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Stated benefits from air quality improvement through urban afforestation in an arid city – A contingent valuation in Mexicali, Baja California, Mexico

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ABSTRACT

Cities in drylands are expected to experience increasing challenges when it comes to air pollution. Currently, concentrations of particulate matter in these cities frequently reach dangerous levels. Urban afforestation represents an alternative to increase human health in arid cities via air-filtering and dry deposition. By simulating a non-existing market through a contingent valuation protocol, this study estimates the willingness to contribute monetarily to an urban afforestation scenario in Mexicali –an arid city located at the US-Mexico border. We estimate an average annual willingness to pay (WTP) of (2019) USD 88 per household. Variations in WTP are associated with the respondent's perception of air quality and the presence of respiratory symptoms in the respondent's household. The smallest WTP (USD 75) is reported by those perceiving poor air quality in their neighborhood and with no household members affected by respiratory symptoms. Respondents perceiving good air quality and with at least one household member facing respiratory symptoms report a WTP of USD 99. The highest WTP represents around 0.8 % of the annual household income. This WTP, when extrapolated to and aggregated over the total number of households in Mexicali, justifies the implementation of an urban afforestation program supplying 30 thousand tree seedlings annually.

1. Introduction

Air pollution is a problem affecting human health in arid and semi-arid cities. The concentrations of PM_{10} in these cities frequently surpass the World Health Organization's recommended thresholds of 20 μg/m^3 annual mean, and 50 μg/m^3 24 -h mean (UNEP et al., 2016). These concentrations are partially due to meteorological events common in drylands and favor the accumulation of atmospheric pollutants –i.e. extreme temperatures, low precipitation, frequent dust storms, and wind erosion processes (Ozer et al., 2006; Li et al., 2008). Anthropogenic factors behind high concentrations of atmospheric pollutants include reduced vegetation, agricultural waste, road traffic, and manufacturing industries (Massey et al., 2013; Radaideh, 2017). Severe cases of PM_{10} in arid and semiarid cities are associated with effects to human health, including morbidity and mortality due to respiratory diseases (asthma, acute bronchitis, pneumonia, influenza, pulmonary function) and cardiovascular affections (De Longueville et al., 2010; Maleki et al., 2016; Wang et al., 2019; Yunesian et al., 2019).

Urban green infrastructure mitigates air pollution and improves humans' health (Jayasooriya et al., 2017). Notably, urban trees improve air quality through air-filtering and dry deposition processes –trees remove air pollution by intercepting particulate matter on plant surfaces and absorbing gaseous pollutants through the leaf stomata (Terzaghi et al., 2013; Janhäll, 2015; Nowak et al., 2018). Reductions in PM_{10} associated to an increase in tree coverage have been reported in arid and semiarid regions, including Denver, Tucson, Northern Negev,

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Mediterranean cities, central Chile and north Mexico (Nowak et al., 2014; Uni and Katra, 2017; Manes et al., 2016; Escobedo and Nowak, 2009; Baumgardner et al., 2012). Consequent positive impacts from urban trees on human health have also been documented (Nowak et al., 2018; Jones and Goodkind, 2019).

However, urban afforestation has been overlooked as a strategy to combat PM_{10} pollution in arid and semiarid cities of emerging economies. The arid city of Mexicali, located at the Mexico-US border, is an illustrative case of how an urban afforestation program has received little attention from both policy makers and the general public. Mexicali has been ranked among the cities with the highest concentration of PM_{10} worldwide (WHO, 2016). Despite this situation, an urban afforestation program launched by the State administration has lacked a strong communication campaign which, in turn, has deterred residents from becoming beneficiaries of this program –which delivers tree seedlings and tree-planting assistance to citizens who request so (Secretaria de Protección al Ambiente (SPA, 2018, 2019). The overlooking of urban trees as instruments to decrease PM_{10} pollution is partly due to stakeholders' lack of awareness about how ecosystem services from urban trees contribute to the functionality of a city (Escobedo et al., 2011). For instance, in explaining the State's urban afforestation program's goal, policy makers highlight urban trees' contribution to water capture and store and reduction of CO_2 emissions but overlook air-filtering services that contribute to controlling PM_{10} concentrations (Secretaria de Protección al Ambiente (SPA, 2017).

