Investigating the use of privately-owned micromobility modes for commuting in four European countries

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Abstract: Micromobility modes such as scooters, e-scooters, skateboards, or hoverboards has recently emerged as part of the urban landscape. In this paper, we analyze the use of modes of micromobility for commuting. We distinguish between monomodality (commuters using one mode of micromobility only) and multimodality (commuters using micromobility as a complement or substitute to other modes of transport). We apply non-parametric ordered methods to a survey that was conducted in 2018 on mobility users in four European countries. The survey gathered 4,873 observations from commuters in France, Germany, Spain, and the United Kingdom (UK). Micromobility commuting is marginal in all four European countries. The sociodemographic characteristics of micromobility commuters are homogeneous and concern mainly male, young, and urban commuters. We find that travel habits account for a large share of the variability explained by the model. Germany has a low level of multimodality, whereas the UK practices complementarity-oriented multimodal commuting. Overall, our results bring new insights showing that micromobility is used as a (partial) substitute to urban transit systems for short distances and as a complement for longer commuting trips made by train. These emerging patterns of commuting require better modal integration between micromobility and public transport, and a more sophisticated design of transport infrastructures.

Keywords: micromobility; commuting; multimodality; privately-owned; mode choice; travel habit.

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1. INTRODUCTION

Micromobility, as exemplified by electric kick scooters (e-scooters), has recently become a prominent feature of the urban landscape. These new microvehicles gained significant visibility with the introduction of large-scale sharing systems in American cities in 2017. In Europe, e-scooter-sharing systems began with the arrival of the first providers in Paris, France, in 2018. In 2019, Lime reported that it had surpassed 100 million e-scooter rides, including more than 1 million rides in Madrid, Spain, Prague, Czech Republic, and major cities in Greece (Dias et al., 2021).[1]

The term 'micromobility', which gained prominence in the scholarship in around 2018 (O'Hern & Estgfaeller, 2020), encompasses a broader range of microvehicles beyond e-scooters: "*micromobility includes all transport modes that allow their users to make a hybrid usage and behave either as a pedestrian or a vehicle at their convenience (*e.g. to cross a road or board on a bus) *or when necessary. Defined as such, microvehicles include all easy-to-carry or easy-to-push vehicles allowing to augment the pedestrian. They may range from lighter rollers and skis to heavier two-wheeled self-balancing personal transporters. They can be motorized or not, shared or privately-owned*" (Christoforou et al. 2021, p. 3).

Privately-owned micromobility modes spans a more diverse range of vehicles than *shared* micromobility modes, resulting in a wider range of users and practices. This study specifically focuses on privately-owned micromobility modes, including human-powered and electric (standing) kick scooters, roller blades, skateboards, solowheels, and hoverboards.[2] Bikes and e-bikes are excluded from our analysis as they do not align with our definition of "hybrid usage". Integrating human-powered micromobility modes as supplementary options for first-

[1] Lime. More Major European Cities Pass 1 Million E-Scooter Ride Milestone. Available online: https://www.li.me/second-street/
more-major-european-cities-pass-1-million-e-scooter-ride-milestone (accessed on 2023/09/15).

[2] Henceforth, the term "scooter" will refer to "standing kick scooter".

mile or last-mile trips alongside other transport modes holds significant value. Ownership also influences specific practices, as owners have the option to carry their microvehicle on board public transport whereas sharing-system users having to leave their microvehicle in the street.

Decision makers may perceive this new category of transport modes as an additional tool for promoting sustainable mobility. Sustainable Urban Mobility Plans (SUMPs) aim to prioritize more sustainable modes of transport for daily mobility, such as using public transport or car-based sharing systems (carpooling/ridesharing and car-sharing), and active modes like walking and cycling. As microvehicles fall within the category of active transport modes, they can be viewed as supplementary options that can contribute to achieving local sustainability objectives by reducing congestion, noise exposure, air pollution, and greenhouse gas emissions. Furthermore, a significant proportion of trips made by mobility users are primarily for work or study (accounting for 35% of total trips in France in 2019)[3], which makes it important for SUMPs to consider these specific trip purposes when promoting a modal shift from solo driving to more sustainable transport modes.

This study investigates the use of micromobility modes for commuting purposes in four European countries: France, Germany, Spain, and the United Kingdom (UK). The research distinguishes between monomodality and multimodality among micromobility users. Monomodality refers to the permanent use of a single transport mode for commuting, whereas multimodality refers to two alternative practices: either selecting one mode of transport over another based on trip conditions, which signifies the *substitution* of another mode for a specific trip, or combining multiple transport modes within the same trip, which signifies the *complementarity* of two or more modes. These micromobility practices offer key advantages, such as easing road congestion and bringing environment benefits, especially by reducing solo

[3] https://www.statistiques.developpement-durable.gouv.fr/resultats-detailles-de-lenquete-mobilite-des-personnes-de-2019, accessed 2023/09/15

driving. However, it is vital to consider possible drawbacks of micromobility commuting, such as increased crowding on public transport when micromobility is used as a complement and potential loss of certain environmental benefits when self-balancing modes substitute for walking.

The environmental impacts of micromobility have been examined in recent studies that focused on comparisons against private car use, public transport, and walking (Fearnley, 2020; Milakis et al., 2020; Abduljabbar et al., 2021; Liao & Correia, 2022). Here we take a unique approach by considering the influence of sociodemographic characteristics, travel habits, and mode choice criteria on the frequency of micromobility commuting (never, occasionally, daily). The study utilizes a survey dataset comprising 4,873 commuters from France, Germany, Spain, and the United Kingdom. We employ non-parametric ordered models to investigate the commuting patterns of users of privately-owned micromobility modes, specifically distinguishing between monomodal and multimodal micromobility practices. While recent studies have examined the characteristics of micromobility users, this study, to the best of our knowledge, is the first to explicitly explore the interplay between micromobility and other transport modes for commuting purposes in multiple countries.

The micromobility commuters surveyed in all four countries examined shared a homogeneous set of sociodemographic characteristics and were primarily young urban males. The findings indicate that travel habits, particularly a constrained travel schedule and the use of route planner applications, play a more significant role than sociodemographics in explaining micromobility commuting behavior. Across the countries studied, the micromobility commuters have different practices (monomodality or multimodality). Factors such as comfort, physical activity, a constrained travel schedule, and a positive perception of travel time are associated with monomodal micromobility commuting; minimizing travel fatigue is associated with multimodal micromobility practices. Bus and tram are the main modes substituted by micromobility, while taxis, ride-hailing services, and various forms of trains are the main complementary modes used.

The paper is structured as follows. Section 2 provides a comprehensive literature review on micromobility. Section 3 describes the database used in this study and outlines the methodology employed to analyze the frequency of practicing micromobility and the commuting patterns of micromobility users (monomodality or multimodality). Section 4 presents the results of our analysis and provides a detailed discussion of the findings. Section 5 provides a synthesis of our results, putting them into perspective in relation to the post-pandemic context of the COVID-19 crisis. It proposes some brief recommendations for the design of local transport policies based on active modes. It also acknowledges certain limitations of our study and outlines avenues for future research.

2. LITERATURE REVIEW

Previous studies have established various criteria for classifying microvehicles based on their capacities, performances, and types of use (Table 1).

Table 1. Typology of microvehicles

	Criteria	Description	Described in
1. Capacity	**1.1. Number of passengers**	=1	Sengul & Mostofi, 2021
2. Performance	**2.1. Mode of propulsion**	Human-powered Self-balancing	Abduljabbar et al., 2021; Bozzi & Aguilera, 2021
	2.2. Max Speed	<=25 km/h <=45 km/h	Bozzi & Aguilera, 2021
	2.3. Distance range	<=10 km	Bozzi & Aguilera, 2021; Liao & Correia, 2022
3. Type of use	**3.1. Ownership status**	Privately-owned Shared	Esztergar-Kiss & Lizarraga, 2021; Reck et al., 2022 Bozzi & Aguilera, 2021
	3.2. Parking mode (if shared)	Docked (station-based) Dockless	Milakis et al., 2020

Source: *Authors*

In this study, we focus on a specific subset of microvehicles that meet the following criteria:

(1) **Sole driver**: the vehicles considered are designed for individual use, thus excluding cars and moped scooters. This criterion includes the weight criterion, with vehicles not exceeding 50 kg.

