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On ferry users' willingness to pay for improving environmental quality: A case study for the Canary Islands

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ABSTRACT

This study, using a contingent valuation framework, provides an initial assessment of the environmental benefits derived from the hypothetical adoption of a low-carbon fuel path, and onshore power supply, by the ferry sector in the Canary Islands in compliance with the FuelEU Maritime Initiative. To this end, a sample of 502 respondents was asked about their willingness to pay (WTP) for the increase in their well-being resulting from improvements in air quality and noise pollution. Special attention was paid to the problem of zero responses and the possible presence of self-selection due to protest responses. The results show that about 75% of the respondents expressed their WTP extra for a single ferry ticket between the most populated cities in the archipelago, with an estimated mean WTP of €13.12. This would represent a 33% increase in current ferry tickets. Aggregating the mean WTP across the population affected, has resulted in a conservative estimate of the total benefits derived from this policy of €65.9 million over a 30-year horizon time, and €94.2 million over a longer horizon time (100 years). In short, this study aims to fill an existing research gap while providing a quantitative basis for decision-making in densely populated port cities connected by ferry.

1. Introduction

In the European Union (EU), with more than 68,000 km of coastlines and about 2400 inhabited islands that have a population over 20.5 million people, ferry transportation is critical in order to ensure connectivity, economic prosperity and social cohesion (Gagatsi et al., 2016). This is particularly true for islands or archipelagos whose economies are usually extremely dependent on sea transport, as it is the case of the Canary Islands (Tovar et al., 2015). However, despite the crucial role ferries play in these areas, the other side of the coin is the pollution they cause due to the ageing of the ferry fleet and, specially, their heavy reliance on fossil fuels (Tovar and Tichavska, 2019). Indeed, although shipping is one of the least carbon-intensive modes of transportation, in the EU the maritime sector accounts for 13.5% of all EU CO_2 emissions from transport and 3–4% of total EU CO_2 emissions (EMSA, 2021). Hence, in a context of growing environmental awareness strengthened by the Paris Agreement on climate change (UNFCCC, 2015) and the 'Conference of the Parties' meetings, the International Maritime Organization (IMO) adopted in 2018 its own strategy focused on the gradual reduction of greenhouse emissions from ships until achieving the complete decarbonisation of the shipping sector (MEPC, 2018). In the same vain, the FuelEU Maritime Initiative, a legislative proposal of the 'Fit for 55' package, also aims to accelerate the decarbonisation of the maritime sector through the adoption of renewable and low-carbon fuels as well as zero-emission technologies at least in the short term (Christodoulou and Cullinane, 2022). Furthermore, the age of the ship is another critical factor in achieving the decarbonisation of the sector since older vessels should be replaced by new ones that are more efficient. Currently two thirds of the EU's ferry fleet are over 20 years old, being the average age of the fleet 35 years old (Siemens Energy, 2022). When in ports, vessels have their diesel auxiliary engines running to generate electrical power to meet the power demand of all on-board facilities, thus producing emissions and noise. This is especially critical considering that ports usually are located close to densely populated areas. Air quality and noise for European Ports have been consistently presented in the Top 10 Environmental priorities of the port sector over the years. The last report available (ESPO, 2022) highlights that air quality ranked 2nd, moving down one spot after a decade in favour of climate change, whereas noise keeps its position ranked 4th.

The contribution of auxiliary engines in ports to the total EU shipping

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CO_2 emissions is about 7% and, when it comes to Ro-pax ship (passenger ferries) these emissions represents a 12,76% (Transport & Environment, 2019). It should be noted that CO_2 emissions, although key for their effect in the global warming, produce the same effect no matter where they are emitted, unlike others pollutants which commonly relate to local detriments in air quality and whose reduction/elimination is desirable for urban ports (Tichavska and Tovar, 2015a). Therefore, Onshore Power Supply (OPS) is a promising solution to reduce all exhaust emissions at berth to zero while reducing noise[1] levels, provided that electricity comes from clean and renewable sources (EMSA, 2021), but even when this is not the case, OPS comes with environmental advantages as it lets us eliminate the local effects that emissions have, in terms of external costs, on the cities and regions in the direct vicinity of a port (Spengler and Tovar, 2021, 2022).

However, to power vessels at berth requires both on shore and on board additional costly infrastructures that could act as barrier to its implementation unless appropriate subsidy policies are implemented to shorten the payback period of the investment (Yin et al., 2020). To this vein, a major initiative to ease the implementation of OPS in Spain was the EUfunded research project OPS Master Plan for Spanish Ports. The project, followed the National Action Framework designed to fulfil commitments in relation to the achievement of port decarbonisation. The emissions released by vessels while hoteling in Spanish ports, calculated as part of the project (Tovar, 2021), allowed to investigate not only the external costs derived from those emissions (Spengler and Tovar, 2021, 2022) but also whether ports could reduce these external costs while keeping their level of service (Tovar and Wall, 2019, 2021).[2]

While full decarbonisation of the ship sector by 2050 will require the gradual deployment of zero-emission vessels from 2025 until achieving climate neutrality as stipulated by the FuelEU Maritime Initiative, meanwhile, in the medium term, a transitional and less costly solution is the use of low-carbon fossil fuels (mainly LNG, LPG and methanol) that, when compared to conventional fuels, allow to achieve substantial CO_2 reductions (Christodoulou and Cullinane, 2022).

With these issues in mind, this paper aims to shed light on the economic evaluation of the environmental benefits derived from the reduction of emissions (and noise) through the deployment of OPS and the use of low-carbon fossil fuels by ferries in the two major ports of the Canary Islands: Las Palmas de Gran Canaria (LPGC, onwards) and Santa Cruz de Tenerife (SCTF, onwards). Considering the non-market nature of these benefits, economists have traditionally approached environmental quality valuation through the use of stated-preference methods, among which the Contingent Valuation Method (CVM) stands out. The CVM is a survey-based approach used to assign a value on public goods that are not usually traded in the market, and thus their value is unknown (Mitchell and Carson, 1989). Therefore, through the use of a survey instrument, a hypothetical valuation framework is constructed in which respondents are asked to state their willingness to pay (WTP) for the provision of a public good (in this particular case, an environmental improvement that positively contributes to their wellbeing) or conversely the amount of monetary compensation they would require (willingness-to-accept or WTA) for the loss of this good and the resulting negative impact on their wellbeing. Whether WTP or WTA is the appropriate measure depends on how property rights over the environment are defined (Carson, 2000).

Specifically, in the case study presented in this paper, a sample of 502 residents in the port cities of LPGC and SCTF were asked about their WTP for the increase in their wellbeing resulting from an improvement in air quality and noise pollution. This improvement, as previously mentioned, would be the result of the deployment of OPS and the use of low-carbon fuels by ferries.

To the best of our knowledge, no previous study has attempted to estimate citizens' WTP for a reduction in ferries emissions in a contingent valuation framework. Thus, this study aims to fill an existing research gap while providing a quantitative basis for decision-making in densely populated port cities connected by ferry. However, in order to provide accurate WTP estimates, the issue of zero and protest responses in CVM studies should be addressed appropriately. To this end, on one hand, following Kriström (1997) a Spike model was applied since more than 50% of respondents stated a zero WTP response. And, on the other hand, a bivariate probit model with selection was estimated to take into account the possible presence of self-selection originated by the presence of protest responses as in Saz-Salazar et al. (2016).

