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Are urban mobility policies favoring the purchase of new vehicles?

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ABSTRACT

This research aims to determine the extent to which citizens are uncertain about the mobility policies adopted by regulators and how the decision to purchase new vehicles may be motivated by doubts that individuals develop regarding the vehicle type to purchase. The automotive industry's technological innovations, promoted by governments, may not have the environmental impact desired in certain regions. To address this issue, a survey was conducted in the city of Madrid. An exploratory factor analysis, followed by a discriminant analysis, was used to validate the constructs and predict the decision-making. The results confirm that the policies adopted by regulators generate uncertainty among individuals regarding which vehicle to purchase. As such, the purchase of a new vehicle may be postponed. This has the opposite effect that is intended, since a delay in the decision to purchase a new vehicle increases the average age of the vehicle fleet, thus contributing to more pollution from the mobility environment. These results highlight the need for governments to work on policies that align environmental needs with the social and economic context in order to achieve the most efficient transition possible, and an global discussion on the technology and innovation applied to consolidate sustainable mobility.

1. Introduction

Sustainable development and environmental stewardship have become key elements in the development of a global society, as evidenced by the large number of scientific publications on sustainability. One area of relevance that contributes to this development is urban mobility, a subject of extensive research due to its social, economic, and environmental relevance (Canitez, 2019; Miskolczi et al., 2021; Pamucar et al., 2022). Mobility and the transport of people have a significant impact on environmental sustainability and therefore occupy a strategic place in the policies developed by authorities in recent decades, with the aim of reducing greenhouse gas emissions. Sustainable mobility progresses toward a context where both technological innovation and connectivity play an important role in achieving a mobility network to meet the challenges set by businesses, in line with their digitisation goals. Key elements, such as teleworking and urban planning, need efficient mobility environments to drive digitisation, and, therefore policies must be challenged to guarantee aggregate development. In fact, policy measures must be followed both to create a sustainable mobility environment and to enhance innovation and to influence entrepreneurship (Zeng and Ren, 2022; Scheu and Kuckertz, 2023), in order to promote the creation of green tech firms (Kim et al., 2023) that may round out the offer side and provide a sustainable model.

The European Commission has adopted a number of policies on sustainable mobility over the last few years, starting with the Green Paper on the Impact of Transport on the Environment, a response to the challenges set by the United Nations in 1987 (Imperatives, 1987), when the term 'sustainable mobility' was used for the first time in this document of the European Commission and different areas of action regarding the transport sector and people's mobility were identified. Almost three decades later, in the wake of relevant global agreements aimed at legislating environmental concerns, such as the Earth Summit (1992), the Kyoto Protocol (1997), the Millennium Development Goals (2000), and the Paris Agreement (2015), the United Nations presented the 2030 Agenda for Sustainable Development, consisting of 17 sustainable development goals (SDGs) and 169 targets (United Nations, 2015), based primarily on "providing safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons". In 2019, a turning point was reached in the European region when the European Commission, through the European Green Deal or Agenda 2050 (European Commission, 2019), required organisations to eliminate CO_2 emissions. Among other agreements, the EU

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Member States agreed that by 2050, no Internal Combustion Engine Vehicles (ICEVs) would remain in circulation, opting instead for non-polluting technologies.

One of the most important measures, given its economic implications, approved by the Council of the European Union in October 2022 (European Council, 2022) and ratified by the European Parliament (European Parliament, 2023), has been the ban of sales both of diesel and petrol vehicles from 2035. However, some EU countries are critical of this measure. Germany, for example, has reached an agreement with the European Commission to allow the sale of ICEVs that run on e-fuels after the 2035 ban.

This regulatory framework involves several additional mobility implications and provisions undertaken by national and local governments in an effort to contribute to improving urban mobility, especially in large central urban areas. To that end, European capitals, such as Madrid, have implemented a number of measures to achieve these objectives. Such measures include restricting and limiting the circulation of vehicles (especially ICEVs) in urban environments, as well as fiscal policies and subsidies to incentivise the acquisition of eco-friendly vehicles under the Madrid City Air Quality and Climate Change Plan (Plan A), approved by the Madrid City Council in 2017 (Ayuntamiento de Madrid, 2017) and ratified in 2021 (Ayuntamiento de Madrid, 2021) following legal challenges to the initial plan.

These measures aim to encourage citizens to use and purchase eco-friendly means of transport. Although incentive policies are not the only element influencing the purchase of electric vehicles, other relevant factors are oil prices and the network of charging points (Wang et al., 2019; Nazari et al., 2019). Studies suggest that these adopted policies, subsidies, emission taxes, regulations, and non-economic incentives are helping the European vehicle fleet transition to a zero-emission model (Axsen et al., 2020; Ledna et al., 2022; Liao et al., 2017; Hardman et al., 2017; Jenn et al., 2018). Other studies, however, indicate that the ban on the sale of ICEVs is not well-received by the public, especially among users of these vehicles (Bennett and Vijaygopal, 2018). With this in mind, this study suggests that the different policies and changes in criteria implemented by the authorities to incentivise the purchase of ecological vehicles may generate uncertainty about which type of vehicle to purchase, subsequently resulting in a negative impact in the short term, since consumers may decide to postpone their purchase, regardless of vehicle type (Alberini et al., 2018). Given the regulatory context, this research aims to answer the following question: To what extent are the changing policies adopted by authorities triggering both regulatory and technological uncertainty among the public and adversely affecting consumers' decisions to purchase new vehicles?

Madrid was chosen for this study as it is an urban environment with very strict policies on sustainable mobility, most notably the 2018 implementation of a large low emissions zone (LEZ) for eco-friendly vehicles called Madrid Central (Ayuntamiento de Madrid, 2018). Despite an increase in absolute terms of registrations of e-vehicles in Europe (European Environmental Agency, 2022) and Spain in 2021 (ANFAC, 2021), for the latter, such vehicle registrations have declined overall considering the motorizations available on the market (ANFAC, 2021). In Spain, the average age of the vehicle fleet has increased in recent years, despite measures adopted to promote the purchase of eco-friendly cars. In 2019, the average age was 12.6 years; in 2020, 13.1 years; in 2021, 13.5 years; and in 2022, the average age was 13.9 years (ANFAC, 2020, 2021, 2022). However, the automotive industry is affected by other factors, including political, technical, and geopolitical uncertainty.