In this context, it does not come as a surprise that there is no previous information on the value that residents of arid cities in emerging economics assign to afforestation efforts in their cities. By taking Mexicali as a case study, this paper carries out a contingent valuation exercise to estimate the stated benefits from improvements in air quality derived from urban afforestation. Following previous contingent valuation studies (see Section 2), we have also explored how this monetary value varies with the respondent's air quality perception at the neighborhood level and the presence of respiratory symptoms in the respondent's household.

Results from this study are useful not only for Mexicali but also for other cities located in drylands. For instance, around 65 % of Mexico's territory is dryland and hosts 30 % of its population (Becerril-Piña et al., 2015). Drylands cover approximately 41 % of Earth's surface and host more than 38 % of human population (Reynolds et al., 2007). Severe droughts are expected to increase their coverage worldwide –across Africa, southwestern Asia, northwestern India, southwestern USA, northern and central Mexico, western South America, and Australia (Gamo et al., 2013; Yao et al., 2020). Adding population growth to the equation, cities in drylands will experience increasingly difficult challenges when it comes to water scarcity and air pollution (Buharg and Urdal, 2013).

2. Previous contingent valuation studies inferring benefits from air quality improvements

Contingent valuation (CV) is extensively used in environmental impact assessments and cost-benefit analysis to estimate benefits provided by goods that are not traded in a market (Mitchell and Carson, 1989). Our CV survey simulates a non-existing market in which respondents trade money and air quality changes generated through an urban afforestation scenario. In general, CV would yield willingness to contribute monetarily (or willingness to pay, WTP) to air quality improvements; and it CV would deliver willingness to take a monetary compensation (or willingness to accept, WTA) when a scenario implies a deterioration in air quality (see Carson et al., 2001). As responses are elicited under a hypothetical market, CV yields stated preferences –as opposed to preferences revealed in a real market. Consequently, estimates resulting from a CV survey can be interpreted as the self-reported monetary value of the benefits that respondents perceive they receive from the changes presented in the CV scenario –i.e. stated benefits from, in this case, an urban afforestation scenario.

Discrete choice experiments (DCE) and hedonic prices method (HPM) represent two alternative methods to CV. Both methods have been implemented in similar context than ours (e.g. Anthon et al. (2005); Sagebiel et al. (2017)). We have deemed CV as the most useful method in our context due to two main reasons. First, we are not aware of available data on house prices that can be linked to afforestation variation in Mexicali –i.e. as a revealed preferences method, HPM relies on market data not available in Mexicali. Second, while an afforestation scenario can be decomposed in attributes and presented in the format of a DCE, this decomposition may imply unrealistic scenarios. In our specific context, we have chosen to describe the good under valuation (i.e. an urban afforestation scenario) as a bundled good to keep it as similar as possible to the afforestation program in place at the State level.

CV has previously been used to estimate benefits from improvements in air quality. Table 1 presents a list of these CV studies.[1] The first column reports authors and year of the study. The second column reports the country or city under study. The third column describes the improved air quality scenario under valuation. The fourth column reports control variables other than the conventional respondents' socioeconomics used in modeling the willingness to pay (WTP). The last column reports estimated annual WTP (in 2019 USD).

The list in Table 1 illustrates three features we wish to highlight. First, previous CV studies have focused on scenarios that improve air quality via regulatory and/or technological measures. Urban afforestation scenarios have yet to be on the radar of contingent valuation studies that estimate benefits from air quality improvements. To the best of our knowledge, only Zhang et al. (2020) have previously discussed the relevance of air filtering services from urban trees. They have investigated the WTP for small green infrastructure based on trees' ecosystem services that people value the most. Respondents ranked air-filtering at the top of their preferences –from among air-filtering, sound barrier, temperature regulation, protection from flood events, and biodiversity conservation.

A second feature illustrated in Table 1 is that particulate matter as received little attention as the pollutant of interest –CO_2 is the pollutant that has received the most attention so far. Consequently, we believe that the focus on PM_{10} is also a novelty in this CV study. The third highlight is that, when modeling respondent's WTP, previous CV studies control for whether a member in the household suffers a respiratory illness and, with less frequency, for the respondent's air quality perception. We follow suit these studies and control for both factors.