(2) **Maximum speed**: we include vehicles that have a maximum speed of less than 25 km/h, thus excluding cars, electric moped scooters, and speed-electric bikes.

Our database comprises *privately-owned* microvehicles only, and we do not specifically address docked (station-based) or dockless sharing systems.

Taken together, the literature recognizes five main types of micromobility modes, including shared bikes (docked or dockless), shared e-bikes (docked), shared e-scooters (dockless), shared (moped) e-scooters, and car-sharing fleets. Several recent studies have examined privately-owned microvehicles (McQueen et al., 2020; Tuncer & Brown, 2020, Christoforou et al., 2021; Esztergar-Kiss & Lizarraga, 2021; Şengül & Mostofi, 2021; Reck et al. 2022). However, with the exception of Oeschger (2020), these studies focus primarily on human-powered or self-balancing kick scooters, thus overlooking other microvehicles.

2.1. Factors favoring micromobility

Despite growing scholarship on micromobility, there has yet to be analysis of micromobility commuting. Micromobility is influenced by several factors, including the characteristics of the mode itself or the micromobility service on offer, socioeconomic attributes of the users, attitudinal variables, and characteristics of the trip.

Characteristics of the micromobility mode/service on offer. Research suggests that travel time savings are a significant motivation for engaging in micromobility practices (Fitt & Curl, 2020; Arias-Molinares et al., 2021), and cost is also a crucial factor (Elmashhara et al., 2022). Some studies have also identified convenience (Arias-Molinares et al., 2021) and comfort (Bretones & Marquet, 2022) as motivations.

Socioeconomic attributes. The literature indicates that users of e-scooter sharing systems are predominantly young (Arias-Molinares et al., 2021; Christoforou et al., 2021), male (Arias-Molinares et al., 2021; Christoforou et al., 2021; Merlin et al., 2021), highly-educated individuals (Arias-Molinares et al., 2021; Christoforou et al., 2021; Merlin et al., 2021; Elmashhara et al., 2022) that have above-average income (Elmashhara et al., 2022; Liao & Correia, 2022; Badia & Jenelius, 2023). Students are also found to be inclined to use e-scooter sharing systems (Hong et al., 2023).

Attitudinal variables. Technophilia, i.e. a positive attitude to technology (Eccarius & Lu, 2020; Bosehans et al., 2021), and environmental values (Arias-Molinares et al., 2021; Zhang & Kamargianni, 2022) are generally associated with higher uptake of electric vehicle-sharing systems. Technophilia is also linked, in part, to a positive attitude towards experiencing new modes of transportation (Hong et al., 2023).

Characteristics of the trip. (Docked) electric bikes are often preferred for commuting, whereas (dockless) e-scooters are preferred for social, shopping, and recreational trips (Reck et al., 2021; Liao & Correia, 2022). Trip purpose is also correlated with distance, as e-scooters are typically used on shorter distances compared to e-bikes (Şengül & Mostofi, 2021). Factors such as rain, low temperatures (Hosseinzadeh et al., 2021), and air pollution (Zhang & Kamargianni, 2022) have been found to reduce the use of e-scooters and bike-sharing systems. Note that elevated terrain may also deter micromobility (Reck et al., 2021).

2.2. Implications of micromobility

The implications of micromobility mostly concern environmental, health and social issues, and safety and regulation policy.

Environmental, health and social issues. Micromobility was initially considered to be a low-carbon alternative to solo driving for first-mile and last-mile trips (Abduljabbar et al., 2021; Liao & Correia, 2022). However, battery production for e-scooter sharing systems, for instance, may have important negative environmental impacts (Milakis et al., 2020), and in operational practice, the collection and redistribution of dockless shared vehicles contribute to specific greenhouse emissions (Abduljabbar et al., 2021). Life-cycle analyses comparing e-scooters and competing modes do not always turn out in favor of scooters: de Bortoli and Christoforou (2020) show that e-scooter sharing systems generated extra CO2 emissions, due to major shifts coming from lower-emitting modes (subway, commuter train and active modes). However,—comparing privately-owned versus shared e-scooters indicate that privately-owned e-scooters tend to have a lower environmental impact (Moreau et al., 2020; Reck et al., 2022). Furthermore, private operators of sharing systems may prioritize revenue maximization over social inclusivity (Hauf & Douma, 2019; Bai & Jiao, 2021). There are also potential barriers to micromobility uptake, including physical ability and technical skills (Milakis et al., 2020). In terms of health, human-powered microvehicles can promote physical activity and enhance mental health (Abduljabbar et al., 2021), but self-balancing microvehicles may replace walking or cycling, thus potentially reducing overall physical activity levels (Milakis et al., 2020).

Safety and regulation. The safety concerns associated with self-balancing micromobility make it vital to establish rules and regulations on helmet use, designated traffic lanes, and parking (Chang et al., 2019; O'Hern & Estgfaeller, 2020). However, given the relative novelty of self-balancing micromobility, regulations still vary significantly across cities, states, and regions (O'Hern & Estgfaeller, 2020; Şengül & Mostofi, 2021). In addition to safety considerations, micromobility sharing systems also need regulations to address liability and operational issues (McQueen et al., 2020).

2.3. Interactions with other modes of transport

Micromobility can serve as either a substitute or complement to other modes of transport. Based on the definition provided in the introduction, substitution may be full, resulting in exclusive use of the new micromobility mode (monomodality), or partial, leading to multimodality where trip conditions dictate whether commuters use their previous mode or the new mode. When micromobility is not available, the primary mode of substitution will primarily be walking (Christoforou et al., 2021; Şengül & Mostofi, 2021; Wang et al., 2022) or else cycling (Lee et al., 2021). Public transport is frequently identified as a substitute for micromobility, particularly in Europe (Esztergar-Kiss & Lizarraga, 2021; Wang et al., 2022). However, the potential for substituting private cars with micromobility modes is less apparent in the United States, except in certain cities (Şengül & Mostofi, 2021; Wang et al., 2022). In terms of complementarity, micromobility is widely recognized as offering flexibility, whereas public transport systems offer higher speeds and broader spatial coverage (Oeschger et al., 2020). Micromobility options such as e-scooters and bikes are particularly well-suited for connecting to transport hubs and facilitating first-mile and last-mile trips (Milakis et al., 2020; Tuncer & Brown, 2020; Bozzi & Aguilera, 2021), and so they consequently have the potential to complement public transport services as an alternative to walking, thereby enhancing the time-competitiveness of multimodal trips compared to solo car trips (McQueen et al., 2020, Wang et al., 2022).

In short, this study aims to address four gaps in the existing micromobility literature by:

(1) Examining privately-owned micromobility modes instead of focusing solely on vehicle-sharing systems;
(2) Broadening the scope of micromobility modes considered, to encompass both human-powered and self-balancing microvehicles and include a wider range of options beyond just scooters;
(3) Concentrating specifically on commuting trips;
(4) Conducting a detailed analysis of micromobility commuting that explores both monomodality and multimodality.

3. MATERIAL AND METHOD / EMPIRICAL STRATEGY

This study utilizes an original online survey conducted in 2018 comprising a sample of 7,000 participants from four European countries. The survey was designed to examine the factors influencing micromobility uptake for commuting, specifically for travel between home and work or home and study. The dataset includes 4,000 observations from France and 1,000 observations each from Germany, Spain, and the United Kingdom. Before presenting our empirical strategy, we first provide an overview of the variables employed in our study, which include sociodemographic characteristics, travel habits, and mode choice criteria.

