Case Studies on Transport Policy 17 (2024) 101217

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

Students' commuting habits to the university: Transportation choices during the Covid-19 era☆

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ARTICLE INFO

JEL:
C35
I23
R4
O18
Q56

Keywords:
Transport
Commuting preferences
University students
Covid-19 pandemic

ABSTRACT

This paper seeks to analyse the drivers behind students' commuting choice in the context of a medium-sized public university (University of Urbino Carlo Bo) in Italy. The study accounts for changes in commuting preferences and choices occurring during the Covid-19 pandemic. The results are based on a 2020 survey on students analysed by means of a mixed multinomial logit model and a latent class model. The University of Urbino is an interesting case study for several reasons. First, it has a higher number of enrolled students (approximately 15,000) than there are residents in the municipality (less than 15,000). Second, Urbino is located far from main roads and transport infrastructures. Third, there are commuting options to and from the city, meaning that local transport policies have a relevant impact on the entire territory. Personal characteristics, distance from home, and price of the transportation mode influence the choice of students. The estimates for the two post-Covid-19 scenarios showed no particular changes in students' transport habits, except when the number of household members was taken into account. The study provides valuable insights into the attitudes towards change in transportation choices that have recently emerged among a specific student population after an extended lockdown, that is now faced with making decisions marked by evident uncertainty about the possible developments of the Covid-19 virus.

1. Introduction

Transport is one of the main hot spots in terms of environmental pressures (EEA, 2013), and it contributes to both greenhouse gas and local pollutant emissions (particulate matter, nitrogen oxides, etc.), as well as noise and congestion, which give rise to high socio-economic costs.

However, transport consumes one third of all final energy in the EU, the majority of which comes from oil products. While other economic sectors (e.g., power generation and industry) have managed to reduce their emissions to some extent since 1990, transport has increased them, accounting for over a quarter of total greenhouse gas emissions in the EU. The European Environment Agency (EEA) asserted that transport emissions steadily increased in the 2013–2019 period because of economic growth, leading to an increase of passenger and inland freight volumes. After this period, and due to the Covid-19 pandemic, transport emissions have only temporarily decreased; projections for the next decade predict a new increase, until 2025 (EEA, 2022). This situation threatens the achievement of the EU's climate protection goals. Among transportation means, road transport (cars, vans, trucks, and buses) is responsible for almost 80 % of all EU greenhouse gas emissions from transport and consumes 95 % of oil-derived fuels (EEA, 2019). Road transport also results in long commutes and traffic congestion, especially in urban areas (Levine, 2006).

At the EU level, different environmental policies regarding transport have been proposed and approved. For example, the EU's Smart Mobility strategy (approved in 2021) focuses on finding solutions while maintaining the individual right to mobility, but also accounting for environmental sustainability and emission reduction goals. Moreover, the European Green Deal is also intended to cut greenhouse gases emissions, reduce the negative impact of air pollution on human health and drive innovation in this sector. These goals should be achieved at

☆ We acknowledge financial support from the Department of Economics, Society, Politics of the University of Urbino Carlo Bo, project UNITRANSPF.
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https://doi.org/10.1016/j.cstp.2024.101217
Received 20 July 2023; Received in revised form 7 May 2024; Accepted 16 May 2024
Available online 22 May 2024

both local and urban levels as they would allow the planning of targeted actions that efficiently combine the pursuit of environmental objectives with raising the awareness of individuals. Specifically, developing the awareness of environmental responsibility at a young age by promoting sustainable travel behaviour could facilitate the adoption of lifelong sustainable mobility habits (ITF, 2021). Since commuting and transport choice are individual-specific and depend on economic, social, cultural, and geographical factors, strategies at the local level require timely and modal choice information to be successful. Travel choice and its impact on the environment has become a challenge, especially when it refers to commuting to difficult-to-reach university towns (Eluru et al., 2012; Rotaris and Danielis, 2014; Zhou et al., 2018; Rerat, 2021; Sottile et al., 2021).

Indeed, according to the Istat report on pre-Covid commuting (Istat, 2021), there were approximately 30 million commuters in Italy (50.7 % of the resident population). Roughly 20 million people (i.e., 68 % of commuters) would commute to work each day, while 10 million (i.e., 32 % of commuters) would do so for school and university. About 3.5 million students commute outside their municipality. As such, universities are huge traffic-generating institutions which may cause severe traffic congestion and air pollution in the cities where they are located.

At the same time, the outbreak of the Covid-19 pandemic heavily impacted the mobility habits of people all over the world (Bagdatli and Ipek, 2022). At the beginning of the pandemic, approximately 3 million people continued to commute in Italy, but only 10 % of these did so on public transport, mainly in northern cities (Campisi et al., 2022). In particular, tertiary education was one of the most affected sectors, due to smart-working and e-learning practices.

Given this context, our paper seeks to determine the main drivers of students' commuting choices, and how they may have changed in view of possible different future scenarios after the first wave of the Covid-19 pandemic. Moreover, we also estimated the effect of multiple policy changes on this type of commuting. Overall, our analysis can also be helpful for the development of future local policies and strategies to reduce emissions, energy consumption, and non-renewables usage in the transport sector, which is currently of great interest and represents a key challenge for policy makers.

We estimated a mixed multinomial logit choice model of the Cameron and Trivedi (2005) and Train (2009) type as well as a latent class model, using data collected by the Mobility Working Group of the Italian Network of Sustainable Universities (RUS) by means of a 2020 online survey (Myftiu et al., 2024). This allowed us to estimate the probability of choosing among a finite set of unordered transport alternatives. Moreover, we also estimated the effects on students commuting preferences with respect to multiple policy changes. At the international level, our paper's main contribution relates to how students' commuting habits may have changed in view of possible future scenarios after the first wave of the pandemic. This pandemic has been one of the most significant crises of the last decade, with a considerable impact on people's lives – especially the young, who have faced their first true global crisis in the form of this pandemic. This led to dramatic changes in their habits. The paper provides evidence, in a very specific context, such as that of a small city heavily dependent on the demand for services related to higher education, of real and potential changes in mobility habits brought about by the pandemic. Specifically, the paper can offer insights for possible transportation choices in the future, which can be characterised by two different scenarios: a resurgence of the virus and its further attenuation. The study leverages a survey conducted in the summer (July 2020) after the lockdown in Italy. This enabled the extraction of information strongly influenced by both the effects of the recently experienced shock and the potential impact it may have on future choices characterised by uncertainty about the evolution of the pandemic. Furthermore, future surveys may provide interesting insights into changes in transportation choices over more extended timeframes beyond the peak of the pandemic event.

The remainder of the paper is structured as follows. Section 2 provides an overview of the existing related literature. Section 3 describes the study context and data sources. Section 4 analyses the methodology, while Section 5 presents the results of the mixed multinomial logit model and of the latent class model. Section 6 concludes with a discussion on policy implications.

2. Literature review

Our paper attempts to bridge together two different research streams: (i) works that examine the impact of university students' commuting habits on the environment; and (ii) works that investigate the pandemic's impact on mobility habits.

2.1. The impact of university students' commuting habits on the environment

Universities are institutions which generate daily traffic. Thus, they can negatively affect their surrounding area in terms of traffic congestion and air pollution. Several studies have examined the community habits of university staff and students with the aim of determining travelling patterns and understanding the main obstacles to the development of sustainable mobility.

Eluru et al. (2012) employed survey data on commuting patterns of students, faculty, and staff from McGill University, Canada, with the aim of analysing the factors that discourage individuals from commuting by public transit, and for people who commute by public transit, which factors influence transit route choice decisions. The results emphasise the role of travel time, number of transfers, walking time, and initial waiting time on propensity to choose transit. Faculty members were the least likely to choose the transit mode for commuting compared to staff and students. The policy sensitivity analysis indicated that the reduction of transfers within transit route alternatives would offer the greatest advantages. Further, reduction in travel times by transit mode could increase the proportion of riders using transit. Using web-survey data on a sample of students and employees at the University of Trieste, Italy, Rotaris and Danielis (2014) analysed the impact of various parking pricing, parking restrictions, and bus subsidisation policies. They found that modifying the parking regulations highly influences mode choice in favour of bus use, in particular for teaching and administrative staff. Alternatively, fully subsidising bus services was also found to significantly impact bus ridership, affecting the mode choice of the teaching staff. Finally, increasing parking prices and imposing new parking restrictions would increase bus ridership by 19 %, whereas reducing both bus and parking subsidies would do so by 13 %.

Zhou (2014), using survey data from the University of California, Los Angeles (UCLA), found that university students are more likely to share a residence in exchange for rent affordability, bus proximity, and short commute. They are prone to jointly determining their housing and mode choices. Transit pass subsidies crucially influence university students' alternative transportation use. These results suggest that affordable housing options with reasonable bus proximity and commuting distance could increase the use of alternative transportation among university students. Rérat (2021) focused on the University of Lausanne, Switzerland, and used web-survey data to study the modal shares of various means of transport and their evolution over 13 years, as well as the ways in which they vary among the university community. His analysis showed that roughly 60 % of university members used public transport, and a further 10 % combined several means of transport (mostly a two-wheeler and public transport). Cycling was found to have experienced remarkable growth, with the doubling of share and tripling of numbers between 2005 and 2017. On the contrary, cars have been in decline since 1990, reaching a use of only 15.8 % in 2017. These trends are the results of the implementation of national and regional policies aimed at developing an efficient offer of public transport. Moreover, the university administration took measures to influence staff and students' mobility habits, such as regulating parking and staggering the start times of classes. Crotti et al. (2022) by using survey data from the University of Insubria, Varese, Italy, investigated which travel demand management policies car users perceived to be the most effective in reducing the number of solo-drivers. They found that restrictive parking policies were supported by female car commuters, students, and employees belonging to science departments. Transit-oriented and multimodal options (including bikes) were chosen by faculty/staff car users, by users willing to leave their cars at home amidst favourable weather, and generally by those living in towns without railway stations. Hidalgo-González et al. (2022), relying on a web-survey conducted at the University of Leon, Spain, showed that male students use bicycles and motorcycles more often than their female counterparts, while the car is the main transportation mode for female workers. The respondents also indicated that unsafe cycle paths, thefts at universities, bus fares, and the frequency of service were the main barriers to a greater use of bicycles and buses.

Various studies have shown that the understanding of university commuting is particularly important for driving more sustainable transportation policies (Danaf et al., 2014). Indeed, university students have specific transportation-related needs and preferences, high mobility (Cadima et al., 2020), and a greater level of flexibility in using different transport modes than other commuters (Zhou, 2012; Whalen et al., 2013). In addition, university students are more capable than other groups to learn the technical knowledge required to implement and promote sustainable mobility management and policies (Leon et al., 2018; Coutts et al., 2018) and are more aware about environment and both mental and physical health is increasing. For example, Sottile et al. (2021) employ an improved Travel Demand Management based on a smartphone application that allows to personalize a travel plan. They investigate the changes of Roma Tre University students' behaviours concerning commuting modes and lifestyle behaviours. Results suggest that the use of the smartphone app causes an increase of 8.1 % in the use of more sustainable transport.

