

# The role of environmental awareness and knowledge in the choice of a seated electric scooter

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## ABSTRACT

This paper presents a study aimed at estimating the role of latent variables when choosing between a seated electric scooter (SES) and a conventional one. As a modeling framework, we opted for the hybrid mixed choice model since it allows the possibility of jointly evaluating the impact of the economic and technical features of the scooter and latent factors on scooter choice, thus gaining a more realistic representation of the choice process. For the latent variables, we focused on concern for the environment and scooter knowledge. We developed a questionnaire specifically targeted at gathering data on choices and indicators capturing the latent variables and surveyed 413 respondents living in the city of Trieste, Italy, who were as diversified as possible in terms of age, education, and profession. The main finding was that besides various financial and technical scooter features (e.g., purchase price, fuel economy, annual cost of circulation tax and insurance premium, driving range, engine power, removable battery, and manufacturer’s country), a higher level of concern for the environment particularly at the local level positively influenced the choice of an SES, while SES knowledge did not play a statistically significant role.

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## 1. Introduction

Italy has the largest motorcycle fleet in Europe, consisting of 8.7 million motorcycles (23% of the EU-28 total), 6.8 million of which are motorcycles and 1.9 million of which are mopeds<sup>1</sup> (ACEM, 2019). Italians use motorcycles for many of their mobility needs. ISFORT (2019) reported that 4.3% of motorized trips are made by motorcycles, which are used primarily for commuting short distances between 2 and 10 km. Users are mostly young men. Motorcycles are particularly successful in medium-sized cities and in the Southern regions, most likely due to the insufficient supply of public transport. Possible explanations for their high use include the physical configuration of Italian cities (narrow roads, low garage availability, hilly streets, and high density), traffic conditions (congestion and lack of parking), favorable weather conditions, low purchase and operating costs, a tradition of using and building motorcycles dating back to the post-war years, and the pleasure of riding motorcycles.

Trieste is one of the Italian cities with the largest density of motorized two-wheelers (one out of five residents own a scooter); 12.6% of commuting trips are performed with motorcycles or mopeds, while non-motorized vehicles (bicycles and standing e-scooters) make up only 0.63% of commuting trips. Common explanations for the preference for motorized two-wheelers are the hilly streets and lack

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<sup>1</sup> Motorcycles are motorized two-wheelers with a displacement of the internal combustion engine higher than 50 cm<sup>3</sup>, while mopeds have an engine displacement up to 50 cm<sup>3</sup> and a maximum speed limit of 45 km/h.

of reserved bicycle lanes. Currently, electric motorized two-wheelers in Trieste are very rare. Out of 48,010 motorcycles registered in Trieste in 2019, only 52 were electric (ACI, 2021). However, their benefits both at the local and global level are well-documented. Locally, they do not emit air pollutants during their use and are significantly less noisy than petrol scooter (Hernandez et al., 2019). From a global standpoint, they have the potential to decrease CO<sub>2</sub> emissions and fossil fuel dependence if the electricity is produced from renewable sources. Koossalapeerom et al. (2019) found that the energy consumption, CO<sub>2</sub> equivalent emissions, and energy cost of an electric motorcycle are about eight, two, and six times lower, respectively, than those of a gasoline motorcycle when driving in a congested urban corridor.

This paper contributes to the previous literature on seated electric scooters (SEs) in two ways. The first is geographical: most of the previous studies investigated consumers' perceptions and purchase intentions with reference to Asian cities. As early as 1999, Chiu and Tzeng (1999) estimated a multinomial logit model (MNL) for Taiwan, Sun and Zhang (2013) used a dogit model for Laos, Zhu et al. (2019) created a contingent valuation method for Macau, Guerra (2019) used a mixed logit model for Solo (Indonesia), and Patil et al. (2021) used a mixed logit model for Hyderabad (India). A common finding was that several technical and economic characteristics of the SES play a role, especially purchase price, range, speed, and charging time.

In general, researchers have found both positives and negatives about the potential of SESs. With reference to the most recent contributions, Guerra (2019) found that in Solo, Indonesia, nearly a quarter of respondents would choose electric motorcycles under a realistic, immediately available, and not particularly convenient charging system, but half of respondents indicated that they would opt for gas-powered motorcycles under most circumstances. Patil and Majumdar (2021) concluded that in India, electric motorcycles with a longer range, higher speed, and faster acceleration rate have a good chance to substitute conventional motorcycles, provided there is an adequate charging and parking infrastructure. Scorrano and Danielis (2021b) published the first study concerning a European country. In 2019, they analyzed the characteristics of the demand for SESs among 518 respondents living in various Italian regions and cities. They estimated a random parameter logit (RPL) model identifying the main technical and economic demand characteristics, but they disregarded the roles of attitudes and knowledge. Scorrano and Danielis (2021b) concluded that although SESs still suffer from a negative stigma and their available supply in Italy is quite poor (especially in terms of prestigious brands, distribution networks, and after sales service), SES demand might increase by 11–16% with proper fiscal incentives and improvements in battery technology. This paper adds a second contribution concerning Italy based on a new survey performed between November 2020 and February 2021 involving 413 respondents living in the city of Trieste. The focus on a single city allowed us to collect a more representative random sample differentiated in terms of age and profession. The difference of one year between the two surveys is interesting since SESs are becoming gradually better known among the general public, although, as shown in this paper, respondents' level of knowledge regarding SESs was still quite low.

The second contribution is methodological. In all the above-mentioned papers, the role of latent variables (LVs) as co-determinants

**Table 1**

Selected papers on the choice among conventional and electric vehicles and scooters using stated-choice experiments with specific attention to the impact of knowledge.

Study	Country	Vehicle type	Experience	Subjective knowledge	Objective knowledge	Modeling
<b>Electric cars</b>						
Krause et al. (2013)	United States	PHEVs	No	No	Yes	Multivariate regression
Jensen et al. (2013)	Denmark	EVs	Yes	No	No	Hybrid choice model
Bühler et al. (2014)	Germany	BEVs	Yes	No	No	Exploratory approach
Skippon et al. (2016)	United Kingdom	BEVs	Yes	No	No	Causal analysis
Schmalfuß et al. (2017)	Germany	BEVs	Yes	No	No	Linear mixed models and multiple linear regression analyses
Wang et al. (2018)	China	BEVs	No	Yes	No	Extended technology acceptance model
Langbroek et al. (2019)	Sweden	BEVs	Yes	Yes	No	Protection motivation theory and transtheoretical model of change
Thøgersen and Ebsen (2019)	Denmark	BEVs	Ownership	No	No	Structural equation modeling
Sovacool et al. (2019)	China	BEVs	Yes	Yes	No	Multivariate analysis and principal component analysis
Rotaris et al. (2021)	Italy	BEVs	Yes	Yes	No	Hybrid choice model
Kowalska-Pyzalska et al. (2021)	Poland	AFVs*	No	No	Yes	Ordered logit model
<b>Seated electric scooters/motorcycles</b>						
Sun and Zhang (2013)	Laos	Electric motorcycles	No	Yes	No	Dogit model
Zhu et al. (2019)	Macau	Electric motorcycles	No	Yes	No	Contingent valuation method
Guerra (2019)	Solo (Indonesia)	Electric motorcycles	No	Yes	No	Mixed logit model
Patil et al. (2021)	Hyderabad (India)	Electric two-wheelers	No	No	No	Mixed logit model
This study	Italy	SEs	Yes	Yes	Yes	Hybrid choice model

\*AFV: alternative fuel vehicles.

of scooter choice was not accounted for, as also underlined by [Eccarius and Lu \(2020\)](#). A more detailed discussion on this topic is presented in the literature review section. Factors such as environmental concern or scooter knowledge are at most modelled as observable, often self-reported, characteristics of the respondents. In this paper, we are the first to make use of the hybrid mixed choice (HMC) modeling framework to account for the role of LVs ([Golob, 2001](#); [Choo & Mokhtarian, 2004](#)) in shaping the scooter choice process. The questionnaire was specifically developed to capture the different dimensions of scooter knowledge (direct and indirect experience as well as objective and subjective knowledge) and environmental concern (global and local).