3.1. Data

The data was obtained from an online survey conducted by L'ObSoCo, a French observatory of societal and consumption trends. The survey was administered to a representative sample of the population in each country. To ensure representativeness, the survey employed the quota method, considering factors such as gender, age, socio-professional category, home region, and home-area population. L'ObSoCo stated that the sample size was chosen to capture micromobility usage patterns that may have low uptake within the population.[4] The survey featured one central question on commuting: "*What modes of transport do you use to go to your place of work or study*?". The following microvehicles were proposed: e-scooter, scooter, roller blades, skateboard, hoverboard, solowheel, and gyropode. Consequently, the sample is limited to *commuters* (4,873 observations).[5] For each specific mode of transport, respondents were provided with three possible answers on the mode used for micromobility commuting: 'never' (n=4659 out of 4,873), 'occasionally' (n=178) and 'main mode of transport' (n=36). Among the respondents, 4.4% of workers (n=214, roughly one out of 23 workers) reported using micromobility either occasionally or as main mode for commuting.[6]

Table A.1 presents the sociodemographic variables considered in this study (commuters only). The selected characteristics include gender, age (4 modalities), marital status (single or living in a couple), presence of child(ren) at home, educational attainment (3 modalities), and population of the area of residence (4 modalities). Out of the 4,873 observations retained, the average age of the participants was 39.1 years. Women were very slightly underrepresented, accounting for 49.7% of the sample. The respondents had a relatively high level of

[4] For further details on the survey, see http://lobsoco.com/, accessed 2023/09/15.
[5] For the sake of simplicity students will be assimilated, like workers, as commuters in the subsequent analysis.
[6] Although the ObSoCo survey was administered to a representative sample of the population in each country, note that the share of France represents around 55% of the sample among commuters (2,664 out of 4,873).

educational attainment, with approximately 55% having obtained at least a Bachelor's degree. The majority of respondents (around 61%) were living in a couple, and 82% lived in urban areas. Around 43% of the participants reported living with children.

Table A.2 lists the travel habits and mode choice criteria captured in the survey (commuters only). Among *travel habits*, respondents were asked to state their use of route planner applications or websites (on a 4-point scale: 'never', 'sometimes', 'often', and 'daily or almost daily'). Respondents were also asked to state whether they looked at the traffic or public transport network situation before setting out on daily trips (on a 5-point scale, from 'never' to 'systematically'). Furthermore, respondents were interviewed on the constraints of their travel schedule (on a 4-point scale, from 'very low' to 'very high'), on their perception of travel time (on a 4-point scale, from 'very negative' to 'very positive'). Respondents were asked whether they had to commute during peak hours, whether they had a driving license, whether they owned a microvehicle, and about the number of cars in their household. Finally, respondents were asked about whether they used micromobility only (monomodality) or to substitute or complement other modes of transport (multimodality).

Among the proposed *mode choice criteria* (Table A.2), respondents had to rank their first three in order of preference. Each rank was then scored ('3' for the first, '2' for the second, '1' for the third, '0' otherwise). The mode choice criteria proposed were speed, convenience, timeliness, comfort, less costly, physical activity, environmentally friendly, and less tiring.

3.2. Econometric model

As the answers on the mode used for micromobility commuting are ordered, we examined the issue of micromobility commuting using an ordered probit model (Greene, 2018). Based on the theoretical framework and descriptive analysis of the data, we posited that micromobility commuting patterns were influenced by various factors, including the respondents' sociodemographic characteristics, travel habits, and mode choice criteria. The ordered probit model is derived from a latent variable model, where we assume the existence of a latent variable $M_i^{□}$ that represents micromobility commuting, and whose value is determined by:

$$M_i^{□} = \beta X_i + \gamma H_i + \delta T_i + \varepsilon_i \quad (1)$$

for $i = 1, \ldots, N$, and where X_i is a vector of sociodemographic characteristics, H_i is a vector reflecting travel habits, and T_i is a vector of mode choice criteria. β, γ, *and* δ are the corresponding parameters to estimate, and ε_i is the error term (assumed normally distributed). The outcome M_i arises according to:

$$M_i = j \; if \; \alpha_{j-1} < M_i^{□} < \alpha_j \quad (2)$$

where α_j are the cut-point parameters to estimate. Thus, $M_{□}^{□}$ is partitioned into J ordered categories.

First, we used dominance analysis to test the relative importance of the explanatory variables in the model (Budescu, 1993; Luchman, 2021). The method used is based on computing the reduction in prediction error associated with each independent variable in a model (Luchman, 2021). Dominance analysis is intended to determine the importance of independent variables from a model. To implement this approach, we estimated the nested models representing all possible combinations of the independent variables, and then collected the model fit statistics. Finally, we compared the marginal contributions to model fit associated with each independent variable (see Luchman, 2021 for further details).

The ordered probit model relies on the assumption that the error term follows a normal distribution. However, if this assumption is violated, the ordered probit model may become inconsistent (Wooldridge, 2010). To mitigate this issue, we employed a semi-nonparametric approach that involves approximating the unknown density by using the product of a squared polynomial and a normal density (Gallant & Nychka, 1987; Stewart, 2004; De Luca, 2008). The approximation is as follows:

$$f_K(\varepsilon)=\frac{1}{\theta}\left(\sum_{k=0}^{K}\gamma_k\varepsilon^k\right)^2\phi(\varepsilon) \quad (3)$$

where K is the order of the unknown polynomial, γ_k is estimated ($\gamma_0=1$ for identification), and $\phi(\varepsilon)$ is the standard normal density function. The unknown parameter θ is equal to:

$$\theta=\int_{-\infty}^{+\infty}\left(\sum_{k=0}^{K}\gamma_k\varepsilon^k\right)^2\phi(\varepsilon)d\varepsilon \quad (4)$$

The cumulative density function is equal to:

$$F_K(u)=\int_{-\infty}^{u}\frac{1}{\theta}\left(\sum_{k=0}^{K}\gamma_k\varepsilon^k\right)^2\phi(\varepsilon)d\varepsilon \quad (5)$$

After choosing K with likelihood-ratio tests, the model can finally be estimated via a pseudo-likelihood function (see Stewart, 2004 for further details).

4. RESULTS AND DISCUSSION

Before delving into the econometric analysis, we first present descriptive statistics.

4.1. Descriptive statistics

Micromobility commuting. Micromobility commuting is marginal in all four European countries studied (Table A.1). However, micromobility commuting patterns varied across countries, with different proportions of commuters engaging in this behavior. In Spain, approximately 7% of commuters report micromobility commuting, followed by 4% in France and Germany, and 3% in the UK. Furthermore, the frequency of micromobility also differed among micromobility commuters: approximately 17% across all countries were everyday users, with 24% in the UK and 22% in France, ahead of 11% in Spain and just 6% in Germany. Interestingly, micromobility commuters shared a similar sociodemographic profile across all countries. In each of the four countries examined, micromobility commuters were predominantly young males living in large urban areas. Women accounted for nearly 50% of all commuters surveyed, but only 40% of occasional micromobility commuters and 25% of main-mode micromobility commuters. However, there were again variations between countries. The proportion of women among micromobility commuters (combining occasional and main users) ranged from 30% in France up to 48% in the UK (41% in Spain, 47% in Germany). The proportion of micromobility commuters living in major urban agglomerations counting more than 100,000 inhabitants was 57% overall, ranging from in the UK up to 64% in France (44% in the whole sample of commuters). User age was significantly negatively correlated with micromobility commuting in all countries. Figure 1 plots this trend by country, with Spain showing higher average usage among young commuters.

Micromobility commuting and multimodality. Figure 2 plots the mean values for micromobility commuting and multimodality variables for each sociodemographic characteristic. The mean values were obtained by assigning a score to each modality of the micromobility commuting variable, as follows: ‘never’ is scored 1, ‘occasional’ is scored 2, and ‘main’ is scored 3.