3. Study area and methods

3.1. Study area

Located at the Mexico-US border (Fig. 1.a), Mexicali hosts 752.6 thousand inhabitants (COPLADE, 2018). Its climate is arid, with winter rainfall (around 75 mm annually), average high temperatures in summer (around 42.2 °C), and average high temperatures in winter (21.1 °C) (Cueto et al., 2013). Air pollution in Mexicali is associated with natural sources, emissions from the transportation sector, electric power generation, industry, and unpaved streets (Rojas-Caldelas et al., 2013).

[1] Studies in table 1 represent a non-comprehensive list of CV studies that have focused on estimating the benefits from improvements in air quality. Closely related literatures include i) CV studies focusing on the benefits from biodiversity conservation strategies in urban contexts (Amirnejad et al., 2006; Madureira et al., 2011; Chu et al., 2020); ii) CV studies estimating the benefits from recreational and cultural amenities in urban contexts (Lo and Jim, 2010; Sirina et al., 2017; Chen and Qi, 2018); iii) CV studies estimating the benefits from mitigation of climate change and heat island effects (Le Tran et al., 2017; Zhang et al., 2019); and iv) CV studies estimating WTP for green areas in terms of coverage and distance from respondent's houses (Sabyrbekov et al., 2020).

Table 1
Studies implementing a contingent valuation protocol to estimate the willingness to pay for improvements of air quality.

Authors (year)	City/ Country	Improved air quality scenario	Control variables in addition to socioeconomic ones*	Annual WTP (2019 USD)**
Wang et al. (2020)	Xingtai, Guiyang (China)	Vehicular restrictions, regulatory and technological measures to industries. Clean energy.	Air quality perception, exposure time to pollution, filter installed in their households, believe that air pollution is caused by enterprises and distrust in government.	49.1 per person
Guo et al. (2020)	Zhengzhou, Pingdingshan, Zhumadian (China)	Improvements in air quality to meet the air quality guideline set by the World Health Organization.	Average air quality index (AQI) from ground-level monitoring stations associated to each survey location.	11.5 per person
Pu et al. (2019)	31 provinces (China)	Program to reduce heavy air pollution days by 50 %. The measures include industrial energy-saving.	Risk perception and attitude: perceived risk of air pollution, environmental awareness of protecting air quality, knowledge of air pollution and related health effects, government control trust.	23.3 per person
Zahedi et al. (2019)	Catalonia, (Spain)	Technological measurements, biofuel production, investment in public transport.	Pro-environment attitude, subjective norms, perceived behavioral control, environmental concern.	100.57 to 200.9 per household
Ouyang et al. (2019)	Shanghai, (China)	Regulatory and economic measures. Higher electricity prices and fuel costs to reduce the use of coal and oil.	Concern about haze, subjective perception of haze, respiratory diseases, social trust in haze data published by the government, household expenditure on preventive respiratory diseases, expenditure on haze mitigation	343.3 per household
Zhang et al. (2019)	Beijing, (China)	Regulatory and economic measures. Sand and dust weather mitigation.	Family members will support respondent`s pro-environment behavior, health conditions of the respondents.	48.58 per household
Dong and Zeng (2018)	Beijing, (China)	Regulatory measures to decrease smog by 30 %, 45 % and 60 %	Respondent's knowledge about smog, risk perception of smog, satisfaction in policy, trust in information.	158 per household
Ardakani et al. (2017)	Shahr-e-Ray, Shoosh, Haft-e-Tir and Tajrish, (Tehran)	Control and reduction in pollution	Geographic region of residence	9 per person
Wei and Wu (2017)	JingJinJi Region, (China)	Regulatory measures to reduce 80 % of severe $PM_{2.5}$ polluting days	Knowledge about health effects related to air pollution, whether respondent believes that the government should take action to control air pollution, member of communist party.	149 per household
Akhtar et al. (2017)	Lahore, (Pakistan)	50 % reduction of pollution through technological and regulatory measures.	espondent's subjective view about air quality, suffering from respiratory illness	135 per household
Sun et al. (2016)	30 provinces (China)	Mitigate smog crisis through clean energy generation systems	Indoors or outdoors job, life expectancy, sources of smog, household energy expenditure	172 per household
Filippini and Martínez-Cruz (2016)	Mexico City, (Mexico)	Air quality improvement through regulatory and technological measures.	Whether a household's member suffers a respiratory illness, concern about economic and environmental issues	92 per household
Yu et al. (2015)	Yangtze River Delta (China)	Reduction in number of days that air pollution and poor visibility occurs (above 349 AQI), through regulatory measures	Objective visibility (through monitoring of sites), respondent's perception of atmospheric visibility, and attitudes towards environment	Not specified
Yang et al. (2014)	Suzhou, China	Reductions of 20 %, 30 %, 40 %, and 45 % in CO_2 emissions through regulatory measures	Perceived risk from increases in greenhouse gas emissions, and attitudes toward government's management practices	56 per person
Wang and Zhang (2009)	Ji'nan, China	Improve air quality going from Class 3 to Class 2 in national standards through technological and regulatory masures.	Whether a household member suffers a respiratory illness, and expenditure on the treatment of respiratory illness	15 per person
Carlsson and Johansson-Stenman (2000)	Sweden	50 % Reduction of harmful substances through regulatory measures	Respondent's location (large city versus smaller city), whether respondent suffers a respiratory illness, and respondent's awareness of actual levels of pollution	47 per person