Another important contribution to the literature on factors affecting active (more environmental-friendly) transport choices is made by Ababio-Donkor et al. (2020). By studying data on Edinburgh residents captured through a survey and analysed with an Integrated Choice and Latent Variable (ICLV) framework, they have found that individuals with pro-environmental attitude are more likely to travel with sustainable travel modes, so activated (social) personal norms and pro-environmental attitude have a significant role on travel behaviours. Moreover, the age of a subject is an important driver of choosing active transport choices; the younger the person, the higher the probability of opting for active transport modes. The same result is obtained when highly educated people are considered.

Some authors have highlighted how both students and university staff are generally more inclined to use active and healthier transportation modes (Whalen et al., 2013). Recently, the 'UN Agenda 2030' and the UNESCO initiative 'Education for Sustainable Development' have emphasised the crucial role of universities in building a greener society (Marques et al., 2019) and in accomplishing 'Sustainable Development Goals' (Leal Filho et al., 2019).

2.2. The impact of the Covid-19 pandemic on the mobility habits

Covid-19 caused drastic changes in daily activities and travel patterns. A growing research stream in the literature has been analysing the pandemic's impact on mobility habits, reaching the conclusion that the pandemic led to a severe reduction in public transport mobility as a result of both personal preferences and the governments' preventative measures (Wang et al., 2020; Transport Focus, 2020). For example, Abdullah et al. (2020), using survey data from various countries around the world, concluded there to have been a significant shift from public to private transport and non-motorised modes. In addition, trip purpose, mode choice, distance travelled, and the frequency of travels for primary needs were significantly different before and during the pandemic. Basu and Ferreira (2021) analysed historical mobility trends in the Boston area and the effects of Covid-19 on mass transit, arguing that the pandemic could be an opportunity to reverse increasing car ownership trends and promote sustainable mobility alternatives. Employing stated-preferences web-survey data collected in India, Das et al. (2021) showed that commuters' socio-economic characteristics, such as age, gender, and monthly income, tend to significantly influence mode switch preferences. Moreover, trip characteristics, such as travel time, overcrowding, and hygiene are related to mode shift preferences from public transport to car use. Specifically, travel patterns indicated a significant reduction in public transport mode choice post pandemic, with higher preferences in selecting a car mode. Respondents sensitive to higher quality services, such as low crowding and cleanliness, showed a higher propensity to switch to cars. Molloy et al. (2021), relying on a GPS tracking panel of 1,439 Swiss residents and web-survey data, found decreases of approximately 90 % in public transport use and 60 % in average daily distance. Cycling increased significantly. Considering socio-demographic variations, the working population with a tertiary education (i.e., from university or technical college) was able to reduce their daily travels more significantly than less-educated populations. This difference became more pronounced towards the end of and after the lockdown. Eisenmann et al. (2021) conducted a representative travel survey in Germany during the first period of the lockdown, and analysed overall and individual attitudes towards transport modes, taking cycling, public transport, and cars into consideration. They also studied changes in the perception of individual mobility options with a focus on car-free households. Their results suggest that public transport lowered during the first period of the lockdown, while individual modes of transport, mainly the private car, increased. In line with these results, Rotaris et al. (2023) use a multinomial logit to model the drivers of children and parents' choice of active commuting to middle school in Trieste. They acknowledge the role played by children in deciding the transport mode, finding that both children and parents' choice is affected by the possibility of contracting Covid-19, resulting into a shift to waling and car as a mean of transportation. In their analysis, Covid-19 infection is one of the main factors that boosts active mobility choices. Dai et al. (2021) investigated the effects of fare-free policies implemented on the daily subway passenger flow in three Chinese cities, i.e., Hangzhou, Ningbo, and Xiamen, to sustain public transport. They used a synthetic control method to establish a counterfactual outcome of interest for these cities. The results demonstrate that the fare-free policy in Hangzhou had no significant effect on subway ridership, whereas it increased subway ridership by approximately 24 % in the first month in Ningbo, and by 2.3 times over 5 in Xiamen. Thus, fare-free policies had a limited effect, and the authors suggested that they should be implemented in conjunction with multi-pronged approaches during the recovery phase of the Covid-19 pandemic.

In light of these findings, our paper advances the related literature by filling a gap in the understanding of the pandemic's impact on students' commuting habits, considering two different scenarios, i.e., a resurgence of the virus and its further attenuation. Bagdatli and Ipek (2022) previously addressed the same issue by investigating the transport mode preferences of university students in the post-pandemic period in Istanbul by using online-survey data. Their results indicate that, after the pandemic, the travel demand for public buses, shared minibuses, and light rail transit critically decreased, whereas there was an increase in the demand for private car use, e-scooters, hoverboards, and active travel modes. Furthermore, Campisi et al. (2022) analysed the changes in travel behaviour of university students at the Kore University of Enna, Sicilia, Italy, by employing survey data during the pandemic period. They found that their participants were likely to maintain their new active way of commuting, such as cycling and walking, while public transport might be negatively affected in the long term.

Fig. 1. Urbino's location on Italian territory. Note. Own elaboration of figure.

Table 1
Geography of enrolled students, academic year 2021/2022.

NUTS 1	NUTS 2	Frequencies	Share
Centre	Lazio	202	4.22
Centre	Marche	671	14.02
Centre	Toscana	98	2.05
Centre	Umbria	142	2.97
Foreigners	–	135	2.82
Island	Sardegna	153	3.20
Island	Sicilia	485	10.14
Northeast	Emilia-Romagna	534	11.16
Northeast	Friuli-Venezia Giulia	76	1.59
Northeast	Veneto	251	5.25
Northeast	Trentino-Alto Adige	0	0.00
Northwest	Liguria	14	0.29
Northwest	Lombardia	178	3.72
Northwest	Piemonte	34	0.71
Northwest	Valle d'Aosta	0	0.00
South	Abruzzo	370	7.73
South	Basilicata	152	3.18
South	Calabria	198	4.14
South	Campania	356	7.44
South	Molise	95	1.99
South	Puglia	583	12.18
Total		**4.785**	**100**

3. Context, data, and descriptive evidence

3.1. Urbino and its university: a 'special' geography

The University of Urbino is an historical university (founded in 1506) located in the Marche region, specifically in the inner area of Pesaro-Urbino province, Italy (see Fig. 1) In the recent decades, the university, in collaboration with local institutions, conducted a remarkable project for the development of the cultural system though a restructuring plan that involved the entire urban and extra-urban fabric with a substantial land-use plan entrusted to the architect Giancarlo De Carlo. The old university buildings were renovated alongside new, modern structures. These buildings were assigned to new faculties, thus marking the beginning of the wider spread of the university in the historic centre. Over time, new courses and faculties were created: Political Science, Maths, Physics and Natural Sciences, Sociology, Foreign Languages and Literature, Environmental Sciences, Education Sciences, and Motor Sciences.

The university grew to such an extent that the city began identifying itself with it. The number of registered students reached a peak of roughly 22,000. However, this number has shrunk in recent years, mainly due to the increase in the number of Italian university locations and to the general decline of enrolled students in Italian universities. Nevertheless, it still is one of the main economic drivers for the city, along with tourism, the public sector, and handicraft. According to the latest available data (2021) from the Italian Ministry of University and Research, the University of Urbino Carlo Bo had 14,721 registered students (9,531 female and 5,190 male), 838 faculty members, including professors, researchers, and collaborators (425 female and 413 male), and 365 technical and administrative staff (210 female and 155 male). In terms of its educational offer, the university provides for 6 departments, 13 schools, and 37 degrees (16 bachelors and 21 masters). It is worth stressing that the student population is almost equivalent to the residential one: Urbino has 13,772 residents.[1]

The location of the university itself, with the existing transportation modes necessary to reach it, has become one of the main variables influencing future students' choice. Logistically speaking, the University of Urbino Carlo Bo suffers from several difficulties. For instance, Urbino municipality is located 485 m above sea level and has no railway station.[2] The nearest train station is in Pesaro, 35 km away along the Adriatic coast.[3] In general, transport to and from Urbino is particularly complex: reaching different geographic areas (neighbouring provinces or regions) requires combining several public means of transport, train and bus, or the use of private transportation. These aspects should be considered by local authorities and the university, given that non-resident or non-domiciled students need an efficient and articulated transport system.

Urbino is a very small city, currently equipped with a fair number of parking spaces following significant infrastructure investments from the municipality administration. Many of the previously-free available areas have now become toll parking, to both finance the allocated investments (including a large, covered parking area) and to try to regulate the rising demand from increased commuting (for a variety of reasons related to economic factors and the origin of the student population; in fact, the number of daily commuting students has significantly increased). The increase in parking expenses seems to have been offset, for many students, by the choice of being non-residential, thus saving accommodation expenses (daily commuting).

Today, the availability of parking spaces and their associated costs do not appear to be factors influencing the modal choices of those who have decided to use private vehicles. This issue could arise in future, especially if public transportation proves to be an unsuitable alternative.

Given the difficulties in reaching the city, a certain number of students decided to directly live within it. However, this has created specific problems in terms of availability of dwelling places and in terms of

[1] 2021 post-census population (Istat).
[2] The train connection to Fano (Adriatic coast) was stopped in 1987.
[3] Altitude data were supplied by the Istat database on the 'Main geographical statistics on municipalities', and the distance between Pesaro station and Urbino Centre was calculated through Google Maps.

Table 2
Average characteristics by main commuting mode.

	Car (driver with passenger)	Car (driver alone)	Car (passenger)	Walking	Public Transport	Total
Total (n of students)	952	3,054	612	3,568	5,098	13,285
Number of respondents (not weighted)	123	393	80	460	657	1,713
Away-from-home	48.5 %	49.3 %	75.1 %	97.4 %	58.8 %	67.0 %
Car owner	97.6 %	99.5 %	81.3 %	31.0 %	50.2 %	61.2 %
Distance from home (km)	30.20	24.76	25.39	1.75	21.15	17.60
Travel Time (mins)	33.35	15.00	15.00	15.00	39.79	25.83
Price (€)	8.15	8.67	1.02	0.00	2.57	3.61
Full-time student	53.1 %	43.6 %	81.1 %	87.0 %	77.1 %	70.5 %
Part-time student	27.5 %	27.8 %	8.8 %	10.1 %	18.0 %	18.4 %
Full-time worker	19.4 %	28.6 %	10.1 %	2.9 %	4.9 %	11.1 %
Days/week at university	2.46	2.39	3.17	3.80	3.40	3.20
Enrolment year	3.07	3.04	2.75	2.76	2.83	2.87
Law, economics, political science and sociology	10.6 %	19.2 %	14.1 %	14.4 %	15.9 %	15.8 %
Sciences	39.8 %	33.5 %	24.1 %	54.0 %	34.7 %	39.5 %
Humanities	49.6 %	47.3 %	61.7 %	31.6 %	49.3 %	44.7 %
Female	66.0 %	60.2 %	84.1 %	62.8 %	62.2 %	63.2 %
Age	25.98	29.48	25.12	22.41	24.04	25.04
Household size	3.50	3.32	3.48	4.08	3.69	3.69

Statistics are weighted with sampling weights.

urban public transport. To understand the importance of organising a sound transport system in Urbino, we must first underline the geography of students. If we consider the academic year 2021/2022 only, Table 1 shows there to be 4,785 newly enrolled students. These predominantly come from Marche (14 %), roughly 11 % come from neighbouring Emilia-Romagna, and 22 % from Sicilia and Puglia. Northwest regions are less represented.