This research is timely and relevant because the results show that there is uncertainty among citizens, causing a delay in the renewal of personal vehicles, thus highlighting the need for authorities to design a sustainable mobility policy with greater guarantees and consistency to generate social confidence and achieve a sustainable and consolidated renewal of the vehicle fleet. Although current ICEVs pollute less than older ones, the authorities must be made aware of the reality of the market and the technological development of eco-friendly propulsion technologies, since policies aimed at banning combustion technologies generate uncertainty for consumers in the short term. This may slow sales of new ICEVs which, though not the most eco-friendly alternative, pollute less than older technologies. The implications of these findings must be considered from a strategic business perspective since urban mobility leads to a context of digitisation based on smart cities and autonomous vehicles, both of which require sustainable investment strategies (Richter et al., 2022).

This paper is structured as follows: a review of the literature is included first to highlight the most relevant contributions in the field, applying the Theory of Planned Behaviour and Technology Acceptance Models to obtain the variables that may influence the decision to purchase a new vehicle in the referred context. The methodology explains how the Exploratory Factor Analysis is used to divide the variables into groups in the proposed model and subsequently test its influence in the dependent variable, followed by a discriminant analysis. Sample and data collection, with TPB- and TAM-based constructs, are then presented, followed by the results and findings. Finally, contributions to the research, including conclusions, implications, limitations, and further research, are discussed in the last section.

2. Literature review and theoretical framework

2.1. Research and theoretical background

The Theory of Planned Behaviour (Ajzen, 1991) is an extension of the theory of reasoned action (Ajzen, 1980). This theory suggests that predictors of behaviour are: a) attitudes that reflect the individual's positive or negative appraisal of a behavioural choice, b) subjective norms, such as perceived social pressure to perform the behaviour in which individual conduct is displayed, in accordance with external opinions, and c) perceived behavioural controls that refer to the perceived ease or difficulty of performing the behaviour. Generally, strong individual behavioural intentions are conditioned by a range of attitude positivity, subjective norms, and higher perceived behavioural controls (Ajzen, 1991). The explanatory power and predictive validity of this theory has been demonstrated by the relevant empirical research (Conner and Armitage, 1998; Bamberg and Möser, 2007; McDermott et al., 2015).

Studies suggest the need for an entrepreneurial and knowledge-based approach to address social issues of desire and acceptability by relying on moderating TPB factors (Liao et al., 2022). In this respect, Drăgan et al. (2022) suggest adopting the TPB model to create an entrepreneurial attitude (Simmou et al., 2023) to the specific context of the research involved in the eco-label industry to determine the factors that could provide further insight into consumer behaviour and consumer decision-making processes, both of which are essential to develop green marketing strategies.

The mobility industry, among others, has adopted the TPB model to analyse the purchasing behaviour of consumers with regard to Plug-in Electric Vehicles (PEVs) (Semeijn et al., 2019; Mohamed et al., 2016; Khan et al., 2020), in an effort to understand consumers adoption of PEVs (Thøgersen and Ebsen, 2019) and their attitudes toward environmental policies (Spangenberg and Lorek, 2019). The model is considered suitable for the purposes of this research because it is based on the premise that the implemented policies trigger uncertainty, and thus affect the purchase decision. Previous research, however, has not widely addressed either how government policies influence purchase decisions or the uncertainty about future policy developments.

Given that the TPB model is open to further extensions with additional constructs to explain purchase intention (Ajzen, 1991; Conner and Armitage, 1998), this research is based on the adapted TPB model to analyse the extent to which the policies implemented incentivise the purchase of green vehicles among consumers, and therefore affect the decision to delay the renewal of their vehicles, causing a negative environmental impact in the short term (Research Hypothesis). Also, the

Technology Acceptance Model (TAM) (Davis, 1989) has been applied to evaluate the extent of consumer awareness of vehicle features available on the market, a variable that heavily influences the timing of decisions.

The decision to purchase a new vehicle is a complicated process for consumers, given that vehicles are long-duration goods that require significant expense. There is existing scientific contribution on decision-making, though mainly from an entrepreneurial perspective, with a tendency toward risky or rational decision-making (Melović et al., 2022). Other studies focused on consumer decision-making identify risk attitudes, aspiration levels, and other preferences as factors that offset the risk perception of certain products (Song et al., 2021). The decision-making process is further complicated when it involves the alternative-fuel vehicles available on the market, given that they are perceived as pricier by consumers (Adepetu and Keshav, 2017) and PEVs present some technological issues, such as battery storage (Nykvist and Nilsson, 2015; Hannan et al., 2017) and range satisfaction (Franke et al., 2017; Noel et al., 2019). Therefore, issues exist in the adoption of PEVs (Rezvani et al., 2015; Abotalebi et al., 2019) that make the decision process riskier for consumers. Another important aspect influences the risk perceived by consumers when purchasing PEVs: their lack of knowledge about the product (Wang et al., 2018). When evaluating the purchase of expensive items, consumers seek to optimise their utility, attributing less importance to environmental issues and more importance to technological aspects. Riskier decision-making processes prompt longer and broader approaches for consumers owing to their difficulty. Given the relationship between uncertainty and risky decisions (Vives et al., 2023), this research is timely considering the importance of understanding the factors that may influence the purchase of new vehicles, addressing the uncertainty that consumers feel about government-implemented policies.

2.2. Hypothesis development

2.2.1. Attitudes

Attitude is a psychological process that conditions an individual's behaviour in each circumstance (Sreen et al., 2018). Therefore, it can be assumed that individuals who are influenced by normative and technological uncertainty are more likely to postpone their purchase decisions in the future. The influence of attitude on purchase intention is significant (Ajzen, 2002; Taylor and Todd, 1995).

Attitudinal factors have been identified as important determinants of vehicle purchase intention (Joshi and Rahman, 2019; Zhou and Wang, 2019; Shalender and Sharma, 2021). There are a variety of factors that can influence an individual's attitude and, in turn, their purchase intentions, such as sociodemographic factors, petrol prices, and travel attributes (Muromachi, 2017). The most recent literature focuses on the influence of attitude on purchase intention for green vehicles. Specifically, the TPB model is applied to explain the influence of environmental awareness on consumer attitudes and intentional purchase response (Yarimoglu and Binboga, 2019; Vafaei-Zadeh et al., 2022). Given that attitude is "the result of a consumer's assessment of particular behaviours" (Ajzen, 1991), it is assumed that in order to address the main hypothesis (research hypothesis), several factors that may influence the way individuals make vehicle purchase decisions have been identified.

