\textstyle\sum_c (\beta_{Hci} D_{nc}\, H_{n,k,i})}_{\substack{\textbf{country-specific} \\ \textbf{availability to charge} \\ \textbf{a BEV or PHEV at home}}}$$

where subscript $h = \{1, 2, 3, 4, 5\}$ denotes the income group and D_{nh} is a dummy variable that equals 1 if the household income of respondent n belongs to group h; subscript c denotes country and D_{nc} equals 1 if respondent n lives in country c.

Table A.2.2. Fixed effects and dummy variables

All effects refer to the difference in utility from choosing alternative i = (BEV, PHEV) instead of ICE

Fixed effect	Interpretation	Corresponding dummy variable [a]	Resolution
$A_{i,c}$	The effect of being in country c instead of the benchmark country (Belgium)	$D_{nc} = 1$ if respondent n lives in country c	9 countries
$A_{i,a}$	The effect of being in age category a instead of the benchmark age category (55+ years)	$D_{na} = 1$ if respondent n belongs to age category a	5 age categories (18-24, 25-34,35-44, 45-54,55+)
$A_{i,s}$	The effect of being located in settlement type s instead of the benchmark category (urban or suburban)	$D_{ns} = 1$ if respondent n lives in location type s	3 location categories (urban or suburban, rural, remote)
$A_{i,l}$	The effect of making an annual number of long distance trips with car that belong to the interval l instead of the benchmark category (no long distance trips)	$D_{nl} = 1$ if respondent n lives makes a number of long distance trips that belong to interval l.	3 categories (0 trips, 1-9 trips, 10+ trips)
$A_{i,\mathrm{H}}$	The effect of living in a single-family house instead of any other option (semi-detached, small multi-family building, large multi-family building).	$D_{n\mathrm{H}} = 1$ if respondent n lives in a single family house	2 dwelling categories (single-family house, semi-detached or multifamily building)
$A_{i,\mathrm{F}}$	The effect of self-identifying as female instead of any other option (male or other)	$D_{n\mathrm{F}} = 1$ if respondent n self-identifies as female	2 gender categories (female, male/other)
$A_{i,\mathrm{C}}$	The effect from being a household that has regular access to at least one car (instead of no access at all)	$D_{n\mathrm{C}} = 1$ if respondent n belongs to a household with access to at least one car	2 access categories (access/no access)
$A_{i,\mathrm{L}}$	The effect from intending to lease one car in the near	$D_{n\mathrm{L}} = 1$ if the respondent n intends to	2 response categories

	future (instead of no such intention)	lease a car in the near future	(yes/no)
$A_{i,W}$	The effect from being able to charge a BEV or a PHEV at work (benchmark: no such possibility)	$D_{nW} = 1$ if the respondent n has the possibility to charge a BEV/PHEV at work	2 response categories (yes/no)
$A_{i,P}$	The effect from being able to charge a BEV or a PHEV at a public location (benchmark: no such possibility)	$D_{nP} = 1$ if the respondent n has the possibility to charge a BEV/PHEV at a public place.	2 response categories (yes/no)

Note: [a] Dummy variables take the value 0 if the stated condition is not satisfied.