After reviewing the literature (Section 2), we illustrate the modeling framework (Section 3) and its application to the city of Trieste (Section 4). The results are then presented (Sections 5 and 6) and discussed (Section 7). The final section (Section 8) draws the main conclusions and suggests future research paths. A descriptive analysis of the indicators used for the LVs of scooter knowledge and environmental concern is presented in the [Supplementary Material \(SM\)](#).

## 2. Literature review on the role of environmental awareness and knowledge in consumers' choice

There are numerous psychological and social factors that might influence the choice of a vehicle, including environmental awareness, knowledge, innovativeness, status symbol, social influence (social norms and peer pressure), and risk aversion. We decided to investigate the role of environmental awareness and knowledge since they are often mentioned in the vehicle choice literature. A deeper understanding of their role is relevant both for vehicle manufacturers and for policy makers.

### 2.1. The role of knowledge

Consumers learn about the vehicles available on the market through many channels. These include direct experience (test drives, renting or sharing, leasing, ownership, or riding as a passenger), indirect experience (information gathered from peers or relatives who had direct experience), or information derived from social media (YouTube, specialized groups, forums, or newsletters) and TV and web advertisements.

A challenge for scientific research is identifying and measuring the impact of these channels on consumers' choices. In the case of electric cars, several papers have explored the impact deriving from direct experience ([Table 1](#)). To test their hypothesis, [Jensen et al. \(2013\)](#) and [Jensen et al. \(2014\)](#) gathered data before and after individuals experienced a battery electric vehicle (BEV) in real life during a three-month period. They found that the real-life experience decreased the probability of buying a BEV. [Bühler et al. \(2014\)](#) conducted a six-month trial with BEV drivers in the Berlin metropolitan area and analyzed their evaluation at three data collection points (before receiving the BEV and after three and six months of usage). Participants reported a wide range of advantages but also barriers. Similarly, after conducting a randomized controlled trial, [Skippon et al. \(2016\)](#) reported that willingness to consider a BEV declined after experience mainly because of driving range limitations. In a similar fashion, [Schmalfuß et al. \(2017\)](#) conducted two studies: an online survey and a 24-hour field test. The former found a positive effect of experience on purchase intention, while the latter showed no effect. However, the authors concluded that providing short-term BEV experience had the potential to change BEV evaluation and might be a promising strategy for promoting BEVs.

With increasing BEV uptake, researchers have had the opportunity to test the impact of long-term experience with driving a BEV. [Langbroek et al. \(2019\)](#), for instance, studied the relationship between BEV rental and BEV adoption. They found that although people who rented a BEV improved their subjective and objective BEV knowledge, they did not seem to be more inclined toward BEV adoption. To the best of our knowledge, no similar studies have thus far been performed for SESs.

A more common approach is to investigate the impact of subjective knowledge on consumers' choices. Through surveys, consumers are asked to rate their level of knowledge of different characteristics of the vehicles (e.g., price, performance, and driving range) or of the existing incentivizing policies. Such data are then used to estimate whether there is a correlation between knowledge and choices or intentions. With reference to BEVs, such a technique has been used by [Krause et al. \(2013\)](#), [Wang et al. \(2018\)](#), [Langbroek et al. \(2019\)](#), [Sovacool et al. \(2019\)](#), and [Rotaris et al. \(2021\)](#), among others, making use of a variety of modeling frameworks (discrete choice models, regression analyses, and structural equations). Regarding SESs, the impact of knowledge has been explored by [Sun and Zhang \(2013\)](#), who asked respondents about their familiarity with electric motorcycles. More recently, [Zhu et al. \(2019\)](#) explored respondents' knowledge concerning the salient features of electric motorcycles in Macau, such as environmental benefits, low charging cost, high price, poor battery lifetime, immature technology, high safety, and low maintenance and repair costs. [Guerra \(2019\)](#) investigated the impact of the familiarity with e-bikes, given their similarities and differences, on e-scooter purchase intentions.

Much less researched is the impact of objective knowledge. Regarding BEVs, one of the first studies to test respondents' knowledge was that of [Krause et al. \(2013\)](#). They assessed the accuracy of respondents' perceptions by comparing them to the actual technical and economic characteristics of BEVs and plug-in hybrid electric vehicles (PHEVs) in the U.S. (purchase price, vehicle maintenance cost, driving range, and recharging time) and the public awareness of available state and local policy incentives to encourage plug-in electric vehicles (PEV) adoption. The correct answers were identified prior to survey administration. Because of the variability in existing PEV technologies, they accepted a relatively broad range of reasonable answers. More recently, [Kowalska-Pyzalska et al. \(2021\)](#) tested whether respondents can assign the type of fuel to three types of vehicles (HEV, PHEV, and BEV) and recognize the brands associated with each vehicle type. No study has thus far investigated the objective knowledge of SESs.

We considered the respondents' knowledge of the existing brands, range, maintenance, uphill performance, circulation tax, acceleration, regenerative braking, fuel economy, purchase price, and subsidy. Our study seeks to trace the impact of all the channels of knowledge (experience and subjective and objective knowledge). These were incorporated into a hybrid choice modeling framework, which allowed us to not only estimate the impact of knowledge on choice but also to investigate its socio-economic determinants.

Since a growing number of studies on life-cycle analysis have concluded that BEVs are more environmentally friendly than conventional vehicles, the literature on BEV adoption has frequently examined the relationship between pro-environmental attitudes and the intent to purchase a BEV. By and large, most papers found that concern for the environment in its many facets (interest in the environment, willingness to be recognized as environmentally aware, and moral obligation to protect the environment) is generally positively associated with the intention to buy a BEV or with a preference for a BEV versus a conventional vehicle (Hackbarth & Madlener, 2016; Degirmenci & Breitner, 2018; Haustein & Jensen, 2018, Kormos et al., 2019; Rotaris et al., 2021). An exception was the study by Orlov and Kallbekken (2019), who did not find any significant relationship between BEV adoption and the statements “Buying a more energy efficient car would reduce my household’s environmental impact” and “Please rate how concerned you are about the environment.” Similarly, Figenbaum and Nordbakke (2019) found that the percentage of Norwegians who perceived BEVs as environmentally beneficial decreased from 2016 to 2018.