2.2.2. Policies and uncertainty

Governments have introduced policies to incentivise electric mobility (Lieven, 2015) through the purchase of green vehicles in an effort to make road transport more eco-friendly (IEA, 2016, Nie et al., 2016). PEVs are currently dependent on strong Electric Vehicle Policies (Münzel et al., 2019) which involve, among others, dedicated road spaces, parking privileges, charging infrastructure, tax deductions, feebate systems, and financial subsidies and exemptions (Wolbertus et al., 2018; Brückmann and Bernauer, 2020).

This paper focuses on the following policies, given that EVs and ICEVs coexist in the transition to a zero-emissions transport model: mobility restriction policies for ICEVs, calls for the automotive industry to cut the manufacturing of ICEVs, and taxation policies to encourage the purchase of cleaner vehicles. Studies suggest that current policies are expensive and therefore not effective (Sheldon and Dua, 2019). Thus, the effectiveness of these policies must be studied from different points of view.

Governments have imposed mobility restrictions, largely in urban areas, to reduce CO_2 emissions and encouraging residents to drive less (Salon, 2015). These mobility restrictions are mainly based on policies designed to limit the mobility of ICEVs in certain areas, while allowing eco-friendly vehicles to circulate (Tang et al., 2022). Regardless, some studies suggest that these policies are not so effective in terms of CO_2 reduction (Dantas et al., 2021). At the same time, these policies may cause uncertainty among consumes when deciding whether to buy a new vehicle. A technological choice could be perceived as risky considering that mobility policies are changing, their effectiveness is in doubt, and they are implemented regionally. Thus, an element of uncertainty may develop in the minds of consumers if there is a change of criteria post vehicle purchase that may affect their satisfaction. These long-term doubts may cause consumers to postpone the purchase of new vehicles until there is more clarity.

h1. Mobility restriction policies negatively affect the intention to purchase a new vehicle.

Governments have also established policies focused on the supply side in terms of emissions levels and automotive manufacturing impositions, the latest being the European Parliament's ban on the manufacture of ICEVs from 2035. Other countries, such as Canada, Japan, Mexico, and the UK, have announced plans to remove ICEVs from the market (United Nations Environment Programme, 2019). These measures aim to encourage consumers to purchase eco-friendly vehicles, but these policies may not be well-received by consumers. Bennett and Vijaygopal (2018) performed quantitative research to measure ICEV users' willingness to buy PEHs, concluding that current ICEV users are unwilling to pay more for this transition, since these bans imply costs for consumers. This suggests that ICEV policies could prompt mistrust of current ICEVs, reducing ICEVs sales due to uncertainty (Jenn et al., 2020). Thus, these potential consequences may affect the decision-making process, such that consumers may postpone the purchase of a new vehicle based on uncertainty. This is an undesirable effect for governments, as the age of vehicles increases and the target to reduce CO_2 emissions by increasing the number of cleaner vehicles on the road is not being addressed. As a result, synthetic carbon-neutral fuels are being considered (Brynolf et al., 2018), but competitiveness among electro-fuels and bio-fuels is questionable, as it depends of the evolution of electric battery costs (Hannula and Reiner, 2019). Some studies maintain that ICEV market must be developed to reduce the footprint from automobiles via synthetic or bio fuels (Towoju and Ishola, 2020; Kalghatgi, 2019).

h2. Bans on the sale of combustion vehicles negatively affect the intention to purchase a new vehicle.

General research maintains that policies must be developed to encourage the purchase of zero-emission vehicles (Silvia and Krause, 2016; Wolinetz and Axsen, 2017). Some policies aim to incentivise the purchase of electric vehicles through subsidies, tax exemptions (Byun et al., 2018; Moon et al., 2018; Breetz and Salon, 2018), or by raising taxes on ICEVs. Lam and Mercure (2021) conducted a study to analyse six policy instruments for the UK, US, Japan, China, and India and they concluded that it was highly effective to combine electric vehicle regulations through taxation and regulation for ICEVs. However, some authors suggest that these policies do not effectively encourage drivers to stop buying ICEVs (Alberini and Bareit, 2019) because the driving population and lobbyist may voice their opposition (Brand et al., 2013). There are studies that conclude that higher taxes on ICEVs do not

significantly promote the purchase of PEVs in China (Ji et al., 2022), while others suggest that purchase incentives are not effective and policies should focus on charger density, fuel prices, and road priority (Wang et al., 2019). Considering that the tax policies implemented to encourage the purchase of PEVs may not be working, a tax increase with the aim of discouraging ICEV purchases could result in a decline in sales for both alternatives, thus an overall drop in sales. This scenario suggests consumers may develop uncertainty when buying a new vehicle.

h3. Vehicle taxation policies negatively affect the intention to purchase a new vehicle.

In this sense, our study aims to identify the extent to which the policies implemented by regulators negatively influence the purchase of new vehicles, thus having an adverse effect on the sustainability of mobility. Specifically, we measure the impact of mobility policies, manufacturer regulations, and taxation policies. It is important to consider that these measurements are underpinned by the presumed uncertainty perceived by the market. Over the last few years, the adopted measures have changed and are presumably generating uncertainty for consumers when buying a new vehicle (Jenn et al., 2020). This uncertainty can influence an individual's attitude and consequently their decision to purchase a new vehicle, which is necessary to meet the emission reduction target.