* Socioeconomic variables include respondent's and respondent household's characteristics such as income, education, age, gender, household size, whether house is rented or owned, etc.
** The reported WTP has been converted to 2019 USD based on exchange rates published by the World Bank's collection of development indicators (WDI, 2019).

Also, mineral dust resuspension and long-range transport (Choi et al., 2006; Carmona et al., 2015) are important sources of emissions.

The annual average concentration of PM_{10} in Mexicali has been reported as 80 % higher than the national regulation (50 μg m^{-3}) (Zuk et al., 2007). The most recent national official report of air quality lists Mexicali with the highest annual PM_{10} concentrations (95 μg m^{-3}), and with the second with the highest 24 -h average PM_{10} concentrations (274 μg/m^3) (INECC, 2018). Particulate matter in Mexicali includes elements of soil mixed with metallic and non-metallic minerals which have been associated with hemolytic and pro-inflammatory effects, cardiopulmonary diseases, and reduced lung function (Osornio-Vargas et al., 2011; Reyna et al., 2018).

Green areas per resident in Mexicali –including recreation, sport, and other public services and functional green areas-roads— are estimated at 7.77 m^2 (Peña-Salmón et al., 2014). This number does not reach the minimum of 9 m^2/inhabitant suggested by the World Health Organization (Russo and Cirella, 2018). Most of these green areas (parks and other areas with recreational use) are shown in Fig. 1.b.

The State Urban Afforestation Program of Baja California[2] aims to increase afforestation and reforestation in schools and public parks, and to increase urban green areas across the State to decrease greenhouse gas emissions (Secretaria de Protección al Ambiente (SPA, 2017). In 2017, the program reported an annual production of 200,000 tree seedlings of native and introduced plants per year in four nurseries. The program provides tree seedlings and tree-planting support to citizens who request so and commit to taking care of the planted trees.

This urban afforestation program, however, lacks a strong communication campaign. For instance, no webpage has been set up to inform specificities about the program. Also, official information about its operation is not readily available online –it is not clear when the program was launched, or its operations costs, among other relevant information. Given the reliance of this program on citizens' self-motivation, the lack of easy access to information has arguably been a

[2] Programa Estatal de Forestación Social y Urbano.