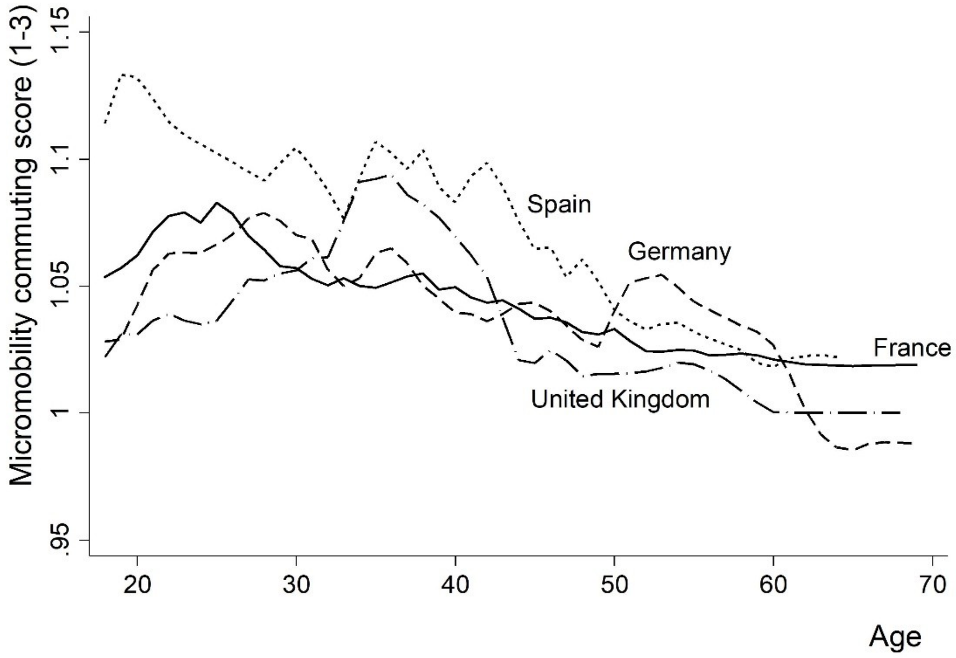

Figure 1 Micromobility commuting and age

Note: Non-parametric regressions.
Source: Authors

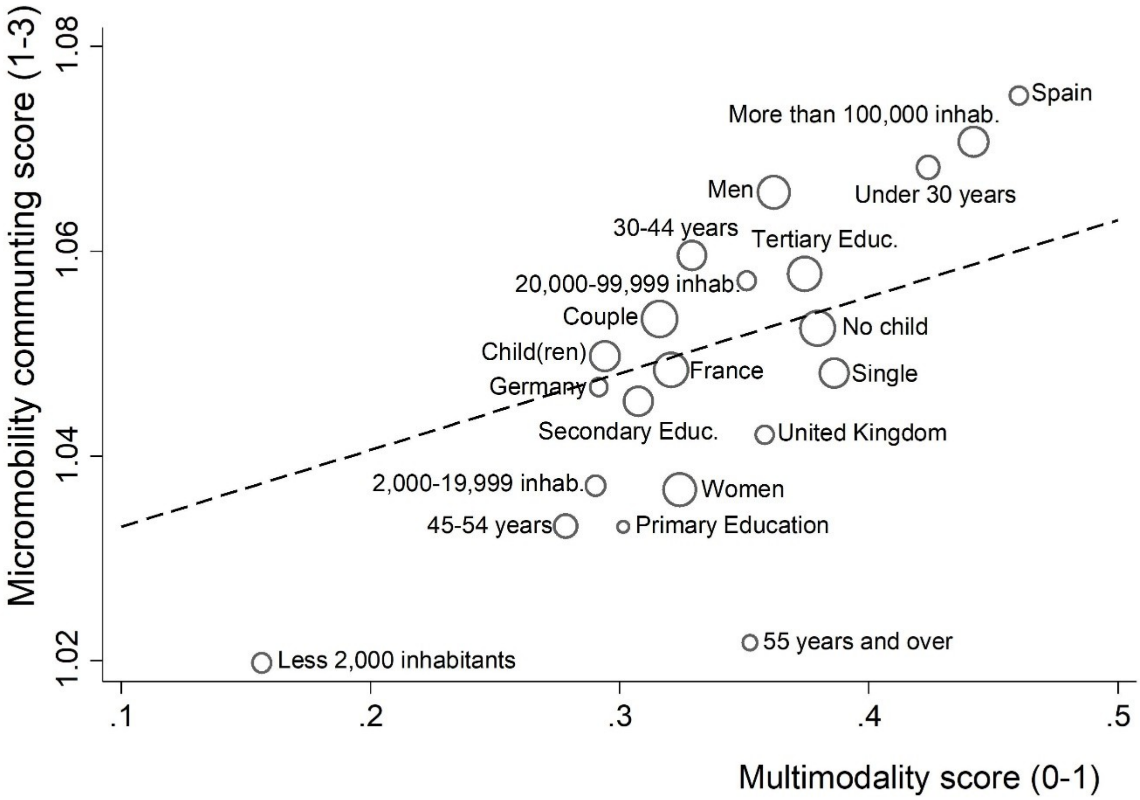

Figure 2 Micromobility commuting and multimodality

Note: The sizes of the circles are proportional to the number of observations. Despite its ordered nature, micromobility commuting is treated as a continuous variable ('never' = 1, 'occasional' = 2, and 'main' = 3).
Source: Authors

Micromobility commuting is expected to be linked to multimodality, particularly due to the typically long distances people need to travel for their commutes. On average, this association between micromobility commuting and multimodality is stronger when the users are men, young, with higher levels of educational attainment, in urban areas, and Spanish (Fig. 2).

Table 2 reports descriptive statistics for the travel habits and mode choice criteria of the entire sample of commuters. The table presents the average values of the travel habits and mode choice criteria variables for each modality of micromobility commuting. Table A.2 gives a more detailed presentation of the variables country-by-country.

Table 2. Descriptive statistics

	Mean values by category			
	Never	**Occasional**	**Main**	**All**
Travel habits				
User of route planner applications	1.68	2.11	2.17	**1.70**
Traffic check before leaving	2.28	2.77	2.75	**2.30**
Household number of cars	1.43	1.32	1.06	**1.42**
Having a driving license	0.90	0.90	0.81	**0.90**
Constrained travel schedule	2.53	2.87	2.72	**2.54**
Travel time perception	2.31	2.71	2.83	**2.33**
Commute during peak hours	0.40	0.33	0.47	**0.40**
Multimodality	0.33	0.67	0.67	**0.34**
Microvehicle owner	0.21	0.50	0.51	**0.21**
Mode choice criteria				
Speed	0.55	0.57	1.08	**0.56**
Convenience	0.40	0.45	0.19	**0.40**
Timeliness	0.26	0.38	0.31	**0.27**
Comfort	0.23	0.28	0.33	**0.23**
Less costly	0.22	0.33	0.64	**0.23**
Physical activity	0.16	0.35	0.08	**0.16**
Environmentally friendly	0.14	0.25	0.17	**0.14**
Safety	0.11	0.18	0.19	**0.12**
Less tiring	0.10	0.21	0.11	**0.11**
Observations	4659	178	36	**4873**

Note: Despite its ordered nature, micromobility commuting is treated as a continuous variable ('never' is scored 1, 'occasional' is scored 2, and 'main' is scored 3).
Source: *Authors*

Analysis of the travel habits found that approximately 22% of commuters reported owning at least one microvehicle for personal use at home. Furthermore, approximately 20% of respondents reported often or systematically using route planner applications or websites and checking road traffic or the public transport network before starting commuting trips. Note too that nearly 90% of respondents possessed a valid driving license, with an average of 1.4 cars owned per household. In comparison to the overall sample of commuters, micromobility commuters had a higher tendency to check traffic before leaving. They also reported being more constrained by their schedule, having a more positive perception of travel time, and commuting more frequently during peak hours, particularly among commuters who use micromobility as their main mode of transport.

The mean values of the mode choice criteria indicate the ranking of importance for commuters (Table 2). ‘Speed’ is the most valued criterion, followed by ‘Convenience’, while ‘Safety’ and ‘Less tiring’ were relatively less of a priority for commuters in general. In comparison to the overall sample of commuters, ‘Speed’ and ‘Cost’ were the criteria that held most importance among commuters who use micromobility as their main mode of transport, whereas ‘Physical activity’ and ‘Convenience’ were only deemed important for occasional micromobility commuters.

In all countries, micromobility commuters shared a similar profile in terms of travel habits (Table A.2). Compared to commuters in general, micromobility commuters tend to check traffic conditions more frequently, have stricter schedule constraints, and perceive travel time more positively. Furthermore, there are similarities in the mode choice criteria across countries. ‘Speed’ was consistently ranked as the most important criterion, except in Germany where ‘Convenience’ and ‘Timeliness’ ranked higher. On the other hand, ‘Safety’ and ‘Less tiring’ were less valued by micromobility commuters. The second most important criterion differs by country : ‘Convenience’ for France, ‘Comfort’ for Spain, and ‘Cost’ for the UK. In addition, micromobility commuting was frequently associated with multimodality in each country, with over 80% of micromobility commuters practicing multimodality in Spain, 72% in the UK, 67% in France, and 44% in Germany (compared to 34% for all commuters).