2.2.3. Technology and uncertainty

In the 1990s, studies combining the TPB model and the Technology Acceptance Model (TAM) emerged to explain consumer purchase intention based on the perceived use and perceived usefulness of the investment (Davis, 1989; Taylor and Todd, 1995). TAM was used to explain how the perceived ease of use and perceived usefulness affect purchase intention (Davis, 1989). This combination of the two theories has resulted in combinatorial theories (C-TAM-TPB) that primarily consist of adding to the TAM model the variables of the TPB model, subjective norms, and perceived behavioural control. However, previous studies have added some e-vehicle purchase intention variables to the model, including price, value, environmental self-image, infrastructure barrier, and perceived risk (Choi and Ji, 2015; Suki, 2019). Regarding the latter, and for the purpose of this study, perceived risk, in the form of the perceived usefulness of available vehicles, is applied to explain how it influences an individual's attitude and how it determines their purchase intention. Other studies identify perceived risk as a main predictor of the intention to use a certain technology (Arfi et al., 2021; Wang et al., 2021), which may explain the extent to which policy uncertainty influences the selection of the appropriate vehicle. The current context, in which several studies maintain that ICEVs should be kept on the market by investing in technological advances to reduce emissions through synthetic or bio fuels (Towoju and Ishola, 2020; Kalghatgi, 2019), while ample literature suggests the sustainable solution is a zero-emission vehicle (Silvia and Krause, 2016; Wolinetz and Axsen, 2017), may cause uncertainty among consumers about which technology to trust, given the high perceived risk associated with making the wrong decision.

In this sense, two constructs are proposed to determine consumer perception with respect to combustion engines and eco-friendly vehicles to be correlated with the consumer decision to buy a new car. Decisions to switch, postpone, or cancel the purchase of PEVs are influenced by perceived risk (Chen and Yan, 2019; Kamal et al., 2020). It is important to analyse the characteristics and attitudes toward technology among consumers (Kalakou et al., 2023) to allow transport sector operators a more comprehensive approach to the problem.

h4. Lack of confidence in combustion engines negatively affects the intention to purchase a new vehicle.

h5. Distrust in eco-friendly engines negatively affects the intention to buy a new vehicle.

2.3. Subjective norms

Subjective norms refer to the social pressure to develop certain behaviours (Abrahamse et al., 2009). We define ourselves by identifying with certain social groups (Tajfel and Turner, 1979). When individuals identify with a certain group, they are motivated to follow the unspoken rules and customs of that group, acting accordingly (Masson and Fritsche, 2014).

Existing studies suggest that social norms influence car purchase intention (Belgiawan et al., 2013; Belgiawan et al., 2017; Yarimoglu and Binboga, 2019; Vafaei-Zadeh et al., 2022). A number of studies focus on the influence of social norms on an individual's decision to buy a PEV. Social norms could influence PEV adoption based on whether the consumer perceives the group to be in favour of it, but social groups may have the opposite effect on PEV adoption if only a few group members are PEVs users (Smith et al., 2017). Axsen et al. (2013) concluded that discussing PEVs with others can influence individual perceptions of PEVs and that research participants were influenced by social interaction. Petschnig et al. (2014) found that subjectivity and social norms were positively related to the intention to use alternative fuel vehicles. Lane and Potter (2007) suggested that social norms influence an individual's willingness to buy a green vehicle.

As subjective norms influence individuals' vehicle purchase intention (Afroz et al., 2015) and both technological and policy uncertainty influence the social group(s) of the individual, this study proposes to measure the correlation between the perception of the individual's reference groups with the consumer's purchase intention, given the normative context.

h6. Influence groups are positively correlated with an individual's attitude and intention to buy a new vehicle.

2.4. Perceived behaviour control (PBC)

PBC is divided in two levels, sense of control and sense of efficacy. Sense of control refers to whether the consumer can make a purchase decision. Sense of efficacy assesses the difficulty of the purchase process (Ajzen, 2002). When an individual understands that there are other opportunities, resources, and fewer anticipated challenges, their perceived control is stronger (Ajzen and Fishbein, 2005). Since the purchase of a vehicle involves high cost and risk, consumers need to assess their capacity to buy a new vehicle; this is what is implied by Perceived Behavioural Control (Ajzen, 1991). Linking this factor to the presumed difficulty of decision-making, given that there are different types of cars to buy and different policies applied to each (Afroz et al. (2015), suggests that consumers will only consider purchasing a PEV if they have the ability to buy and use them. However, studies like the one conducted by Ye et al. (2021) for the Malaysian market suggest that PBC does not strongly influence consumers' PEV purchase intention when there are applicable incentive policies in place.

In this study, PBC refers to the consumer's perceived degree of difficulty when deciding to buy a new vehicle, given the factors that may influence the decision.

h7. Perceived security and control over decision making are positively correlated with purchase intention.

3. Research methodology

Based on a review of the literature and the issues noted, the methodology used to analyse how uncertainty about the implemented policies can influence an individual's decision to purchase a new vehicle is defined below, starting from the hypothesis that such uncertainty can motivate individuals to postpone their decision to renew their vehicle (research hypothesis).

To test this research hypothesis, a specific questionnaire was circulated on-line between 27 March 2023 and 18 April 2023. A total number

of 400 effective surveys were conducted. Table 1 shows the variables and items used in the study.

The selected research target includes individuals with driving licenses, owning private cars, and living within the autonomous community of Madrid. Data has been collected using an original survey circulated via email. Four hundred valid responses were obtained. For a universe considered finite ($N > 10.000$), we assume a maximum sampling error of +5 % (P = Q = 50 %) with a confidence level of 95.5 %.

Madrid was chosen given the government's ample involvement in regulatory matters designed to promote a sustainable mobility environment. With a 95 % confidence interval and a universe of 3,667,765 individuals with a driving license in the Community of Madrid (Dirección General de Tráfico, 2021), the sample obtained is representative to test the research hypothesis, without prejudice to its suitability and novelty, considering that there are no empirical studies of this nature to measure the extent to which policies can lead consumers to postpone their purchase decisions, thus generating the opposite effect desired by regulators.

For data analysis and validation of the research hypotheses, a combination of statistical analysis methodologies based on bivariate analysis (ANOVA) and multivariate analysis, exploratory factorial with principal component factor in the extraction method and Varimax rotation and discriminant analysis is used. The 4-factors obtained from the Exploratory Factor Analysis among the set of constructs proposed are tested to check their influence and significance on the dependent variable, followed by a discriminant analysis.

This methodological combination of analysis enables both a statistical and exhaustive understanding of the relationships between variables under the hypotheses, providing us an understanding of the positive or negative effect between the dependent variables to be calculated. SPSS, version 28.0.10 (142), has been used for the statistical calculations. SPSS analysis techniques are among the most comprehensive for analysing models in which relationships between variables and their disaggregated measures of influence are identified and are widely used for research related to the study of consumer vehicle purchase behaviour (Leng and Chin, 2017; Narayan et al., 2022).