3.2. Data sources

This paper's main data source was a survey promoted by the Mobility Working Group of the Italian Network of Sustainable Universities (RUS). It concerned mobility behaviours of Italian university students and personnel immediately prior to the Covid-19 pandemic (i.e., 2019) and potential changes in mobility behaviours induced by the pandemic.[4] The highly detailed questionnaire consisted of different sections, including[5]:

1. Personal characteristics of the interviewee: place and study/work schedules, smart working, distance learning (both pre-pandemic and during the Covid-19 period), and choices related to residence/domicile.
2. Characteristics of mobility capital: any private transportation means used or intended to be purchased.
3. Pre-pandemic home-to-university commuting habits in terms of frequency, transportation means used (investigating both the predominant means and the multimodal chain), distance, and travel time.
4. Anticipated changes in habits during the Covid-19 period regarding the mode of transportation, investigating reasons for a potential different choice, and hypothesising two alternative scenarios of low or medium–high health risk (Scenario 1, 'optimistic'; Scenario 2, 'pessimistic').
5. Any other changes: for students, the possible intention to change the attended university or residence during class periods; for all users, the willingness to modify schedules and/or days of in-person lessons or work (including evening hours and Saturdays).
6. The inclination to adopt more sustainable transportation choices, such as walking or carpooling.

A highly sensitive issue relates to the definition of 'commuting' in our framework. There is a wide range of logistical options that students not residing in Urbino may select to participate in teaching and related activities. For example, some students rent rooms or share apartments in Urbino. Among these, some remain in Urbino throughout the year, while others travel back to their hometown on weekends. Finally, other students commute to Urbino on a daily basis. In theory, the questionnaire was designed so as to be able to distinguish among all these possible options, as students were asked to disclose their student residence situation, commuting, domicile (including temporary), and permanent residence status. However, by inspecting the responses, we identified a number of discrepancies needing to be resolved.[6] Once done, we interpreted 'commuting' as the daily travel from the domicile to Urbino, and vice versa.

Regarding the scenarios considered to describe the socio-health risk in the questionnaire, they were defined (and presented to the respondents) as follows:

SCENARIO 1 (Optimistic): The virus has been almost eradicated, new infections have been reduced nationwide, distancing and protective measures are relaxed, and school activities for children are taking place regularly. University education, while taking precautions and avoiding excessive student concentration, is delivered in person, except for

[4] Although the survey was designed to be representative of the entire academic community via ex-post stratification and reweighting, the usual possible sample selection bias may be an issue as long as non-respondents systematically differ from respondents within each stratum.

[5] A full report on the university commuting choices during Covid-19 was reported by RUS in their White Paper (2021), 'Le attività del Gruppo di lavoro Mobilità della Rete delle Università italiane per lo sviluppo sostenibile'. The specific elaborated database used for this paper is available upon request.

[6] For example, a number of students stated that they were away-from-home, but Urbino was identified as their domicile and they also declared themselves to commute on a daily basis from the Puglia region (about 8 h travel time). In these few cases, we decided to directly correct the discrepancies by: 1. setting Urbino as domicile for away-from-home students and by selecting 'walking' as commuting mode, using the average walking time for those domiciled in Urbino in our sample; and 2. replacing outlying data points about travel time by regressing travel time on distance and substituting outliers with the linear fit.

Table 3
Regression results of the mixed logit choice model for students (base alternative: Public Transport).

Choice:(base alternative: Public Transport)	Car driver alone	Car driver with passenger	Car passenger	Walking
Away-from-home	0.622	1.186	2.398**	−1.630**
	(0.597)	(0.807)	(0.990)	(0.701)
Distance from home (km)	−0.0386	0.489*	−0.472*	−2.681***
	(0.266)	(0.296)	(0.244)	(0.285)
Car owner	6.066***	3.796***	1.918***	−0.139
	(1.029)	(0.639)	(0.363)	(0.199)
Female	0.0914	0.326	1.289**	−0.120
	(0.233)	(0.298)	(0.535)	(0.236)
Age	0.0313*	−0.0112	0.0327	−0.106***
	(0.0177)	(0.0269)	(0.0292)	(0.0334)
Days at university	−0.181***	−0.272***	−0.0684	0.0778
	(0.0638)	(0.0812)	(0.0913)	(0.0711)
Household size	−0.188**	−0.129	−0.121	0.242***
	(0.0929)	(0.127)	(0.145)	(0.0870)
Full-time student	[base category]	[base category]	[base category]	[base category]
Part-time student	0.599**	0.508*	−0.974*	−0.0436
	(0.268)	(0.306)	(0.568)	(0.292)
Full-time worker	1.198***	1.152**	−1.042	0.531
	(0.399)	(0.496)	(0.856)	(0.466)
Enrolment year	−0.0965	−0.0249	−0.137	0.0935
	(0.0746)	(0.0870)	(0.121)	(0.0799)
Law, economic, political science, sociology	[base category]	[base category]	[base category]	[base category]
Sciences	0.0383	0.753*	−0.0833	0.264
	(0.310)	(0.446)	(0.571)	(0.296)
Humanities	−0.595**	0.109	−0.0302	−0.631**
	(0.290)	(0.421)	(0.498)	(0.288)
Alternative specific variables	Average effect	Spread		
Travel Time (mins)	−0.0319**	0.0309**		
	(0.0137)	(0.0146)		
Price (€)	−0.0978***	0.0781**		
	(0.0294)	(0.0385)		

Mixed logit choice model (weighted with sampling weights). Distribution of coefficients of alternative-specific variables: uniform. N of cases: 1360. Robust standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Correctly predicted outcomes: 83.9 %.

specific cases. For courses fully delivered in person, complete online education is not available.

SCENARIO 2 (Pessimistic): The virus is still dangerous, the infection rate has slowed but continues, strict distancing and protective measures are necessary, and school activities for children are not regular. University education is conducted in person only for smaller courses and is only partially available (not all lectures). The entire offering is fully available online.[7]

The survey was distributed to 44 universities, distributed throughout the national territory, in July 2020, and was based on an online questionnaire submitted to students, academic staff, and technical-administrative staff who participated in the initiative. The partial results presented here refer to data collected by the University of Urbino Carlo Bo only. The sample included 1,745 observations and was structured as follows: 82.81 % students, 9 % faculty members, and 8.19 % technical and administrative staff. Although the survey was submitted to both students and university personnel, our primary focus was on the former. On the one hand, they represent the bulk of the university's community and, on the other, commuting to Urbino has been growing in the past few years – particularly due to students' transportation. In the past, the students' university life was mostly of a residential nature with long-term stays, so transport and mobility policies were not handled by local administrations as a priority or as worthy of investment. However, with the increase of students' commuting, related to changes in their studying organisation (for example, lectures organised by semester), living habits, and local rental policies, they now ask for a more efficient transport system to reach the university. Led by these motivations, students represent the real sample for our analysis, composed of 1,360 observations.

3.3. *Descriptive evidence*

Table 2 reports the average characteristics of students broken down by the modal choices in the year 2019.

Public transport represents the preferred choice (38 %), followed by the use of a car (either as a driver or passenger, 35 %), and walking (27 %). Interestingly, substantial (unconditional) differences emerged across students choosing different modes. For example, as expected, car ownership was the most popular choice among car drivers (almost 100 %) and much less for those walking or using public transport. As for the distance, those who walked clearly lived within short distances of the university. The student's status was also important: the share of full-time students was the lowest among those driving alone and the largest among those walking to the university.

4. Econometric framework

To analyse the drivers of the University of Urbino Carlo Bo students' commuting patterns, we estimated the preferences of students by means of discrete choice models. Each individual must choose just one among a finite set of unordered mutually exclusive alternatives (Cameron and Trivedi, 2005; Train, 2009). The most common estimators used to model the drivers of discrete choices are the multinomial logit (or probit), the nested logit, the latent class model and the mixed multinomial logit. These estimators differ in the assumption made about the characteristic of the error component.[8] The mixed multinomial logit features a number of advantages over other discrete choice models. As pointed out by Train (2009), the mixed multinomial logit is a flexible tool for estimating a random utility model, as it '*obviates the three limitations of standard logit by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors*' (Train, 2009, p. 134).

The mixed multinomial logit model specifically uses random coefficients to model the correlation of choices across alternatives. This characteristic allows one to relax the assumption of independence of irrelevant alternatives (IIA), which is conversely imposed by the conventional multinomial logit model. This advantage comes at the cost of

[7] The description and use of both scenarios is presented in Section 4.2.

[8] The multinomial logit (or probit) assumes that the ratio of the probabilities of choosing any alternatives is independent of the attributes or the availability of another alternatives (the independence of irrelevant alternatives – IIA – property) (Mc Fadden et al., 1977). The nested logit, instead, allows relaxing some of the assumptions of the multinomial logit assumptions. It is a generalization of the multinomial logit model where alternatives may be joined in several nests (groups). In the nested logit model, the IIA assumption is relaxed, and random components are assumed to be independently and identically distributed as extreme-value, so alternatives' errors may be correlated in the same nest but uncorrelated for different nests (McFadden, 1978; Heiss, 2002). Finally, the latent class model could be represented as a semiparametric approach to multinomial logit and similar to the mixed logit. In the latent class model heterogeneity of coefficients is assumed to be discrete and distributed across a given number of classes.

requiring identifying ex ante how random coefficients are distributed.[9]

This mixed multinomial logit model is derived from a utility framework, so an i^{th} student chooses the alternative that would provide them with the highest (unobserved) utility. Given that utility is unobserved, it represents a latent variable, which depends on q^{th} measured individual-specific attributes, alternative-specific characteristics, random coefficients, and components. In our model, alternatives were represented by the most important means of transportation used by each i^{th} student to commute to university. Five different alternatives were presented: car driver without passengers, car driver with passengers, car as passenger, public transport, and walking. Means of transport were indexed by $j = 1, \cdots, J$, where $J = 5$ and the choice among them were unordered. Students were assumed to be drawn at random from a population. The utility U_{ij} associated with the discrete j^{th} most important transport mode for the i^{th} student, expressed as follows:

$$U_{ij} = \beta_i X_j + \delta_j q_i + \varepsilon_{ij} \tag{1}$$

where β_i represents random coefficients that can vary among students, so they coincide with their taste. X_j is the vector of observed alternative-specific variables. δ_j represents the fixed alternative-specific coefficients, and q_i refers to a vector of student-specific variables. Finally, ε_{ij} is the random term that is *iid* extreme value (type I). Students were asked to compare the random utility of each alternative and choose the transport mode that provides the maximum utility. In other terms, the decision maker knows the value of their β_i and ε_{ij}'s for all alternatives and chooses a specific alternative j if and only if $U_{ij} > U_{in} \forall j \neq n$.

