Barriers to the adoption of electric cars: Evidence from an Italian survey

Marco Giansoldati *, Adriana Monte, Mariangela Scorrano

Dipartimento di Scienze Economiche, Aziendali, Matematiche e Statistiche "Bruno de Finetti", Università degli Studi di Trieste, Via dell'Università, 1, 34123, Trieste, Italy

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A B S T R A C T

Italy has a very low level of uptake of electric cars (ECs), equal to 0.6% for the year 2019, despite significant efforts put in place by policy makers to stimulate their use. This paper investigates the barriers to wider EC diffusion via a survey administered in 2019 to a representative sample (N = 870) of the Italian population. We discuss and rank the barriers, aggregate them via principal component analysis (PCA) on the basis of the polychoric correlation matrix, perform a cluster analysis and analyse the socio-economic determinants of the respondents. The findings of this paper suggest a series of improvements that could be made by various actors. To overcome the financial barriers to EC uptake, Italian policy makers should reinforce incentives at the national and local levels and car manufacturers should bring to the market cheaper ECs belonging to the A and B segments. The charging-related barriers require investments on fast charging stations along the main toll highways and a new regulation regarding multi-house dwellings. Finally, reliable and complete information is needed to enhance knowledge about the technological and environmental pros and cons of ECs.

1. Introduction

In 2017, road transport in Italy contributed to 22% of total national carbon dioxide emissions (ISPRA, 2019). Electric vehicles (EVs) have the potential to reduce this share and at the same time also reduce local air pollutant emissions. However, the share of registered electric-battery cars (ECs)[1] in 2019 was a meagre 0.6% (UNRAE, 2020a), lagging far behind other European countries. Several factors explain the heterogeneous degree of EC uptake across European countries (Browne et al., 2012; Biresselioglu et al., 2018; Haustein and Jensen, 2018). A first group of factors relates to demand, such as driver preferences, attitudes and beliefs regarding financial, technical and practical aspects of EC use and management. A second group relates to supply factors such as auto manufacturers' production and marketing decisions in the various national markets, in association with users' mobility needs and available disposable income. The interaction between demand and supply factors is certainly influenced by the fiscal, administrative and regulatory policies enacted at the national and local levels. Finally, EC uptake is greatly affected by the bidirectional interplay with the charging infrastructure, both along the highways and in urban areas. The supply of charging stations is the result of decisions made by private companies who invest in this new market (with different business models) and the incentivizing policies promoted by various public entities (European and national funds, private/public energy providers, etc.).

This paper is focused on the first group of factors, meaning the demand factors, or more specifically, the barriers to wider diffusion of ECs as this factor is perceived by potential buyers. However, as will be made clear from the following discussion, the relative strength of ECs is co-determined by the evolution of supply factors; the enacted fiscal, administrative and regulatory policies; and the supply of charging infrastructure. Building on relatively abundant studies in the literature, which we review in Section 2, we performed a survey in 2019 to investigate the barriers that prevent Italian drivers from acquiring an EC. We administered a computer-assisted web interview (CAWI) to a sample of Italian driver's licence holders (N = 870), asking them to declare their level of agreement with 20 statements regarding potential barriers to the purchase of an EC. Making use of principal components analysis (PCA) based on the polychoric matrix of correlations, the cluster analysis and the chi-square test, we a) ranked the barriers and compared our results with previous studies; b) aggregated them in broader typologies; c) identified homogenous groups of respondents; and d) compared the socio-economic groups of respondents.

To the best of our knowledge, this is the first study analysing the EC barriers for a Southern European country. We compare our results with those obtained in previous studies to identify whether there are Italian specificities and to evaluate how the perception of the barriers evolves

* Corresponding author.
E-mail addresses: mgiansoldati@units.it (M. Giansoldati), adriana.monte@deams.units.it (A. Monte), mscorrano@units.it (M. Scorrano).

[1] Throughout the paper EC refers to fully battery-electric passenger cars, excluding plug-in cars, as well pick-up trucks, vans and heavy-duty vehicles.

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Table 1
Barriers to the adoption of electric vehicles identified in the literature (ranking is reported in brackets).

Barrier	Previous studies [ranking]
Poor practicality due to limited driving range	Schuitema et al. (2013) [n.a.]
Need for travel planning	Axsen et al. (2013) [6/11][a]; Graham-Rowe et al. (2012) [n.a.]
Range anxiety	Wellings et al. (2011) [n.a.]; Egbue and Long (2012) [1/6]; Axsen et al. (2013) [1/11][a]; Axsen and Kurani (2013) [1/8]; She et al. (2017) [3/14]; Berkeley et al. (2018) [5/19]; Noel et al. (2020) [1/53]
Long-distance trips	Graham-Rowe et al. (2012) [n.a.]; Egbue and Long (2012) [n.a.]; She et al. (2017) [10/14]
Long charging times	Graham-Rowe et al. (2012) [n.a.]; Egbue and Long (2012) [n.a.]; Zaunbrecher et al. (2014) [n.a.]; Berkeley et al. (2018) [7/19]; Noel et al. (2020) [11/53]
Charging problem in the absence of a garage	Berkeley et al. (2018) [13/19]; Noel et al. (2020) [5/53]
Cost for adaptation of the electrical system	Patt et al. (2019) [n.a.]
Increased costs in electric bills	Graham-Rowe et al. (2012) [n.a.]; Egbue and Long (2012) [n.a.]
Insufficient number of charging stations	Egbue and Long (2012) [3/6]; Axsen et al. (2013) [2/11][a]; She et al. (2017) [5/14]; Berkeley et al. (2018) [2/19]; Noel et al. (2020) [3/53]
Poor safety due to the risk of fire	Egbue and Long (2012) [6/6]; Graham-Rowe et al. (2012) [n.a.]; She et al. (2017) [1/14]; Noel et al. (2020) [36/53]
Mistrust of new technologies	Zaunbrecher et al. (2014) [n.a.]; Berkeley et al. (2018) [19/19]
Doubts about environmental benefits	Egbue and Long (2012) [n.a.]; Graham-Rowe et al. (2012) [n.a.]; Berkeley et al. (2018) [15/19]
Problem of battery disposal	Flamm and Agrawal (2012) [n.a.]; Axsen et al. (2013) [1/6][b]; Zaunbrecher et al. (2014) [n.a.]
Risk of battery degradation	Graham-Rowe et al. (2012) [n.a.]; She et al. (2017) [6/14]; Berkeley et al. (2018) [4/19]; Noel et al. (2020) [17/53]
High purchase price	Egbue and Long (2012) [2/6]; Graham-Rowe et al. (2012) [n.a.]; Axsen et al. (2013) [2/6][b]; She et al. (2017) [11/14]; Berkeley et al. (2018) [1/19]; Noel et al. (2020) [2/53]
Risk of rising electricity prices	Noel et al. (2020) [32/52] and [41/53]
Risk of loss of residual value	Berkeley et al. (2018) [10/19]; Noel et al. (2020) [16/53]
Insufficient maintenance and repair service	Graham-Rowe et al. (2012) [n.a.]; Berkeley et al. (2018) [6/19]
Poor acceleration	Graham-Rowe et al. (2012) [n.a.]; Axsen et al. (2013) [3/11][b]; She et al. (2017) [14/14]; Noel et al. (2020) [30/52]
Reduced driving pleasure due to the lack of an internal combustion engine	Graham-Rowe et al. (2012) [n.a.]; Axsen et al. (2013) [1/6][a]