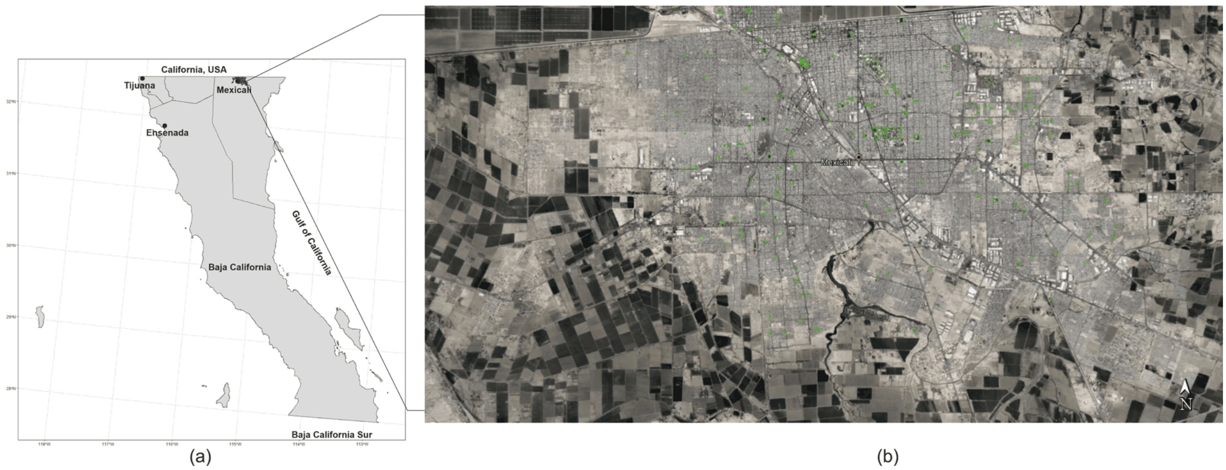

Fig. 1. Location of Mexicali, Baja California, Mexico (32.55 °N, 115.47 °W) (a). Functional green areas and for recreational uses (polygons in green) in urban area of Mexicali downloaded from Google Earth Pro 2020 (b) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

deterrent to reach as many beneficiaries as possible.

3.2. Questionnaire design and data collection

The design of our questionnaire has accounted for the recommendations from the National Oceanic and Atmospheric Administration (NOOA) Panel (Arrow et al., 1993). In particular, adopting a face-to-face interview, pretesting, a referendum question when gathering the respondents' WTP a thorough description of the contingent valuation scenario (including photographs). Also, some recommendations were adapted to developing countries' contexts to deal with possible sources of bias. The interviewer bias was treated with training and a prior explanation of each question to the interviewers, who have a background in environmental issues, which is relevant to provide explanation when the surveys are implemented face-to-face. Partial response bias was treated locating possible sensible questions such as income and education level after the WTP question. Other possible sources of bias pointed out by Riera et al. (2016) in developing countries are non-neutrality and complacency due to respondents' perceptions about potential political usage of the data. This bias was addressed, assuring the respondent that the purpose of the exercise was entirely academic, and no political organization was supporting its implementation.

Data were gathered during January 2019. The protocol was piloted on 30 respondents to define the bids presented through the double-bounded format and to polish the questions. The final instrument is composed of 36 questions. Respondents spent around 20 min answering it. A total of 270 face-to-face surveys were conducted in open spaces (e.g. malls, parks, etc.) to 18 years old or older individuals. This sample size allows for representability at the household level in Mexicali –with an error type I of 5%[3] . From the 270 surveys, 240 were fully responded, and 223 include the geographical references (neighborhood, ZIP code) of the respondent's house. The sites and geographical coverage achieved in the final sample are presented in Fig. 2.

The questionnaire is composed of five sections.[4] The first section introduces the respondent to the air pollution issue in general and describes the conditions in Mexicali. We first present the respondent to a Likert-scaled question that measures awareness of environmental issues in Mexicali. Then, we explain what particulate matter is and its effects on human health. We present graphical information about the number of days in a year that PM_{10} concentrations surpass the national regulation in Mexicali [see Fig. S1. in Supplementary Material]. Then, urban trees are described as providing air-filtering services that can decrease PM_{10} concentrations and consequently improve human health.