We can directly observe X_{ij} but not the coefficients β_i, which vary across students with a distribution characterised by an $f(\beta)$ density function. To choose the most appropriate distribution function among the possible alternatives, we considered the AIC and BIC criteria: the favourite distribution is the uniform distribution for both alternative-specific variables.[10]

In sum, we estimated following the mixed logit probability of choosing the j^{th} most important mean of transportation by the i^{th} student:

$$Prob_{ij}(\beta) = \int \frac{e^{\beta' X_{ij} + \delta_j q_i}}{\sum_{j=1}^{5} e^{\beta' X_{ij} + \delta_j q_i}} f(\beta) d\beta \tag{2}$$

where $\frac{e^{\beta' X_{ij} + \delta_j q_i}}{\sum_{j=1}^{5} e^{\beta' X_{ij} + \delta_j q_i}}$ are the logistic probabilities evaluated at parameters β. Equation (2) was estimated by the maximum simulated likelihood. Since our dataset revealed only the student's chosen alternative, we deemed it necessary to normalise for the location of utility by taking the differences between each alternative j and a base alternative a as a base alternative. Ultimately, we chose the 'Public Transport' option.

Individual-specific variables

Individual-specific variables refer to personal characteristics of the respondent. Specifically, we considered a dummy for students living away-from-home, travel distance in km, a dummy for car ownership, gender, age, average number of days spent at university per week, household size, academic enrolment year, and the academic subject area (Law, Economics, Political Science, and Sociology; Sciences; Humanities).

Alternative-specific variables

We considered the actual travel time, expressed in minutes, from the declared domicile to Urbino depending on the chosen means of transportation. This does not refer to the travel time revealed by students, but rather to the time estimated by Google Maps. We built an origin–destination matrix of travels to and from Urbino to obtain a Google API Distance Matrix, which supplies information on the estimated travel time for three different commuting modes (driving, public transport, and walking).

We also considered an estimate of the mode-specific price paid for a one-route travel. Data on tariffs for public transportation were inferred from Adriabus (public transport limited liability consortium of the province of Pesaro-Urbino) and Trenitalia (national railway company), with 2019 as the reference period for prices. The price of car trips considers the official cost per km as estimated by ACI (Automobile Club d'Italia) and used by the Italian government. As for carpooling options, we considered an equal split of costs (including operation costs and depreciation) among passengers. Finally, we considered a null price for walking.

Table 4
Quantification of average marginal effects of alternative-specific variables.

	Estimated change in the number of students choosing:				
10-minute increase in time for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−254	132	16	21	86
Car driver alone	132	−469	53	59	226
Car passenger	16	53	−171	34	69
Walking	21	59	34	−402	288
Public transport	86	226	69	288	−668

	Estimated change in the number of students choosing:				
1€ increase in cost for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−77	36	5	6	30
Car driver alone	36	−139	15	18	70
Car passenger	5	15	−52	11	22
Walking (subsidy of 1€ for walking)	−6	−18	−11	123	−88
Public transport	30	70	22	88	−209

5. What drives students' choice of transportation modes?

5.1. Baseline scenario: before Covid-19

Our main estimates are shown in Table 3, where mixed multinomial logit model coefficients are reported, and 'Public Transport' is considered as base category. However, to more accurately interpret the results, we also quantified average marginal effects for alternative-specific variables in Table 4 and for selected student-specific variables in Figs. 1 and 2. Concerning the distribution of coefficients of our variables, in the adopted model, the dependent variable 'Choice' was distributed as a logistic function, while the alternative-specific variables, 'Travel Time

[9] As an alternative, we also consider a latent class model (section 5.3) where coefficients are assumed to vary across a finite set of latent classes, thus not requiring any assumption about the distribution of coefficients. However, most of the discussion will revolve around results based on the mixed multinomial logit model, as it provides direct evidence about the (conditional) role played by original individual-specific variables in driving agents' choice, thus enabling a more simple and transparent support for policy makers in designing ad hoc interventions targeted to specific groups of individuals.

[10] We considered the following distribution functions: normal, correlated normal, truncated normal, uniform, and triangular. The results for all distribution functions were highly similar and remain available upon request.

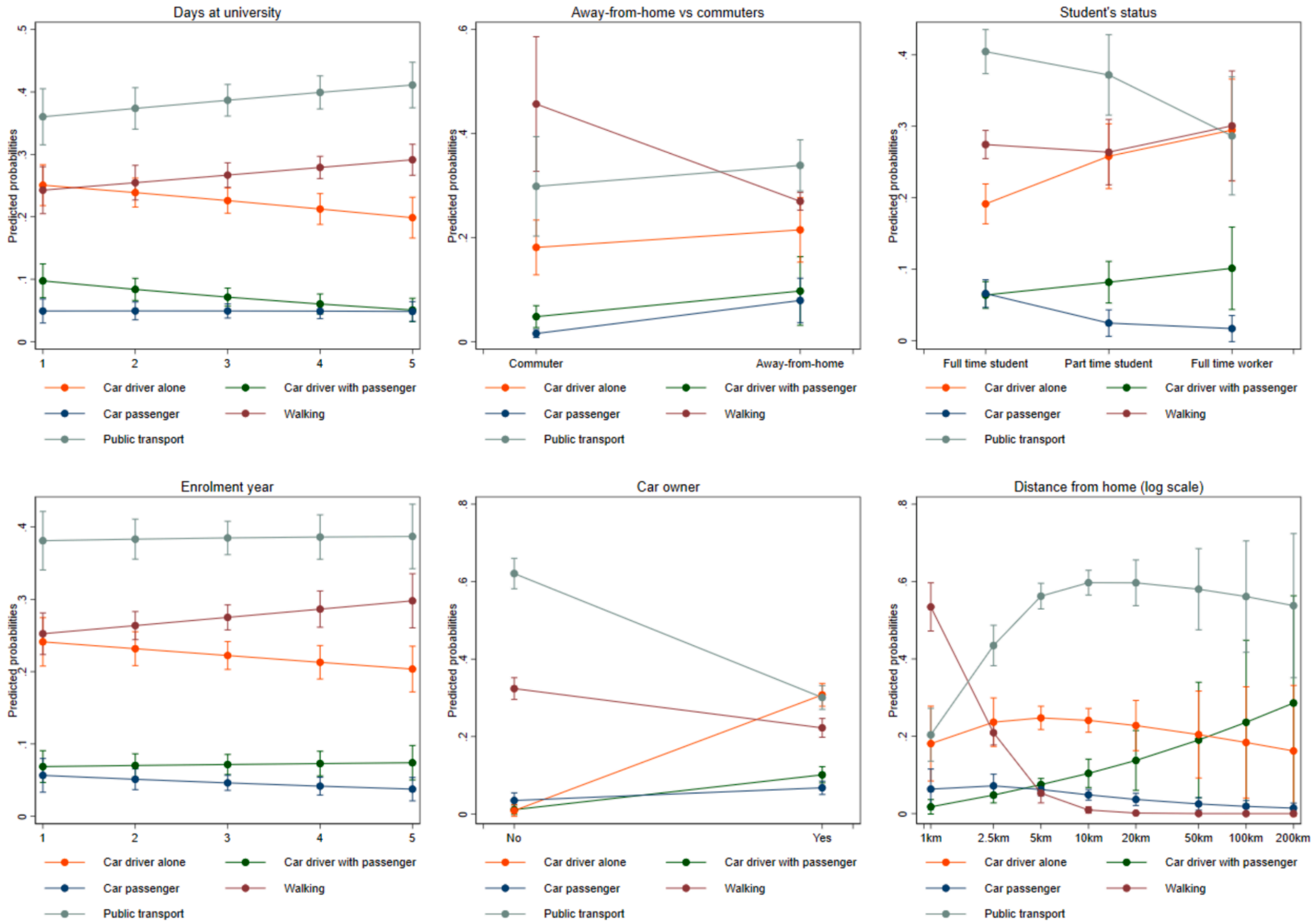

Fig. 2. Conditional predicted probabilities for main individual-specific variables.

(mins)' and 'Price (€)' were uniformly distributed.[11]

As shown in Table 3, we found that car ownership generated a higher probability of choosing a private car instead of public transport as the principal means of transportation. Moreover, away-from-home students were more prone to be car passengers than to opt for public transport. Conversely, away-from-home students were less likely to walk than use public transport. The same result was obtained when analysing the distance between home and university. The higher the distance, the lower the probability of being a car passenger or walking, meaning that students would opt for public transport. These results underline the importance of organising an effective public transport network to and from Urbino, especially since we observed a high share of students coming from Southern regions.

An increase in the number of days spent at the university generated a lower propensity of being a car driver, both alone and with passengers, with respect to being a user of public transport. We obtained similar results regarding household size: the higher the number of family members, the higher the probability of driving a car alone than taking public transport. In terms of work/study status, being a full-time worker, or a part-time student, clearly boosted students' likelihood of choosing a car over public transport. These latter two results reflect the need to be freer from time and other passengers' constraints because of study/work and family commitments. Finally, we found academic subject area to have no impact on principal means of transport, except for humanities: students enrolled in a humanity course (compared to those who chose law, economics, political science, or sociology) were more prone to travel with public transports than to drive or walk.

To better understand the consequences of alternative-specific variables, we evaluated an increase of 10 min in travel time and a 1€ increase in the cost of the route, respectively. Table 4 shows the average marginal effects of these scenarios in terms of estimated change in the number of students for each means of transportation. All average marginal effects were statistically different from zero, with a p-value at least lower than 5 %. Furthermore, we found that the number of students choosing a specific means of transportation decreases in response to an increase in travel time. This result was particularly remarkable for public transport: 668 fewer students chose public transport if a 10-minute increase in travel time was verified. Furthermore, when applied to driving alone, this scenario prompted students to opt for public transport (−469 car driver students and +226 students that use public transport); the same held true when the analysis involved walking (−402 students decided to walk to Urbino and +288 opted for public transport). We can thus assert that a small variation in time is sufficient to make a large number of students opt for an alternative way to reach university. The second part of Table 4 points to the same conclusion concerning the cost increase. A peculiar situation concerns walking. In this sense, we did not consider a higher cost, but rather an incentive for those who chose walking: 1€ for walking appears to be enough to encourage a rather large number of students (123) to walk instead of taking a car or public transport.

[11] We selected the uniform distribution after having compared the most common distribution functions (normal, truncated normal, uniform, correlated, and triangular). The uniform distribution was chosen by considering the AIC and BIC.