Notes: [a] indicates that the ranking refers to Table 5 from Axsen et al. (2013), while [b] indicates that the ranking refers to Table 6 from Axsen et al. (2013).
We first provide comments regarding each of the 20 selected barriers.

as a consequence of the rapid pace of innovation, which continuously alters the technical and economic characteristics of ECs, and of increasing knowledge and experience with ECs. The Italian case might be of interest given that, in Italy, the regulatory framework regarding ECs (parking, installing charging equipment in multi-household dwellings) is still largely undefined, and the car culture is still predominantly based on conventional fuel vehicles.

2. Related literature

The first investigations of the barriers to the acquisition of EVs date back to a decade ago. These studies are highly heterogeneous with regard to how the barriers are defined and the methodologies that were used to perform the analysis. Graham-Rowe et al. (2012), for instance, reported on the statements made by their interviewees at the end of an EV trial. Zaunbrecher et al. (2014) collected perceptions and beliefs through focus groups. Egbue and Long (2012) and Noel et al. (2020) instead asked respondents what barriers EVs currently face. She et al. (2017) directly asked interviewees how great of an impediment the proposed barriers presented. Berkeley et al. (2018) used predetermined statements to which respondents were asked to express their level of (dis)agreement through a Likert scale. In our study with 20 defined barriers, we will follow the latter methodology. Table 1 lists the 20 barriers and includes a look at how these barriers ranked among the ones considered by the authors.

Poor practicality due to limited driving range. Schuitema et al. (2013) concentrated on the UK experience in 2010 to understand how private car drivers' perceptions of a vehicle's attributes may affect their intention to adopt battery electric vehicles (BEVs).[2] They observed that 'compared to a normal car, plug-in hybrid electric cars/plug-in fully electric cars are impractical', but there was no explicit reference to the connection between poor practicality and limited driving range, an issue we address in our contribution.

Need for travel planning. Graham-Rowe et al. (2012) and Axsen et al. (2013) tackled this issue with similar results. The former contribution relied on a survey undertaken in 2010, which showed that 'charging considerations forced drivers to plan their journeys and sometimes change their lifestyle'. The latter refers to this barrier as 'having to plan your journeys so careful'. Axsen et al. (2013) rank this barrier sixth out of 11.

Range anxiety. This is one of the most widely investigated barriers, although phrased in a variety of ways. Wellings et al. (2011) relied on blogs, mostly from the UK, and detected in many of the recorded statements that the stressful nature of range anxiety was perceived from 'the emotive language used to describe it'. Egbue and Long (2012) defined range anxiety as 'the fear of being stranded in a BEV because it has insufficient range to reach its destination'. The largest share of their respondents, 33%, reported it as the most important barrier. 'Limited range' was also the most cited private-functional drawback in the study carried out by Axsen et al. (2013), and it is also in line with Axsen and Kurani (2013). Range anxiety seemed to still be the most pressing barrier in more recent studies. She et al. (2017) undertook a questionnaire survey in Tianjin (China) in 2016 and reported that range anxiety ranked third out of 14 barriers. More recently, Berkeley et al. (2018) found that in the UK, 'Limited vehicle driving range for day-to-day needs' ranked fourth out of 19 barriers. Noel et al. (2020) interviewed 227 transportation and electricity experts from 201 institutions across 17 cities in Denmark, Finland, Iceland, Norway and Sweden in 2017 and found that 'driving range' was the top concern among the 53 investigated.

Long-distance trips. Graham-Rowe et al. (2012) reported that one of the interviewees stated 'There's just some journeys I don't think I'd do. If it was a really long journey or if I was… on the M25 for any length of time I'd be worried the power would just drop off''. Egbue and Long (2012) reported that 'occasional long trips may not be possible on BEVs without recharging the battery during the trip'. She et al. (2017) referred to this barrier as 'Infrastructure availability on highway', and found that it ranked 10th out of 14.

[2] Throughout the literature review, for the sake of consistency, we will maintain the acronyms used by the authors in their contributions. This does not alter the precision of our review because the contributions (or part of them) that we reported primarily refer to fully battery ECs, labelled as battery electric vehicles (BEVs). Even in those cases in which the reviewed papers make use of the acronym EVs, which stands for electric vehicles, they refer to fully battery ECs.

Table 2
The questionnaire.

Category	Short definition	Statement
Indicate your level of agreement to the following statements, using a value of 1–4, where 1 indicates complete disagreement, 2 partial disagreement, 3 partial agreement and 4 complete agreement.		
Barriers related to usability	Poor practicality due to limited driving range	The need to charge frequently, given limited battery life, makes the electric car very impractical for daily use.
	Need for travel planning	Using an electric car requires careful travel planning.
	Range anxiety	If I drove an electric car, I would always be worried about running out of charge.
	Long-distance trips	Using an electric car for long distances is difficult due to the lack of charging stations along the highway.
	Long charging time	Charging an electric car during a journey takes too long.
Barriers related to the charging infrastructure	Charging problem in the absence of a garage	The electric car poses a Problem of where to charge and at what cost, especially for those who do not own a garage.
	Insufficient number of charging stations	I believe that the current number of charging stations is still too low. I prefer to wait.
	Cost for the adaptation of the electrical system	The construction of a domestic charging infrastructure is a bureaucratically complicated and expensive process, especially in a condo.
	Increased costs in electric bills	I am worried that the price of electricity for domestic charging could lead to a significant increase in my bill.
Barriers related to safety and technology	Poor safety due to the risk of fire	I would not feel safe driving an electric car given the large size of the battery and considering the risk of fire.
	Mistrust of new technologies	I do not trust the new technologies electric cars are based on because they are complex. I prefer a simple car.
	Doubts about environmental benefits	I am not convinced that electric cars pollute less than conventional cars given that electricity is also generated by coal and oil.
	Problem of battery disposal	I am not convinced that electric cars pollute less than conventional cars due to battery disposal.
	Risk of battery degradation	The batteries used in electric cars are expensive, and it is not yet known how long they last.
Barriers related to economic uncertainty	High purchase price	The purchase price is still too high. I prefer to wait.
	Risk of rising electricity prices	If many switch to electric cars, the cost of electricity will probably increase, so they will become less advantageous.
	Risk of loss of residual value	There is a strong risk that the electric car bought today will depreciate very quickly.
	Insufficient maintenance and repair service	As there are few electric cars, there are not enough mechanics prepared to work on them.
Barriers related to performance	Poor acceleration	Electric cars do not have sufficient acceleration.
	Reduced driving pleasure due to the lack of an internal combustion engine	Electric cars do not let you hear the engine roar when changing gears.