The second section of the survey presents the contingent valuation scenario. It is described as an urban afforestation program that would mitigate air pollution by planting native species[5] —*Prosopis glandulosa* (mesquite dulce), *Prosopis juliflora* (mesquite), *Acacia farnesiana* (huisache) and *Parkinsonia aculeate* (palo verde). The potential to reduce the PM_{10} concentration associated with this strategy is described as a decrease between 10% to 20% in PM_{10} concentration —these numbers are based on results reported by studies focusing on air-filtering services from canopy species in arid and semi-arid environments (McDonald et al., 2016; Manes et al., 2016; Uni and Katra, 2017).

Before being faced to the DBDCV question, respondents were asked the following:

> *considering what we have previously described to you, would you be willing to contribute monetarily for the afforestation program with native trees to be maintained and expanded? The contribution is on a household and monthly basis for two years.*
> *When the respondent answers no to this question, a follow-up question was presented to identify protest zeros.*

If the respondent was willing to contribute with a monetary contribution, then he/she was asked:

> *Would you be willing to contribute B_j^I Mexican pesos? Keep in mind that this contribution is on household and monthly basis for two years.*

If the respondent answered yes to B_j^I, the initial bid, then a follow-up question presented B_j^H, where $B_j^H > B_j^I$,

[3] In research where the variable of interest is qualitative, an alpha value is usually assumed at 0.05. The sample size formula for categorical data when the total of observational units (inhabited particular homes) are known *is* $n = N(Z)^2 * (p)(q)/(d)^2(N-1) + (Z)^2(p)(q)$, where $Z =$ value for selected alpha level in each tail, in this case, 1.96, $(p)(q) =$ estimate of variance, maximum possible proportion (0.5)*1- maximum possible proportion (.5) produces maximum possible sample size. $d =$ acceptable margin of error (error researcher is willing to accept), 0.05. N=291763 inhabited particular homes, Census 2015 (INEGI, 2015). (Bartlett et al., 2001)

[4] The questionnaire is available from the corresponding author upon request.

[5] Native tree species have adapted to the local high temperatures and limited precipitation, and require less water than non-native species. These species are considered ecologically relevant for arid and semi-arid environments of northern Mexico (Herrera-Arreola et al., 2007; Prasad and Tewari, 2016).

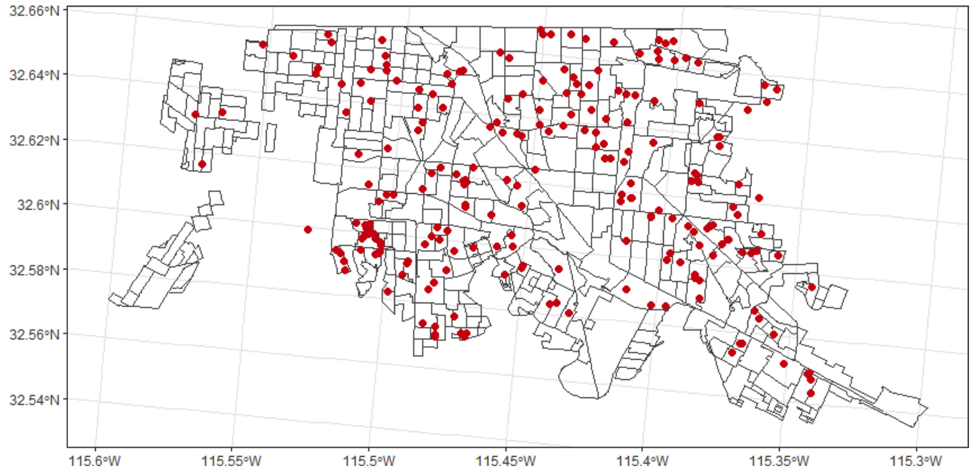

Fig. 2. Survey coverage. Red dots represent respondents' place of residence (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Would you be willing to contribute B_j^H Mexican pesos? Keep in mind that this contribution is on household and monthly basis for two years.

If the respondent answered no to B_j^I, the initial bid, then a follow-up question presented B_j^L, where $B_j^L < B_j^I$,

Would you be willing to contribute B_j^L Mexican pesos? Keep in mind that this contribution is on household and monthly basis for two years.