With specific reference to motorized two-wheelers, contributions that have analyzed the relationship between environmental concern and interest in an electric vehicle are listed in Table 2. More than a decade ago, Chiu and Tzeng (1999) documented that emissions levels codetermine choice, but only for women. More recently, Thuy and Hong (2019) found that the attitude toward electric two-wheeler usage was influenced (in descending order) by perceptions of economic benefit, usage convenience, environmental awareness, and stylish design, while environmental pollution caused by fuel motorcycles and their lack of safety had no significant relationship with electric two-wheeler usage. Performing a contingent valuation analysis, Zhu et al. (2019) found that environmental benefits played a positive role in the consideration to purchase an electric motorcycle. Guerra (2019) used smokers as a proxy for lack of concern about local air quality. They found that they were less likely to choose electric motorcycles, while respondents who think a lot about the environment valued electric motorcycles about 17% above the average purchase price. In contrast, the respondents who rarely think about the environment would need around a 50% discount on average to choose an electric motorcycle. Liu and Lai (2020) found that motorcyclists in Macau were concerned with the impact of motorcycle emissions on air quality, and their perceptions of pollution reduction positively influenced their attitudes toward electric motorcycles. Our study used a number of indicators to characterize and measure environmental concern with the hybrid choice modeling framework, which allowed us to not only estimate the impact of environmental concern on choice but also investigate its socio-economic determinants, including gender, age, education, and current choice of scooter type.

### 3. Modeling framework

An individual  $n$  is assumed to consider the full set of  $J$  proposed alternatives in each choice situation  $t \in T$  and to choose the alternative with the highest utility. The (relative) utility  $U_{njt}$  a person receives from choosing alternative  $j \in J$  in the choice task  $t$  is defined as<sup>2</sup>:

$$U_{njt} = ASC_j + \beta_j'X_{njt} + \gamma_j'Z_n + \varepsilon_{njt} = V_{njt} + \varepsilon_{njt} \quad (1)$$

where  $ASC$  is the alternative-specific constant;  $X$  is the vector of the attributes presented in the stated choice experiments;  $Z$  is the vector of socioeconomic characteristics; and  $\beta$  and  $\gamma$  are the vectors of fixed and unknown coefficients, respectively. If the random part of the utility unknown to the analyst ( $\varepsilon_{nj}$ ) is an independent and identically distributed extreme value type 1, the model is a standard MNL. MNL assumptions, however, are restrictive in that they do not allow for correlation across choices over time, flexible substitution across the choice alternatives, and variation in consumer preferences. The RPL model overcomes these limitations by allowing parameter values to vary across the population according to some pre-specified distributions. The model is reformulated as follows:

$$U_{njt} = ASC_{nj} + \beta_{nj}'X_{njt} + \gamma_j'Z_n + \varepsilon_{njt} \quad (2)$$

where the vector  $\beta_n$  differs across individuals, reflecting respondents’ tastes and following a distribution that is up to the researcher to choose when testing which one best fits the data (e.g., normal, lognormal, uniform, triangular, etc.). In  $f(\beta|\varphi)$ , the density function of  $\beta$  with  $\varphi$  refers to a vector of parameters of that density function (mean and variance), and the choice probability becomes a weighted average of the logit formula evaluated at different values of  $\beta$ , with the weights given by the density  $f(\beta|\varphi)$ .

$$P_{nj} = \int \frac{e^{V_{nj}(\beta)}}{\sum_j e^{V_{nj}(\beta)}} f(\beta|\varphi) d\beta \quad (3)$$

Since the probability is not a closed form, the probabilities are approximated through simulation for any given value of  $\varphi$ . Furthermore, since there are repeated observations for the same individual, the longitudinal dimension of the data was taken into account, assuming that the random parameters of individual  $n$  are the same for all choice situations.

The previous models, however, do not consider important aspects of behavior, as decision makers’ attitudes, tastes, perceptions, beliefs, values, etc. that may influence the choice process. Unlike socio-demographic characteristics that are directly measurable, underlying perceptions and attitudes are unobserved and can at best be inferred from other variables called indicators (Golob, 2001;

<sup>2</sup> For a thorough explanation of discrete choice models, refer to Mc Fadden (1974), Kadane et al. (1984), Ben-Akiva and Lerman (1985), and Train (2009).

**Table 2**

Selected papers on the choice among conventional scooters and SESs using stated-choice experiments with specific attention to the impact of environmental concern.

Study	Country	Variable	Modeling	Main findings
Chiu and Tzeng (1999)	Taiwan	Emission levels	MNL	Emission levels codetermine choice, but only for women.
Thuy and Hong (2019)	Hanoi (Vietnam)	Perception of environmental friendliness	Theory of planned behavior; structural equation modeling	Attitude toward electric two-wheeler usage is positively influenced by friendly environmental awareness but not by environmental pollution and unsafety of fuel motorcycles.
Zhu et al. (2019)	Macau (China)	Environmental benefits	Contingent valuation	Environmental benefits play a positive role when people consider whether to purchase an electric motorcycle.
Guerra (2019)	Solo (Indonesia)	Smokers; people who think a lot about the environment	Mixed logit model	Smokers are less likely to choose electric motorcycles. Respondents who think a lot about the environment value electric motorcycles about 17% above the average purchase price.
Liu and Lai (2020)	Macau (China)	Reduced pollution performance; Energy saving performance	Partial least squares structural equation modeling	Pollution reduction positively influences attitudes toward electric motorcycles. No differences by gender.
This study	Italy	Environmental activism; concern for the local and global environment	Hybrid choice model	Positive impact on electric scooter choice. Higher sensitivity for middle-age respondents, women, and e-scooter owners.

Choo & Mokhtarian, 2004). Hybrid choice models represent an attempt to identify such unobservable (latent) factors and include them in a discrete choice analysis in order to represent a behaviorally more realistic choice process.

Hybrid choice models consist of three components: (1) the latent variable structural equation model, (2) the latent variable measurement equation model, and (3) the choice model. The structural relationship indicates the causal relationships between observable exogenous variables (e.g., socio-demographics) and LVs. In the measurement relationship, multiple indicator variables are used to identify the LVs. The choice model describes the choice between the two propulsion systems by integrating both the LVs and the observed exogenous variables into the utility function of the choice alternatives.

### 3.1. The structural model

The structural equation for latent variable  $l = 1, \dots, L$  and for individual  $n$  is given by:

$$LV_{nl} = \vartheta_l Z_n + \eta_{LV_{nl}} \quad (4)$$

where  $Z_n$  is the vector of socioeconomic characteristics,  $\vartheta$  is a coefficient vector, and  $\eta_{LV_{nl}}$  follows a standard normal distribution across respondents, capturing the random component of the latent attitude.

### 3.2. The measurement model

Since a latent variable cannot be directly observed, the researcher must acquire information from indirect measurements. The relationship between a latent variable and these measurements is expressed by a measurement equation, the form of which depends on the nature (continuous or discrete) of the measurement itself. Since in this survey respondents were asked to evaluate each statement using a Likert scale with a number of categories, the measurement has a discrete nature. Thus, we expressed the measurement equation as:

$$I_l = \begin{cases} I_1 & \text{if } LV_l < \omega_1 \\ I_2 & \text{if } \omega_1 \leq LV_l < \omega_2 \\ \dots & \dots \\ I_i & \text{if } \omega_{i-1} \leq LV_l < \omega_i \\ \dots & \dots \\ I_w & \text{if } LV_l \geq \omega_{w-1} \end{cases} \quad (5)$$

Here, the measurement is represented by an ordered discrete variable  $I$  taking the values  $I_1, I_2, \dots, I_w$  for each latent variable  $l$ , and  $\omega_1, \omega_2, \dots, \omega_{w-1}$  are parameters to be estimated, such that.

$$\omega_1 \leq \omega_2 \leq \dots \leq \omega_{w-1} \quad (6)$$

The probability of a given response  $I_i$  is.

$$\Pr(I_i) = \Pr(\omega_{i-1} < LV_l \leq \omega_i) = \Pr(\omega_{i-1} \leq LV_l < \omega_i) = CDF(\omega_i) - CDF(\omega_{i-1}) \quad (7)$$

where  $CDF$  is the cumulative distribution function of the error term. When a normal distribution is assumed, the model is called ordered probit.