Long charging times. This is a widespread concern among respondents across nations and time. Graham-Rowe et al. (2012) reported that ‘Charging was made difficult by lengthy charge times and a lack of public charging points, differences made particularly salient when comparing plug-in EVs and [internal combustion engine] ICE cars’. They also report that the ‘time spent waiting for the car to charge was commonly viewed as “dead time”, and waiting was seen to compromise freedom of movement, so negating a highly valued affective benefit of driving’. In a similar fashion, Zaunbrecher et al. (2014) described that participants in a focus group in Germany in 2012 ‘criticized long recharging times’. Berkeley et al. (2012) reported that the ‘Length of time it takes to charge an EV’ ranked seventh out of 14, while according to the experts interviewed by Noel et al. (2020) ‘Long charging time’ ranked 11th out of 53 reported barriers.

Charging problem in the absence of a garage. This barrier was not explicitly addressed in the literature, although there were some contributions that related to this issue. Berkeley et al. (2018) found that ‘My dwelling would be unsuitable for home charging’ did not represent a barrier for most respondents. It ranked 13th out of 19 barriers. On the contrary, Noel et al. (2020) reported that ‘apartment charging’ ranked fifth out of 53 barriers.

Cost for the adaptation of the electrical system. Patt et al. (2019) conducted a survey in Switzerland in 2018 among people who rent their house or apartment. They found that ‘Access could also be problematic for people living in multi-family housing, where they park off-street in a shared multi-car lot or covered garage. These people would have to negotiate with the owner of the building or parking lot to install a charging unit. If many such units are required, this could require a substantial upgrade of the electrical wiring in order to handle multiple cars charging simultaneously. It is typically unclear who should bear this expense’ (Patt et al., 2019).

Increased costs in electricity bills. Only Egbue and Long (2012) addressed this issue. Conversely, Graham-Rowe et al. (2012) reported respondents’ problems assessing how much a unit of electricity costs. No ranking was available.

Insufficient number of charging stations. Egbue and Long (2012) found this concern to be important (third out of six). Axsen et al. (2013) also reported that it was the second most cited barrier out of 11. It appeared to be a problem for She et al.’s (2017) respondents as well, since it ranked fifth out of 14 barriers. Berkeley et al. (2018) reported that ‘Availability of charging stations’ ranked as the second most cited barrier out of 19. Noel et al. (2020) ranked ‘Public charging infrastructure’ third out of 53. There was agreement that this was a very important concern for most people.

Poor safety due to the risk of fire. There was a certain degree of heterogeneity in how this barrier was perceived across nations. Ebgue and

Table 3
Descriptive statistics of the sample.

Socio-economic information

- Gender: Men: 53.2%; women: 46.8%.
- Age: From 18 to 24 years old, 9.0%; from 25 to 34 years old, 17.4%; from 35 to 44 years old, 25.6%; from 45 to 54 years old, 24.6%; from 55 to 65 years old: 23.4%.
- Educational level: Up to junior high school, 5.8%; professional institute diploma (3 years), 3.1%; high school diploma, 39.7%; university in progress or no degree, 7.7%; university diploma or short degree, 4.0%; three-year degree, 9.2%; five-year degree, 22.1%; master's degree or specialization school, 6.3%; doctorate, 2.1%.
- Current employment: Entrepreneur, 3%; craftsman, 0.5%; dealer, 1.1%; other autonomous, 2.5%; freelance professional, 9.2%; manager, 2.1%; academic, 3.1%; teacher, 1.5%; supervisor, 7.2%; white-collar employee, 34.7%; other type of employee, 3.6%; worker, 4.6%; farmer, 0.1%; student, 7.7%; looking for first occupation, 1.7%; housewife, 7.7%; retiree, 2.9%; unemployed, 6%; other or not working, 0.7%; no answer, 0.1%.
- Household income: Less than €30,000 per year, 48%; between €30,000 and €70,000 per year, 45.2%; more than €70,000 per year, 6.8%.
- Perceived level of wealth: Question: 'If you were to take stock, you would say that your family income allows you to live… '. Answers: 'In a wealthy fashion', 1.7%; 'Comfortably', 44.8%; 'With some difficulties', 39.5%; 'With severe difficulties', 11.4%; 'I feel I am poor', 2.5%.

Location

- By city size: More than 500,000 inhabitants, 19.20%; 100,000–500,000 inhabitants, 17.93%; 50,000–100,000 inhabitants, 12.99%; 10,000–50,000 inhabitants, 29.77%; less than 10,000, 20.11%.
- By region: Piedmont, 6%, Liguria, 3.3%, Lombardy, 18.4%, Trentino-South Tyrol, 0.7%, Veneto, 8.2%, Friuli Venezia Giulia, 1.8%, Emilia Romagna, 6.7%, Tuscany, 4.3%, Umbria, 1.6%, Marche, 2.2%, Lazio, 11.7%, Abruzzo, 2.2%, Molise, 0.1%, Campania, 8.2%, Apulia, 8.2%, Basilicata, 1.1%, Calabria, 2.9%, Sicily, 9.4%, Sardinia, 3.1%.

Car and garage ownership

- No. of owned cars in the household: 0 autos, 0.9%; 1 auto, 39.5%; 2 autos, 46.5%; 3 autos, 9.4%; 4 autos, 3.1%; 5 autos, 0.3%; 6 autos, 0.2%.
- No. of individuals in the household who have a driver's licence: 1, 14.8%; 2, 44.3%; 3, 24.6%; 4, 13.8%; 5, 2.2%; 6, 0.2%; 8, 0.1%.
- Availability of a garage: Yes, 70.9%; No, 29.1%.