4. Results

4.1. Descriptive analysis

The distribution of the sample according to socio-demographic variables is shown in Table 2.

Table 3 shows the results for the targeted dependent variable that is subsequently influenced by the factors addressed in the hypothesis. As illustrated in Table 3, only 34.8 % of respondents would not postpone the decision to renew their vehicle.

As shown in Table 4, a test to reject the null hypothesis that there is no relationship between the purchase decision and the variables under study is conducted. It consists of an analysis-of-variances test between the dependent and independent variables under study.

For most of the variables, the null hypothesis is rejected. We can, therefore, assume that there is a relationship between perceptions of the regulatory, social, and technological environment and greater or lesser uncertainty when making a purchase decision. The relationship is not demonstrated with the perception of traditional vehicle technology, and thus the assumption is that this perception does not correlate with greater or lesser uncertainty during decision-making. However, this test does not explain how the variables are correlated.

4.2. Exploratory factor analysis

To explain the relationship between the variables and the validity of the constructs, an exploratory factor analysis was carried out with the uncertainty perception variables, using the Principal Component Method with Varimax Rotation (Covariance between factors =0)

Table 1
Variable, constructs, items, and sources.

Latent variable	Code	Item	Sources
Dependent variable	Dependent variable	I would prefer to buy a new vehicle or renew mine at a later date	Research gap
ATTITUDES	ATTREG_RESTMOB1	Mobility restrictions ➔ Make me uncertain about the type of engine to buy (diesel, petrol, gas, hybrid, electric, etc.).	Ajzen (1991) Byun et al. (2018) Moon et al. (2018) Wolinetz and Axsen (2017)
	ATTREG_RESTMOB2	Mobility restrictions ➔ They create such uncertainty that I would prefer to wait to renew my vehicle.	
	ATTREG_RESTIND1	Restrictions on manufacturers ➔ Make me uncertain about the type of engine to buy (diesel, petrol, gas, hybrid, electric, etc.).	
	ATTREG_RESTIND2	Restrictions on manufacturers ➔ They create such uncertainty that I would prefer to wait to renew my vehicle.	
	ATTREG_TAX1	Tax policies ➔ They create such uncertainty that I would prefer to wait to renew my vehicle.	
	ATTREG_TAX2	Tax policies ➔ Make me uncertain about the type of engine to buy (diesel, petrol, gas, hybrid, electric, etc.).	
	ATTTECH_1	I believe that the technology of traditional engines (diesel, petrol and gas) is adequate and has a long-term future.	
	ATTTECH_2	I believe that the technology of the green engines (hybrid, plug-in hybrid and electric) is insufficient and should be improved.	
SUBJECTIVE NORMS	SN1	People around me know very well what type of engine they would choose if they bought a new vehicle.	Ajzen (1991); Abrahamse et al. (2009); Belgiawan et al. (2013); Belgiawan et al. (2017); Yarimoglu and Binboga (2019); Vafaei-Zadeh et al. (2022)
	SN2	People around me think it is better to wait to buy a vehicle later because of uncertainty.	

(continued on next page)

Table 1 (*continued*)

Latent variable	Code	Item	Sources
PERCEIVED BEHAVIOUR CONTROL	PBC_1	I would find difficult to buy the right vehicle with the right engine at the moment.	Ajzen (1991); Ajzen and Fishbein (2005); Abrahamse et al. (2009); Belgiawan et al. (2013); Belgiawan et al. (2017); Yarimoglu and Binboga (2019); Vafaei-Zadeh et al. (2022)
	PBC_2	If I had to buy a new car or renew it, it would be difficult for me to make a decision about which engine to choose.	

Table 2
Demographic characteristics of participants.

Variable		Frequency (N = 400)	%
Gender	Male	203	50.8 %
	Female	193	48.3 %
	Other	4	1 %
Age	18–30	81	20.3 %
	31–40	89	22.3 %
	41–50	100	25 %
	51–60	100	25 %
	> 60	30	7.5 %
Education	Primary school	14	3.5 %
	Secondary School	44	11 %
	Undergraduate	40	10 %
	Graduate	134	33.5 %
	Post-graduate	168	42 %
Job	Self-Employed	40	10 %
	Employed - private sector	295	73.8 %
	Cooperativist	2	0.5 %
	Unemployed	24	6 %
	Retired	15	3.8 %
	Other	24	6.0 %
Madrid residential location	In the urban area of the city of Madrid	127	31.8 %
	In the peripheral zone	273	68.3 %

Table 3
Targeted dependent variable.

I would prefer to buy a new vehicle or renew mine at a later date ➔ Dependent variable	%
I would not need to postpone the decision ➔ Decision not to be postponed	14.3 %
I would like to be clearer, but I would not postpone the decision ➔ Decision not to be postponed	20.5 %
If possible, I would prefer to postpone the decision until it is clearer ➔ Decision to be postponed	39.3 %
I wouldn't decide anything until it was clearer to me ➔ Decision to be postponed	26 %

(Tavakol and Wetzel, 2020) to check the measurement model and to generate independent components of each, which could be used in a subsequent discriminant analysis without fear of interpretative bias caused by the covariance between factors.

Analysing the correlation matrix (Table 5), we opted to exclude three of the perception variables from the exploratory factor analysis (Table 6) because they had poor sampling adequacy values (MSA in the anti-image correlation matrix in Table 5).

Excluding the three variables with a coefficient lower than 0.7, the Kaiser-Meyer-Olkin test was used to confirm whether the remaining nine variables generate an adequate correlation matrix for the factor analysis, defining a statistical level higher than 0.7 as acceptable. As shown in Table 7, the coefficient obtained is very high, confirming the adequacy of the model.

The 4-component factorial solution was chosen. The total variance explained by this model is sufficiently high: 81.9 %. All the variables included in this model obtain, from the principal component analysis, a high extracted communality ($\geq$ 0.7) as shown in Table 6.

To interpret the factors, we used the rotated component matrix, as shown in Table 8. The first conclusion is that perceptions of the regulatory environment are integrated into a single dimension or factor.

The factors obtained from the exploratory analysis are used to validate the significance of the relationship between the 4-factors with the dependent variable, as shown in Table 9. Overall, the model has satisfactory predictive significance.