The remainder of this manuscript is organized as follows. Section 2 provides a review of the existing literature on waterborne transport and WTP for emissions reduction. Section 3 presents the case study, the survey design and data collection. Section 4 presents the theoretical framework while outlining the procedure followed to deal with the problem of zero and protest responses. Section 5 presents de results. Finally, Section 6 presents the discussion and conclusions.

2. Literature review

A review of the literature on waterborne transport and related emissions shows that there has been a particular focus not only on technological aspects such as fuel efficiency, emission reductions, use of alternative fuels and electrification (see, among others, Ben Brahim et al., 2019; Isikli et al., 2020; Yan et al., 2021; Sæther and Moe, 2021; Laasma et al., 2022), but also on economic/regulatory issues to support policy abatement measures (Tichavska and Tovar, 2017; Tichavska et al., 2019). However, to the authors' knowledge, little attention has been placed on estimating public WTP for the reduction of ship emissions and other environmental impacts. While technical aspects are of great importance for achieving the decarbonisation of the shipping industry, not less important for decision-making is to know public acceptance, in terms of their WTP, of more environmentally friendly technologies since the higher costs related to their deployment will, sooner or later, lead to an increase in ferry tickets.

The first study aimed at assessing the environmental impact of ferry traffic was conducted by Kriström (1997) in Sweden. Considering that at that time climate policy was less prominent in the public debate than it is today, not surprisingly, the study focused on the economic evaluation of the damage caused by waves to private properties as a consequence of large-passenger-ferry traffic in the Stockholm archipelago. Property owners in the vicinity were asked about their WTP for moving the ferries from their current fairways in order to avoid the damage. A Spike model was applied due to the fact that about two thirds of the respondents refused to pay for this policy. The mean WTP estimated was SEK 1500 or about €128 (Exchange rate: SEK 11.72 per €).

More recently, Bigerna et al. (2019), also in a contingent valuation framework, estimated tourists' WTP for the introduction of electric boats in a protected area in Italy (Trasimeno Lake) in order to reduce CO_2 emissions. A total of 263 useable responses were received and, using a payment card, they found that tourists were willing to pay an extra of €1.07 to €1.27 per single boat ticket, being the current ticket €6.50. In exploring WTP determinants, the variables that had a stronger effect on respondents' WTP were sex, age and the length of the stay. To replace the current fleet of diesel boats, two electrification alternatives were considered: hybrid-electric boats and all-electric boats. However, they

[1] It should be noted that when it comes to Ro-Ro vessels, the only sources of noise that can be avoided when the vessel is taking power from shore are the exhaust from auxiliary engines and ventilation associated with the engine room because the ventilation associated with the cargo/passenger deck has to work at all times (Santander et al., 2018).

[2] The project had a budget of 6 million Euros and is co-financed with 1.5 million Euros by the Connecting Europe Facility (CEF) program for the construction of the Trans-European Transport Networks (TEN-T) and includes the realization of a series of regulatory, technical and eco-environmental studies to identify existing barriers and propose appropriate solutions for the supply of electric power to ships at berth in Spanish ports.

found that in neither case would the annual users' WTP be enough to cover the total cost of the renewal of the fleet.

Another study in this area was carried out by Wahnschafft and Wolter (2023) in Berlin, where sightseeing by boat is a major attraction for tourists, as the city has about 200 km of navigable waterways. A vast majority of tourist ships in Berlin are powered by diesel engines, thus contributing significantly to local air pollution. Using an open-ended question, passengers travelling on board solar-battery-electric boats were asked "how much they were willing to pay more for this given trip on an electric ship if compared with a trip on a diesel-powered ship". However, in our opinion, the question used to elicit WTP could had been problematic since passengers on board these electric boats have already paid a slightly higher ticket price than their counterparts on diesel-powered ships. So respondents could have taken this information as a clue about the value of the environmental improvement resulting from the use of these electric boats, thus affecting their responses and biasing the results. When analysing the data, they addressed the use of heterogeneity among respondents using cluster analysis and found that more environmentally aware respondents had a higher WTP (€7.14) than the rest of the sample (€5.91). In addition, they did not explore the determinants of the stated WTP through the estimation of a WTP function that, given the censored nature of the dependent variable, would have required the use of a Tobit model.

Finally, a recent study by Nyári et al. (2024), which surveyed about 2000 ferry passengers from different nationalities in the Northern European region, found that 41% of respondents would be willing to pay to voluntarily offset their CO_2 emissions and 78% of them would be willing to pay a higher ferry fare if the vessel used low-carbon fuel. Although this study is undoubtedly interesting and has some similarities to ours, it can in no way be classified as a contingent valuation study, as the authors themselves admit. Indeed, there are some limitations of this study that should be addressed in order to provide valuable information for decision making. To name a few, as the data was collected through an online questionnaire there is the risk of incurring in a non-response bias which can lead to biased estimates of WTP.[3] Another source of selection bias relates to the treatment of protest responses. Nothing is said in this case study about how they distinguished between true zero responses and protest zero responses and the treatment of the latter, as censoring protest responses can lead to a sample selection bias (Strazzera et al., 2003).

3. Case study and survey design

The Canary Islands is a Spanish archipelago made up of eight islands and several islets. It is located in the Atlantic Ocean at a distance of about 1000 km south west from the Iberian Peninsula while its closest point to mainland Africa is at a distance of only 100 km from the Western Sahara territories (see Fig. 1). Given it remoteness, this archipelago is one of the nine outermost regions of the European Union which have a special status in order to better address their specific needs. In 2022 its population amounted to 2,261,654 inhabitants, being the most populated cities LPGC (378,797 inhabitants) and SCTF (208,688 inhabitants). These cities have, respectively, a density of population of 3767 and 1386 inhabitants per square kilometre.

The ports of these two cities are the busiest ones in this archipelago. In particular, in 2022 the total number of ferry passengers[4] in Las Palmas Port amounted to 1,488,004 while in Santa Cruz de Tenerife port the same figure was even higher (1,727,077).[5] These figures show that the traffic of passengers has fully recovered to its pre-pandemic level (see Table 1).

Although both ports have experienced expansion projects that have led to the migration of several terminals towards peripheral locations (Tichavska and Tovar 2015b) and the urban renewal of their waterfronts, as it is the case with other major port cities around the world (Saz-Salazar et al., 2014), it is no less true that in these cities port facilities are still very close to some of their most populated districts (see the area demarcated by the red lines in the sketch of both cities in Fig. 1 or, for more detail, Fig. 2 below). As a result, air pollution and noise remain among the most important environmental externalities affecting the well-being of nearby residents. It is therefore understandable that people living near port facilities could often see the port as a threat rather than a source of wealth (Saz-Salazar and García-Menéndez, 2016).

In a contingent valuation framework, the use of focus groups and pilot surveys is key to test the comprehension of the information provided in the questionnaire, to identify the appropriate payment vehicle, to develop information on the bids amounts used to elicit WTP, and to identify the population of beneficiaries, i.e. those who hold economic values regarding a project (Bateman et al., 2006; Boyle, 2017). In this particular case, the discussion group, led by a skilled moderator, was conducted twice with about 25 participants from all the neighbourhoods of each city in order to assess people's awareness and understanding of the causes and nature of potential harm arising from port activity. Following Saz-Salazar and García-Menéndez (2016), potential participants underwent a screening process to assemble a group that approximated the demographic composition of the community in terms of age, gender, education, and income. For the pilot survey a group of 50 respondents were surveyed, i.e. 10% of the final sample as it is customary. The pilot survey, and the focus groups, revealed that spending more effort on interviewing in the districts of both cities that were farthest away from the port facilities was a waste of time and money. Indeed, people living in these districts stated that they were not affected in their well-being by the negative externalities resulting from port activity. For this reason, the final survey instrument was administered in spring 2023 by a market research company in the districts that are closer to the port facilities since these individuals are the main beneficiaries of the proposed policy: "Isleta-Puerto-Guanarteme", "Centro" and "Vegueta, Cono Sur y Tafira" in the case of LPGC, and "Centro-Ifara" and "Salud-La Salle" in the case of SCTF (see Fig. 2).