Fig. 1. The best-selling SES (Askoll, ES1, on the left) and seated petrol-fueled scooter (Honda SH 125, on the right) in Italy in 2019.

The LV measurement equations can therefore be written as:

$$I_{wn} = \bar{I}_w + \tau_{I_w} LV_{nl} + \nu_{w,n} \quad (8)$$

where  $\nu_{w,n} \sim N(0, \sigma_{I_w}^2)$  and  $\tau_{I_w}$  are estimated parameters that measure the impact of the latent variable  $LV_1$  on  $I_w$ . If statistically significant, the latent attitude  $LV_1$  has a statistically significant impact on the answers provided to the attitudinal question  $I_w$ .

### 3.3. The choice component

Finally, we looked at the joint estimation of the different model components. The utility function for powertrain alternative  $j$  and individual  $n \in \{1, \dots, N\}$  in the choice situation  $t \in \{1, \dots, T\}$  is given by:

$$U_{njt} = ASC_{nj} + \beta_{nj}' X_{njt} + \gamma_j' Z_n + \alpha_{nl}' LV_{nl} + \varepsilon_{njt} \quad (9)$$

The utility specification thus includes the alternative specific constant, choice attributes, socioeconomic characteristics, and LVs.

## 4. Application to the city of Trieste (Italy)

We prepared a questionnaire consisting of three parts. The first part concerned questions regarding socio-demographic information, including gender, age, profession, educational level, and scooter ownership. In addition, we asked questions regarding the self-assessed knowledge of SESs and seated conventional scooters (SCSs), direct and indirect experience with SESs, and SES/SCS objective knowledge. For a more detailed description, see Section 5 and SM 2.0. The second part of the survey was comprised of a set of 10 hypothetical choice exercises. Respondents were asked to choose amongst two labelled alternatives: SES vs. conventional (petrol-fueled) scooter. Using the picture shown in Fig. 1, we made it clear that for the purposes of our study, by the category “scooters” we meant seated motorized two-wheelers, such as mopeds and motorcycles with an engine displacement up to 125 cm<sup>3</sup>. The category excluded electric bicycles and was not to be confused with standing electric scooters that have become popular in recent years.

We described the two alternatives using the following financial and technical attributes: purchase price, fuel economy, and annual cost of circulation tax and insurance premium, driving range, engine power, removable battery, and country of manufacture. An example of a choice scenario is depicted in Fig. 2.

The attribute levels used in the experiment are reported in Table 3 and in SM 1.1. We developed an efficient design using the Ngen software (Bliemer & Rose, 2011). We selected the same attributes and attribute levels successfully used by Scorrano and Danielis (2021b), in which a comparison with the previous literature was also carried out. The third part consisted of a number of questions aimed at identifying individual attitudes and specific beliefs concerning the environment. We placed them in the final part of the questionnaire in order to avoid influencing respondents by suggesting a “politically correct” or expected choice between the two alternatives.

We collected data through online questionnaires administered between November 2020 and February 2021 using different

Attributes	Seated electric scooters	Seated conventional scooters
<b>Manufacturer Country</b>	China	Europe
<b>Purchase price</b>	€4,000	€3,500
<b>Fuel economy (€/100 km)</b>	€0.6	€5.5
<b>Insurance premium + circulation tax</b>	€125	€300
<b>Max driving range</b>	100 km	300 km
<b>Power</b>	7 kW	3 kW
<b>Removable battery</b>	Yes	
<b>YOUR CHOICE</b>	<input type="checkbox"/>	<input type="checkbox"/>

Fig. 2. Example of a choice task.

Table 3  
Attributes' levels.

	Seated electric scooters	Seated conventional scooters
Purchase price (€1,000)	2; 3; 4; 5; 6; 7	2; 2.5; 3; 3.5; 4
Driving range (100 km)	0.5; 0.75; 1; 1.25; 1.5	2; 2.5; 3; 3.5; 4
Power (kW)	2; 3; 4; 5; 6; 7; 8; 9	2; 3; 4; 5; 6; 7; 8; 9
Fuel economy (€/100 km)	0.5; 0.6; 0.7; 0.8; 0.9; 1	3; 3.5; 4; 4.5; 5; 5.5; 6
Circulation tax and insurance premium (€100)	1; 1.25; 1.5; 2	2; 2.5; 3; 3.5
Removable battery	Yes; No	

channels. We invited high school and college students as well as staff and employees of major private and public firms to participate through their institutional websites. The invitation was also extended to the entire population of Trieste via the major local newspaper, *Il Piccolo*, which published a link to the questionnaire.<sup>3</sup> We collected 708 questionnaires. An initial question asked whether the respondent has or might be interested in buying a scooter. Only those who replied positively ( $n = 431$ , 60.9%) proceeded completing the questionnaire.

The detailed sample composition is reported in SM 1.2. More than half of the respondents were less than 30 years of age. A large majority of these were students, half of them owned a scooter, and more than half were male. The respondents belonging to the middle age category (30–59 years old) were mostly employed, male, and owned a scooter. A minority of the respondents (7.7%) belonged to the over 60 age group. They consisted of both working and retired persons, were primarily male, and were primarily scooter owners. Relative to the population of Trieste, the sample overrepresented young men. In terms of actual scooter users, our sample is, from our everyday experience of living in Trieste, quite representative, although we cannot prove this with statistical data since there are no national or regional statistics on scooter users. Similar difficulties to prove the representativeness of the sample have been reported in previous studies (e.g., Patil et al., 2021).

## 5. Latent variables

### 5.1. Seated scooter knowledge

To investigate the respondents' knowledge of SCSs and SESs, we asked them to self-assess their level of knowledge using a three-level scale (high, average, or low). More than two-thirds (69%) stated they had a low level of knowledge about SESs, 24% a medium level, and only 7% a high level. Concerning SCSs, the level of knowledge was much higher: 25% had a low level, 51% a medium level, and 24% a high level of knowledge. Analyzing the answers (see SM 2.1), SES knowledge was lower than SCS knowledge across all age groups. In relative terms, SES knowledge was higher for middle-aged respondents, not for the young respondents as we had expected. To evaluate their objective scooter knowledge, we asked respondents 10 questions regarding SESs (Table 4) and three questions regarding SCSs (see SM 2.2).

The underlined answers are the ones we considered correct. Correct answers were given a score of 1 and incorrect answers 0. When multiple answers were possible, we considered the answer correct if all the answers were correct, without penalties for incorrect answers. A descriptive analysis of the answers is reported in SM 2.2. The main finding is that very few people (10.7%) were able to give

<sup>3</sup> Since the questionnaire was web based, respondents could complete it using either a smartphone or a computer. Although a large majority of the population of Trieste has at least a smartphone, there is a potential representation bias toward scooter riders familiar with the web.

**Table 4**

Questions to test the objective SES knowledge.