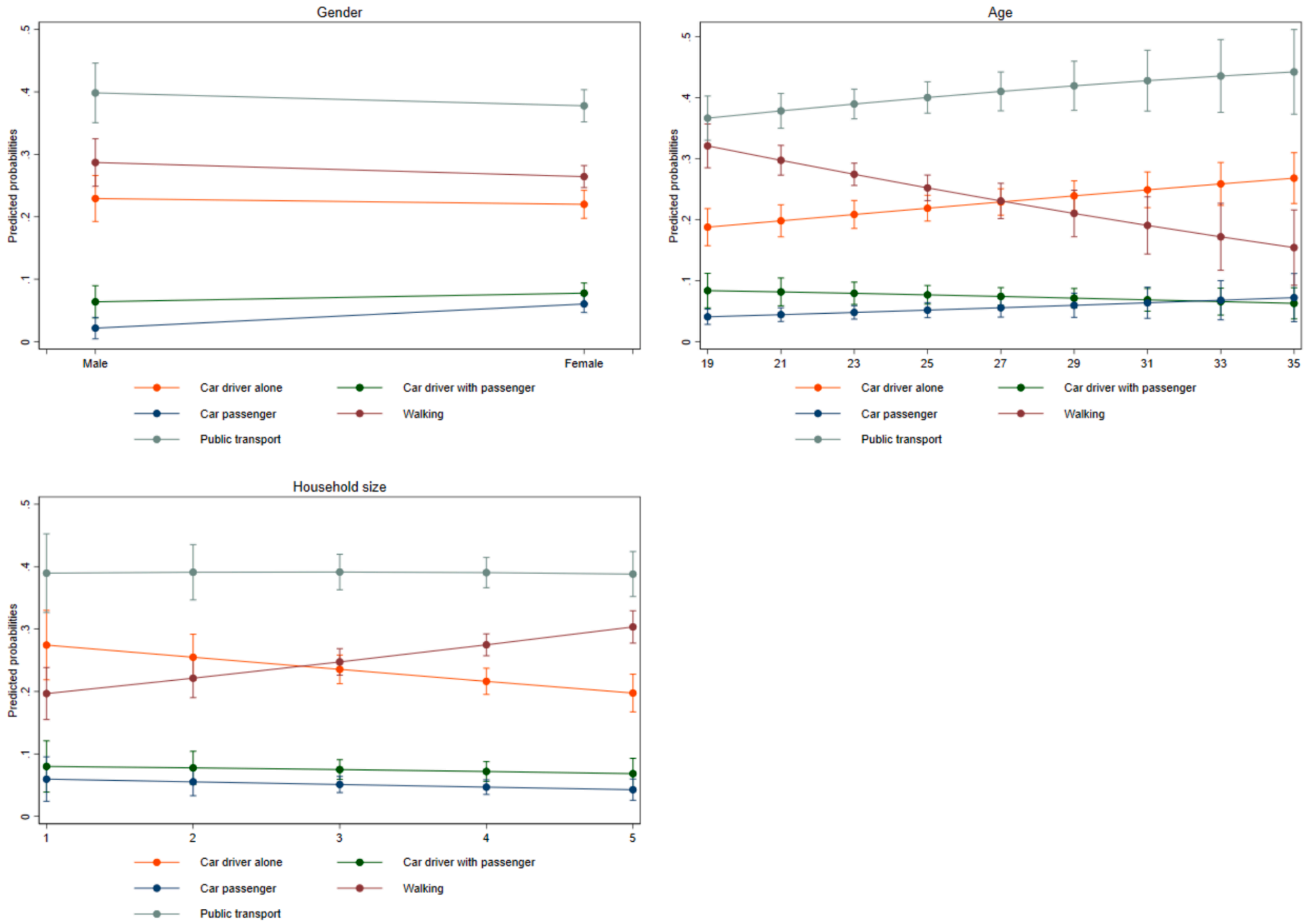

Fig. 3. Conditional predicted probabilities for additional demographic individual-specific variables.

The analysis on the driving factors of the principal transportation mode involved the study of the main individual-specific variables, including the demographic ones. Fig. 2 reports the conditional predicted probabilities of each transportation mode for different levels of individual-specific variables. Concerning the use of public transport as the principal means of transportation, we can assert that all evaluated individual-specific variables were relevant drivers of public transport demand. The increase in the number of days spent at the university and in the distance from home, or being an away-from-home student, positively affected the probability of using public transport. Focusing on distance, we found 1 km to be an important threshold for prompting the decision to be a car driver with a passenger or to use public transport instead of walking or driving alone. Workers and/or car owners had a lower probability of using public transport. The enrolment year appeared not to influence the probability of choosing public transport.

By analysing the estimates for car passengers, Fig. 2 shows that conditional predicted probabilities for this group of students reflect a similar trend of public transport. The results differed only with respect to enrolment year and car ownership variables. The higher the enrolment year, the lower the probability of sharing a car and being a passenger. Conversely, even if a student were to own a car, they would have a higher probability of being a passenger.

Concerning students as car drivers, owning a car or being a worker increased the probability of driving alone. The more time spent at work, the higher the conditional probability of students taking their car without passengers. These results could be a signal that working students are more likely to afford the ownership of a car and decide to drive alone so as not to be bound by other people's commitments. Students were found to substitute the possibility of driving alone with other types of transport modes if they had to stay in Urbino for almost a week. This means that, if days spent at university increase, the conditional probability of being a car driver alone decreases. Indeed, Fig. 2 shows that the probabilities of walking or taking public transport grow if the number of days at the university increases.

A surprising result on single car drivers refers to the distance from home variable. As shown by the figure, we can see that, up to a specific distance (<10 km), the probability of choosing a car as the principal means of transportation increases but, after this threshold, the same conditional probability starts to decline. Generally, it is convenient for students to use their own cars when coming to Urbino if the distance is not excessive, otherwise they tend to prefer using public transports or being a car driver with passenger(s) and share the costs of transportation with others, even if the estimated conditional probability is lower in the second option.

Finally, the probability of choosing to walk to the university was found to grow with the number of days spent at the university and with the year of enrolment. Another interesting result pertained to distance from home: if the students lived more than 1 km away from university, they would not come on foot. Walking was the most probable choice if the distance from university was lower, or equal, than 1 km.

Fig. 3 reports estimated conditional probabilities for different values of demographic individual-specific variables. We found females to have a higher conditional probability of choosing walking or public transport as the principal means of transportation, and a lower probability of choosing cars compared to males. This result could accord with prior research, which has stated that females are more likely to adopt pro-

Table 5
Average marginal effects of changes in commuting habits in post-Covid scenarios.

Probability of changing commuting habits post-Covid	Optimistic post-Covid scenario	Pessimistic post-Covid scenario
Away-from-home	0.110**	0.037
	(0.054)	(0.064)
Distance from home (km)	0.0176	0.007
	(0.019)	(0.023)
Travel Time (mins)	−0.000	0.000
	(0.000)	(0.000)
Car owner	−0.009	−0.015
	(0.024)	(0.030)
Days at university	−0.008	0.0173**
	(0.007)	(0.008)
Full-time student	[base category]	[base category]
Part-time student	−0.041	−0.035
	(0.030)	(0.038)
Full-time worker	−0.056	0.0025
	(0.044)	(0.061)
Enrolment year	0.009	0.010
	(0.008)	(0.009)
Law, economics, politics, sociology	[base category]	[base category]
Sciences	−0.018	−0.053
	(0.035)	(0.041)
Humanities	−0.008	−0.0005
	(0.033)	(0.040)
Female	0.040	0.039
	(0.026)	(0.0312)
Age	−0.002	−0.003
	(0.002)	(0.003)
Household size	0.004	0.006
	(0.010)	(0.013)
Intention to reduce presence post-Covid	0.132***	0.142***
	(0.022)	(0.032)
Observations	1369	1369

Average marginal effects based on probit estimates (weighted with sampling weights). Robust standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

environmental behaviours and pay more attention to environmental problems (Zelezny et al., 2000; Polk, 2003; Beirão and Cabral, 2008; Zavareh et al., 2020). Furthermore, age had a relevant role in choosing the means of transport: the older the student, the higher the probability of reaching the university by car, driving alone, or by public transport. When household size increases, the probability of walking grows, while that of using a car alone declines.

5.2. Transport sector changes and post-Covid scenario

This section addresses whether individual characteristics systematically related to an expected change in commuting habits after the Covid-19 pandemic. The analysis, as well as the literature, on the pandemic's impact on mobility habits concerns the rising awareness over the last two years and is strictly connected with both the personal preferences of individuals and the government measures to contain the spread of the virus.

5.2.1. The transport sector during the pandemic in Italy

During the pandemic, the Italian Ministry of Sustainable Infrastructure and Mobility (MIMS) took many actions in the transport sector to constantly guarantee commuters' safety and their possibility to travel, and to economically support the sector. From an organisational standpoint, during the first lockdown, which was more restrictive and envisaged less mobility needs, different national measures were taken for the different means of transportation; for example, air travel operation was limited to some airports only, with the personnel of other airports being made available. In general, many rail and air routes were reduced or removed. During lockdowns and in the following phases, the availability of public transport was also limited, with vehicles being repeatedly sanitised at close intervals and their capability being reduced. Commuters were asked to wear FPP2 masks, maintain a distance of at least one metre from each other, be provided with a certification attesting the absence of the virus[12] and, in some situations, respect a quarantine after a trip, even if they were asymptomatic (fiduciary isolation). All these interventions were applied to avoid the overcrowding of transport vehicles so as to curb the spread of the virus and relieve pressure on hospitals. During 2021 and 2022, given the diffusion of new virus variants, the government's decisions continued to adapt to the situation but, also thanks to vaccination campaigns, transport restrictions were gradually relaxed: routes to and from Italy were restored, public transport capacity slowly returned to maximum and, in June 2022, the obligation to wear masks was relaxed. The MIMS has recorded that, in 2020 and 2021, the frequency of choosing local public transport and rail transport decreased with respect to the pre-pandemic situation; air transport also decreased but, in 2022, saw an increase, although still remained below pre-pandemic levels (MIMS, 2022).

The various transport sectors (rail, road, air, and maritime) also received economic support. Between 2020 and 2021, 10.2 billion euros were allocated to them, further to prior financing for integration funds, payments moratorium, and investment support measures.

The adopted measures were more complex for private means of transportation. Italian regions were classified into coloured zones (red, orange, yellow) depending on the severity of the contagion, meaning different displacement rules.[13] Moreover, in terms of car behaviour, specific rules were enacted and constantly modified.[14] Indeed, the pandemic fostered an increase in car commuting compared to pre-Covid levels, likely due to a lower risk of contagion.

These situations shed light on the necessity to propose new visions and policies about mobility. The return of interest in the private car or, more generally, in road transport as a safe, but most polluting, travel mean. On the one hand, numerous ministerial and European funding plans have been developed (Sustainable Mobility Plans, PNRR, and Complementary plans) to transform public mobility into a more socio-economic and environmentally-sustainable sector that could generate benefits for citizens and future generations. On the other hand, the emergency phase also drew attention to the importance of developing greener solutions for the road mobility sector.