As illustrated in Table 9, there is a strong correlation between Factor 1, which includes the variables related to the uncertainty perceived by consumers about government policies, and decision-making about the purchase of a new vehicle, confirming that policy uncertainty creates doubts on the market, affecting the purchase of new vehicles.

4.3. Discriminant analysis

Based on the hypothesis that the factors cited explain greater or lesser uncertainty when decision-making, a Discriminant Analysis was carried out applying the following premises:

- Dependent variable: I would prefer to buy a new vehicle or renew mine later [0 = "No"; 1="Yes"].
- Independent variables: the a components of the exploratory factor model.
- Intra-group covariance matrix is used, assuming that both groups have the same prior probability.

As a result, we obtain the classification in Table 10, which confirms that the 4-factor model correctly predicts uncertainty in 80 % of the cases.

Since the factors are independent of each other, we used the Structure Matrix (Table 11) to calculate the influence or weight of each factor.

Perceptions of the regulatory context are the key factor causing uncertainty when deciding to buy new vehicles, with perceptions of the social environment and the appropriateness of technologies having limited influence.

From the methodology applied, we can accept hypothesis 1, hypothesis 2, and hypothesis 3, given the strong correlation with the dependent variable and results obtained. Hypothesis 4 and hypothesis 5 cannot be accepted due to the lack of consistency in the results obtained. Hypothesis 6 and hypothesis 7 cannot be accepted on the basis that the variables do not contribute positively to the model prediction obtained and results are not consistent.

5. Discussion

The policies established by the authorities, with the aim of encouraging a sustainable mobility model, are generating a series of repercussions of various kinds. Policies focus mainly on encouraging the purchase of eco-friendly means of transport and discouraging the use of ICEVs to achieve the consolidation of sustainable mobility (Lieven, 2015; Nie et al., 2016). These policies are mainly (i) mobility restriction policies for ICEVs, (ii) calls for the automotive industry to cut the manufacturing of ICEVs, and (iii) taxation policies to encourage the purchase of PEVs. There are studies that suggest that these policies may

Table 4
Null hypothesis test (ANOVA).

Hypothesis	Dependent variable	Independent variable	Scale	Mean		Coefficient		Null Hypothesis acceptance
				Decision not to be postponed	Decision to be postponed	F/df	Significance	Non-rejected (sig < 0.05) Rejected (sig > 0.05)
h1	I would prefer to buy a new vehicle or renew mine at a later date	ATTREG_RESTMOB1	1 = Totally disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Totally agree	3.3165	4.0536	35,573	0.000	NON-Rejected
h1		ATTREG_RESTMOB2		2.8849	4.1341	100,508	0.000	NON-Rejected
h2		ATTREG_RESTIND1		3.2662	4.1226	43,458	0.000	NON-Rejected
h2		ATTREG_RESTIND2		3.0072	4.2222	96,874	0.000	NON-Rejected
h3		ATTREG_TAX1		3.1799	4.0958	59,019	0.000	NON-Rejected
h3		ATTREG_TAX2		3.0216	4.1954	94,563	0.000	NON-Rejected
h4		ATTTECH_1		3.6691	3.7126	0,097	0.756	Rejected
h5		ATTTECH_2		3.9784	3.9655	0,011	0.918	Rejected
h6		SN1		2.5396	2.3257	2982	0.085	Rejected
h6		SN2		3.6187	4.1111	21,112	0.000	NON-Rejected
h7		PBC1		3.5108	4.295	45,773	0.000	NON-Rejected
h7		PBC2		2.9065	4.1801	94,391	0.000	NON-Rejected

Table 5
Correlation Matrix.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ATTREG_RESTMOB1	1	0.576	0.629	0.543	0.575	0.534	0.252	0.042	0.395
(2) ATTREG_RESTMOB2	0.576	1	0.626	0.766	0.557	0.749	0.183	−0.014	0.484
(3) ATTREG_RESTIND1	0.629	0.626	1	0.724	0.73	0.641	0.295	0.023	0.414
(4) ATTREG_RESTIND2	0.543	0.766	0.724	1	0.649	0.851	0.227	0.003	0.419
(5) ATTREG_TAX1	0.575	0.557	0.73	0.649	1	0.736	0.29	0.068	0.38
(6) ATTREG_TAX2	0.534	0.749	0.641	0.851	0.736	1	0.252	0.031	0.396
(7) ATTTECH_1	0.252	0.183	0.295	0.227	0.29	0.252	1	0.252	0.208
(8) ATTTECH_2	0.042	−0.014	0.023	0.003	0.068	0.031	0.252	1	0.086
(9) SN1	0.395	0.484	0.414	0.419	0.38	0.396	0.208	0.086	1

Table 6
Factor loadings for item correlation.

Variable	Test	*Re*-test	Communalities
ATTREG_RESTMOB1	0.943	0.929	0.668
ATTREG_RESTMOB2	0.917	0.895	0.757
ATTREG_RESTIND1	0.855	0.833	0.742
ATTREG_RESTIND2	0.846	0.824	0.83
ATTREG_TAX1	0.846	0.821	0.731
ATTREG_TAX2	0.817	0.788	0.83
ATTTECH_1	0.820	0.844	0.951
ATTTECH_2	0.756	0.732	0.995
SN1	0.932	0.929	0.965
SN2	0.477	Excluded	Excluded
PBC1	0.557	Excluded	Excluded
PBC2	0.576	Excluded	Excluded

Table 7
Model adequacy (KMO and Bartlett test).

Kaiser-Meyer-Olkin test for sampling adequacy	0.844
Bartlett's test of sphericity	
Chi-squared approx.	2089,889
gl	36
Sig.	0

Table 8
Factor loadings rotated component matrix.

	Factor 1: ATTREG	Factor 2: ATTTECH_1	Factor 3: ATTTECH_2	Factor 4: SN1
ATTREG_RESTMOB1	0.903	0.103	0.039	0.045
ATTREG_RESTMOB2	0.898	0.156	0.014	0.004
ATTREG_RESTIND1	0.825	0.062	0.210	0.051
ATTREG_RESTIND2	0.816	0.159	0.223	−0.032
ATTREG_TAX1	0.801	0.337	−0.045	−0.022
ATTREG_TAX2	0.665	0.276	0.221	−0.031
ATTTECH_1	0.294	0.932	0.088	0.049
ATTTECH_2	0.167	0.078	0.948	0.139
SN1	0.000	0.038	0.127	0.989

contribute to reducing CO2 emissions by encouraging people to drive less (Salon, 2015), increasing the usage of eco-friendly modes of transport (Tang et al., 2022), and incentivising the acquisition of electric vehicles through taxation (Byun et al., 2018; Moon et al., 2018; Breetz and Salon, 2018). But other studies conclude that the effect of these policies is limited in terms of CO_2 reduction (Dantas et al., 2021).