4.2. Econometric results

The econometric results are presented in Table 3, which shows the effects of each potential explanatory variable on micromobility commuting, taking into account the influence of all other variables. The analysis begins by examining the choice of a micromobility mode for the entire sample of commuters, taking into account sociodemographic characteristics, travel habits, and mode choice criteria. Moreover, country fixed effects were added in the model to capture country heterogeneity. The analysis is then narrowed down to monomodality and multimodality. Column [1] presents the results of dominance analysis, which assesses the importance of each explanatory variable or groups of variables for micromobility commuting. To test the effect of each explanatory variable on micromobility commuting, columns [2] and [3] compare the results of ordered probit and Semi-Non Parametric (SNP) ordered probit models. Columns [4] and [5] report results of our specific models for monomodality and multimodality.

Table 3. Micromobility commuting - econometric results

	DA	**Ordered probit**	**SNP**	**Mono-Modality**	**Multi-modality**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Sociodemographic characteristics	**37.2**				
Gender: Women	7.5	-0.256***	-0.309**	-0.739***	-0.125
		(0.070)	(0.139)	(0.154)	(0.089)
Age (ref. under 30)	12.7				
Between 30 and 44		-0.123	-0.166	-0.328*	-0.152
		(0.089)	(0.121)	(0.184)	(0.122)
Between 45 and 54		-0.314***	-0.391**	-0.473**	-0.358**
		(0.110)	(0.194)	(0.218)	(0.154)
55 and over		-0.556***	-0.824**	-1.347***	-2.432***
		(0.158)	(0.330)	(0.421)	(0.474)
Couple (vs. single)	0.2	0.166**	0.200*	-0.098	0.335***
		(0.082)	(0.116)	(0.197)	(0.125)
Child(ren) at home	0.0	-0.206*	-0.315	-0.303	-0.361**

		(0.105)	(0.202)	(0.248)	(0.147)
Education attainment (ref. primary)	0.6				
Secondary education		0.035	0.118	0.066	0.970***
		(0.164)	(0.262)	(0.359)	(0.312)
Higher education		0.017	0.101	-0.071	0.965***
		(0.164)	(0.257)	(0.363)	(0.315)
Agglomeration size (ref. <2000 inhabitants)	9.9				
2000 to less than 20,000		0.220	0.345	1.007***	0.036
		(0.141)	(0.225)	(0.315)	(0.183)
20,000 to less than 100,000		0.318**	0.510**	1.095***	0.163
		(0.141)	(0.249)	(0.318)	(0.183)
More than 100,000		0.336***	0.492**	1.124***	0.029
		(0.130)	(0.237)	(0.284)	(0.172)
Country (ref. France)	6.3				
Germany		-0.017	0.045	0.272	0.017
		(0.108)	(0.144)	(0.205)	(0.154)
Spain		0.210**	0.310*	-0.406*	0.414***
		(0.094)	(0.168)	(0.222)	(0.124)
United Kingdom		-0.157	-0.184	-0.662**	0.005
		(0.115)	(0.156)	(0.285)	(0.138)
Travel habits	**50.2**				
User of route planner applications	12.8	0.123***	0.154*	0.196**	0.058
		(0.040)	(0.080)	(0.088)	(0.048)
Traffic check before leaving	8.3	0.071**	0.095**	0.190***	0.089**
		(0.028)	(0.047)	(0.057)	(0.038)
Household number of cars	1.9	-0.078	-0.071	-0.255**	0.027
		(0.049)	(0.065)	(0.114)	(0.063)
Having a driving license	0.3	0.080	0.108	0.435*	0.146
		(0.116)	(0.162)	(0.259)	(0.149)
Constrained travel schedule	15.0	0.230***	0.326**	0.558***	0.242***
		(0.049)	(0.146)	(0.109)	(0.069)
Perception of travel time	9.7	0.100***	0.131*	0.227***	0.085**
		(0.029)	(0.068)	(0.060)	(0.041)
Commute during peak hours	2.2	-0.135*	-0.224*	-0.036	-0.406***
		(0.071)	(0.134)	(0.158)	(0.132)
Mode choice criteria	**12.6**				
Speed	0.3	-0.011	-0.032	-0.141	-0.115**
		(0.032)	(0.044)	(0.089)	(0.045)
Convenience	0.2	-0.037	-0.039	-0.118	-0.097**
		(0.038)	(0.059)	(0.096)	(0.047)
Timeliness	0.5	0.009	-0.010	0.077	-0.067
		(0.042)	(0.058)	(0.098)	(0.056)
Comfort	0.2	-0.001	-0.012	0.222**	-0.079
		(0.046)	(0.057)	(0.093)	(0.055)
Less costly	3.6	0.115***	0.116*	0.155	0.004
		(0.042)	(0.068)	(0.103)	(0.051)
Physical activity	3.5	0.083*	0.129	0.374***	0.043
		(0.047)	(0.081)	(0.104)	(0.054)
Environmentally friendly	1.3	0.040	0.035	0.004	-0.064
		(0.053)	(0.067)	(0.156)	(0.062)
Safety	1.0	0.053	0.062	-0.176	-0.068
		(0.059)	(0.073)	(0.196)	(0.064)
Less tiring	2.0	0.083	0.123	-0.479	0.132**
		(0.058)	(0.083)	(0.383)	(0.053)
Observations	**4873**	**4873**	**4873**	**3200**	**1673**

Log likelihood	-880.98	-883.82	-880.51	-315.30	-499.53
Skewness		0	0.50	1.75	0.82
Kurtosis		3	4.13	10.04	8.86
Likelihood-ratio test of the OP model against the SNP model					
Chi-2(1)			6.61	23.89	27.19
p-value			[0.010]	[0.000]	[0.000]

Note: 'DA' is dominance analysis. Standard errors are given in brackets. Significance levels are 1% (***), 5% (**) and 10% (*).
***Source*: Authors**

The standardized dominance analysis is presented in column [1].[7] The analysis reveals that travel habits account for half of the variability explained by the model, followed by sociodemographic characteristics (around 37%) and mode choice criteria (around 13%). Specifically, among travel habits, constrained travel schedule and use of route planner applications have the strongest effects, explaining 15% and 13% of the variability, respectively. Among sociodemographic characteristics, age explained around 13% of the variability in micromobility commuting, followed by place of residence (around 10%) and gender (around 8%). Among the mode choice criteria, cost and physical activity had the most influential effects, explaining each around 4% of the variability in micromobility commuting.

The results of the ordered probit and SNP ordered probit models are reported in columns [2] and [3]. Both specifications yield similar results in terms of significance levels, although the parameter estimates cannot be directly compared due to differences in the fitted densities. The likelihood-ratio test indicated that the SNP model outperformed the standard ordered probit model at a 5% significance level (Chi-2(1) = 6.61, p-value = 0.010).[8] Among sociodemographic characteristics, after controlling for other factors, being male, young, in a couple, and living in a medium-sized or large agglomeration were associated with a higher probability of engaging in micromobility commuting.[9] There was a significant difference in

[7] We used ordered logit models for computational reasons (2,097,151 sub-models have been estimated). Pseudo-R^2 is 0.097.
[8] Log-likelihood values and likelihood-ratio statistics for different values of K from 3 to 6 were tested and suggest a polynomial order of three.
[9] We also tested the same model with 'Age' treated as a continuous variable: age was negatively linked to micromobility commuting, but did not present any quadratic form.

micromobility commuting behavior between France and Spain, with Spanish users being more likely to engage in micromobility commuting. However, we found no significant differences for Germany and the UK.[10] In terms of travel habits, individuals who experience a constrained travel schedule or have a positive perception of travel time were more likely to engage in micromobility commuting. However, the need to commute during peak hours correlated negatively with micromobility commuting.