#	Question/statement	Possible answers
Q1	Which of these manufacturers sell SESs in Italy?	a) Tesla, b) <u>Askoll</u> , c) <u>Piaggio</u> , d) Honda, e) <u>Niu</u> , f) I do not know. Multiple answers are possible.
Q2	What is the driving range of an SES?	a) <50 km, b) <u>between 50 and 100 km</u> , c) more than 100 km, d) I do not know
Q3	Does an SES require more maintenance than a petrol scooter?	a) Yes, b) <u>No</u> , c) I do not know
Q4	An SES has higher acceleration due to instant torque than a petrol scooter.	a) <u>True</u> , b) False, c) I do not know
Q5	What is the uphill performance of an SES with a 2-kW electrical engine?	a) Max inclination <15°, b) <u>max inclination equal to 15°</u> , c) max inclination <30°, d) I do not know
Q6	An SES has regenerative braking.	a) <u>True</u> , b) False, c) I do not know
Q7	How much does it cost to charge an SES with a 2.8 kWh battery?	a) <u>€0.60</u> , b) €1, c) €2, d) I do not know
Q8	An SES costs on average more than a petrol equivalent.	a) <u>True</u> , b) False, c) I do not know
Q9	How high is the Italian subsidy on SESs?	a) <u>30% discount with a maximum amount of €3,000</u> , b) 20% discount with a maximum amount of €2,000, c) €2,000 discount, d) I do not know
Q10	The circulation tax for SESs is equal to that of a petrol scooter.	a) True, b) <u>False</u> , c) I do not know

eight or more correct answers. The highest frequency was four correct answers, with a quite large number of respondents (36.2%) providing less than four correct answers.

The question with the largest number of correct answers was Q8, concerning the higher SES costs relative to SCS, followed by Q3 on the relatively lower maintenance costs (Table 5). Surprisingly, the question with less correct answers was Q9, regarding the amount of the subsidy, followed by Q5 on the uphill performance (most likely because this was stated in technical terms). As expected, SES owners had a better objective knowledge of SESs but not for all properties. In particular, they had a weak knowledge of uphill performance (Q5) and purchase subsidy (Q9).

Finally, we asked respondents whether they had a direct (via ownership or sharing) or indirect (via friends/acquaintances) experience with driving SESs. Only seven out of 431 respondents owned an SES, 48 had direct riding experience, and 29 had heard about it through friends/acquaintances.

## 5.2. Environmental awareness

In order to understand the respondents' concern for the environment, we asked them whether they participated in environmental events or were members of environmental associations. A quarter of them answered positively, with the percentage of positive answers reaching almost 40% in the under 20 age category (see SM 3.1).

Next, we proposed 11 statements, partially derived from the works of Dunlap et al. (2000) and Dunlap (2008). We asked respondents to indicate their level of agreement with each statement. We adopted a 4-point Likert scale: strongly disagree, disagree, agree, or strongly agree. We decided to force respondents to take a stance, avoiding the indifferent/neutral choice due to its ambivalence (Borriello et al., 2019).

As summarized in Table 6, most respondents stated having a strong environmental concern (note that Q2 has a reverse coding).

More than 80% of the respondents perceived the importance of climate change and humanity's responsibility for the environment and other living species. An even large number of people were aware that there is a need for change and were in favor of government legislation. A surprisingly large number of respondents (85%) were aware that their choice of which vehicle to use for their transportation needs has an impact on the environment. The perception regarding the air quality in Trieste was mixed. Almost half of the respondents strongly disagreed or disagreed that it is very poor. Most respondents, however, felt that bad air quality negatively affects health. It was confirmed that respondents were aware that the type of scooter might have an impact on local air pollution. Regarding the proper parking policy, most respondents were not in favor of limiting the number of parking spaces for cars and scooters unless the space was used for new bicycle lanes. A more detailed descriptive analysis of the replies is presented in SM 3.2.

## 5.3. Factor analysis

We performed an exploratory and confirmatory factor analysis to identify which indicators revealed the most information about the LVs. Details about the factor analysis can be found in SM 5.0. After performing a normal data screening and checking for accuracy and multivariate assumptions, we tested a three-factor model with a maximum likelihood estimation and an oblimin rotation because of expected factor correlation. The results are illustrated in Table 7. The first factor was associated with the measurement indicators related to environmental awareness at the global level, thus termed "concern for the global environment." The second factor was associated with the "concern for the local environment," while the third factor concerned "SES knowledge." Global fit indices revealed a good fit: CFI = 0.959; TLI = 0.946; SRMR = 0.041; RMSEA = 0.038 (90% CI = 0.021, 0.052).

The resulting HMC model is illustrated in Fig. 3.

**Table 5**

Percentage of correct replies to the objective SES knowledge.

Owner type	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
SCS owner	30%	52%	63%	49%	20%	51%	27%	74%	16%	47%
SES owner	71%	100%	100%	100%	29%	100%	86%	100%	57%	86%
Total	30%	53%	63%	50%	20%	52%	28%	74%	17%	48%

**Table 6**

Questions and statements on environmental concern.

Question/statement	Strongly disagree	Disagree	Agree	Strongly agree
Q2. The ongoing discussions on the greenhouse effect are somewhat overstated.	50.8%	27.8%	14.6%	6.7%
Q3. Authorities should promote legislation that forces citizens and businesses to protect the environment.	3.5%	5.1%	43.2%	48.3%
Q4. My decision on the type of vehicle to buy has a significant impact on the environment.	3.0%	12.3%	51.3%	33.4%
Q5. We are approaching the limit of the number of people that the Earth can support.	7.4%	16.2%	39.9%	36.4%
Q6. Plants and animals have the same rights as human beings.	5.3%	8.8%	34.1%	51.7%
Q7. If we do not change our behavior, we will soon experience a great ecological catastrophe.	2.6%	6.5%	38.3%	52.7%
Q8. The air quality of my city is very poor.	9.7%	39.2%	36.9%	14.2%
Q9. The bad air quality of my city certainly has negative effects on health.	3.2%	9.5%	37.8%	49.4%
Q10. My decision on the type of scooter to buy has a major impact on local pollution.	4.2%	15.5%	48.0%	32.3%
Q11. In my city, the number of parking spaces for cars and scooters should be decreased.	43.9%	31.6%	17.6%	7.0%
Q12. In my city, the number/length of bicycle lanes must be increased, even at the detriment of parking spaces for cars and scooters.	9.0%	21.1%	30.9%	39.0%

**Table 7**

Confirmatory factor analysis.

Factor	Estimate	SE	z-value	P(> z )	Std.lv	Std.all
Concern for the global environment =~						
I <sub>2</sub> - exaggerated CO <sub>2</sub>	1.000	-	-	-	0.375	0.407
I <sub>3</sub> - need for tougher legislation	1.068	0.165	6.462	< 0.001	0.400	0.561
I <sub>5</sub> - population threshold	1.174	0.192	6.098	< 0.001	0.440	0.492
I <sub>6</sub> - animal and plant rights	0.941	0.167	5.621	< 0.001	0.352	0.420
I <sub>7</sub> - catastrophic risks	1.430	0.205	6.964	< 0.001	0.536	0.765
Concern for the local environment =~						
I <sub>8</sub> - air quality in Trieste	1.000	-	-	-	0.528	0.621
I <sub>9</sub> - impact of air quality on health	0.871	0.105	8.257	< 0.001	0.460	0.613
I <sub>10</sub> - impact of my scooter on air quality	0.815	0.104	7.82	< 0.001	0.431	0.551
I <sub>11</sub> - reduce parking places	0.535	0.108	4.930	< 0.001	0.283	0.304
SES knowledge =~						
I <sub>13</sub> - self-assessed knowledge	1.000	-	-	-	0.531	0.884
I <sub>14</sub> - objective knowledge	2.498	0.463	5.392	< 0.001	1.326	0.547
I <sub>15</sub> - direct experience	0.246	0.049	5.025	< 0.001	0.130	0.404

## 6. Results

### 6.1. Econometric estimates

Table 7 illustrates the results of the HMC model, estimated with the Apollo package in R (Hess & Palma, 2019).