The transport sector's main aim is to pave the way for advantages in terms of safety, conditions of liveability in urban centres, health, the environment, and ecosystems.

[12] Issued if a molecular or antigenic test was carried out by swab and a negative result obtained.

[13] Red zone: travelling at any time of the day is prohibited unless accompanied by self-certification proving a valid reason (work, purchase of primary goods, or health) even within one's own municipality. Returning to one's home is always permitted. Orange zone: travelling between 10 pm and 5 am is prohibited, except for proven reasons. At other times of the day, it is possible to travel within one's own municipality without having to present any self-certification. Travelling in and out of one region to another is prohibited, except for proven reasons. Yellow zone: there is a curfew from 10 pm to 5 am. Night is thus the only time when it is necessary to provide a self-certification explaining the reasons for the move. Travel for health, work, and necessity reasons is permitted.

[14] Only those who travel with members of the same household and share the same dwelling, or who are simply cohabiting or roommates, are exempt from wearing masks in the car. In all other cases, a mask must be worn in the car. Furthermore, a maximum of three passengers was allowed.

5.2.2. Post-Covid scenario estimates

The survey employed proposes two alternative post-Covid scenarios. In Scenario 1 ('optimistic'), the pandemic has been almost eradicated and new infections have reduced throughout the country. Moreover, social-distancing and protective measures have been relaxed, and school activities for children are running smoothly. University teaching activities, albeit with precautions and avoiding excessive concentrations of students, is provided in attendance, except in special situations. As to courses fully held in-person, full online teaching is not available. In contrast, in Scenario 2 ('pessimistic'), the virus remains dangerous despite contagions having slowed. Strict social-distancing and protective measures are still in place, and educational activities are not regularly active. Only the smaller university courses are delivered in-person, with the rest being fully offered online.

To study these two scenarios, it was necessary to account for the fact that the mobility habits questionnaire was submitted in July 2020, that is, immediately after the first Covid-19 wave when vaccines were not yet developed/available. This means that attitudes towards university commuting choices were still highly affected by the pandemic. It should be noted, in this respect, that all teaching activities (lectures, graduation sessions, etc.) for the second semester of the 2019/2020 academic year (February–May 2020) were held fully online.

As a first step, we estimated the drivers of the probability of changing commuting habits in the two post-Covid scenarios compared to the 2019 habits by way of a probit model. Results on average marginal effects related to changes of commuting habits in both post-Covid scenarios are reported in Table 5.

Only two variables were found to be statistically significant as drivers of changing students' university commuting habits. In the optimistic one, away-from-home students (i.e., those more distant to Urbino) were found to have a higher probability of changing means of transportation compared to commuter students. Among previous studies on the pandemic's effect on modal choices, this result could be in line with Abdullah et al. (2020) and Basu and Ferreira (2021). The former highlighted how, among different variables, the distance travelled significantly affected travel choices compared to the pre-pandemic situation. The latter analysed historical mobility trends in the Boston area and the effects of Covid-19 on public transport, arguing that the pandemic may have presented an opportunity to reverse personal transport choice.[15]

Concerning the pessimistic scenario, days spent in Urbino in university activities were found to play a positive and statistically significant (5 %) role in driving the commuting behaviours of students. An increase in the number of days at university generated a 1.73 % growth in students' probability of rethinking their transport choices. Finally, in both scenarios, the probability of changing transportation modes increased by 13.2 % and 14.2 %, respectively, if students decided to reduce the opportunities to travel to Urbino due to Covid-19: the *Intention to reduce presence post-Covid* variable was statistically significant at the 1 % level.

Our results on the drivers of mobility choices in the university environment in a post-pandemic scenario are useful for drawing mobility management policies that could be effective in similar crises. The results suggest that transport management policymakers should especially focus on the distance from the university and all variables related to it, other than user characteristics. This was also confirmed by Tolentino et al. (2024).

As a next step, we repeated the analysis described in Section 3 for stated commuting modes in the two post-Covid scenarios. Tables 6 and 7 show the estimated marginal effects of a 10-minute increase in travel/transport time and of a 1€ increase in travel/transport cost for each analysed principal means of transportation. For both scenarios, the results somewhat aligned with the pre-Covid situation, in that increased travel time or costs led fewer students to choose the specific analysed means of transport. Referring to travel time increase, if related to driving

Table 6
Average marginal effects of alternative-specific variables: optimistic scenario.

	Estimated change in the number of students choosing:				
10-minute increase in time for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−259	149	17	23	71
Car driver alone	149	−517	66	78	224
Car passenger	17	66	−193	42	69
Walking	23	78	42	−432	289
Public transport	71	224	69	289	−653

	Estimated change in the number of students choosing:				
1€ increase in cost for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−64	33	4	6	22
Car driver alone	33	−122	14	20	56
Car passenger	4	14	−46	11	17
Walking (subsidy of 1€ for walking)	−6	−20	−11	107	−71
Public transport	22	56	17	71	−166

Table 7
Average marginal effects of alternative-specific variables: pessimistic scenario.

	Estimated change in the number of students choosing:				
10-minute increase in time for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−704	401	53	75	174
Car driver alone	401	−1553	331	303	517
Car passenger	53	331	−735	156	195
Walking	75	303	156	−1313	778
Public transport	174	517	195	778	−1664

	Estimated change in the number of students choosing:				
1€ increase in cost for:	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
Car driver with passenger	−46	23	3	4	15
Car driver alone	23	−94	18	19	34
Car passenger	3	18	−43	10	12
Walking (subsidy of 1€ for walking)	−4	−19	−10	82	−49
Public transport	15	34	12	49	−110

[15] Specifically, they asserted that the growing trends in car ownership can be substituted by more sustainable mobility alternatives.

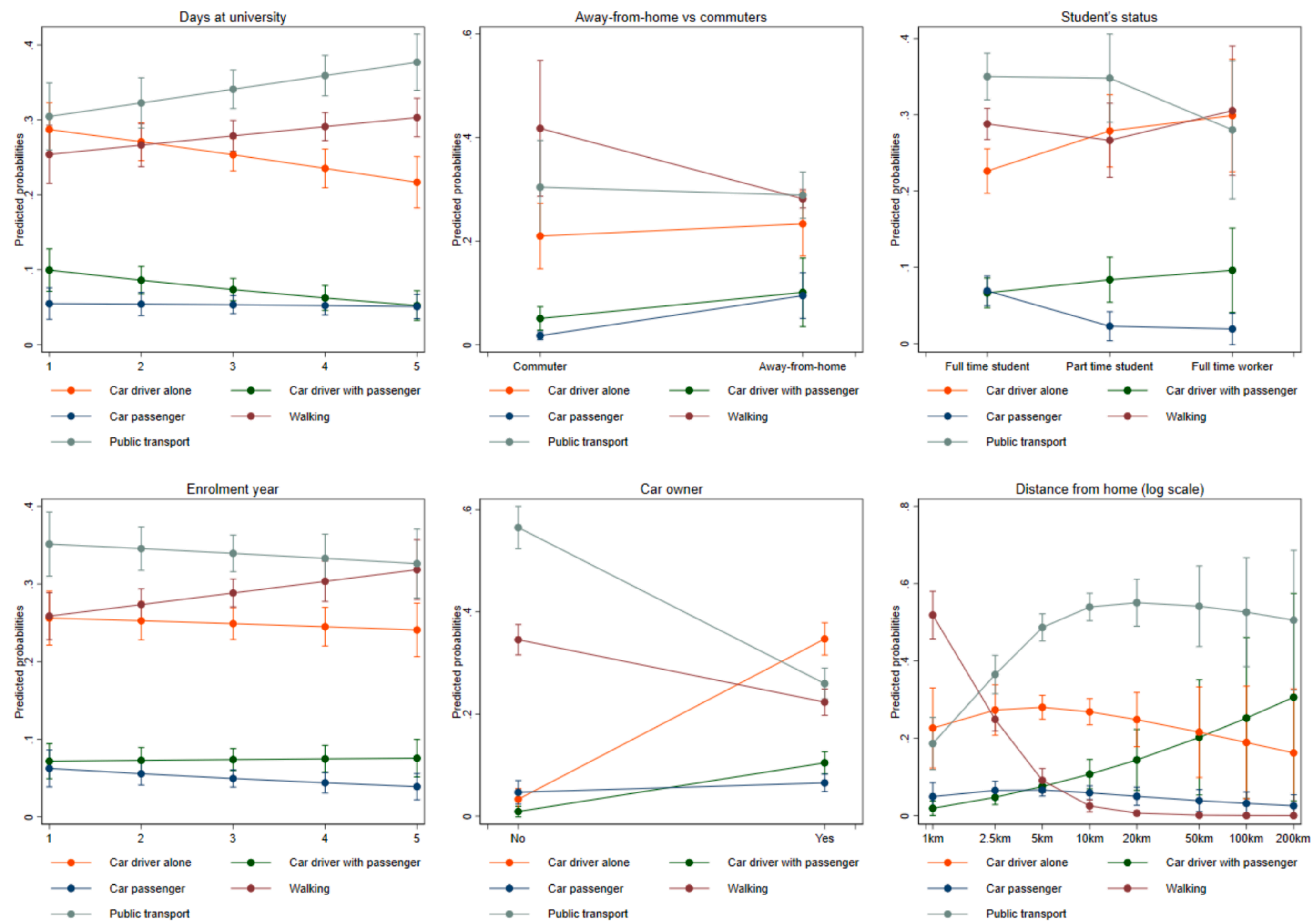

Fig. 4. Conditional predicted probabilities for main individual-specific variables: optimistic post-Covid scenario.

a car alone, travelling as a car passenger, or walking, students generally switched to public transport while, if travelling as a car driver with passenger(s) or if public transport became more time consuming, they would change their habits and decide to drive without passenger(s).

Concerning the increase in travel tariffs, the average marginal effects reflect the results of simulated travel time growth. A different result was obtained for walking with respect to the pre-pandemic situation: giving students an incentive to walk would increase, on average, the number of students that choose to go to university on foot, but also the ones who opt for public transport. This behaviour was not recorded in the pre-Covid scenario.

In terms of the previous section, we computed conditional predicted probabilities related to individual-specific variables for each transport mode in the post-Covid scenarios (with the results reported in Figs. 4–7). The estimated predicted probabilities of variables in Scenario 1 reflect the estimates of the pre-Covid scenario except for enrolment year: in the pre-covid situation, students were more likely to use public transport, but the related predicted probability remained constant across different enrolment years.

When comparing the two scenarios, it became apparent that, for most variables, the conditional predicted probabilities were almost identical to the pre-Covid situation. Indeed, our estimates underlined that, even if the situation were characterised by the presence of risk and uncertainty (pandemic) and the existence of few public transport links, students would still prefer to use public transport to reach Urbino. This was mainly dependent on where the students would come from, and it is worth remembering that a huge number of students were not daily commuters. From a policy perspective, a possible intervention seems to emerge quite clearly. In spite of the critical situation, students persist in choosing public transport as the main mode of transportation, so a better and more efficient public transportation system is required, as well as a closer collaboration between local authorities and transport companies.