The effectiveness of these mobility policies is being questioned by researchers given (i) the cost of implementation (Sheldon and Dua, 2019), (ii) the fact that higher taxes on ICEVs do not significantly promote the purchase of PEVs (Ji et al., 2022) and thus drivers are not encouraged to stop buying ICEVs (Alberini and Bareit, 2019), and (iii) because these policies may not be well received by consumers since current ICEV users are not willing to pay more for the green transition (Bennett and Vijaygopal, 2018).

The situation is causing uncertainty in society and consequently significantly reducing ICEV sales (Jenn et al., 2020). This is a major issue, considering that policies are not effective in encouraging electric vehicle purchases (Alberini and Bareit, 2019). Some authors suggest that it is necessary to combine policies to incentivise both ICEVs and PEVs to attain a sustainable mobility ecosystem (Lam and Mercure, 2021).

The results obtained from this research, which aims to provide further insight into the topic, are in line with authors concluding that the policies developed do not meet the objectives set forth. The results confirm that citizens do not trust the green transition, since uncertainty toward the policies adopted strongly influences individual decision-making. This uncertainty could develop from a mistrust of policies, given their nature and the changing criteria of authorities. The policies adopted discourage individuals from buying new cars because, given

Table 9
Factorial hypothesis testing from the factorial model.

Independent variable	Dependent variable	Scale	Factor means		ANOVA	
			Decision not to be postponed	Decision to be postponed	F	Sig.
Factor1	I would prefer to buy a new vehicle or renew mine at a later date	Normalised factor values	−0.63	0.33	105,243	0.000
Factor2			−0.15	0.08	4842	0.028
Factor3			0.13	−0.07	3829	0.051
Factor4			−0.01	0.01	0,029	0.865

Table 10
Classification results from discriminant analysis.

I would prefer to buy a new vehicle or renew mine at a later date	Belonging to predicted groups		
	I would not postpone the decision	I would postpone the decision	Total
I would not postpone the decision	**105**	34	139
I would postpone the decision	46	**215**	261
I would not postpone the decision (%)	**75.5***	24.5	100
I would postpone the decision (%)	17.6	**82.4***	100

* 80,0 % of original grouped cases classified correctly

Table 11
Structure matrix.

Factors	Load	Coef^2 (%)
Factor 1: ATTREG	0.939	92 %
Factor 2: ATTTECH_1	0.201	4 %
Factor 3: ATTTECH_2	−0.179	3 %
Factor 4: SN1	0.016	0 %
Combined within-group correlations between discriminant variables and standardised canonical discriminant functions.		100 %

Note: Variables ordered by the absolute size of the correlation within the function.

their uncertainty, they prefer to postpone the purchase. The decision to postpone the purchase of a new vehicle, whether ICEV or PEV, is absolutely contrary to the target established by authorities to reduce CO2 emissions. Even if people are not convinced to buy a PEV vehicle, it is worth noting that new ICEVs pollute less than old ones, especially considering synthetic or bio-fuel options (Brynolf et al., 2018; Towoju and Ishola, 2020; Kalghatgi, 2019). Therefore, the purchase of a new ICEV, while not the greenest option, is cleaner than postponing the decision to renew an old ICEV.

Comparing this research results to the literature reviewed shows the policies adopted are focused on incentivising electric vehicles, which present higher prices (Adepetu and Keshav, 2017) and technological limitations (Hannan et al., 2017; Noel et al., 2019). This is unacceptable to a society unwilling to make the effort (Bennett and Vijaygopal, 2018). And at the same time, PEV inactivation is strongly enforced by stablishing policies against ICEVs, such that policies put people in a difficult position where neither green vehicles nor newer vehicles are trusted in the long-term. As a result, neither are purchased in the short-term. Therefore, the mobility policies implemented in Madrid are not effective, as they increase the average age of the fleet, thus contributing to an increase of CO_2 emissions.

5.1. Theoretical implications

This research confirms that the uncertainty of individuals has a significant influence on the consumers decision-making regarding the moment of purchase and the type of vehicle to choose. In line with the theoretical approach, the results show that mobility restrictions, taxation policies, and bans on the manufacture of ICEVs generate uncertainty for individuals, causing them to postpone the purchase decision due to doubts about which type of engine to choose at the moment. However, the present research does not show a significant correlation between the perception of available technology, social norms, and perceived behavioural control, because there is indeed a high level of uncertainty caused by the policies adopted by the authorities. Also, it is worth considering that the acceptance of technology, as a variable, matters less in decision-making, given the uncertainty surrounding both ICEVs and PEVs. This confirms the need to develop alternative models to include a wider range of variables that may influence peoples' uncertainty about the aforementioned policies, since self-confidence, attitudes, and perceptions are nullified by uncertainty. TAM is widely used to explain acceptance of the green transition through electric vehicle purchases, but the independent application of this theory may cause researchers to fail to provide insights on the understanding of consumers' purchase intentions with regard to PEVs and the green transition, in light of this uncertainty. Other uncertainty theories and approaches should be considered and incorporated into TAM (or others) to obtain variables and indicators that may help us understand the uncertainty about targeted mobility ecosystems.

5.2. Practical implications

The results of this research prompt political implications within a regulatory framework of guarantees and a transition period agreed by the different agents (Richter et al., 2022) in the transport sector with a clear road map. It is also important to take into consideration the automotive industry and the flow of its investments. In recent years, there has been ample investment in ICEVs in an effort to adapt them to the established regulations. These investments must be capitalized to provide sustainability to a strategic sector like the automotive industry, regardless of the fact that ICEVs offer eco-friendly solutions through synthetic and bio fuels, thus contributing to lower carbon emissions (Towoju and Ishola, 2020; Kalghatgi, 2019). It is worth noting that the automotive industry plays an important role in developed economies in terms of GDP contribution and, as such, the financial sustainability of this industry is critical to the global economy. This means the huge investment of car manufactures, both in ICEV and PEV technologies, should be balanced with benefits to guarantee sustainable technological development led by car manufacturers. Thus, interventions in the sector limiting ICEV production does not help an industry that has been stressed by a recent financial crisis, Covid-19, and is exposed to other externalities, such as climate conditions that weaken global economies and consequently leading companies (Saura et al., 2023a), such as automotive companies. Car manufacturers' contribution to technological development is critical, but may be compromised if revenues are cut due to government intervention.