The definition of a vehicle payment in Mexico is particularly complicated. For instance, suggesting an increase in taxes is unrealistic and unpopular. Thus, based on what we observed in focus groups, we allowed respondents to choose their preferred vehicle payment from three alternatives –through an environmental fund administered by an NGO, water bill, or electricity bill.

The third section gathers demographic and socioeconomic information at the individual and household levels –such as age, sex, education, household size and residence (zip code, neighborhood, and street).

The fourth section gathers the respondent's air quality perception and health concerns. The perception of air quality is associated with the proximity to environmental risks and varies by the unit of aggregation, i.e., the perception at the neighborhood level is usually different than at the city level (Bickerstaff and Walker, 2001). To address this issue, respondents answer a five-point Likert-scaled question: "very good," "good, " "regular," "poor," and "very poor" air quality both at the neighborhood level and at the city level. Health concern includes the knowledge of health effects and the presence of frequent respiratory symptoms in household members.

The fifth section gathers indicators of civic engagement. Civic engagement involves individual and community attitudes and behaviors related to community and political involvement, through formal (neighborhood associations) or informal (participate in walks, tree planting) relationships to address issues of public concern (Adler and Goggin, 2005). Participation in community activities such as neighborhood meetings was measured as the ability to work for a common purpose (Paldam, 2000). On the other hand, the variable "visits to public park" on a Likert scale (frequently, occasionally, rarely, very rarely, never) was included because the use of green spaces promotes the maintenance and appropriation of these areas. The two variables can lead to generating awareness and influence pro-environmental behaviors.

3.3. Estimation of WTP via a double-bounded dichotomous contingent valuation question

This study gathers stated preference data by implementing a double-bounded dichotomous contingent valuation (DBDCV) protocol. In a contingent valuation protocol, once the air improving scenario is described to the respondent, the respondent is asked whether he/she would be willing to contribute monetarily to implement the described scenario. The DBDCV protocol presents respondent j to a randomly assigned bid (B_j^I) to which the respondent can answer yes or no. If his/her initial answer is yes, then a follow-up question presents the respondent to a bid (B_j^H) that is higher than the initial one ($B_j^H > B_j^I$). If his/her initial answer is no, then the follow-up question presents the respondent to a bid (B_j^L) that is lower than the initial one ($B_j^L < B_j^I$).

Consequently, respondents provide one of the following sequences of responses: i) both answers are yes (y,y); ii) both answers are no (n,n); iii) the initial answer is yes and the subsequent is no (y,n); and iv) the initial answer is no and the subsequent is yes (n,y).

Assuming that WTP is normally distributed, then an empirical distribution can be inferred by maximizing an interval-regression likelihood function (see Hanemann et al. (1991) and Lopez-Feldman (2012) for details); i.e.

$$\sum_{j=1}^{J}\left[d_j^{yy}\ln\left(\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^H}{\sigma}\right)\right)+d_j^{nn}\ln\left(1-\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^L}{\sigma}\right)\right)+d_j^{yn}\ln\left(\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^I}{\sigma}\right)-\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^H}{\sigma}\right)\right)+d_j^{ny}\ln\left(\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^L}{\sigma}\right)-\Phi\left(x_j'\frac{\beta}{\sigma}-\frac{B_j^I}{\sigma}\right)\right)\right]$$

where d_j^{yy}, d_j^{nn}, d_j^{yn} and d_j^{ny} are indicators variables defining which sequence of answers where provided by respondent j; x_j is a vector of control variables; and σ is the standard deviation of the normal distribution.

The DBDCV question sets out to increase the statistical efficiency of the single-bounded dichotomous contingent valuation (SBDCV) question (Hanemann et al., 1991). This increase in efficiency implies smaller sample sizes in comparison to the SBDCV protocol. However, the DBDCV

Table 2
Descriptive statistics of respondents' characteristics on entire sample (n = 240) and on sample with non-zero WTP responses (n = 189). Fisher's exact tests are reported to test for systematic differences. Results of the Kruskal-Wallis H test for statistically significant differences among zero response and non-zero response groups. Consist of the chi-square test with ties (χ^2), the degrees of freedom (df), and the significance level (p-value).