Car mobility habits

- Average number of kilometres travelled *per* day: ≤ 10 km, 28.1%; 11–50 km, 53.2%; 51–100 km, 14.9%; >100 km, 3.8%.
- Average number of kilometres travelled *per* year: ≤ 5000 km, 23.8%; 5001–10,000 km, 23.8%; 10,001–20,000 km, 35.3%; 20,001–50,000, 14.3%; >50,000 km, 2.8%.
- Number of yearly car trips over 400 km: ≤ 10, 93.7%; >10, 6.3%.

Car knowledge

- Self-evaluated level of EC knowledge (1=None, 7=Very high): 1, 11.4%; 2, 18.5%; 3, 20.0%; 4, 15.3%; 5, 23.1%; 6, 8.0%; 7, 3.7%.
- EC driving experience: Yes, 15.5%; No, 85.5%.
- Proximity to fast charging stations: Question: 'Is there a fast charging station for ECs close to where you live or work (or study)?' Answers: 'Yes', 38.5%. 'No', 39.7%. 'I do not know', 21.8%.

Attitude towards the environment

- Environmental association: Question: 'Have you ever participated in an environmental demonstration, or have you ever registered with an environmental association?' Answer: 'Yes', 18.7%; 'No', 81.3%.
- Environmental concern: Question: 'The environmental situation in the place where I live increasingly worries me'. Rate your level of agreement. Replies: 'Full agreement', 29.3%, 'Partial agreement', 57.4%, 'Partial disagreement', 11.8%: 'Full disagreement', 1.5%.

Long (2012) reported that '57% of the respondents agreed or strongly agreed that EVs are a safe mode of transportation, while 26% indicated they were unsure'. Graham-Rowe et al. (2012) stated that 'BEV drivers lacked confidence in some driving situations, which raised safety concerns'. A Chinese sample of respondents analysed by She et al. (2017) ranked safety as their major concern out of 14. Noel et al. (2020) placed 'Battery fire and safety' quite low in their ranking (36th out of 53).

Mistrust of new technologies. Zaunbrecher et al. (2014) reported evidence of the immaturity of the technology, especially with respect to the power available from the grid. More recently, Berkeley et al. (2018) addressed the 'belief that EVs are an inferior/unreliable technology' and found that it ranked as the lowest concern (19th out of 19).

Table 4
Ranking of the values assigned to the barriers (percentage distribution of scores and means).

Ranking	Barriers	Mean score	1=Completely disagree	2=Quite disagree	3=Quite agree	4=Completely agree
1	Insufficient number of charging stations	3.45	1.80%	7.40%	34.90%	55.90%
2	High purchase price	3.43	1.50%	8.60%	34.90%	54.90%
3	Long-distance trips	3.42	2.50%	7.20%	35.70%	54.50%
4	Need for travel planning	3.28	3.20%	10.70%	40.60%	45.50%
5	Charging problem in the absence of a garage	3.25	3.20%	11.10%	43.40%	42.20%
6	Long charging time	3.18	3.70%	11.60%	47.80%	36.90%
7	Cost for the adaptation of the electrical system	3.16	4.60%	14.80%	40.90%	39.70%
8	Risk of battery degradation	3.06	4.00%	16.70%	48.70%	30.60%
9	Insufficient maintenance and repair services	3.04	4.50%	18.00%	46.30%	31.10%
10	Poor practicality due to limited driving range	2.93	5.70%	22.60%	44.90%	26.70%
11	Increased costs in electric bills	2.92	8.90%	20.00%	41.70%	29.40%
12	Risk of rising electricity prices	2.85	6.70%	25.60%	43.60%	24.10%
13	Risk of loss of residual value	2.83	7.20%	25.20%	44.80%	22.80%
14	Range anxiety	2.77	11.00%	23.10%	43.30%	22.50%
15	Problem of battery disposal	2.76	10.70%	24.60%	42.60%	22.10%
16	Doubts about environmental benefits	2.54	18.40%	28.30%	34.30%	19.10%
17	Mistrust of new technologies	2.33	24.90%	30.50%	31.60%	13.00%
18	Poor safety due to the risk of fire	2.32	22.20%	35.90%	29.40%	12.50%
19	Poor acceleration	2.30	24.30%	31.70%	33.70%	10.30%
20	Reduced driving pleasure due to the lack of an internal combustion engine	2.29	29.20%	26.80%	29.80%	14.30%

Table 5
Total explained variances.

k	Eigenvalues	Variance, %	Cumulative variance, %
1	7.14	44.7%	44.7%
2	1.63	10.2%	54.9%
3	1.23	7.7%	62.6%
4	0.81	5.1%	67.7%

Table 6
Component matrix.

Barrier	Component 1	Component 2
Insufficient number of charging stations	0.694*	−0.393
High purchase price	0.690*	−0.196
Long-distance trips	0.661*	−0.439
Need for travel planning	0.635*	−0.362
Charging problem in the absence of a garage	0.757*	−0.217
Cost for adaptation of the electrical system	0.729*	−0.076
Long charging time	0.721*	−0.217
Insufficient maintenance and repair services	0.706*	0.056
Risk of battery degradation	0.742*	0.241
Increased costs in electricity bills	0.672*	0.154
Poor practicality due to limited driving range	0.684*	−0.043
Risk of rising electricity prices	0.661*	0.383
Risk of loss of residual value	0.647*	0.307
Range anxiety	0.602*	−0.055
Problem of battery disposal	0.567*	0.536
Doubts about environmental benefits	0.461	0.630*

Notes: * denotes the highest value.

Doubts about environmental benefits. This opinion seemed to be associated with the early stages of EC diffusion. Egbue and Long (2012) reported that 'some of the sampled technologically minded respondents question environmental impacts of EVs'. Similarly, Graham-Rowe et al. (2012) reported that 'many participants were sceptical about the green credentials of EVs, questioning the "green" nature of the electricity they use and the overall carbon footprint created by EV manufacturers'. More recently, Berkeley et al. (2018) found that the 'concern over the real environmental impact of electric vehicles' was only a minor issue, ranking it only 15th out of 19.

Problem of battery disposal. Flamm and Agrawal (2012) observed that a number of the focus groups 'believed battery disposal is more environmentally damaging than the combustion of motor fuel'. Axsen et al. (2013) and Zaunbrecher et al. (2014) confirmed the existence of this issue. Axsen et al. (2013) ranked it first out of six.

Risk of battery degradation. The uncertainty about battery life has been acknowledged since 2010 by Graham-Rowe et al. (2012). The issue was confirmed by She et al. (2017), who found that battery degradation concerns ranked sixth out of 14. Similarly, Berkeley et al. (2018) ranked it fourth out of 19, and Noel et al. (2020) ranked it 17th out of 53.