In addition, interviewers were instructed to emphasise both the academic nature of the study and the importance of the responses in informing policy. In other words, the aim was to convey the idea that this was a rigorous research project and that respondents' answers would have consequences (Poe and Vossler, 2011). In order to ensure the representativeness of the sample, quotas were set according to the demographic structure of the population of the above-mentioned districts, so that the main sample parameters (age, gender, etc.) closely resembled those of the population as a whole. A representative stratified random sample of 500 face-to-face interviews was obtained. The margin of error was 4.38% (at the 95% confidence level).

As proposed by Bateman et al. (2002), the survey instrument comprised four sections. The first covered the respondents' profile. The second aimed at finding out the respondents' environmental awareness

[3] Certainly, when using online surveys, individuals can choose whether or not to participate in the survey, i.e. there may be self-selection by the individuals since the researcher does not control the selection process (Heckman, 1979). In this case, if respondents differ from non-respondents on the variables of interest, it is not possible to extrapolate value estimates and make inferences from the sample to the population (Bonnichsen and Olsen, 2016). This might have occurred in this study because, as the authors themselves acknowledge, more than half of the respondents who opened the online survey did not complete it, and those who completed it admitted that the survey was challenging to complete.

[4] The islands are connected by Ro-Ro ferry and by fast Ro-Pax ferry.

[5] It should be noted that the higher number of regular line passengers in Tenerife port than in Las Palmas port is explained because in Gran Canaria there are two alternative ports (Las Palmas and Agaete ports) for travelling between both island whereas in Tenerife it is not the case.

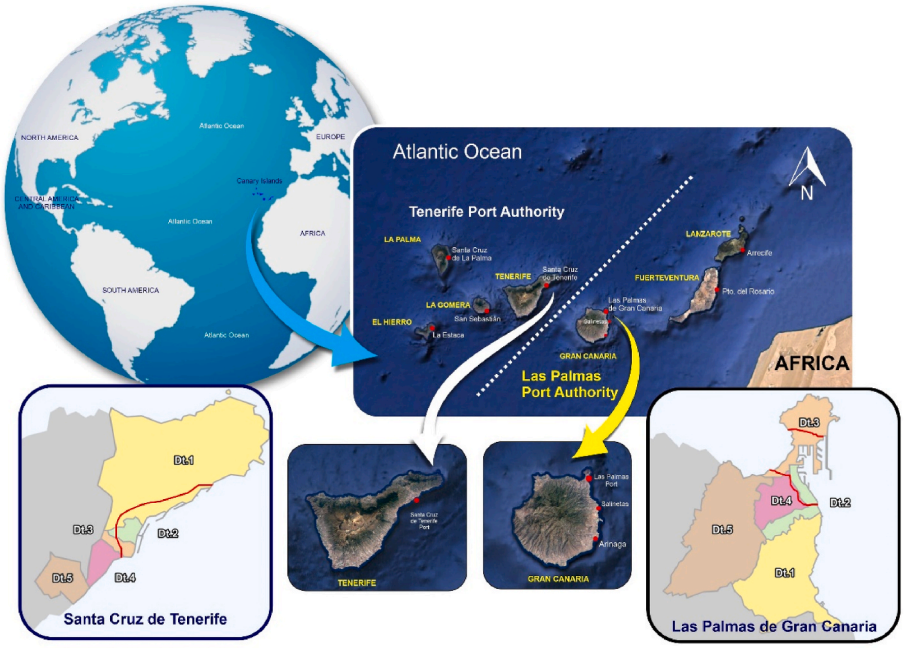

Fig. 1. Canary arquipelago and main islands location. Main cities districts.
Note: The survey area is the one demarcated by the red line(s) in the sketch of each cities.

Table 1
Number of ferry passengers.

	2018	2019	2020	2021	2022
Las Palmas Port	1,209,164	1,278,637	925,408	1,123,866	1,488,004
S.C. de Tenerife Port	1,548,210	1,664,843	972,451	1,232,398	1,727,077
Total					3,215,081

Source: Instituto Canario de Estadística (ISTAC).

mainly using the New Ecological Paradigm scale (Dunlap et al., 2000). In parallel, in this same section, other questions were included to determine the main environmental externalities from ferry traffic, such as air pollution and noise, affecting nearby residents. Respondent were further queried regarding the health implications arising from their exposure to ambient air pollution and noise. The third section described the proposed policy aimed at improving air quality and noise pollution through the gradual deployment of OPS and the use of low-carbon fuels by ferries. As emphasized by Hoyos and Mariel (2010), this step is crucial as it serves to establish the credibility of the proposed trade-off between respondents' WTP and the suggested change in environmental quality.

The elicitation method used was the discrete choice question format (Bishop and Heberlein, 1979) since it is incentive compatible and it mimics price taking in market behaviour (Arrow et al., 1993; Loomis et al., 1997). Nevertheless, respondents were first asked another binary question to find out whether or not they were in the market for the public good. This made it possible to apply a Spike model (Kriström,

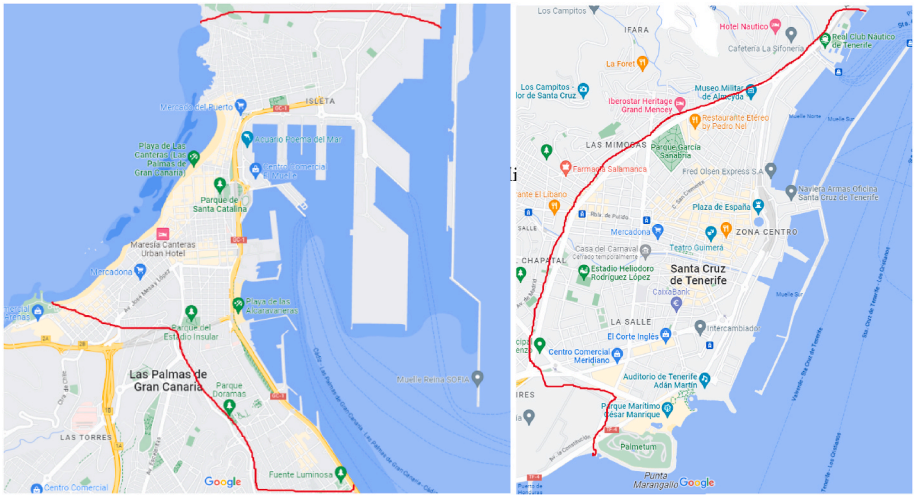

Fig. 2. LPGC and SCTF survey areas
Note: The survey area is the one demarcated by the red line(s) in the sketch of each cities.
The survey area is the one demarcated by the red line(s) in the sketch of each cities. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

1997) in order to explain the two decisions made by the respondent: (i) whether or not to participate in the market, and (ii) their response to the offered payment once they have decided to enter the market.