The upper left part of Table 8 reports estimated parameters of the choice component of the HMC model. All the attribute coefficients were statistically significant. The financial attributes (purchase price, fuel economy, and circulation tax + insurance premium) had the expected negative sign. The technical attributes (engine power and driving range) had a positive impact on utility. Note that the SES driving range had a coefficient greater than six times than that of the conventional scooter, signaling that respondents were highly sensitive to the range issue for SESs. The possibility of removing the battery was valued positively by respondents. The location of the manufacturer (Europe vs. China) signaled a preference for products made in Europe, although Chinese-made e-scooters are entering the Italian market in large numbers. The ASC\_SES indicated that, *ceteris paribus* (all specified attributes equal), respondents assigned a negative utility to SES relative to SCS, deriving from unspecified variables. With some minor magnitude differences, these estimates confirmed the ones obtained by Scorrano and Danielis (2021b) based on data collected in various Italian regions in 2019.

The HMC model specification allowed us to understand the impact of the attitudes on scooter choice and to disentangle the impact of each component of the hybrid model. Based on the factor analysis, we focused on three LVs: concern for the global environment (LV1), concern for the local environment (LV2), and SES knowledge (LV3). All LVs have the expected sign, being positively associated

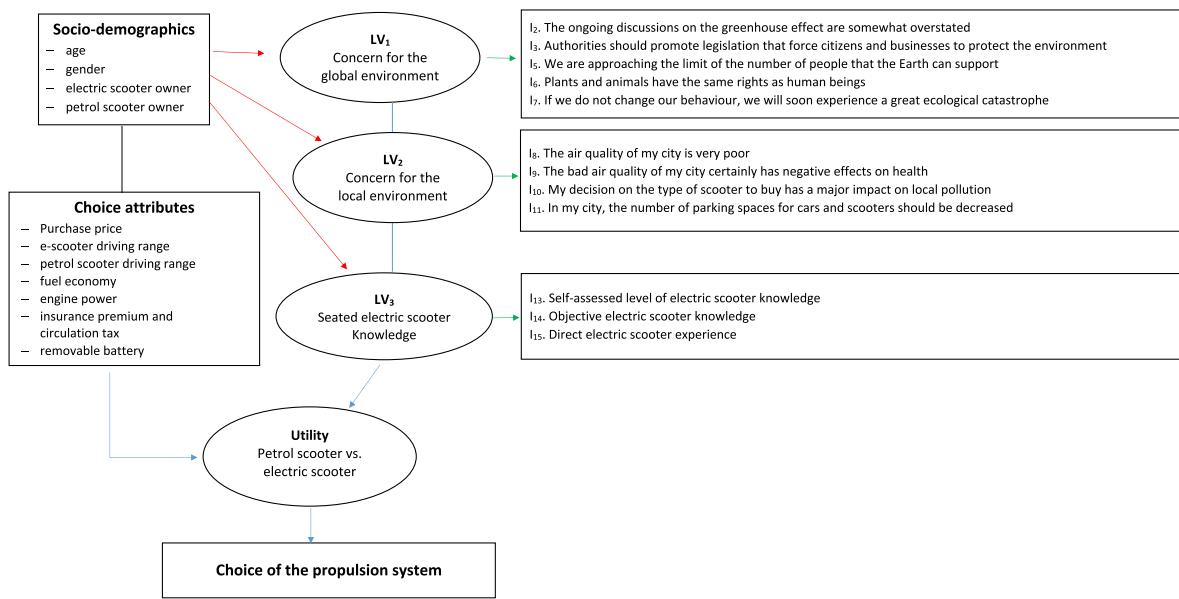


Fig. 3. HMC model.

with SES utility, but only the  $\alpha$  coefficient of LV2 was statistically significant. We also checked for a correlation between LV1 and LV2. We found a positive but not significant correlation.

A useful addition of the HMC relative to the RPL model is the information derived from the structural and measurement models. The structural equation informed us on whether the identified LVs are correlated with observable socio-economic characteristics. With reference to concern for the global environment (LV1), we found that it plays a larger role with women and respondents between the ages of 21 and 55. The concern for the local environment (LV2) affected all respondents over 20 years old, with no differences between men and women. SES owners appear to be significantly less concerned than non SES owners. With regards to SES knowledge, although it does not significantly affect SES utility, male respondents and SES owners are unsurprisingly relatively more informed about SES characteristics.

The measurement equation illustrates how indicators are associated with the LVs: the coefficients of the measurement model had the expected positive sign and were statistically significant, confirming the results of the factor analysis.

The overall fitness of the model was satisfactory. Focusing on the LL of the choice-only HMC model (LL = -2285), we found a large improvement over the MNL (LL = -2533) but a loss of performance with respect to the RPL model (LL = -2284). Since we introduced the same socio-economic variables as separate explanatory variables in the HMC model, as suggested by [Vij and Walker \(2016\)](#) and [Schmid and Axhausen \(2019\)](#), it is unlikely that the lower LL of the HMC model was due to the mistake illustrated by [Vij and Walker \(2016\)](#) in the case of Monte Carlo III. A possible explanation could be a potential correlation between the choice and measurement indicators, since, as mentioned by [Vij and Walker \(2016\)](#), the likelihood function of the HMC model could fit parameters both to the choice indicators and the measurement indicators, as opposed to just the choice indicators in the case of the reduced form RPL.

Nevertheless, as argued by [Schmid and Axhausen \(2019\)](#), there are several advantages of the HMC model approach, such as the consideration of the socio-economic variables that were nonsignificant in the RPL model (e.g., gender was nonsignificant and age was poorly significant in the RPL but proved significant, mediated via the LV, in the HMC model) and the possibility to disentangle direct and indirect effects of socio-economic characteristics, which are illustrated in the next section.

## 6.2. Parameter decomposition: the role of latent variables in our model

As [Hess et al. \(2018\)](#) and [Schmid and Axhausen \(2019\)](#) pointed out, a useful feature of HMC models is the possibility to break down the impact of sociodemographic variables into their direct and indirect components. This requires that they enter the utility function both directly and via the LVs' structural models. Following their suggestion, [Table 9](#) presents such a decomposition, which highlights the underlying sources of heterogeneity, some of them directly influencing the utility levels, while others mediated via the LVs. The sum of the direct and indirect impact is the total effect.

Two sociodemographic variables impacted SES choice directly: 21 to 35-year-old respondents and non-petrol scooter owners had a higher propensity to choose an SES. The above 21 age groups reinforced their favorable propensity towards SES via the indirect effect connected to the concern for the local environment (LV2). The remaining LVs did not significantly contribute to the overall effect. As a result, not owning a petrol scooter and being in the age class of 21–35 years was associated with a higher propensity to choose an SES. SES knowledge played no statistically significant role in the choice process.