High purchase price. Purchase price is the most reported barrier to EV uptake. For Egbue and Long (2012) it ranked second out of six. Graham-Rowe et al. (2012) reported that some drivers deemed the 'comparatively high cost of an EV as unjustifiable'. Axsen et al. (2013) confirmed the issue. Berkeley et al. (2018) argued that it was the most pressing barrier out of 19. Similar findings were reported by Noel et al. (2020), who ranked the barrier second out of 53. Conversely, the Chinese experience reported by She et al. (2017) seemed different given that the original price without subsidies ranked 11th out of 14 barriers.

Risk of rising electricity prices. To the best of our knowledge, this concern had not been addressed specifically in the literature, and only Noel et al. (2020) reported two barriers that are partially related to it. They were 'electricity taxation' and 'increasing use of conventional electricity', which ranked, respectively, 32nd and 41st out of 53.

Risk of loss of residual value. The economic loss associated with strong depreciation was acknowledged by Berkeley et al. (2018), placing it in the 10th position out of 19 barriers. The 'resale value' was considered a non-negligible barrier by Noel et al. (2020), who ranked it 16th out of 53.

Insufficient maintenance and repair service. The lack of personnel to perform maintenance and repair services was spotted early by Graham-Rowe et al. (2012) and more recently by Berkeley et al. (2018), who ranked it sixth out of 19 barriers.

Poor acceleration. Graham-Rowe et al. (2012) reported that BEV drivers found it 'difficult to adjust to the less powerful acceleration at higher speed'. Axsen et al. (2013) indicated that poor acceleration was the fourth most reported perceived drawback of BEVs. On the contrary, She et al. (2017) indicated 'max speed and accelerating ability of BEVs' as the last concern. More broadly, Noel et al. (2020) referred to 'Worse performance', a barrier that stood at 30th out of 53.

Reduced driving pleasure due to the lack of the sounds of an internal combustion engine. To the best of our knowledge, there has been no contribution that explicitly addressed this issue. Two papers pointed out related aspects. Graham-Rowe et al. (2012) reported that a respondent claimed that '[EVs are suitable for] someone who's not so interested in having a performance vehicle'. Axsen et al. (2013) reported a statement from a respondent saying, 'I don't know if they [can] produce… a sporty version of an electric car yet'.

3. The survey and the sample

The study illustrated in this paper is part of a larger investigation effort aimed at gathering information on car choice in Italy. The investigation started in October 2018 with a questionnaire administered by the Trieste-based company SWG s.r.l. (https://www.swg.it/home-en). The aim was to carry out a stated choice experiment including a petrol and an electric car. The survey, which resulted in 996 valid interviews, is presented in Danielis et al. (2020a). The sample is randomly drawn from the SWG community of over 60,000 members, who were paid to participate in the survey. SWG selected the members of the community over the years through targeted internet campaigns and telephone recruiting. The main socio-demographic data of the members are periodically updated, and those who do not pass quality checks are disabled. Persons aged between 18 and 65 with a driver's licence were eligible to fill out the questionnaire. The sample was stratified by region of residence, gender and age with respect to the five Italian Nielsen macro-zones.[3] The parameters of the stratification and the sample shares were proportional to the distribution of the population derived from the most recent data made available by the Italian National Institute of Statistics (ISTAT). The data were weighted according to the macro-zone, gender, age and educational level.

In June 2019, we asked SWG to administer a second questionnaire to the same individuals who participated in the 2018 survey. The redemption rate was quite satisfactory; the 2019 survey resulted in 870 valid interviews. Our goal was to investigate the main obstacles that individuals perceive to EC adoption. The questionnaire made this aim clear, explicitly starting with the following statements: 'Many persons state their interest in electric cars, but the share of those who actually buy them is still low. This survey focuses on the barriers that might prevent you from buying an electric car'. The questionnaire consisted of a sequence of statements illustrating potential barriers to EC adoption. We asked respondents to state to what extent they agreed with the statements, making use of a four-level Likert scale to force respondents

[3] Area 1 includes the regions of Piedmont, Aosta Valley, Lombardy and Liguria. Area 2 includes the regions of Veneto, Trentino-South Tyrol, Friuli Venezia Giulia and Emilia-Romagna. Area 3 includes the regions of Tuscany, Lazio, Umbria and Marche. Area 4 includes the regions of Campania, Abruzzo, Molise, Apulia, Basilicata and Calabria, whilst Area 5 includes the regions of Sardinia and Sicily. For each of the five areas, the SWG computed the gender (male and female) and age quotas (six age groups), leading to a 2 × 6 matrix for a total of 60 quotas on the five macrozones.

to place themselves in a non-neutral position. We opted for a four-level Likert scale because respondents are likely to perceive less effort when the number of available levels is low (Nemoto and Beglar, 2014). Moreover, the use of a four-level Likert scale seems to be more appealing 'when social desirability is suspected to affect the construct intended to be measured' (Asún et al., 2016).

The questionnaire is illustrated in Table 2. The respondents were presented with a web page where they were asked to provide their degree of agreement with the set of statements grouped and labelled as shown in Table 2.

Table 3 reports the main features of the selected sample.

The geographical coverage of the sample is quite satisfactory: all regions except for the Aosta Valley are represented in the sample, which is also proportionally distributed amongst the regions with an accuracy of ±10%. The share of men is slightly larger than women (53.2% vs. 46.8%). Most of the respondents have a high school diploma, are white collar, and have a household income lower than €70,000 per year. The family conditions are quite favourable for EC adoption: most families own two cars, 70.9% own a garage, and less than 4% perform daily trips longer than 100 km. However, not many drivers could take advantage of the fact that for high annual travel distances, ECs have a lower total cost of ownership relative to conventional cars, as documented by Danielis et al. (2018) and Scorrano et al. (2019, 2020a). In fact, almost half of the respondents drive less than 10,000 km/year, and less than 15% drive between 20,000 and 50,000 km per year. With regard to EC knowledge, more than one-third of the respondents claimed to have quite good knowledge about ECs (corresponding to levels 5, 6 and 7 of the Likert scale), despite a mere 15.5% having driven one. Almost 40% of the respondents stated that there are no fast charging stations close to the place where they live/work/study. With regard to the environmental attitude, 18.7% of the respondents had participated in an environmental demonstration or were members of an environmental association, 57.4% *partially* agreed with the statement that the environmental situation where they live is increasingly worrisome, and 29.3% *completely* agreed.