More specifically, the wording of the WTP scenario read to respondents was:

> "In order to reduce pollution from ships, the European Union has recently adopted a novel initiative -known as FuelEU Maritime Initiative- which aims (1) to promote the use of low-carbon fuels within the shipping sector and (2) to connect ships to the electricity grid during port arrival, berthing, and departure. The implementation of these novel technologies will result in a decrease in noise levels, emissions of greenhouse gases, and suspended particulate, all of which have adverse impacts on the environment and human health. However, this entails substantial financial investments until to achieve the full decarbonisation of the sector by 2050, thereby necessitating a permanent increase in ferry tickets in the Canary Islands for current and future users to provide financial support for this proposal. Given the multitude of environmental and health benefits associated with the aforementioned proposal, would you willing to pay higher ferry tickets to support it?"

Prior to responding to this inquiry, participants were provided with substitute and budget constraint reminders in accordance with the guidelines suggested by the NOAA Panel on Contingent Valuation (Arrow et al., 1993):

> "*Before finalizing your decision regarding this proposal, we kindly request that you consider the fact that if it is approved, this environmental policy will lead to a reduction in the monetary resources you would have for supporting other environmental policies, as well as for purchasing everyday consumer goods.*"

Respondents who responded positively to the initial question were subsequently presented with a payment proposal in the second question:

> "*As a current or future ferry user, would you be willing to pay a €A surcharge on your one-way ferry ticket? This surcharge, as previously said, would compensate for your emissions of gases and particulate matter that affect human health and the environment. It would also contribute to the reduction of noise generated by ferries*."

Following Sonnenschein and Smedby (2019), respondents who did not use the ferry service in the past year were also asked to respond to the payment proposal. In particular, they received the following conditional message:

> "We are aware that you previously answered that you did not use the ferry service in the past year. However, we ask you to imagine that you are in a situation where you, for one reason or another, have to use the ferry in the future".

For this second discrete choice question, based on the open-ended responses from the pilot survey and following the procedures of Boyle et al. (1998) and Cooper (1993), an optimal and balanced survey design was developed in order to determine the bid amounts as well as the sample sizes corresponding to each bid amount. Thus, five different bids were considered (€2, €4, €6, €8 and €12) and each respondent was randomly assigned to a single bid. In this respect, Clinch and Murphy (2001) argue that a larger number of bid levels would allow greater precision in estimating the bid curve, albeit at the expense of smaller subsamples, resulting in increased sampling error. In any case, the challenge is to find the right balance between exploring a sufficiently wide range of cost figures and keeping these cost figures within a credible range (Schläpfer, 2008).

The use of a non-voluntary payment mechanism, specifically a ferry ticket, was intended to mitigate the occurrence of free-rider responses commonly observed in voluntary payment schemes. On the other hand, individuals who opted not to participate were asked a follow-up question to elucidate the underlying factors influencing their decision. This enabled us to discern between genuine zero responses, where no payment was desired, and protest responses, which reflected a deliberate objection or dissent.

The survey concluded with a series of validation questions, aimed at facilitating the interpretation and validation of the WTP estimates from a theoretical perspective. These questions encompassed various socio-economic, attitudinal and behavioural indicators. Socio-economic indicators included factors such as membership in neighbourhood and environmental groups, aspects pertaining to respondents' social status, such as family size, gender, age, family income after tax, and educational attainment.

4. Theoretical framework

4.1. The discrete choice model

The dichotomous choice question model has gained widespread popularity as the preferred approach for determining individuals' WTP for non-market goods. So, let us consider an individual facing a decision regarding the acceptance or rejection of a project that offers an improvement in air quality and noise levels in exchange for a specified amount of money, denoted as A. The probability that an individual's WTP does not exceed the amount A can be expressed as $P(WTP \leq A) = F(A)$, where $F(A)$ is a continuous, non-decreasing function with values ranging from 0 to 1, or in other words: $P(Accept) = 1 - F(A)$.

Now, for each individual i, it is possible to define an indicator variable IA_i which shows whether this individual is willing to pay the proposed payment (A_i):

$$IA_i = \begin{cases} 1 \text{ if } WTP > A_i \\ 0 \text{ if } WTP \leq A_i \end{cases} \quad (1)$$

Once the indicator function is introduced, the probability that an individual i is willing to pay the proposed amount can be calculated as $P(i \text{ accepts } A_i) = P(IA_i = 1) = 1 - F(A_i)$. One commonly used distributional assumption for $F(A)$ is the logistic function:

$$F(A) = \frac{1}{1 + e^{\alpha + \beta A}} \quad (2)$$

This leads to the well-known Logit model proposed by Hanemann (1984). However, a drawback of this model is the assumption that all the individuals are in the market for the public good, i.e. all of them have a positive WTP. For that reason, it precludes the existence of individuals who do not perceive any positive contribution of the good to their utility function and, accordingly, they ignore it even when the price is set at zero (Haab and McConnell, 1997).

The Spike model (Kriström, 1997) is particularly well-suited for situations where a significant portion of the population has a zero WTP. Consequently, it is assumed that some individuals are not in the market for the public good in question, i.e. the proposed improvement in the environmental quality does not increase their utility and therefore decline to participate in the hypothetical market created. Hence it is assumed that the distribution function of WTP has the following form:

$$(A) = \begin{cases} 0 \text{ if } A < 0 \\ \dfrac{1}{1 + e^{\alpha}} \quad \text{if } A = 0 \\ \dfrac{1}{1 + e^{\alpha + \beta A}} \text{ if } A > 0 \end{cases} \quad (3)$$

In its most basic form, this model splits the sample into respondents with zero WTP and those with positive WTP. So two valuation questions are necessary: the first asks whether the respondent is inclined to contribute to the project, while the second suggests a price A. Thus, for each individual i, two indicator variables can be observed: IO_i and IA_i. The first indicator variable, IO_i, determines whether the individual is in the market for the public good that is being valued. This indicator is defined

as follows:

$$IO_i = \begin{cases} 1 \text{ if } WTP_i > 0 \\ 0 \text{ if } WTP_i \leq 0 \end{cases} \quad (4)$$

Therefore, only for those individuals that wish to enter into the market of this public good ($IOi=1$), a price A is suggested, giving:

$$IA_i = \begin{cases} WTP_i > A_i \text{ and } IO_i = 1 \\ 0 \quad \text{otherwise} \end{cases} \quad (5)$$

Under the assumption that WTP is positive, Hanemann (1984) demonstrated that for the Logit and Probit models the expected value of WTP can be derived using the following expression:

$$E(WTP) = -\frac{\alpha}{\beta} \quad (6)$$

While for the Spike model (Kriström, 1997), it is given by:

$$E(WTP) = -\frac{\log(1+e^{\alpha})}{\beta} \quad (7)$$

4.2. A sample selection model: addressing the problem of protest responses

Despite its popularity over other non-market valuation techniques, CVM is not without its flaws. For example, it is usually the case that for many policy issues CVM surveys often yield a substantial number of zero responses (Johnson and Whitehead, 2000). While true zero responses are the result of some mitigating circumstance (e.g. the respondent cannot afford to pay), protest zero responses are an objection to some aspects of the contingent valuation scenario (e.g. the lack of enough information or a rejection of the payment vehicle). On the grounds that they do not represent true economic values, it is common practice in CVM studies to remove protest responses from the sample (see, among others, Garcia et al., 2009; Petrolia et al., 2010; Ramajo-Hernández and Saz-Salazar, 2012; Saz-Salazar et al., 2016; O'Connor et al., 2020), as otherwise they could lead to an underestimation of WTP by assigning a zero value to some respondents who are likely to have a positive WTP, which they do not show since they reject the hypothetical market created. However, censoring protest responses may lead to a selection bias if the characteristics of protesters differ significantly from those of other respondents whose bids are accepted as legitimate (Jorgensen et al., 1999). As it is obvious, how protest responses are treated largely affects the size of the mean WTP estimates (Lindsey, 1994; Liu and Chuang, 2022).