5.3. Latent class analysis

On the one hand, the mixed multinomial logit model, implemented for previous estimations, allows one to estimate random parameters for alternative-specific variables that vary across respondents; nevertheless, this comes at the cost of assuming a certain distributional form for the random parameters. On the other hand, latent class models allow parameters for alternative-specific variables to differ across different (unobserved) latent classes of respondents; any distributional assumption about random parameters is required (Greene and Hensher, 2003). Latent class models estimate each individual's conditional probability of belonging to each latent class. We considered the same set of respondent-specific variables used in the mixed multinomial logit model as drivers of latent class membership.[16] We employed the expectation–maximisation algorithm developed by Pacifico and il Yoo (2013) and il Yoo (2020). By considering AIC and BIC, the selected number of latent classes was two. The results are reported in Table 8.

Latent class 1 featured students who lived closer to Urbino

[16] Due to convergence issues in estimating standard errors, we excluded the variables of household size and enrolment year, and aggregated full- and part-time workers into a single category.

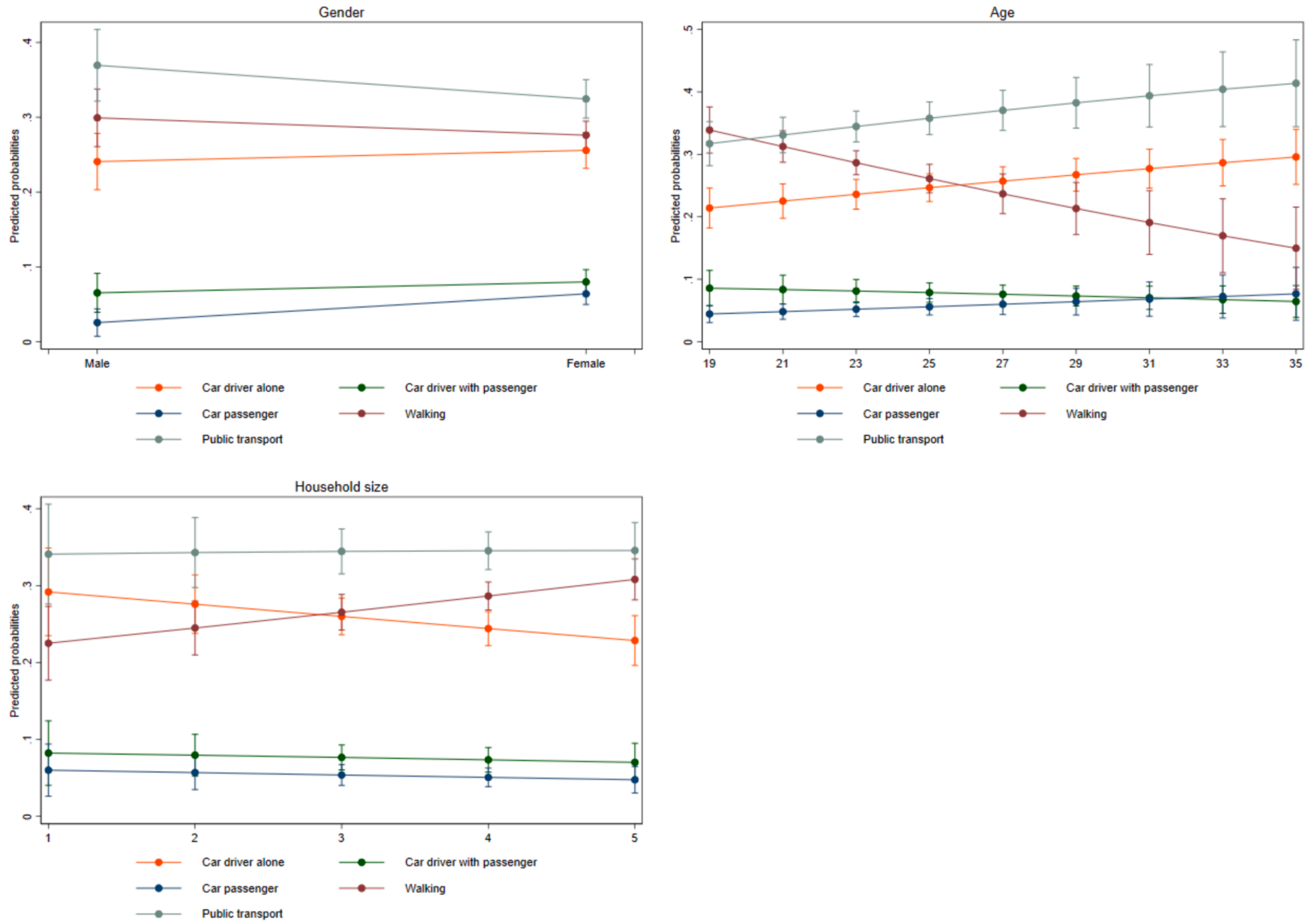

Fig. 5. Conditional predicted probabilities for additional demographic individual-specific variables: optimistic post-Covid scenario.

(compared to latent class 2), were less likely be away-from-home and car owners, were younger, spent more than one day at the university, and were more likely to be part- or full-time workers. Overall, 71.3 % of respondents belonged to latent class 1. According to our estimates, students in latent class 1 were moderately sensitive to both the travel time and price of transportation modes with an expected negative sign: faster or cheaper means of transportation were preferred over slower and more expensive ones. Latent class 2 students were extremely sensitive to travel time, much more than those in latent class 1. Moreover, they appeared to promote more expensive solutions with respect to cheaper ones. It should be noted that, on average, respondents in latent class 1 were more likely to choose the 'car driver alone' option than those in latent class 2 (42.6 % vs 15.4 %); furthermore, they were less likely to opt for walking (1.9 % vs 36.7 %). Latent class 1 students tended to prefer driving alone than carpooling (either as drivers or passengers: 10.3 % vs 12.5 %). Since these students need to combine work and study commitments, flexibility is key, thus leading them to exploit car ownership. This result underlines that they place a high value on travelling time.

5.4. Simulating policy actions towards more sustainable commuting habits

As a final step and starting from our baseline results (Table 3), we considered the predicted effect of alternative policies in the field of commuting choices on the shifts across different transport modes. We considered a series of policy options aimed at promoting more environmentally-friendly travel patterns, touching upon strategies for reducing energy use and emissions. These include both 'stick' and 'carrot' types of policies, considering either increases in the relative cost of the most polluting transport mode or support for the cleanest ones. Finally, we also considered changes to ticket prices (occurring in 2022) to evaluate the predicted consequence of this event.

Table 9 shows that policies targeting the costs of the different means of transport or that incentivise car-pooling could be the more efficient ones. In September 2022, the local bus company decided to increase the price of tickets (action a). According to our estimates, this would imply a shift of 35 students away from public transportation and mostly to car usage. Action b, which reflects an increase of the cost of driving alone, pushes students to switch from driving alone to public transports or, at the limit, to share the higher cost of driving with passengers. This result was also achieved by implementing action d: when a discount for carpooling was applied, 324 extra students opted for driving. Finally,

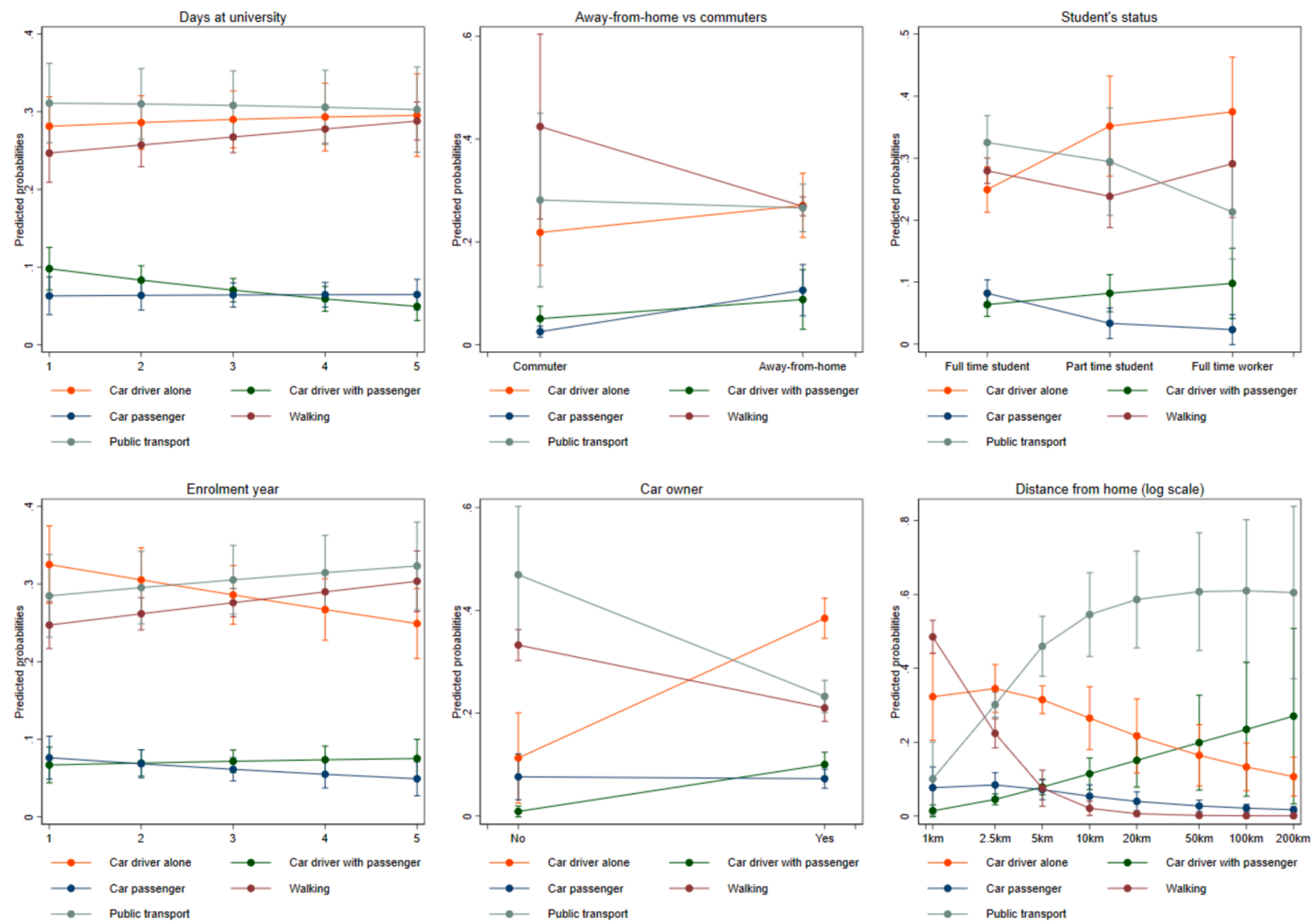

Fig. 6. Conditional predicted probabilities for main variables: pessimistic post-Covid scenario.

policies strictly related to the possibility of increasing the speed of public transport prompted students to choose such transport as their preferred means of travel. They could reach university faster – and with fewer connection problems – with other means of transport. If local authorities or the local transport company were to offer free transport tickets to students, they would be more likely to choose public transport to come to university. Although the shift might not appear to be massive (424 more students), it could require a substantial increase in the capacity of public transport.