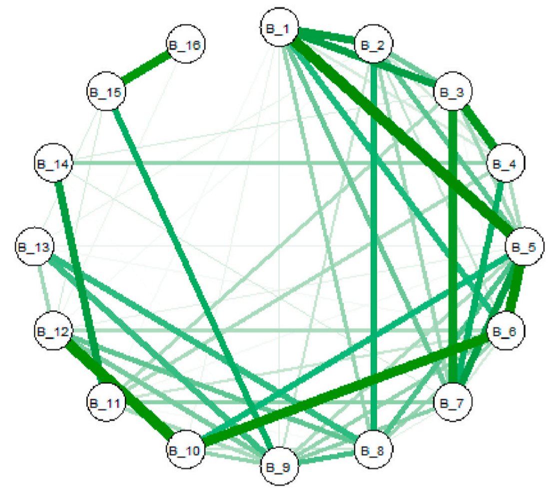

Fig. 1. Linkages amongst barriers within the polychoric matrix of correlation.
Legend:
B_1: Insufficient number of charging stations.
B_2: High purchase price.
B_3: Long-distance trips.
B_4: Need for travel planning.
B_5: Charging problem in the absence of a garage.
B_6: Cost for adaptation of the electrical system.
B_7: Long charging time.
B_8: Insufficient maintenance and repair service.
B_9: Risk of battery degradation.
B_10: Increased costs in electricity bills.
B_11: Poor practicality due to limited driving range.
B_12: Risk of rising electricity prices.
B_13: Risk of loss of residual value.
B_14: Range anxiety.
B_15: Problem of battery disposal.
B_16: Doubts about environmental benefits.

4. Results

4.1. A ranking of the barriers

Table 4 reports the average score on the Likert scale for each statement, in decreasing order.

The barrier with the highest score was the insufficient density of fast charging stations. Although it ranked high in most of the previous studies, as illustrated in Table 1, in our case, the ranking was relatively higher, signalling a special concern among the Italian respondents.

The second most important obstacle was the high purchase price. Similar findings were reported by Graham-Rowe et al. (2012), Egbue and Long (2012), Axsen et al. (2013), and more recently, Berkeley et al. (2018) for UK motorists. Noel et al. (2020) found the same among Scandinavian expert respondents. This highlights the importance of fiscal policies and the need to reduce the price of ECs relative to the conventional counterparts in the Italian market (Danielis et al., 2018; Pavan et al., 2019; Scorrano et al., 2019).

Next, there were a number of barriers associated with charging and long trips. In Italy, this issue is aggravated by the lack of fast charging stations along Italian highways (Autostrade). The need to carefully plan journeys, already documented by Graham-Rowe et al. (2012) and Axsen et al. (2013), and the long charging times rank high in the perception of Italian drivers. We also found significant concerns regarding the cost of charging, especially among those respondents who did not own a garage (fifth out of 20). This result contrasts with the ranking reported by Berkeley et al. (2018) but is in line with Noel et al. (2020). The relevance of this issue is compounded by the cost of owning a garage in Italian urban areas. This barrier is also associated with the bureaucratically complicated and expensive process of setting up a domestic charging infrastructure in multi-family settings, similar to the Swiss case documented by Patt et al. (2019).

The risk of battery degradation was valued slightly lower (eighth out of 20) than in previous studies. The lack of maintenance and repair services ranks slightly lower than in Berkeley et al. (2018). The middle part of the rank ordering consisted of a group of financial barriers, such as the increased cost of electricity bills, the risk of rising electricity prices and the risk of loss of residual value. These findings are in line with Graham-Rowe et al. (2012), Egbue and Long (2012), Berkeley et al. (2018) and Noel et al. (2020).

Range anxiety ranked quite low in our ordering, while it was the top concern in Egbue and Long (2012), Axsen et al. (2013) and Axsen and Kurani (2013). In addition, She et al. (2017) ranked it third out of 14, Berkeley et al. (2018) fifth out of 19, and Noel et al. (2020) first out of 53. This difference might stem from the fact that Italy is a quite densely populated country, and daily commuting takes place over short to medium distances.[4] Consequently, the driving range of the ECs available in the market, even those belonging to the segments A and B, such as the widely sold Smart fortwo and Smart forfour or the Renault Zoe, are capable of satisfying the large majority of daily driving needs. A further motivation is that over the years, car manufacturers have been able to increase the battery size used in EC models, but holding their list prices nearly constant (thanks to falling battery costs and increased energy density).

[4] When Monte and Danielis (2015) analysed census data for the Friuli Venezia Giulia Region of Italy, they estimated that 95% of the daily commuting for work and 88% of the daily commuting for study purposes took place within a distance of less than 100 km.

Table 7
Scores by cluster of individuals.

Barrier	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	Adverse	Focused on economy	Focused on usability	Favourable
Poor practicality due to limited driving range	3.54***	2.69*	2.89**	2.11
Need of travel planning	3.77***	3.08*	3.36**	2.46
Range anxiety	3.42***	2.27*	2.88**	1.98
Long-distance trips	3.84***	3.38*	3.46**	2.58
Long charging time	3.71***	3.10*	3.17**	2.25
Charging problem in the absence of a garage	3.77***	3.52**	3.01*	2.29
Insufficient number of charging stations	3.85***	3.71**	3.28*	2.62
Cost for adaptation of the electrical system	3.70***	3.50**	2.88*	2.15
Increased costs in electricity bills	3.50***	3.25**	2.54*	2.04
Doubts about environmental benefits	3.18***	2.01	2.55**	2.02*
Problem of battery disposal	3.42***	2.48*	2.65**	2.10
Risk of battery degradation	3.69***	3.04**	2.86*	2.23
High purchase price	3.85***	3.68**	3.24*	2.63
Risk of rising electricity prices	3.48***	3.02**	2.48*	2.14
Risk of loss of residual value	3.43***	2.78**	2.63*	2.13
Insufficient maintenance and repair services	3.63***	3.29**	2.72*	2.16
Number of respondents	266	195	276	133

Notes: *** denotes the highest value, ** denotes the second highest value and * denotes the third highest value.
We then identified the main socio-demographic characteristics of the respondents in each cluster (Table 8).

Two barriers related to scepticism about EC environmental benefits: the impact of battery disposal and EC contributions to the reduction of air pollution. These barriers had already been reported by Graham-Rowe et al. (2012), Egbue and Long (2012), Flamm and Agrawal (2012), Axsen et al. (2013) and Zaunbrecher et al. (2014). Our finding was that they ranked 15th and 16th out of 20, respectively. Overall, Italian respondents seemed to be quite convinced of the environmental benefits associated with substituting ECs for fossil fuel-based cars. The growing share of renewable resources in the Italian electricity mix, largely documented in the social media, and the technological progress in battery re-use have most likely contributed to this result.