To test for the presence of sample selection bias, following Calia and Strazzera (2001) and Strazzera et al. (2003), we apply a bivariate probit model with sample selection (Van de Ven and Van Pragg, 1981). So the responses provided by the individuals can be simultaneously modelled using two equations: the first one being the selection equation and the second one being the participation equation. Consequently, we introduce the binary variable IO_i for the participation equation and the binary variable IS_i for the selection equation. These variables are dependent on two corresponding latent variables, IO_i^* and IS_i^*. The equation for the latent variable IO_i^* can be expressed as follows:

$$IO_I^* = \alpha + \beta A_i + \gamma_1 X_{1,i} + \gamma_2 X_{2,i} + \cdots + \gamma_M X_{M,i} + \varepsilon_{IO,i} \quad (8)$$

Where $X_{IO} = (X_1, X_2, \cdots X_M)$ is a vector of variables that explain the decision to participate in the market while A is the payment offered to the respondent. Now, with the inclusion of this new indicator variable (IO_i^*), the decision rule for each individual i concerning its participation in the market can be described as follows:

$$IO_i = \begin{cases} 1 \text{ if } IO_i^* > 0 \\ 0 \text{ if } IO_i^* \leq 0 \end{cases} \quad (9)$$

Analogously, it could be assumed that there is a latent variable IS_i^* behind the decision whether to protest, which is described as follows:

$$IS_I^* = \delta_0 + \delta_1 V_{1,i} + \delta_2 V_{2,i} + \cdots + \delta_M V_{M,i} + \varepsilon_{IS,i} \quad (10)$$

Where $V_{IS} = (V_1, V_2, \cdots V_M)$ is a vector of variables that explain the decision of whether to protest, while the decision rule is:

$$IS_i = \begin{cases} 1 \text{ if } IS_i^* > 0 \\ 0 \text{ if } IS_i^* \leq 0 \end{cases} \quad (11)$$

The disturbance terms are assumed to have a bivariate normal distribution with a correlation parameter ρ, that is $(\varepsilon_{IO}, \varepsilon_{IS}) \sim BVN(0,0,1,1,\rho)$. If the parameter ρ is found to be significantly different from zero (whether positive or negative), it indicates that there is a correlation between unobserved factors influencing both outcomes; otherwise, when this parameter is not found to be significantly distinct from zero, it implies that both outcomes are independent, suggesting that concerns about potential selection bias can be relaxed and therefore censoring protest responses does not lead to a selection bias (Bonnichsen and Olsen, 2016). Thus, unbiased estimates can be obtained by fitting two separate equations for IO_i^* and IS_i^*.

5. Results

5.1. WTP estimates

Just over half of the respondents declined to pay an increase in ferry tickets in order to reduce emissions and noise from ships, a proportion that is lower than the 77% of zero responses obtained by Kriström (1997) in the Finnish ferry study. While some zero bids may genuinely reflect individual's preferences, it is important to acknowledge that others might be driven by protest behaviour. In particular, in this case study protest responses accounted for 37.4% of the sample, a rate which falls within the normal range in CVM studies: from 20% to 40% according to Carson (2001). As shown in Table 2, the main reasons behind a protest response were "I already pay enough taxes" (20.7%; 104 respondents) and "I have the right to enjoy a clean environment without having to pay for it" (10.9%; 55 respondents), while the main factors behind genuine zero responses were "I cannot afford to pay anything since I have no money" (7.8%; 39 respondents) and "I do not consider emissions and noise from ferries a problem" (6.6%; 33 respondents).

The coefficients of the different models used in order to derive the mean WTP estimates are shown in Table 3. In estimating these models, protest responses were removed since, as it will be shown below, there is no selection bias, i.e. the group of protesters is not significantly different from the rest of the sample. After excluding protest responses, the percentage of those willing to pay increased from 46 to 74%. As it can be seen, WTP estimates clearly differ depending on the model chosen and

Table 2
Reasons behind a "No" WTP response.

Reason	N (%)
Genuine zero responses	
I cannot afford to pay anything since I have no money	39 (7.8)
I do not consider emissions and noise from ferries a problem	33 (6.6)
I would rather spend my money on other things	11 (2.2)
Protest zero responses	
I do not have enough information to answer your question	29 (5.8)
I already pay enough taxes	104 (20.7)
I have the right to enjoy a clean environment without having to pay for it	55 (10.9)
Total rejection (true zero + protest responses)	271 (54.0)

Note: Percentages are calculated over the full sample (502 interviews).

Table 3
Estimated models and mean WTP (excluding protest responses).

	Las Palmas de G.C.		Santa Cruz de Tenerife		All the sample	
	Logit	Spike	Logit	Spike	Logit	Spike
Constant	2.8296[a] (5.56)	2.6368[a] (8.72)	2.9686[a] (6.23)	0.2120[a] (6.59)	−0.2592[a] (−6.40)	2.0276[a] (11.69)
Bid (A)	−0.1681[a] (−2,70)	0.1430[a] (4.45)	−0.4074[a] (−5.86)	1.6026[a] (7.27)	2.7503[a] (8.52)	0.1639[a] (7.94)
Mean WTP (€)	16.83	18.92	7.29	8.42	10.61	13.12
Mean WTP 95% C.I. (€)	12.22–41.19	12.64–25.20	6.25–8.59	6.46–10.38	9.34–12.66	10.67–15.57
Log likelihood	−68.6431	−86.2833	−72.1399	−120.2197	−158.1004	−221.4197
Pseudo R2	0.0517		0.2613		0.182	
LR chi2 (1)	7.49	19.78	51.05	43.40	46.49	63.11
Prob. > chi2	0.0062	0.0000	0.0000	0.0000	0.0000	0.0000
N	168	168	146	146	314	314

Note: Z-statistic in parentheses. For the Spike model, the Wald chi2(1) is shown instead of the LR chi2(1).
[a] 1% significance level.

on which city the interview was carried out (Bengochea-Morancho et al., 2005). Thus, for the entire sample, the Spike[6] model yields higher WTP estimates (€13.2) than the Logit model (€10.61). Regarding the spatial analysis of WTP, in general for the different models considered the mean WTP estimates are higher for LPGC than for SCTF. For example, in the case of the Logit model, the mean WTP estimate for the residents in LPGC is more than twice as high (€16.83) than in SCTF (€7.29).

A key concern related to the validity of these results revolves around the plausibility of the mean WTP estimates obtained. So these estimates are compared with the average ferry ticket for a resident[7] in the Canary Islands (€39) in order to find out their relative size. Thus, the hypothetical increase in ferry tickets resulting from this policy would be in between 27 and 33% depending on the model chosen for calculating the WTP estimates, with the highest increase for respondents residing in LPGC due to their higher WTP (see Table 4).

5.2. Selection model and WTP determinants

To verify the theoretical validity of the results obtained, WTP determinants must be analysed. This implies the estimation of an equation predicting respondents' WTP with a reasonable explanatory power and coefficients with the expected signs, thus providing evidence that the survey has successfully captured the intended construct (Carson, 2000). The explanatory variables used for this purpose and their main descriptive statistics are shown in Table 5. They have been grouped into five categories: (i) economic factors, (ii) respondents' characteristics, (iii) environmental awareness, (iv) environmental quality, and (v) variables related to the use of the ferry service.