We ran further analysis distinguishing between monomodality and multimodality.[11] The results for each model are presented in columns [4] and [5]. In both cases, the likelihood-ratio test indicated that the SNP model outperformed the standard ordered probit model at a significance level of 1% (Chi-2(1) = 23.89, p-value = 0.000 for monomodality, and Chi-2(1) = 27.19, p-value = 0.000 for multimodality).

The results for *monomodal micromobility commuting* (column [4]) reveal several positive relationships with our explanatory variables. Individuals who live in urban areas (regardless of size) and individuals who use route planner applications and check traffic before leaving are more likely to engage in monomodal micromobility commuting. Individuals who have to contend with a constrained travel schedule and have a positive perception of travel time are also more likely to engage in monomodal micromobility commuting. Valuing comfort and physical activity as mode choice criteria is also positively associated with monomodal micromobility commuting. Conversely, being female, over 30 years old, living in Spain or the UK, and owning multiple cars are factors that are negatively related to monomodality.

The results for *multimodal micromobility commuting* (column [5]) generally overlap with the results for monomodality, but with a few differences. Gender and agglomeration size are not significant factors in explaining multimodal micromobility commuting. However, being in a

[10] To test across-country differences, we modified the reference country using the same specification: the effect was only statistically significant when Spain was the reference country (vs. all other countries).
[11] For endogeneity reasons, the variable 'Multimodality' has not been included in the model.

couple, having a higher level of education, living in Spain, and valuing low fatigue as a mode choice criterion are positively associated with multimodality but either negatively associated (living in Spain) or not significantly associated with monomodality. Commuting during peak hours and valuing speed and convenience as mode choice criteria are negatively associated with multimodality but not significantly associated with monomodality. Among micromobility commuters, substitution is more prevalent on average (43%) than monomodality (33%) and complementarity (24%). These percentages are similar for both occasional and everyday users. In contrast, among the entire sample of commuters, the majority (66%) engaged in monomodal transport, followed by substitution (24%) and complementarity (10%).

We addressed the combination of transport modes by asking commuters how frequently they had used different modes in the past twelve months, via the following question: “Please indicate how frequently you used the different transport modes listed below in the past twelve months (outside of leisure and free time): (1) ‘never’, (2) ‘rarely during the year’, (3) ‘every month or almost’, (4) ‘two or three times a month’, (5) ‘one or two times a week’, (6) ‘every day’.” Car travel emerges as the dominant commuting mode in all four countries studied, ahead of bike, taxi, and other specific modes of public transport that were all comparatively less prevalent (Table A.3). To analyze the concepts of substitution and complementarity between transport modes, we created new variables to represent the frequency of use for each mode. These variables were constructed based on the responses to the above question, where the three lower-frequency modalities (‘never’, ‘rarely during the year’, and ‘every month or almost’) were coded '0', and the remaining modalities (‘two or three times a month’, ‘one or two times a week’, ‘every day) were coded '1'. Next, we calculated the mean values of the two dichotomous variables, i.e. ‘Substitution’ and ‘Complementarity’, among occasional and main-mode micromobility users for each transport mode and country (Fig. 3).

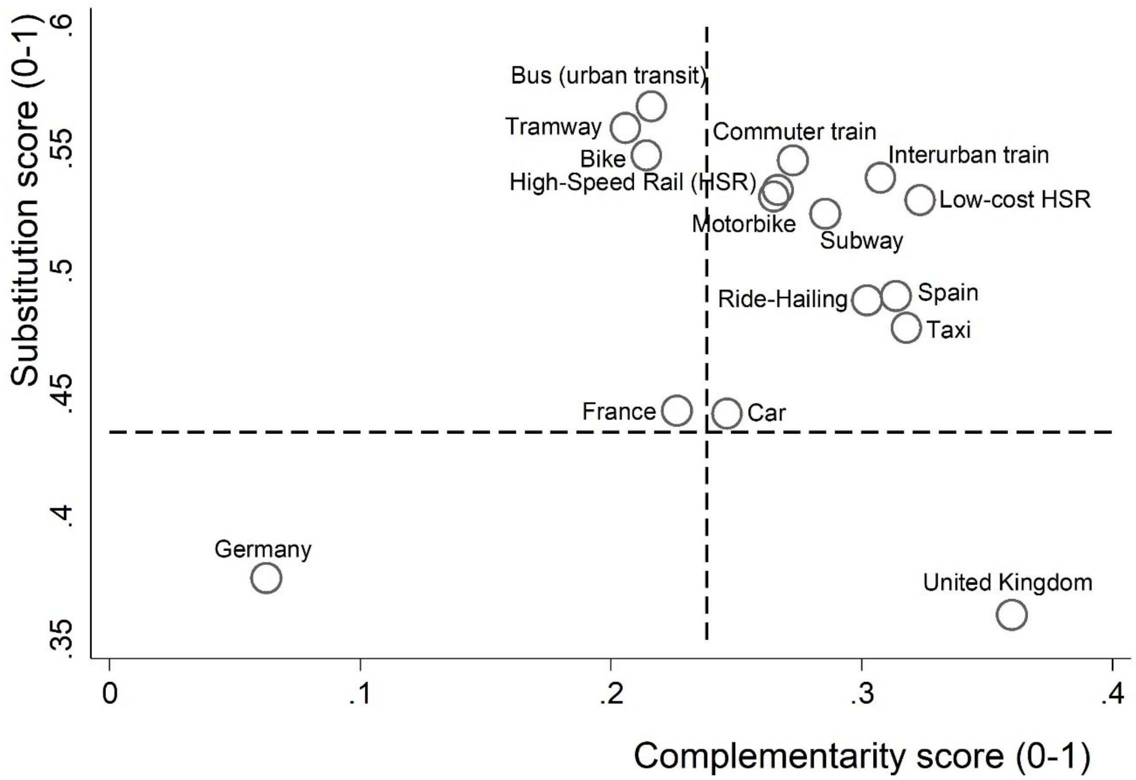

Figure 3 Substitution and complementarity practices among micromobility users
Note: Number of observations = 214
Source: Authors

Figure 3 illustrates that micromobility users tend to engage more in multimodal practices, both as substitutes and complements, compared to other transportation users. Among micromobility users, bus and tram were the primary modes of substitution while taxi, ride-hailing services, and various forms of train transit were commonly used as complementary modes with micromobility. Interestingly, the data also revealed that private cars were utilized both as substitutes and complements to micromobility modes. The level of multimodality in Germany was relatively low compared to the other countries. The UK showed a higher level of complementarity-oriented multimodal practice. Spain had a good balance between substitution and complementarity practices, while France falls in an intermediate position.

4.3. Discussion

Numerous studies have examined rates of substitution between traditional transport modes, such as private cars and public transport, and micromobility modes in the broadest sense, such as bikes, e-bikes, and e-scooters. However, it is delicate to differentiate between monomodality (patterns of full substitution based on mode characteristics and individual attributes) and multimodality (patterns of partial substitution influenced by varying trip conditions) (Milakis et al., 2020; Reck et al., 2021; Liao & Correia, 2022). The concept of full substitution, where individuals fully replace one mode with a new mode, is not the only practice observed when adopting a new mode. Eccarius & Lu (2020) argue that e-scooter sharing systems tend to increase commuters' multimodality by providing an additional mode option, with regular users of e-scooter sharing systems also reporting a more frequent weekly use of public transport (64%) than non-users (46%).