The last four statements are not perceived as barriers given that the majority of the respondents did not agree with them, and their average score was below 2.5. These were mistrust towards new technologies, poor safety due to the risk of fire, poor acceleration and reduced driving pleasure due to the lack of an internal combustion engine. This finding confirms previous results by Egbue and Long (2012) for the United States, Berkeley et al. (2018) for the UK, and more recently, Noel et al. (2020) for Denmark, Finland, Iceland, Norway and Sweden. She et al. (2017) reported an opposite result for China. To the best of our knowledge, no contribution has analysed the issue of reduced driving pleasure due to the lack of an internal combustion engine. While Graham-Rowe et al. (2012) and Axsen et al. (2013) investigated the topic in the past, their studies did not have comparable statements. Because the four above-mentioned areas were not perceived as barriers, we excluded them from the PCA and cluster analysis, similar to Berkeley et al. (2018).

4.2. Aggregation of the barriers via principal component analysis

In order to place the number of perceived barriers into coherent groups, we performed a PCA, based on data measured with an ordinal 1–4 Likert scale. Since the data were ordinal, the normality distributional assumptions of the PCA were violated, leading to biased and inconsistent estimates (Kolenikov and Angeles, 2004, 2009). A way out was to perform a two-step procedure (Lee et al., 1995). First, we estimated the polychoric correlation matrix, and then we carried out the usual PCA analysis (Holgado–Tello et al., 2010; Asún et al., 2016). Fig. 1 illustrates the polychoric correlation coefficients amongst the 16 investigated barriers, obtained using the package qgraph in R (Epskamp et al., 2012). The lines are depicted only when the value of the polychoric correlation is at least 0.4. The line thickness represents the amount of correlation. The highest correlations were between.

Table 8
Selected socio-demographic characteristics for individuals in each cluster.

Socio-demographic characteristic	Adverse	Focused on economy	Focused on usability	Favourable
Age				
Average age (years)	47	43	42	40
EC knowledge				
Average level of self-declared EC knowledge (1=lowest, 7=highest)	3.3	3.6	3.7	4.1
Gender				
Share of males	46.6%	51.8%	57.2%	60.2%
Household income				
Share of respondents with household income greater than €70,000 per year	4.9%	5.6%	7.6%	10.5%
Share of respondents with household income lower than €30,000 per year	53.4%	49.2%	43.1%	45.9%
EC driving experience				
Share of respondents who had driven an EC at least once	13.2%	13.8%	17.8%	18.0%
Environmental association				
Share of respondents who had participated in an environmental demonstration or registered with an environmental association	13.5%	16.9%	21.0%	27.1%
Level of education				
Share of respondents with education only up high school diploma	61.7%	54.9%	54.0%	52.6%
Type of occupation				
Share of entrepreneurs or executive employees	18.0%	15.9%	18.8%	21.8%
Share of non-executive employees	50.0%	57.9%	59.1%	50.4%
Share of respondents who were housewives and retirees	16.2%	10.3%	6.9%	7.5%

Table 9
Summary of Chi-square results. (Only p-values <0.05).

Barriers	Gender	Income	Education	Occupation	EC knowledge	EC driving experience	Environmental association	Environmental concern
Barriers related to usability								
Poor practicality due to limited driving range	0.001		0.017	0.06	0.007			
Need for travel planning		0.030			0.011			
Range anxiety	0.000	0.000		0.002	0.001			0.042
Long-distance trips					0.000		0.000	
Long charging time							0.015	
Barriers related to the charging infrastructure								
Charging problem in the absence of a garage	0.016				0.000		0.000	
Insufficient number of charging stations					0.000		0.001	
Cost for the adaptation of the electrical system	0.001	0.033			0.002		0.023	
Increased costs in electricity bills	0.000	0.001	0.004		0.005		0.004	
Barriers related to safety and technology								
Poor safety due to the risk of fire	0.000		0.000					0.006
Mistrust of new technologies	0.000		0.000	0.040				
Doubts about environmental benefits			0.001					
Problem of battery disposal		0.029						
Risk of battery degradation	0.044				0.026		0.028	
Barriers related to economic uncertainty								
High purchase price		0.026		0.032	0.000	0.049		
Risk of rising electricity prices	0.002	0.001	0.003					
Risk of loss of residual value			0.044					
Insufficient maintenance and repair services	0.003	0.018	0.001		0.003			
Barriers related to performance								
Poor acceleration	0.000	0.002	0.001	0.002		0.019		
Reduced driving pleasure due to the lack of an internal combustion engine	0.005		0.000			0.049	0.006	0.025

Note: EC = All-battery electric cars.

- the charging problem in the absence of a garage (B_5) and the insufficient number of charging stations (B_1): 0.65;
- the cost for the adaptation of the electrical system (B_6) and the charging problem in the absence of a garage (B_5): 0.63;
- the risk of rising electricity prices (B_12) and the increased costs in electricity bills (B_10): 0.62;
- the increased costs in electricity bills (B_10) and the cost for the adaptation of the electrical system (B_6): 0.62; and
- doubts about the environmental benefits of ECs (B_16) was isolated from the rest of the barriers, with the exception of the association with problem of battery disposal (B_15), which had a correlation of 0.60.

Next, we performed the PCA. Although three eigenvalues had a value greater than 1 (Table 5), we opted for considering only the first two components, accounting for a cumulative variance of 55% because we could not meaningfully interpret the third component.

Table 6 shows that there is a positive correlation between all barriers except for the last one on the list with the first component. Such a result indicates a multifaceted negative stigma for ECs comprising charging issues, economic risks (purchase price, energy costs and residual value loss) and technical issues (adaptation of the electrical system, maintenance and repair, limited driving range). Such a negative perception is in line with the findings by Valeri and Danielis (2015) and Giansoldati et al. (2018). The second component is indicative of scepticism about the environmental impact of ECs, linked in part to the battery disposal issue.

4.3. Grouping individuals via the cluster analysis

We then applied a cluster analysis to identify homogenous groups of respondents. We used the first four components isolated via the PCA, opting for the k-means algorithm, which requires establishing *ex ante* the number of groups. We repeated the analysis several times for a different number of groups and identified four clusters, selecting the final segmentation on the basis of the R^2. Table 7 reports the average scores for each barrier on a 1–4 Likert scale for the individuals belonging to each cluster.