Table 4
Hypothetical increase in ferry tickets.

	Las Palmas de G.C.		Santa Cruz de Tenerife		All the sample	
	Logit	Spike	Logit	Spike	Logit	Spike
Mean WTP (€)	16.83	18.92	7.29	8.42	10.61	13.12
Hypothetical increase in ferry fares (%)	43.3	48.5	18.7	21.6	27.2	33.6

Note: the average price (for a resident) of a return ferry ticket between both port cities is around 39€.

Results are shown in Table 6, and the estimated models only include variables that are statistically significant at standard confidence levels. To check for the possible presence of a sample selection bias, a maximum-likelihood probit model with sample selection was first fitted (columns 1 and 2), later WTP determinants were analysed using a probit regression model (column 3).

The selection equation shows that the probability of protesting is positively correlated with respondent's age (AGE), as in Liu and Chuang (2022), and the fact of residing in Santa Cruz de Tenerife (RESIDING_SCT). Conversely, more environmentally conscious respondents are less prone to protest as it is indicated by the negative coefficients of the variables EARTH_CAN_SUPP and JOB_LOSS, i.e. respondents that agree with the statements "We are approaching to the limit of number of people that the Earth can support" and "Environmental protection measures should be carried out, even if this reduces the number of jobs in the economy" have a lower probability of protesting. In the same vein, respondents that voluntarily participate in activities aimed at preserving the environment (VOLUNTEER_ENV) have also a lower probability of protesting.

In the participation equation (column 2 in Table 6), results show that, as expected, the higher the respondent's income (FAM_ICOME), the greater the probability of entering into the market as in Saz-Salazar et al. (2016) and Alguacil-Duarte et al. (2020). Highly environmentally conscious respondents (HIGH_ENV_CONS) and respondents with Spanish nationality (SPANISH) are also more willing to participate in the market. On the other hand, those respondents that stated that LPGC (or SCTF) is a quiet city since in a normal day noise levels are low (NOISE_CONDITIONS), are less willing to enter into the market as they do not consider it necessary to implement the proposed policy aimed at improving environmental quality. Also, people who are engaged in housework (HOMEMAKER) are less likely to enter into the market since time spent on housework usually is unpaid, which limits their purchasing power. Finally, the correlation between the disturbance terms in the selection and participation equations (parameter ρ) is not statistically different from zero, so it seems that the decisions on whether to protest and on whether to enter into the hypothetical market are not correlated. Accordingly, protest responses can be removed from the sample since doing so does not lead to any sample selection bias and WTP estimates will not be biased. Therefore, in this case it will be possible to extrapolate WTP estimates and make valid inferences directly from the sample to the target population at it will be shown below (Bonnichsen and Olsen, 2016).

WTP determinants are shown in column 3, Table 6. As theoretically expected, the higher the bid offered to the respondent, the lower the probability of accepting it, i.e. the proportion of "yes" responses to increasing bids should be monotonically decreasing. Also, as expected, WTP decreases with family size. This is because having more family

[6] In the Spike model, the mean WTP is obtained following the expression shown in equation number 7. The coefficient of the bid variable (beta) should be positive, i.e. the marginal utility of money must be positive in order for the mean to exist, as noted by Kriström (1997).

[7] Given that the Canary Islands are one of the outermost regions of the European Union and have a fragmented territory, in order to improve internal cohesion, trips between islands are subsidised. The amount of the subsidy is 75% of the market price of a ferry ticket.

Table 5
Explanatory variables and summary statistics.

Variable	Description	Mean (SD)	% of 1s	Max	Min
Economic factors					
FAM_INCOME	Respondent's household monthly income after taxes in sixteen €300-intervals ranging from interval 1 (<€300) to interval 16 (>€4500)	8.00 (3.61)		1	16
UNEMPLOYED	1 if the respondent is unemployed, 0 otherwise		8.37	1	0
Respondents characteristics					
AGE	Respondent's age	46.43 (16.23)		18	87
SPANISH	1 if the respondent has Spanish nationality, 0 otherwise		92.43	1	0
RESIDING_SCT	1 if the respondent resides in Santa Cruz de Tenerife, 0 otherwise		50.20	1	0
HOMEMAKER	1 if the respondent is a homemaker, 0 otherwise		2.59	1	0
FAMILY_SIZE	The total number of household members residing in a dwelling unit	2.75 (1.37)		1	9
EMPLOYEE	1 if the respondent is an employee (a person who is paid to work for someone else), 0 otherwise		52.19	1	0
Environmental awareness					
HIGH_ENV_CONS	1 if the respondent is highly environmentally conscious, 0 otherwise. Highly environmentally conscious in this case means that the respondent on a 1–7 scale (1 = strongly disagree; 7 = strongly agree) answered a value equal or greater than "6" when asked about the different statements of the New Ecological Paradigm scale (Dunlap et al., 2000)		5.38	1	7
EARTH_CAN_SUPP	Respondent's agreement with the statement "We are approaching to the limit of number of people that the Earth can support" (1 = strongly disagree; 7 = strongly agree)	5.12 (1.87)		1	7
RIGHT_MODIFY	Respondent's agreement with the statement "Humans have the right to modify the natural environment to suit their needs" (1 = strongly disagree; 7 = strongly agree)	3.26 (1.96)		1	7
JOB_LOSS	Respondent's agreement with the statement "Environmental protection measures should be carried out, even if this reduces the number of jobs in the economy" (1 = strongly disagree; 7 = strongly agree)	3.95 (1.95)		1	7
VOLUNTEER_ENV	Respondent's level of volunteering in activities aimed at preserving the environment (1 = never volunteers; 7 = always volunteers)	3.03 (2.10)		1	7
Environmental quality					
AIR_POLL_RISK	Respondent's agreement with the statement "air pollution poses a serious risk to my health" (1 = strongly disagree; 7 = strongly agree)	4.25 (1.96)		1	7
NOISE_CONDITIONS	Respondent's agreement with the statement "Las Palmas de Gran Canaria (or Santa Cruz de Tenerife) is a quiet city since in a normal day noise levels are low" (1 = strongly disagree; 7 = strongly agree)	3.16 (1.76)		1	7
NOISE_AFFECTED	Respondent's perception of how noise from ferry traffic affects him (1 = not at all affected; 7 = strongly affected)	3.30 (1.94)		1	7
Ferry use variables					
FERRY_USER	1 if the respondent used the ferry service at least once in the past year, 0 otherwise		71.12	1	0
HIGHLY_FREQ_USER	1 if the respondent used the ferry service more than five times in the past year, 0 otherwise		65.54	1	0

member means that the household expenses increase, thus reducing the disposable income of the family (Zegeye et al., 2023). Again, as mentioned above, respondents residing in Santa Cruz de Tenerife (RESIDING_SCT) not only have a higher probability of protesting, but also a lower probability of accepting the proposed payment and consequently a lower mean WTP as it has been shown in Table 3. Regarding the employment status of the respondents, employees have a higher probability of accepting the proposed bid than the rest of respondents maybe because they have a contract and receive a regular payment.