Given the policy uncertainty demonstrated by citizens, governments should first address this eco-mobility context by understanding the socioeconomic context, and second, should consider fine-tuning the marketing side, since communication of the value proposition via the green transition could be improved. Governments should enhance their communication strategy and avoid limiting their message to citizens

through exclusively legislative means. Governments should also understand and measure citizens' concerns and perceptions about the green transition, capitalising on the power of digital technologies to optimise communication, thus improving the marketing to citizens through machine learning and data automation, etc., as relevant studies suggest (Saura et al., 2021; Saura et al., 2023b). This would enhance government communication and improve interaction with citizens regarding environmental issues, which is also possible through artificial intelligence technologies (Saura et al., 2022). This would allow governments to adapt their policies to societal and socioeconomic concerns and better communicate the value proposition to citizens in order to effectively convince them of the upside achievable through the green transition.

These results have another set of implications in terms of the consolidation of smart cities and the digitisation of the transport sector. The technology currently promoted by government policy is perceived with misgivings by citizens, causing a backlash in which current technological development cannot be maximised by transport agents and where poor acceptance of technology may prompt a change of technological perspective that could delay the consolidation of smart cities based on sustainability, digitisation, and social development. Sustainable and smart mobility is crucial to enable the digitisation of urban areas, since telework, among other factors, is already causing both a multidisciplinary shift and smart cities depend on technological advancement to empower the efficient development required for technology to grow organically. Furthermore, big urban areas currently present a challenging mobility context, given their demographics. Some studies conclude that populations are moving away from city centres due to (i) the high price of city living (Liu et al., 2023), (ii) the fact that household income stretches farther in rural areas (Zhou et al., 2023), (iii) digitisation facilitating economic growth in rural areas (Hao et al., 2023), and (iv) telework reducing commutes (Moeckel, 2017). Mobility policies may also have an effect on demographic flows in both ways, such that better mobility policies and infrastructure planning could contribute to a better understanding of demographic trends and a more efficient, orderly use of resources, such as public transport, thus contributing to a cleaner urban ecosystem adapted to demographic flows.

5.3. Limitations and future research lines

The limitations of this research were that the sample was obtained for the city of Madrid, which, though representative due to the size of its population and the variety of policies adopted by the government to achieve sustainable mobility models, Madrid has inherent features different to other European capitals that could influence individuals, such as lower purchasing power, which could influence eco-friendly attitudes; a strong services sector that contributes to local labour market; weather conditions affecting mobility patterns; urban infrastructures; ample public transport options; and a set of policies adopted by the local government. The authors thus propose extending this research to other regions to confirm whether this proven circumstance is a trend that justifies the reconsideration of government policies. We also propose the continued research of this topic to determine the degree of knowledge and confidence of individuals about the policies adopted, given the possibility that they are not sufficiently aware of the fundamentals of the policies adopted. In this regard, it would be useful to understand how individuals weigh the advantages and disadvantages of the policies implemented and define their importance in order that authorities can align the regulatory framework with the economic and social context, without prejudice to the aim of promoting sustainable mobility. Notwithstanding the foregoing, it is worth noting that there are other externalities that may influence a citizen's uncertainty, such as Covid-19, the current armed conflict in Western Europe, or the subsequent increase in worldwide CPI that is sharply affecting microeconomics and thus household purchasing power.

Finally, given the lack of studies on this topic, authors have built the conceptual model based on commonly used theories, such as TPB and TAM, due to their wide usage in vehicles purchase intention studies. However, given the results, authors encourage the adoption of uncertainty theories in future empirical contributions to incorporate other sets of indicators that may help delve deeper into variables influencing the uncertainty of citizens. In addition, future studies should incorporate moderating and mediating effects by sociodemographic variables into the analysis of uncertainty since there could be different segments showing certain homogeneous patterns toward both uncertainty and the green transition. This aims to allow governments a clearer picture of the socioeconomic context to better design mobility policies to achieve a smooth and sustainable green transition.

6. Conclusions

The results of this empirical research confirm that the policies adopted, without prejudice to the analysis of their detailed effectiveness, are not effective with regard to the objective of removing ICEVs from circulation by 2050 through taxation, mobility restrictions, and industry bans. The results confirm that citizens prefer to postpone their decision to purchase new vehicles, causing an effect contrary to the governments' target, which is the aging of the vehicle fleet or a slowdown in its renewal. In the case of Madrid, the decline is evident from the results obtained. The policies implemented by the authorities are not effective because citizens develop doubts, and thus uncertainty, about the future of the automotive industry. This uncertainty is exacerbated by the fact that a car is a long-duration good that requires a significant expense.

Governments must reconsider their policies to allow a smooth green transition by accepting the reality that citizens are not willing to spend money on it. Also, it is worth noting that focusing on incentivising electric vehicles (which have a higher purchase price and limited upsides compared to ICEVs) by demonising ICEVs, prompts additional long-term concerns among citizens. This leads citizens to postpone the decision to purchase new cars, and therefore older vehicles remain in circulation. This causes an effect contrary to government targets since CO_2 emissions are increased.

Governments should consider an ecosystem where both ICEVs and PEVs coexist considering the socioeconomic context, industry viability, and the environmental viability of the ICEVs supported by the upside of new technologies and by synthetic or biofuel options until green technology is globally accepted by society and represents a strong mobility alternative.

CRediT authorship contribution statement

Álvaro Hernández Tamurejo: Conceptualization; Formal analysis; Investigation; Methodology; Project administration; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing.

Álvaro Saiz Sepúlveda: Conceptualization; Formal analysis; Investigation; Methodology; Supervision; Validation; Visualization; Writing - original draft; Writing.

Francisco Javier S. Lacárcel: Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing - original draft; Writing - review & editing.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Data availability

Data will be made available on request.

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