The first cluster was composed of 266 respondents labelled as *Adverse* to ECs. On average, they completely agreed with the proposed statements. They were older, mostly women, with a low level of EC knowledge, lower income and less education. This cluster had the largest share of retirees and housewives, the lowest percentage of motorists who had ever driven an EC, and the lowest share of respondents who were members of an environmental association. Conversely, the fourth cluster was made up of 133 respondents we defined as *Favourable* to ECs, given that on average, they partially disagreed with the proposed statements. These respondents were younger, mostly men, had high levels of EC knowledge, higher income and more education. This cluster comprised a large share of entrepreneurs and executives, had the largest share of respondents who had driven an EC and had a large proportion of interviewees who were members of an environmental association. Cluster 2, labelled as *Focused on economy*, was made up of 276 individuals. They expressed concern primarily on the economic uncertainty around acquiring an EC and had socio-demographic characteristics close to the *Adverse* group. Cluster 3 consisted of 133 individuals. We labelled it *Focused on usability* because they perceived limited practicality with the use of ECs. These individuals had socio-demographic characteristics that were fairly close to those of the *Favourable* group.

4.4. Barriers and socio-economic characteristics of the respondents

Along the lines suggested by Egbue and Long (2012), we decided to check whether each barrier was perceived differently by select socio-economic characteristics. Using chi-squared, we tested the null hypothesis H_0 that two variables X and Y were independent. We cross-tabulated each barrier with a socio-economic feature (Table 9). For the sake of clarity, we reported only p-values lower than 0.05. The comments we provide below are based on the contingency tables, which we do not report in this paper but are available from the authors.

The greatest number of significant cross-tabulations was recorded when considering gender and EC knowledge. With regard to gender, there was evidence that it mattered for 12 out of 20 proposed barriers, with females usually reporting a greater level of concern than men. An identical frequency applied to EC knowledge. Respondents with more EC knowledge had lower levels of concern. Education played a role for 10 out of 20 barriers, mostly related to safety and technology and to economic uncertainty. Household income made a difference in 9 out 20 barriers. Respondents earning more than €70,000 per year expressed fewer concerns about factors related to economic uncertainty, such as the high purchase price of ECs and the risk of rising electricity prices. They also appeared less concerned with the cost for the required adaptation of the electrical system or for the increased costs in electricity bills due to home charging. Members of an environmental association were concerned primarily with EC usability and with the charging infrastructure. These respondents mostly worried about the environmental degradation of the place where they live\work\study and were relatively more concerned about range anxiety, poor safety due to the risk of fire and reduced driving pleasure due to the lack of an internal combustion engine. Respondents who worked as entrepreneurs or executive employees usually expressed lower levels of concern, although it seems quite hard to provide a rationale to justify this outcome for each of the barriers. Not surprisingly, individuals who have driven an EC appreciated their performance more and did not manifest reduced driving pleasure due to the lack of an internal combustion engine.

5. Conclusions and policy implications

The current uptake of ECs in Italy is very limited. The country is lagging behind several European countries due to the presence of a number of barriers that deter prospective customers. This paper tried to shed light on the main barriers by administering a set of 20 statements to a sample of 870 adults, who had to express their level of agreement with the statements.

The three barriers that respondents perceived the most were the insufficient density of charging stations, the difficulty using an EC due to the lack of charging stations along highways and the purchase price. Conversely, four out of the 20 hypothesized barriers were not considered barriers by more than half of the respondents. These were poor safety due to the risk of fire, mistrust of new technologies, poor acceleration and reduced driving pleasure due to the lack of an internal combustion engine. One of the main differences of our findings relative to previous studies was the relatively less important role played by range anxiety. Italian drivers, instead, were still extremely sensitive to the charging issue. As for the environmental implications of ECs, our sample was rather convinced that ECs could contribute to reducing the environmental impact, more so than reported in previous studies. A similar, more positive appreciation related to technological features, such as safety and technical reliability. The latter two results prove that some of the initial concerns associated with ECs have been dispelled.

The findings of this paper suggest a series of improvements that could be made by various actors to overcome some of the barriers to EC uptake. As for the most relevant ones, the financial barriers, in 2019, Italian policy makers enacted a series of incentives at the national and local levels that certainly will help with EC uptake. In March 2019, the Italian government enacted the 'Ecobonus' purchase subsidy, thus considerably reducing the acquisition cost. The operational cost advantage of ECs has also been strengthened by regional and local policies such as the zero-circulation tax for the first 5 years, reduced or exempted parking fees and unrestricted access to limited traffic zones (Danielis et al., 2020b; Scorrano et al., 2020b). On the supply side, car manufacturers could reduce financial barriers by producing cheaper ECs belonging to the A and B segments. In fact, the Italian car fleet consists mostly of small and medium-sized cars, and the A and B segments account for, respectively, 16.9% and 34.9% of the market (UNRAE, 2020b). Yet, in 2019, only two ECs were available in these segments: the Daimler Smart fortwo and the Renault Zoe. In segment C, which accounted for 33.9% of the market, the only available EC model for the year 2019 was the Nissan Leaf. To date, FCA, which is the leading Italian car manufacturer for the A and the B segments, has not offered a fully electric model. Only recently, in March 2020, did FCA open orders for the Fiat e500, with deliveries expected to take place in October 2020. Similarly, other manufacturers such as Volkswagen (including Seat and Skoda) and PSA have started offering ECs belonging to the A and B segments.

Other improvements relate to charging. There are stringent infrastructure needs, such as the lack of charging stations along the main Italian toll highways (Autostrade) and the unclear regulation of parking costs at charging stations and in multi-house dwellings. Despite Italy benefitting from European funds, the country is still lagging behind in terms of number and type of charging points. In fact, according to the European Alternative Fuels Observatory, in 2019, there were 864 fast charging points (more than 22 kW) in Italy, while in Germany, there were 5088 fast charging points, corresponding to 1.4 and 6.1 fast public charging points per 100,000 inhabitants, respectively (https://www.eafo.eu/countries/germany/1734/infrastructure/electricity/compare).

Finally, our results demonstrate that knowledge about the technological and environmental pros and cons of ECs has made important progress in recent years. However, as innovation occurs and the electricity mix incorporates an increasing share of renewable sources in Italy, reliable and complete information is needed and could be provided by academia, traditional and internet-based media outlets and the car manufacturers.

CRediT authorship contribution statement

Marco Giansoldati: Conceptualization, Data curation, Formal analysis, Software, Writing - original draft, Writing - review & editing. **Adriana Monte:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing - original draft. **Mariangela Scorrano:** Conceptualization, Data curation, Formal analysis, Software, Writing - original draft, 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.

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