In relation to environmental awareness, respondents who actively engage in voluntary activities aimed at preserving the environment (VOLUNTEER_ENV) have a higher WTP which might suggest that these individuals attach a greater value to the protection of the environment and accordingly are more inclined to support initiatives that contribute to this purpose. Indeed, pro-environmental attitudes and behaviour are found to be significant predictors of WTP (Spash, 2006). Furthermore,

Table 6
Sample selection model and WTP determinants.

Variable	Selection equation	Participation equation	Probit regression
	Coefficient (Z-statistic)	Coefficient (Z-statistic)	Coefficient (Z-statistic)
CONSTANT	0.0933 (0.27)	−6.2450*** (−13.00)	0.3488 (0.64)
BID			−0.1701*** (−5.38)
Economic factors			
FAM_INCOME		0.0695** (2.22)	
UEMPLOYED	−0.8173*** (−3.01)		
Respondents characteristics			
AGE	0.0092** (2.49)		
SPANISH		5.4601*** (18.44)	
RESIDING_SCT	0.3686*** (2.93)		−1.340*** (−4.89)
HOMEMAKER		−5.3645*** (−16.67)	
FAMILY_SIZE			−0.19876*** (−2.85)
EMPLOYEE			0.6899*** (3.28)
Environmental awareness			
HIGH_ENV_CONS		5.7865*** (9.47)	
EARTH_CAN_SUPP	−0.0612* (−1.87)		
RIGHT_MODIFY			−0.14933*** (−2.67)
JOB_LOSS	−0.0862*** (−2.58)		
VOLUNTEER_ENV	−0.0730** (−2.38)		0.1906*** (3.02)
Environmental quality			
AIR_POLL_RISK			0.2578*** (4.11)
NOISE_CONDITIONS	−0.0619* (−1.73)	−0.1429** (−2.14)	
NOISE_AFFECTED			0.1137* (1.93)
Ferry use variables			
FERRY_USER			0.7892*** (3.13)
HIGHLY_FREQ_USER			0.5970** (2.29)
N (observations)	485		314
Log likelihood	−380.2669		−107.3605
Wald Chi-squared (p-value)	449.77 (0.0000)		
Wald test of indep. eqns. (rho = 0): Chi-squared (p-value)	0.4 (0.5182)		
LR Chi-squared (p-value)			147.97 (0.0000)
Pseudo R-squared			0.408

Note: ***, ** and * mean significant at 1 %, 5 % and 10 %, respectively.

the variable RIGHT_MODIFY, which identifies respondents who strongly agree with the statement that "humans have the right to modify the natural environment to suit their needs", is negatively and significantly associated with respondents' WTP since, as expected, these individuals are probably less environmentally conscious. In the same vein, respondents who think that "air pollution poses a serious risk to their health" (AIR_POLL_RISK) and that stated "to be strongly affected by the noise emissions from the ferry traffic" (NOISE_AFFECTED) are more willing to pay.

It should also be noted that respondents who have used the ferry service at least once in the past year (FERRY_USER) and those who use the ferry service frequently (HIGHLY_FREQ_USER) have a higher WTP. The former accounted for 71% of the sample, while the latter accounted for 66% of the sample. Presumably, familiarity with the service makes them more aware of the environmental impact of this mode of transport and therefore more willing to pay.

Now, to assess the magnitude of the impact of explanatory variables on WTP, we have calculated marginal effects (see Table 7). However, the inherent nonlinearity of the probit model implies that the relationship between a change in an independent variable and the estimated change in the probability of a positive outcome cannot be directly determined from the coefficient of the explanatory variables, i.e. the estimated coefficients do not have a direct interpretation as it is the case with linear models. Additionally, the inclusion of dummy variables in the set of explanatory variables is challenging (Bartus, 2005). So, to ensure appropriate estimation of the marginal effects, we use the *margeff* command within the Stata software which is well-suited to address the challenges arising from nonlinearity and the incorporation of dummy variables into the analysis. Thus, marginal effects are computed at sample means of the continuous explanatory variables, while in the case of the dummy variables, they compute the change in the probability of accepting the proposed payment when the binary variable changes from 0 to 1. With regard to variables related to the quality of the environment, being aware of the risks of air pollution on human health (AIR_POLL_RISK) and exposure to noise from ferries (NOISE_AFFECTED), increase the probability of a "yes" response by 5.1 and 2.3%, respectively. Similarly, respondents engaged in voluntary activities aimed at preserving the environment (VOLUNTEER_ENV) are 3.8% more likely to give a "yes" response to the offered payment. Also in the case of ferry users, the WTP probability increases by 16.8%. On the other hand, a unitary increase in the variable FAMILY_SIZE decreases this probability by −4%. Finally, the variable that has the strongest effect on this probability is RESIDING_SCT, i.e. residing in Santa Cruz de Tenerife decreases the WTP probability by −28.2%.

5.3. Aggregation

In the context of cost-benefit analysis, the primary purpose of the CVM is to provide an estimate of the aggregated benefits resulting from a change in environmental quality, thereby enabling policymakers and decision-makers to evaluate the desirability and feasibility of environmental projects and policies. However, aggregation entails making several assumptions that could be troublesome. First, it is necessary to define the population of beneficiaries of this policy. Thus, given (i) that the payment vehicle used was a hypothetical increase in ferry tickets, (ii) that a majority of respondents reported to have used the ferry in the past year, or even that they were frequent users of this service, and (iii) that respondents were asked about their WTP as current or future ferry users, the aggregation criterion in this case could be precisely the number of ferry users which in 2022 amounted to a total of 3,215,081 passengers (see Table 1). Also, when considering the aggregation criterion, in order to have a more conservative estimate of the social benefits of this policy, it would be prudent to focus on the population living in the districts of

Table 7
Probit regression: Marginal effects in percentages.

Variable	Marginal effect (Z-statistic)
BID	−3.4 (−6.60)***
RESIDING_SCT	−28.2 (−4.42)***
FAMILY_SIZE	−4.0 (−3.04)***
EMPLOYEE	14.1 (4.02)***
RIGHT_MODIFY	−3.0 (−2.82)***
VOLUNTEER_ENV	3.8 (3.15)***
AIR_POLL_RISK	5.1 (4.63)***
NOISE_AFFECTED	2.3 (1.94)*
FERRY_USER	16.8 (3.71)***
HIGHLY_FREQ_USER	12.1 (2.60)***

Note: *** and * mean significant at 1 % and 10 %, respectively.

both cities that are adversely impacted by emissions and noise resulting from ferry traffic. So in this latter case the population affected would amount to 334,794 inhabitants. Second, in view of that the model that best suits to the structure of the data is the Spike model, the mean WTP estimate chosen is €13.2. Finally, it is necessary to consider both a horizon time and a discount rate. Again, this process is critical since the present value of the benefits enjoyed by local residents depends directly on the particular value assigned to these two variables. Following OECD (2018) we apply a discount rate of 4.64% that is the average discount rate reported by OECD countries for impacts occurring in the first 30 years in projects related to the transport sector. In the same way, considering that the FuelEU Maritime Initiative, as a part of the 'Fit for 55' package, aims to achieve climate neutrality in 2050, a horizon time of 27 years has been chosen, i.e. the difference between the year in which climate neutrality is to be achieved and the current year (2023). Nevertheless, as pointed out by O'Mahony (2021), we are aware that the horizon time may even have a more significant impact on results than the discount rate. Thus, for comparison purposes and to ensure that the analysis is not biased towards the present generation, we also have considered a longer horizon time (100 years) considering that extending time horizons has become the norm in project appraisal in OECD countries (OECD, 2018).