Examining multimodality enabled us to determine whether various modes of micromobility serve as partial substitutes or complements to other transport modes. Christoforou et al. (2021) considered different levels of substitution (occasional, intermediate, and frequent) and found that 16% of shared e-scooter trips in Paris in 2019 replaced a motorized mode, such as a private car, taxi, or motorcycle. This indicates a partial substitution with motorized modes. Here we also observed patterns of partial substitution with motorized modes, specifically with motorcycles (substitution score between the modes or SS > 0.5) and taxi/ride-hailing services (SS of around 0.5, see Fig. 3). In addition, our study reveals a significant level of modal complementarity between micromobility modes (partially human-powered) and taxi/ride-hailing services, with complementarity scores (CS) of around 0.3 (see Fig. 3). This suggests that micromobility users often carry their privately-owned microvehicle with them in a taxi or ride-hailing vehicle, unlike shared e-scooters that have to be left on the street after use. The relationship between private cars and micromobility modes showed a more ambiguous pattern. On one hand, Fig. 3 suggests the presence of both substitution and complementarity between micromobility modes and private cars (SS of around 0.4 and CS of around 0.2): possible substitution using self-balancing microvehicles for some trips, and complementarity using human-powered microvehicles for other trips.[12] On the other hand, these findings align with previous research conducted in Europe, which finds relatively lower levels of multimodality between micromobility and private cars in Europe compared to the United States (Wang et al., 2022): in four different studies conducted in 2019 in Oslo, Norway, and in the cities of Paris, Lyon, and Marseille, France, less than 5% of car trips were reported to have a shared e-scooter as a transfer mode. Conversely, a broader range of values, spanning from 10% to 46%, was reported across 15 distinct studies conducted in the United States. Notably, only three American studies reported values falling within the range of 5% to 9%, specifically in the locales of San Francisco, California, and Arlington County, Virginia. This difference could be attributed to differences in human population density and the development of public transportation systems, where the USA has a less extensive network, making micromobility a more competitive alternative for replacing car trips rather than trips made by public transport.

Our analysis indicates that for public transport, short micromobility trips are more likely to be substituted with bus or tram services (SS of around 0.6), whereas trains are used as a complementarity option (CS of around 0.3, see Fig. 3). This can be attributed to the average length of train trips, which are typically longer and less suitable for substitution with micromobility modes. However, micromobility is commonly used as a complementary mode for first-mile trips, as trains offer greater microvehicle carrying capacity compared to buses or trams. Findings reported in Moinse et al. (2022) support our observations regarding the

[12] Unfortunately, the survey does not make it possible to differentiate between the use of self-balancing (e-scooters, hoverboard, solowheel, gyropode) and human-powered microvehicles (scooter, roller blade, skateboard).

complementary use of privately-owned scooters and e-scooters as an access and egress mode for train riders in the South-East of France. The authors found that 85% of scooter and e-scooter owners who commute by train use their microvehicle as both an access and egress mode.[13] Focusing on the population of micromobility users rather than intermodal train riders, Christoforou et al. (2021) found that 23% of e-scooter owners load their vehicle onto a public transport. This rather low figure may be attributed to: (1) the aggregation of different types of public transport modes in the study (urban and non-urban), and (2) the inclusion of only self-balancing microvehicles. It is likely that the longer range of self-balancing microvehicles compared to human-powered ones contributes to the lower prevalence of multimodal practices in Christoforou et al.

The fact that the use of (shared) e-scooters as a complement to public transport varied between different cities highlights the importance of technology, regulations, and incentives in promoting modal integration and complementarity (Wang et al., 2022). The differences observed among the four countries in our study may be attributed to variations in these factors. For example, Germany is characterized by a low level of multimodality (CS < 0.1). The high proportion of commuting trips made during peak hours (45% of all commuting trips, see Table A.2) can pose challenges for loading microvehicles onto a public transport, especially self-balancing vehicles which are heavier and more cumbersome than human-powered ones. To address this issue, incentives can be implemented to encourage employers and employees to stagger their commuting hours, such as offering time-based fare modulation in public transport. However, the effectiveness of such incentives may vary between countries like Spain and France, where commuters already have lower rates of peak-time travel (38% and 35% of all commuting trips, respectively).

[13] However, the sub-sample of scooter and e-scooter owners used in the article only comprises 53 users.

Addressing multimodality between micromobility and public transport requires efforts from both micromobility suppliers and city planners. Micromobility suppliers need to focus on improving battery range and charging infrastructure, and reducing the weight of microvehicles to make them more compatible with public transport (Shaheen et al., 2022). City planners need to prioritize improving public transport infrastructure. Indeed, cities with well-developed and high-quality public transport networks tend to have higher levels of multimodality (McQueen et al., 2020). The issue of microvehicle boarding capacity for public transport also warrants needs attention (Oeschger et al., 2020). The secondary focus for public policy regarding multimodality between micromobility and public transport is road design, especially in transfer zones where different modes intersect. It is important to develop environments that are conducive to walking and cycling (McQueen et al., 2020). Better connections between cycle paths should also be sought (Oeschger at al., 2020). Such developments are expected to limit conflicts of use with motorized modes, including parking. Furthermore, a regulatory environment favorable to active modes, such as traffic calming measures, is needed on roads that are shared with motorized modes.

Finally, we investigate the relationship between regulation and city size to try to explain differences in micromobility practices. Compared with rural areas (< 2,000 inhabitants), we revealed that medium-sized and large agglomerations (> 20,000 inhabitants overall) were associated with greater use of privately-owned microvehicles (See Models [2] and [3] in Table 3). Human-powered microvehicles are considered to be pedestrians and must generally be used on sidewalks. On the other hand, regulations governing the use of self-balancing microvehicles are specific and differ from country to country: registration and insurance requirements, minimum age, maximum speed limit, etc. These regulations may also differ within a given country, between urban and rural areas. For example, in France, self-balancing microvehicles are authorized on the roadway in urban areas where there are no cycle lanes, whereas they are generally not authorized in rural areas for safety reasons. In our study, however, this discrepancy cannot explain the homogenous behavior of (monomodal) micromobility commuters in urban areas, as opposed to rural areas (model [4] in Table 3). Indeed, our database dates back to 2018, the year in which e-scooter sharing systems were deployed in major European cities. This implies that the users of privately-owned self-balancing microvehicles were not subject yet, in any of the four countries considered, to any specific regulations (whereas the users of human-powered microvehicles, on the other hand, were considered to be pedestrians both in urban and rural areas even before 2018). The explanation for this urban/rural divide must therefore be sought more reasonably in average travel distances (not observed in the study), which would be higher, on average, in rural than in urban areas, or simply in safety reasons.

5. CONCLUDING REMARKS

This study contributes to the existing literature by examining the intersection of multimodality and trip purposes in the context of micromobility practices. We utilized data from a survey conducted in four European countries to investigate how micromobility commuting can serve as a complement or substitute to traditional transport modes. In all four countries studied, micromobility commuting is marginal. The low ownership rates and age segmentation among users pose significant barriers to wider adoption of micromobility commuting. Micromobility commuters share a homogeneous sociodemographic profile, primarily consisting of young urban males. We find that travel habits, such as having a constrained travel schedule and using route planner applications, play a more significant role in explaining the variability in micromobility commuting than sociodemographic characteristics and mode choice criteria. We also find that the desire for physical activity is closely related to monomodal micromobility, whereas a preference for limiting fatigue during travel is positively linked to multimodal micromobility.

In summary, our study provides valuable insights showing that micromobility commuting is used as a partial substitute to urban transit systems for short distances and as a complement for longer trips made by train transport. Various forms of train transport offer higher carrying capacity, making them suitable for accommodating microvehicles. However, our study does not give conclusive results on the type of multimodality observed with private car usage. We also find that monomodal micromobility is relatively rare among commuters, regardless of their home country. This can be attributed to the commuting distances involved and the specific characteristics of the microvehicles considered here, which include both self-balancing and human-powered options. Germany may be an exception, as its well-developed cycling infrastructure may contribute to the popularity of monomodal micromobility practices. Furthermore, we observe variations in multimodal micromobility commuting patterns across countries. The United Kingdom practices complementarity-oriented multimodal commuting, while Spain shows a balance between both practices, and France falls somewhere in between.

Our data is from 2018. The Covid-19 pandemic has led to changes in mobility behavior, with a shift away from urban public transport towards privately-owned modes of transport such as cars and bikes/e-bikes. At mid-2022, the modal share of public transport networks in France had still not fully recovered to pre-pandemic levels. While it is unclear whether there has been a decrease in multimodal micromobility commuting as a result of the pandemic, there may be opportunities to promote greater uptake of micromobility by maintaining the specific cycling infrastructure implemented during the pandemic. In addition, the rise in work-from-home arrangements in the four countries studied may reduce the number of micromobility commuting trips, but could also generate an increase in the number of other local trips, such as shopping, that are favorable to micromobility and other active modes of transport.

This study provides valuable insights for the design of local transport policies that aim to promote micromobility commuting. Ongoing investments in public transport networks and better integration with microvehicles are necessary. Infrastructure policy needs to prioritize environments that are conducive to walking and cycling. Regulations should be brought in to favor active mobility over motorized modes of transport. The design of transfer zones, where several modes intersect, needs to be handled with particular care.