These results also represent a signal towards the adoption of policies that promote a more sustainable (and thus, less polluting) way of travelling; preferring carpooling or/and public transport to move from origin to destination generates lower emissions of greenhouse gases and might contribute to the greening of the transport sector, as well as establishing an effective and efficient transport network. Naturally, this transition must also be supported by increased infrastructure investment.

6. Conclusions

This study seeks to understand the drivers of university commuting choices, with a specific focus on students, and how transport habits change in view of different Covid-19 scenarios. The study simulated the effect of multiple policy changes on commuting habits, which could contribute to developing local policies and strategies that help reduce emissions of the transport sector and promote more sustainable commuting habits.

Section 1 illustrated the importance of the traffic generated by the student population within cities hosting a university. This importance is even more crucial in such small towns as Urbino, where the university plays a pivotal role in the entire urban economy, to the extent that it can be considered one of the main, if not primary, sources of the city's income. Analysing variables influencing students' mobility can be of fundamental importance in guiding investment choices in the transportation sector. Studying students' commuting habits is essential for the development of Home-Work Travel Plans (PSCL)[17] and for the implementation of efficient and effective transportation policies, especially considering changes in the organisation of educational, administrative, and research activities before and after the pandemic. The analysis proposed in this study aims to contribute to this direction, adding to the existing literature. The study also capitalised upon the opportunity to analyse student trends in transportation choices following various possible pandemic evolution scenarios presented to respondents in a timeframe very close to the lockdown, thus with a

[17] The Home-Work Travel Plans (*Piani Spostamento Casa Lavoro*) have become a mandatory tool in Italy following Decree-Law No. 34 of May 19, 2020, known as the 'Relaunch Decree', converted into Law No. 77 on July 17th, 2020, entitled 'Measures to promote sustainable mobility'. To promote the decongestion of traffic in urban areas (by reducing the use of individual private transport), transport companies and public administrations must adopt a plan for commuting employees aimed at reducing the use of individual private transport. Drafting these plans requires specific information about the modal choices and transportation preferences of the relevant commuters.

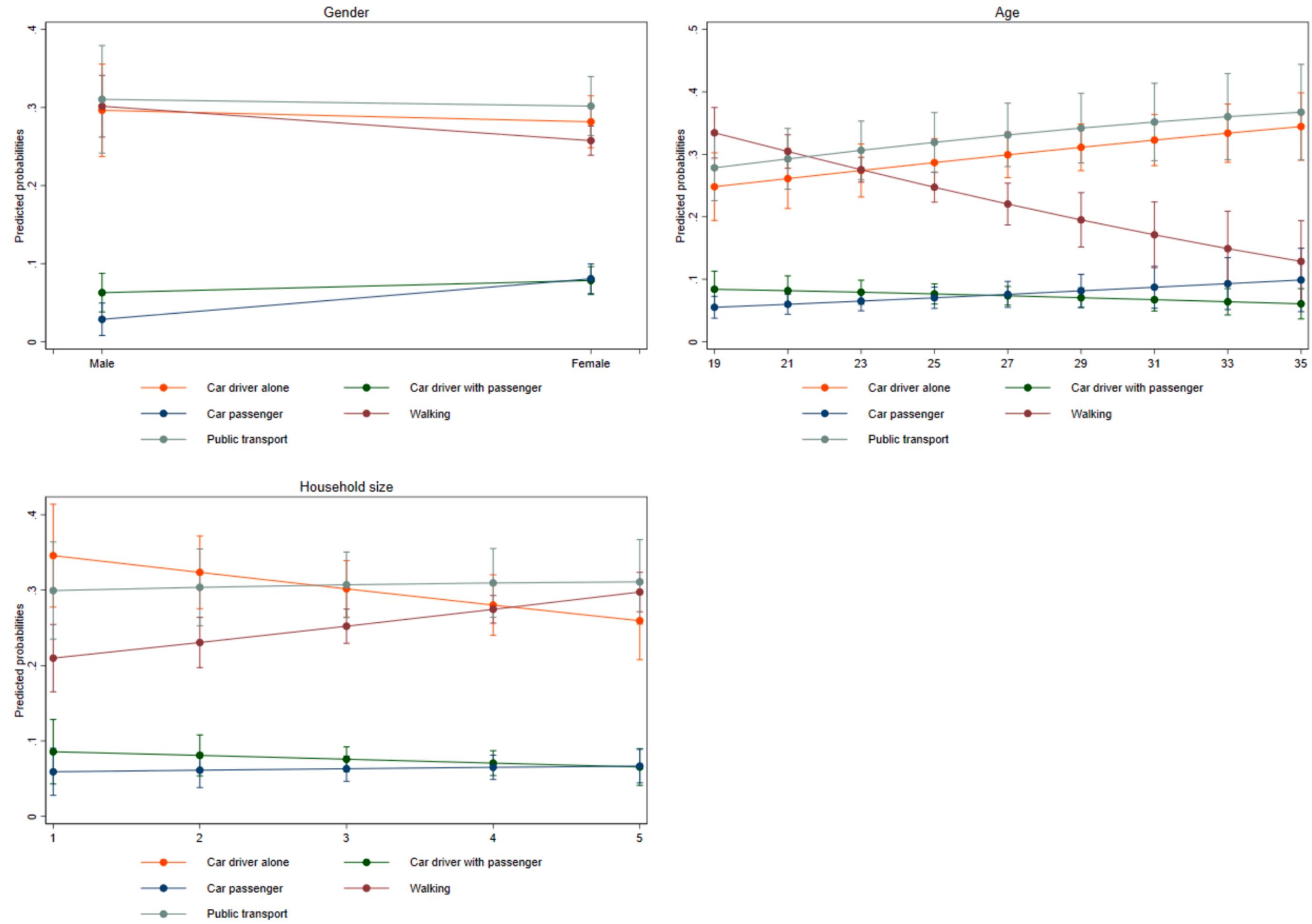

Fig. 7. Conditional predicted probabilities for additional demographic individual-specific variables: pessimistic post-Covid scenario.

highly specific set of individual preferences.

In the pre-Covid period, the results suggest that public transport represents the principal means of student-chosen transportation. The likelihood to choose public transport is particularly high for students who: i. spend several days in Urbino due to university activities; ii. live at a considerable distance from Urbino; and iii. live away-from-home. On the other hand, the probability to drive a private car alone is particularly high if: i. they are full-time workers; ii. they own a car; and iii. They live relatively close to Urbino. Car sharing, as a passenger or driver, appears to have mainly been chosen by students living far from the university. Walking became appealing when the distance from university was small. Female students had a higher propensity to choose greener means of transport, such as walking or public transport, than males and, referring to age, older students were more likely to reach the university alone by car or through public transport. Estimates on 'optimistic' and 'pessimistic' post Covid-19 scenarios showed no relevant changes regarding pre-Covid ones.

Some policy implications can be derived from the simulations on policies that promote more effective and sustainable ways of transportation and that pay higher attention to the economic aspects of transport. Measures aimed at subsidising more environmentally-friendly means of transportation or that incentivise carpooling appear to contribute to virtuous shifts. It should be noted, however, that the simulation did not consider the supplier side, that is, the need to improve the infrastructure and capacity for public transport as well as the organisation of the service.

Notwithstanding this paper's relevance to transport policies and contributions to policymakers, there were certain limitations that were strictly connected with the structure of the questionnaire. For example, we were not able to measure the environmental impact of university student commuters, which is becoming highly relevant in European policies. Moreover, the available information did not allow for a fuller understanding of whether, and how frequently, away-from-home students commute back to their hometowns, and which transportation mode they use. Moreover, our data did not allow us to model the choice between commuting and being an away-from-home student – which could certainly determine one's daily routine. The literature has highlighted the crucial role of the quality of public transport, such as connection quality (waiting time among connecting services, horizontal and vertical distance between connection services, insurance availability, access and egress time to first/last transport points), travel comfort, and overcrowded transport (Paulley et al., 2006; Allard and Moura, 2018; Calastri et al., 2019), which is highly relevant for our work, especially due to the connection with the pandemic. However, unfortunately, the survey we used provided no data on this measure, so we could not estimate its effect on student commuters.[18]

Our analysis can represent a basis for further extensions, which should, of course, resolve the above-described limitations. In this direction, the research group, in collaboration with the local bus company (Adriabus) and RUS, is already working on a new and more focused questionnaire able to capture more information on commuting choices,

[18] See Redman et al. (2013) for a research review.

Table 8
Latent class logit model.

Choice model parameters	Latent class 1	Latent class 2
Travel Time (mins)	−0.00360*** (0.000479)	−0.765*** (0.0738)
Price (€)	−0.0175** (0.00687)	2.617*** (0.386)
Class share	0.713	0.287
Class members model parameters(class 2 is the reference class)		
Away-from-home	−3.262*** (0.624)	
Distance from home (km)	−0.474*** (0.147)	
Car owner	−0.823*** (0.231)	
Female	0.120 (0.250)	
Age	−0.0351** (0.0160)	
Days at university	0.262*** (0.0637)	
Full-time student	[base category]	
Part-time or full-time worker	0.837*** (0.265)	
Law, economic, political science, sociology	[base category]	
Sciences	0.618* (0.365)	
Humanities	−0.657* (0.340)	

Latent class logit model. N of cases: 1360. Log-likelihood: −2490.6727. Bootstrapped standard errors in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Correctly predicted outcomes: 74.8 %.

Table 9
Simulations for different policy actions.

Action	Estimated change in the number of students choosing:				
	Car driver with passenger	Car driver alone	Car passenger	Walking	Public transport
a) 2022 increase of the local public transport bus company	7	16	3	9	−35
b) 30 % increase of cost for drivers alone	89	−277	44	4	139
c) 50 % discount for passengers of carpooling	−2	−10	22	0	−9
d) 50 % discount for drivers of carpooling	324	−146	−29	−2	−147
e) Free tickets for public transports	−82	−173	−57	−112	424
f) Public transports improve speed by 20 %	−80	−210	−46	−82	419

independent of pandemics or other crises, to study the environmental effect of commuting to and inside Urbino, and directly construct the distance matrix so as to determine the quality of public transport (mainly trains and buses). Other steps could be devoted to matching data on the lectures' and local public transport timetables so as to further improve the local public transport service, which, thanks to a reduced travel time, may be less preferred to other solutions. Finally, the collection of information on effective applied transport policies at the local level (especially after the first pandemic wave) can also help us obtain further insights.

CRediT authorship contribution statement

Chiara Lodi: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Giovanni Marin:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Paolo Polidori:** Writing – review & editing, Writing – original draft, Conceptualization. **Désirée Teobaldelli:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

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

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