Therefore, using a discount rate of 4.64% and multiplying the mean WTP (€13.2) by the number of ferry users (3,215,081), we find that the present value of the benefits derived from this policy amounts to a minimum value of €645.9 million if the time horizon considered is 27 years, while if the time horizon is longer (100 years) these benefits will amount to a maximum value of €905 million (see Table 8). On the other hand, if the aggregation criterion is the population of the districts adversely impacted from ferry traffic externalities, these same figures will be, respectively, €65.9 million and €94.2 million, i.e. these latter results are most likely conservative estimates of these benefits. Finally, the use of a discount rate of 3%, which has become a standard in many advanced economics for the assessment of long-term environmental impacts (O'Mahony, 2021), leads to higher estimates of the net present values of the benefits, as shown in the last two rows of Table 8.

6. - Discussion and conclusions

The research presented in this paper provides an initial assessment of the environmental benefits derived from the hypothetical adoption of a low-carbon fuel path, and OPS, by the ferry sector in the Canary Islands in compliance with the FuelEU Maritime Initiative. In doing so, this study aims to fill a research gap in the literature while paving the way for future research in this area until the complete decarbonisation of the sector. The case study refers to the LPGC and SCTF resident's willingness to pay extra per single ferry ticket between islands.

The findings of this study reveal a predominantly positive WTP among respondents for the implementation of low-carbon fuels and OPS in the Canary Islands. Indeed, after excluding protest responses, approximately 75% of the participants expressed their willingness to pay extra per single ferry ticket, with the mean WTP estimated at €13.12 when the Spike model was applied. At a practical level, this WTP figure would correspond to a notable 33% increase in the current ferry tickets, thus proving that public acceptance is as critical as technical maturity for the successful introduction of these new fuels and technologies aimed at reducing emissions, otherwise failure to garner public acceptance may hinder the diffusion and effective implementation of these innovations and policymakers can use WTP measures to make key strategic decisions.

Willingness to pay (WTP) is an accepted approach for deriving monetary values of transport policies. Therefore, the resulting range of WTP values could be used in a cost-benefit analysis to derive policy conclusions about the value to ferry users and society of adopting a low-carbon fuel path and/or OPS, allowing environmental externalities to be internalised through an efficient policy-making process. On the other hand, the majority of respondents are willing to pay more than the actual market prices to reduce the associated externalities, so subsidy reduction could be a viable policy option with majority public support. Furthermore, knowing the drivers of ferry users' WTP can guide the targeting and segmentation of policy interventions, thereby increasing their effectiveness. Finally, linking the revenue saved by subsidy reduction to emission reduction may increase public acceptance. Based on our findings, we conclude that there is a large potential for voluntary contributions to reduce emissions from passenger ferry transport in the Canary Islands.

A comparison of our results to those from the previous literature on alternative-energy boats, has revealed that our mean WTP estimates, ranging in between €10.61 and €13.12, are higher than the values obtained by Bigerna et al. (2019) that found that tourists in Italy were willing to pay an extra per single boat ticket in between €1.07 and €1.27, which represents an increase in between 16 and 19% in current boat tickets. In the study on boat sightseeing conducted by Wahnschafft and Wolter (2023) in Berlin, respondents were willing to pay a premium between 16 and 19% for sightseeing on electric boats that are more environmental friendly than their diesel counterparts. The higher increase in boat tickets found in our study can be due to the fact that we are comparing different boat services, while in our case we are referring to an essential service aimed at ensuring connectivity between islands, in the other two studies what is being evaluated is a recreational activity that can be enhanced using electric boats. So it seems that people residing in the Canary Island are aware of the crucial role played by ferries not only in ensuring connectivity, but also in promoting economic prosperity and strengthening social cohesion.

Assuming that only the population of the districts surrounding the port area will benefit from this policy, and using a discount rate of 4.64%, has resulted in a conservative estimate of the total benefits of €65.9 million over a 30-year horizon time, and €94.2 million over a longer horizon time (100 years). The sensitivity analysis carried out has also shown that the aggregated benefits largely depend on the extent of the market or population of beneficiaries. In any case, these figures would be meaningless if they were not based on an underlying value construct. Therefore, special attention was paid to the problem of zero and protest responses, and also to the possible presence of self-selection by those who protested. The results have shown that the decisions of protesting and entering into the market are not correlated, thus excluding the presence of sample selection bias. In the same way, these results have also been supported by the estimation of a bivariate probit model with selection in which the main variables had the expected sign and significance level. Likewise, although controversial (Hausman, 2012), monetising non-market benefits is necessary if we intend to have a complete picture of the impact of this policy on peoples' well-being; otherwise, policy decisions that ignore these values could be incomplete and misleading.

Table 8
Expected social benefits.

	Aggregation criterion	
	Number of ferry users (3,215,081)	Residents adversely impacted (334,794)
Expected social benefits (€) (hor. time: 27 years; disc. rate: 4.64%)	645,990,799	65,954,925
Expected social benefits (€) (hor. time: 100 years; disc. rate: 4.64%)	905,030,160	94,222,038
Expected social benefits (€) (hor. time: 27 years; disc. rate: 3.0%)	777,954,643	79,002, 786
Expected social benefits (€) (hor. time: 100 years; disc. rate: 3.0%)	1,341,325,526	139,644, 435

The credibility of the valuation scenario created is another issue that deserves discussion. It may be that asking the public about their WTP for the introduction of low-carbon fuels (LNG, LPG and methanol) in the ferry sector is a modest proposal, especially considering the existence of renewable fuels (e-methanol, e-LNG, e-H2, e-NH3, etc.) and the availability of all-electric boats. However, a contingent valuation scenario must be credible and pragmatic in order to obtain honest answers from the respondents. Therefore, given (i) the high capital and operating costs associated with the use of renewable fuels, (ii) the non-availability of appropriate charging infrastructure and long charging times in the case of all-electric boats, and (iii) the higher perceived risk associated with the use of some renewable fuels such as hydrogen (highly explosive) and ammonia (highly corrosive), it would have been rather unrealistic at this stage to ask respondents about their WTP for the adoption of these new technologies and fuels by the ferry sector in the short term. However, it would be useful to revisit this question in the coming years, particularly from 2040 when stricter standards for ship emissions will come into force (Christodoulou and Cullinane, 2022).

Finally, given the important policy implications that follow from this study, there are some limitations that need to be considered. Firstly, the results of this study are based on a survey carried out in the two main port cities of the Canary Islands. While these results are theoretically robust, in the near future it would be necessary to replicate the survey in other ports cities in the Canary Islands, and elsewhere, to confirm their validity. Secondly, these results also showed that the protest response rate was higher for residents in Santa Cruz de Tenerife than for residents in Las Palmas, which had an impact on the mean WTP estimates. Given that the same survey instrument was pre-tested in both cities and that no significant differences were found in terms of response rates, understanding of the questions and completion time, further research would be needed to determine the factors behind this difference in protest behaviour. And thirdly, in order to capture all the environmental benefits of this policy, it should be recognised that the owners of houses close to the port area are also likely to benefit from this policy, as a reduction in pollution is expected to increase the value of their houses. In this case, therefore, the hedonic pricing model will be of great help in providing a full picture of these benefits (Montero et al., 2018).

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Declarations of interest

None.

CRediT authorship contribution statement

Salvador del Saz-Salazar: Conceptualization, Data curation, Visualization, Writing – original draft, Writing – review & editing, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation. **Beatriz Tovar:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing, Methodology, Project administration, Writing – original draft.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2024.05.023.

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