This study carries several limitations. First, we were unable to differentiate between human-powered and self-balancing microvehicles, which may have affected the analysis of average distances traveled and the types of multimodality practices observed among users. Second, the limited number of micromobility commuters prevented us from conducting a detailed econometric analysis specific to each country. Expanding the survey and developing separate models for each country would provide additional information on the specificities of micromobility behaviors in different contexts.

Further research is needed on multimodal micromobility and the diversity of micromobility modes and owners. Regarding multimodal micromobility, the integration of public transport systems and different types of micromobilities such as shared and private e-scooters should be investigated (Oeschger et al., 2020). Regarding road design, the ability to modify bicycling infrastructure to serve a wide range of microvehicles is critical (McQueen et al., 2020). Regarding last-mile micromobility users, the specific needs and preferences of integrated transport users should be taken into account when planning and developing measures (Oeschger et al., 2020). Future research could also include more thorough analysis of micromobility owners. Studies focused on micromobility owners could instructively investigate technical issues such as micromobility maintenance and charging habits (Christoforou et al., 2021).

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APPENDICES

Appendix 1: Socio-demographic characteristics of commuters by country

Table A.1. Socio-demographic characteristics of commuters by country (%)

	France				Germany				Spain				United Kingdom				**All**			
	All	(1)	(2)	(3)	All	(1)	(2)	(3)	All	(1)	(2)	(3)	All	(1)	(2)	(3)	**All**	**(1)**	**(2)**	**(3)**
Gender: Women	51.0	51.9	30.1	30.4	48.4	48.5	50.0	0.0	46.4	46.8	43.5	20.0	49.8	49.9	57.9	16.7	**49.7**	**50.3**	**39.9**	**25.0**
Age																				
Under 30	28.1	27.7	36.1	52.1	23.1	22.7	33.3	0.0	17.6	16.9	30.4	0.0	26.9	27.0	26.3	16.7	**25.6**	**25.2**	**33.1**	**36.1**
30 and 44	40.4	40.3	42.2	34.8	34.5	34.3	40.0	50.0	41.0	40.5	47.8	60.0	38.2	37.2	68.4	66.6	**39.3**	**39.0**	**46.1**	**44.4**
45 and 54	23.5	23.8	19.3	8.7	25.2	25.6	16.7	0.0	28.9	29.5	17.4	40.0	24.7	25.3	5.3	16.7	**24.7**	**25.1**	**16.9**	**13.9**
55 and over	8.0	8.2	2.4	4.4	17.2	17.4	10.0	50.0	12.5	13.1	4.4	0.0	10.2	10.5	0.0	0.0	**10.4**	**10.7**	**3.9**	**5.6**
Couple	63.1	63.1	67.5	52.2	58.3	58.1	6.3	50.0	61.6	60.8	69.6	100	56.4	56.5	63.2	33.3	**61.1**	**61.0**	**66.9**	**55.6**
Child(ren)	47.6	47.8	49.4	26.1	30.9	30.8	36.7	0.0	41.2	40.8	45.7	60.0	36.5	36.4	42.1	33.3	**42.5**	**42.5**	**45.5**	**30.6**
Education																				
Primary	3.6	3.7	1.2	0.0	6.1	6.0	3.3	50.0	6.6	6.6	6.5	0.0	15.5	15.6	15.8	0.0	**6.2**	**6.3**	**4.5**	**2.8**
Secondary	36.1	36.5	28.9	17.4	63.4	63.0	76.7	50.0	32.2	31.7	41.3	20.0	37.9	37.9	42.1	16.7	**39.8**	**39.9**	**41.6**	**19.4**
Tertiary	60.3	59.8	69.9	82.6	30.5	31.0	20.0	0.0	61.2	61.7	52.2	80.0	46.6	46.5	42.1	83.3	**54.0**	**53.8**	**53.9**	**77.8**
Agglomeration size																				
< 2000 inhabit.	27.0	27.8	8.4	8.7	8.3	8.6	3.3	0.0	3.1	3.0	6.8	0.0	7.3	9.3	0.0	16.7	**18.3**	**18.8**	**6.4**	**8.3**
2000 - 20,000	16.6	16.8	13.3	8.7	31.2	31.7	30.0	0.0	20.3	21.4	18.2	0.0	20.4	25.7	26.7	0.0	**20.6**	**20.9**	**18.6**	**5.6**
20,000 - 100,000	11.2	11.1	15.7	13.0	23.9	24.1	23.3	50.0	25.2	26.5	25.0	0.0	22.0	27.3	40.0	16.7	**17.6**	**17.4**	**21.5**	**13.9**
> 100,000	45.2	44.3	62.6	69.6	36.6	35.6	43.4	50.0	51.4	49.1	50.0	100	50.3	37.7	33.3	66.6	**43.5**	**42.9**	**53.5**	**72.2**
Observations	2664	2558	83	23	727	695	30	2	745	694	46	5	737	712	19	6	**4873**	**4659**	**178**	**36**

Micromobility commuters: Never (1), Occasional (2), Main (3).
Reading note: Women represent 49.7% of all commuters, but only 39.9% of occasional micromobility commuters and 25% of main micromobility commuters (last column).
Source: Authors

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Appendix 2: Travel habits and mode choice criteria

Table A.2. Travel habits and mode choice criteria by country (mean values, commuters only)

	Min	Max	France	Germany	Spain	United Kingdom	All
Travel habits							
User of route planner applications	1	4	1.59	1.92	1.70	1.88	**1.70**
Traffic check before leaving	1	5	2.22	2.74	2.05	2.43	**2.30**
Household number of cars	0	3	1.52	1.31	1.34	1.25	**1.42**
Having a driving license	0	1	0.93	0.91	0.91	0.77	**0.90**
Constrained travel schedule	1	4	2.63	2.32	2.55	2.43	**2.54**
Perception of travel time	1	4	2.16	2.51	2.60	2.48	**2.33**
Commute during peak hours	0	1	0.37	0.45	0.38	0.46	**0.40**
Multimodality	0	1	0.32	0.29	0.46	0.36	**0.34**
Microvehicle owner	0	1	0.24	0.27	0.18	0.32	**0.22**
Mode choice criteria							
Speed	0	3	0.54	0.43	0.72	0.56	**0.56**
Convenience	0	3	0.36	0.56	0.38	0.40	**0.40**
Timeliness	0	3	0.18	0.53	0.39	0.21	**0.27**
Comfort	0	3	0.13	0.38	0.54	0.15	**0.23**
Less costly	0	3	0.22	0.30	0.02	0.43	**0.23**
Physical activity	0	3	0.15	0.15	0.27	0.12	**0.16**
Environmentally friendly	0	3	0.13	0.17	0.21	0.09	**0.14**
Safety	0	3	0.10	0.13	0.19	0.09	**0.12**
Less tiring	0	3	0.10	0.14	0.14	0.08	**0.11**
Observations			**2664**	**727**	**745**	**737**	**4873**

Source: Authors

Appendix 3: Frequency of use of transport modes

Table A.3. Frequency of use of transport modes (commuters only)

	Mean	Min	Max	Mean values by category		
				Never	**Occasional**	**Main**
Car	4.72	1	6	4.75	4.05	3.89
Bike	1.92	1	6	1.88	3.01	2.08
Taxi	1.56	1	6	1.53	2.23	1.75
Bus (urban transit)	1.53	1	6	1.51	1.80	2.22
Subway	1.58	1	6	1.56	1.94	2.25
Tramway	1.46	1	6	1.44	1.71	2.08
Commuter train	1.40	1	6	1.39	1.58	1.83
Motorbike	1.39	1	6	1.36	2.16	1.86
Ride-hailing	1.37	1	6	1.34	2.08	1.83
High-speed rail	1.27	1	6	1.25	1.49	1.67
Interurban train	1.17	1	6	1.16	1.46	1.31
Low cost high-speed rail	1.13	1	6	1.12	1.32	1.25
Observations	**4873**			**4659**	**178**	**36**

Note: 'SD' is standard deviation.
Source: Authors