**Table 8**  
Estimates with the HMC model.

The choice component	Coeff. (t-stat)	LV1: Concern for the global environment	Coeff. (t-stat)
ASC_SES	-1.479*** (-4.5)	$\alpha^{LV1}$	0.106 (1.1)
SD of SES ASC	1.371*** (13.5)	<b>Structural equation</b> ( $\theta^{LV1}$ )	
Purchase price (£ 1,000)	-0.84*** (-18.3)	Age: 21–35 years old (vs. under 21)	0.318** (2.1)
SD of purchase price	0.493*** (11.7)	Age: 36–55 years old (vs. under 21)	0.299* (1.8)
Fuel economy (£/100 km)	-0.19*** (-3.7)	Age: over 55 years old (vs. under 21)	0.002 (0.01)
Circulation tax + insurance premium (€)	-0.343*** (-6.2)	Gender: Male (vs. Female)	-0.262** (-2.1)
SES driving range (100 km)	2.107*** (10.6)	SCS owner	-0.028 (-0.2)
SCS driving range (100 km)	0.338*** (4.3)	SES owner	-0.566 (-1.2)
Engine power (kW)	0.18*** (10.3)	<b>Measurement equation</b> ( $\tau^{LV1}$ )	
SD of engine power	0.173*** (9.2)	I <sub>2</sub> – exaggerated CO <sub>2</sub>	-0.946*** (-6.8)
Removable battery (Yes = 1, No = 0)	0.486*** (4.5)	I <sub>3</sub> – need for tougher legislation	1.383*** (6.8)
SD of removable battery	0.402 (1.5)	I <sub>5</sub> – population threshold	1.134*** (7.4)
Manufacturer country (Europe = 1, China = 0)	0.484*** (7.98)	I <sub>6</sub> – animal and plant rights	0.897*** (6.2)
SD of manufacturer country	0.467*** (5.1)	I <sub>7</sub> – catastrophic risks	2.784*** (4.9)
<b>Sociodemographics</b>			
Gender: Male (vs. Female)	0.058 (0.3)		
Age: 21–35 years old (vs. under 21)	0.506** (2.3)		
Age: 36–55 years old (vs. under 21)	0.014 (0.1)		
Age: over 55 years old (vs. under 21)	-0.032 (-0.1)		
SCS owner	-0.745*** (-3.8)		
SES owner	0.246 (0.4)		
<b>LV2: Concern for the local environment</b>		<b>LV3: SES knowledge</b>	
$\alpha^{LV2}$	0.338*** (2.9)	$\alpha^{LV3}$	0.089 (0.8)
$\alpha^{LV1-LV2}$	0.067 (0.8)		
<b>Structural equation</b> ( $\theta^{LV2}$ )		<b>Structural equation</b> ( $\theta^{LV3}$ )	
Age: 21–35 years old (vs. under 21)	0.421*** (2.7)	Age: 21–35 years old (vs. under 21)	-0.166 (-0.9)
Age: 36–55 years old (vs. under 21)	0.676*** (4.1)	Age: 36–55 years old (vs. under 21)	0.153 (0.8)
Age: over 55 years old (vs. under 21)	0.678*** (3.3)	Age: over 55 years old (vs. under 21)	0.101 (0.4)
Gender: Male	-0.159 (-1.2)	Gender: Male	1.196*** (6.3)
SCS owner	-0.326** (-2.4)	SCS owner	0.207 (1.2)
SES owner	0.061 (0.1)	SES owner	2.405*** (4.1)
<b>Measurement equation</b> ( $\tau^{LV2}$ )		<b>Measurement equation</b> ( $\tau^{LV3}$ )	
I <sub>8</sub> – air quality in Trieste	1.914*** (6.3)	I <sub>13</sub> – self-assessed knowledge	1.877*** (5.1)
I <sub>9</sub> – impact of air quality on health	1.578*** (6.6)	I <sub>14</sub> – objective knowledge	1.077*** (5.8)
I <sub>10</sub> – impact of my scooter on air quality	1.144*** (6.5)	I <sub>15</sub> – direct experience	1.453*** (5.1)
I <sub>11</sub> – reduce parking places	0.606*** (4.6)		
<b>Model diagnostics</b>			
LL(start)	-9531	AIC	14,542
LL(final)	-7185	BIC	15,157
LL(Choice)	-2285	Estimated parameters	86

Note: Statistical significance at 1% (\*\*\*), 5% (\*\*), and 10% (\*) levels. Number of inter-individual draws: 1000 (Halton). Estimation method: Broymen–Fletcher–Goldfarb–Shanno algorithm. Total estimation time: 20 h 38 m.

**Table 9**  
Direct, indirect, and total effects in the HMC model.

Variable	Direct effect	Indirect effect: concern for global env.	Indirect effect: concern for local env.	Indirect effect: SES knowledge	Total effect
	Coeff. (t-stat)	Coeff. (t-stat)	Coeff. (t-stat)	Coeff. (t-stat)	Coeff. (t-stat)
Gender (Male vs. Female)	0.058 (0.3)	-0.028 (-0.9)	-0.054 (-1.1)	0.106 (0.7)	0.083 (0.5)
21–35 years old	0.506** (2.3)	0.034 (0.9)	0.142** (2.0)	-0.015 (-0.6)	0.667*** (3.1)
36–55 years old	0.014 (0.1)	0.032 (0.9)	0.229** (2.4)	0.014 (0.5)	0.288 (1.3)
over 55 years old	-0.032 (-0.1)	0 (0.01)	0.229** (2.2)	0.009 (0.4)	0.206 (0.7)
SCS owner	-0.745*** (-3.8)	-0.003 (-0.2)	-0.11* (-1.8)	0.018 (0.6)	-0.84*** (-4.3)
SES owner	0.246 (0.4)	-0.06 (-0.8)	0.021 (0.1)	0.213 (0.7)	0.419 (0.8)

Note: Standard errors were calculated using the delta method (Daly et al., 2012).

## 7. Discussion and policy implications

Our survey demonstrates that SES knowledge in Trieste is low. Out of the 431 respondents, only 2% owned an SES, 11% had direct experience riding an SES, and 7% had indirect experience (meaning that they drew their knowledge from friends, relatives, or social media). Unsurprisingly, the self-assessed knowledge was low, and the objective knowledge, checked by the number of correct answers

to a series of questions on current brands, technological, and economic characteristics of SESs, was also modest.

On the basis of the common assumption that a pre-requisite for market uptake is knowledge of the product, an obvious policy implication is that SES manufacturers and/or policy makers should increase their efforts to improve potential users' SES knowledge. Potential channels are advertisements, promotional test drives, and reviews by specialized magazines and social media influencers.

However, the question arises: does increased SES knowledge lead to higher SES market share? Contrary to what is often assumed, our statistical evidence is that knowledge does not significantly influence the choice between an SES and an SCS. Two explanations are possible. First, the coefficient is not significantly different from 0, meaning that SES knowledge does not determine choices. Second, the impact is both positive and negative, so that the two impacts balance out and neither prevails. According to our perception, the latter is likely since currently SESs have both positive and negative features. As underlined by various respondents' comments added to our questionnaire, while there are several financial advantages (reduced purchase price thanks to subsidies, reduced circulation tax for the first five years, and extremely low operating costs), SESs still suffer from many technical drawbacks.

SESs need technological improvements. Many respondents commented that SESs are suitable for urban areas but not for suburban ones use due to insufficient speed and driving range. Other respondents feared a poor uphill performance in the hilly streets of Trieste. To some extent, these concerns are overcome by the new generation of electric motorcycles that recently appeared on the Italian market (e.g., Super Soco CPX) but at a higher sticker price. Hence, SES uptake is likely to take place in significant numbers when battery technological improvements allow for higher energy density and longer riding range at reasonable prices. On a more positive side, the current supply of SESs in the Italian market is characterized by a large product variety: there is a large number of small and large brands, both Italian and foreign, offering SESs and electric motorcycles of all shapes and sizes. A less positive aspect is that many of these firms appear and quickly disappear from the market, lacking adequate pre- and post-acquisition services.

A second relevant aspect that needs improvement is the charging experience. Only a limited percentage of scooter users, about 40% in Trieste, have the capability to charge at home (i.e., own a garage or a parking space with charging capability). For the remaining users, the possibility to remove the battery in order to recharge it in a separate location is certainly an interesting feature, as our estimates demonstrate. However, the issue of charging is still a significant barrier to SES acceptance. Currently, there is no specific infrastructure dedicated to SES charging. To the best of our knowledge, neither the city administration of Trieste nor the main private or public institutions (firms, schools, universities, etc.) have equipped their garages or parking lots with charging infrastructures for SESs. In addition, no SES manufacturers have thus far invested in a swappable battery infrastructure, similar to the one developed by Gogoro in Taiwan, or to the on-demand battery delivery and swapping service recently launched by Kymko. The combination of the above limitations, obstacles, and barriers means that direct and indirect experiences with SESs are not always successful and determine the uncertain relationship between SES knowledge and choice. The national regulator and the city administration could play a relevant role by supporting, via regulation or financial incentives, the deployment of a widespread and strategically located SES charging network, similarly to the one being developed for electric cars.

The main second finding is that in Trieste, the concern for the local environment is a statistically significant determinant of scooter choice. Respondents with higher awareness of the air pollution and noise caused by SCS are more likely to choose SESs, thus confirming the results already presented in the literature review. This attitude was particularly strong among middle-aged respondents. One implication of such a finding is that a policy tool to accelerate SES uptake would be to strengthen environmental awareness, for instance, by providing statistical and medical evidence associated with improved air quality and reduced ambient noise (Sheng et al., 2016). Another action, as suggested by Liu and Lai (2020), could be organizing workshops in primary and secondary schools to educate students (as potential motorcyclists) about the environmental impacts of conventional motorcycles.

A further possibility is to take stock of the existing and probably growing environmental awareness to improve the acceptance and facilitate the implementation of policy incentives favoring SESs and/or discouraging conventional scooters (Huang et al., 2018). In fact, while SESs currently enjoy fiscal advantages by the national or regional government (Ecobonus subsidy and annual circulation tax discounts) in Italy (as in many other countries), there are no regulatory incentives for SESs at the city level, despite their evident air pollution and noise advantages.<sup>4</sup> In fact, SCSs and SESs share very similar usage regulations in terms of vehicle registration, driving license, rear license plate, and insurance requirements. The major difference being that in Europe, conventional motorcycles have been subject to Euro 5 standards since 2020, a policy tool used to decrease their exhaust emissions and improve air quality.

With reference to traffic regulation, however, in contrast with electric cars, which are subject to priority traffic regulation such as unrestricted access to city centers or residential areas, free or reduced parking fees, or access to reserved bus lanes, SESs in Italy do not enjoy traffic regulation privileges relative to their conventional counterparts. An exception is in the city of Milan, Italy, which enacted differentiated scooter regulations in some areas of the metropolitan area. When the pollution levels exceed the European standards, all scooters except electric ones are prohibited from circulation. Older scooters and motorcycles (classified by EURO engine technology) are gradually being banned from entering the central area (Area C) and the large metropolitan area (Area B). These regulations send a signal to both manufacturers and consumers in favor of SESs. Such an example has not been followed so far by the city of Trieste or any other Italian city. At the international level, the strongest policy measure ever adopted has been the ban of motorcycles powered by fossil fuels implemented in Chinese cities. In the Netherlands, a phase out of conventional motorcycles and moped sales has been considered (Bakker, 2019) but not yet implemented. A further possibility would be to design low-emission zones in a city to exclude conventional motorcycles.

<sup>4</sup> Bakker (2019) arrived at a similar conclusion: "In various countries, a limited number of policy initiatives are taken to promote electric mobility on two wheels. Yet in general, it can be stated there is a lack of policy attention, particularly in comparison to policy and research on other electric vehicles such as cars and buses."

## 8. Conclusions

We carried out a study aimed at estimating the role of LVs when choosing between an SES and a conventional scooter besides the common economic and technical features investigated in previous studies. Specifically, we focused on concern for the environment and SES knowledge. As a modeling framework, we adopted the HMC model, which allowed us to identify the impact of the attitudes on scooter choice by including them in a discrete choice framework in order to represent a behaviorally more realistic choice process.

The main finding was that besides the various financial and technical features (purchase price, fuel economy, annual cost of circulation tax and insurance premium, driving range, engine power, removable battery, and manufacturer's country), the concern for the local environment played a significant role, while the concern for the environment at the global level and SES knowledge were not significantly associated with SES stated choice.

The policy implications are that strengthening environmental awareness might accelerate SES adoption, and policy incentives and traffic regulations favoring SESs and discouraging conventional scooters are possible due to the existing and seemingly growing environmental awareness. The lack of a significant relationship between SES knowledge and purchase intention, as documented in some previous literature (mainly relative to electric cars), depends, in our view, on the technical limitations (in terms of power, speed, and range) of the current SESs available in Italy compared with SCSs in the same price category.

Apart from the common limitations of empirical studies (such as a larger and more differentiated sample), a potential improvement of our research would be extending the number of LVs. Particularly interesting, in our view, would be the introduction of social influence factors such as imitation effects, social norms, or peer pressure. In combination with a growing environmental awareness and the need to decarbonize transport (Danielis et al., 2022), social factors might play a relevant role in accelerating SES acceptance. We would also be interested in monitoring the evolution of scooter preferences over time, since they are a relatively new and immature product. Therefore, it is quite likely that scooter preferences might change over time as consumers' awareness of the pros and cons of SESs increases. Finally, it would be worthwhile to perform a comparative study with the choices made in countries/cities where an SES charging infrastructure exists (e.g., Taipei) to evaluate how different infrastructural conditions impact preferences and choices.

Our study is based on stated preference data only; hence, we are unable to predict actual market share. In our scenario assumptions, 50.5% of the sample would choose an SCS and 49.5% an SES, a modal share that differs enormously from the actual market share in Trieste, where SES modal share is very small. An easily implementable improvement could be to estimate a stated preference/revealed preference model and use it to simulate the market uptake along the lines of Scorrano and Danielis (2021a)'s experiment regarding electric cars.

### *CRedit authorship contribution statement*

**Mariangela Scorrano:** Investigation, Data curation, Methodology, Formal analysis, Software, Writing – original draft, Writing – review & editing. **Lucia Rotaris:** Conceptualization, Methodology, Supervision, Writing – review & editing.

### **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.

### **Appendix A. Supplementary material**

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tra.2022.04.007>.

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