Variables	Categories	Entire sample		Non-zero WTP sample		Kruskal-Wallis test
		n = 240		n = 189		
		No.	Percentage (%)	No.	Percentage (%)	
	Above the median	122	50	86	45	$X^2 = 0.74$
Age Median: 38 years	Below the median	118	50	103	55	df = 1
	Fisher's exact: 0.02					p-value = 0.388
	Male	93	39	70	37	$X^2 = 0.014$
Gender	Female	147	61	119	63	df = 1
	Fisher's exact: 0.332					p-value = 0.906
	No school attendance	7	3	5	3	
	Elementary school	21	9	15	8	
	Middle school	44	18	35	19	$X^2 = 0.118$
Education	High school	63	26	50	26	df = 1
	Bachelor	84	35	68	36	p-value = 0.732
	Graduate	21	9	16	8	
	Fisher's exact test: 0.894					
	< USD 135.7	22	9	17	9	
	USD 135.7 to USD 354.9	73	30	57	30	
	USD 354.9 to USD 605.4	64	27	47	25	
Monthly household income (2019 US dollars)	USD 605.4 to USD 1,352	47	20	42	22	$X^2 = 1.339$
	UD 1,352 to USD 1,826	12	5	9	5	df = 6
	USD 1,826 to USD 2,347	15	6	11	6	p-value = 0.969
	> USD 2,347	7	3	6	3	
	Fisher's exact test: 0.494					
	Yes	168	70	127	67	$X^2 = 0.409$
House ownership	No	72	30	62	33	df = 1
	Fisher's exact test:0.085					p-value = 0.523
	Above the median	120	50	94	50	$X^2 = 1.520$
Household size Median: 3 members	Below or equal than the median	120	50	95	50	df = 1
	Fisher's exact test: 0.500					p-value = 0.210
	Yes	108	45	87	46	$X^2 = 0.343$
Frequent respiratory symptoms[a]	No	132	55	102	54	df = 1
	Fisher's exact: 0.635					p-value = 0.558
	Regular-good	124	52	91	48	$X^2 = 0.052$
Air quality perception at neighborhood level[b]	Poor- very poor	116	48	98	52	df = 1
	Fisher's exact: 0.041					p-value = 0.820
	Regular-good	71	30	53	28	$X^2 = 0.377$
Air quality perception at city level[b]	Poor- very poor	169	70	136	72	df = 1
	Fisher's exact: 0.387					p-value = 0.539
	Yes	59	25	47	25	$X^2 = 2.254$
Participation in neighborhood committees' meetings	No	181	75	142	75	df = 1
	Fisher's exact: 0.999					p-value = 0.133
	Yes	176	73	138	73	$X^2 = 1.202$
Visits to public parks[c]	No	64	27	51	27	df = 1
	Fisher's exact:0.999					p-value = 0.273

[a] Cough, phlegm, and difficulties of sleeping caused by coughing or wheezing mainly in children or a household member.
[b] Variables of air quality perception were dichotomized due to small observations in extreme categories.
[c] Yes, if respondent visits public parks frequently or rarely; no if respondent never visits public parks. The variable was reduced to two categories due to small number of responses in the middle categories.

Table 3
Reasons for zero WTP and perception of air quality at neighborhood level, N = 51.

Reasons for zero WTP	Poor and very Poor	Regular and good	Frequency	%
Insufficient income	11	5	16	31
Lack of trust on institutions	11	4	15	29
Those who pollute should be charged	4	4	8	16
Clean air is a human right	5	2	7	14
Other reason	1	2	3	6
More green areas are not necessary	1	1	2	4
Total	33	18	51	100

is not free of criticism. Besides the usual issues when it comes to contingent valuation protocols –e.g. warm glow effect, anchoring, sensitivity to scope, and hypothetical bias (Carson et al., 2001; Carson, 2012;)—, there is space for inconsistent answers to the follow-up question (Cooper et al., 2002).

Finally, we use the estimated coefficients from the DBDCV through the maximum likelihood estimation in Stata, as implemented by Lopez-Feldman (2012), to estimate the WTP under different scenarios. The maximum likelihood estimation begins with a linear function for a dichotomous choice model and estimates the linear function:

$$WTP_i(x_i, u_i) = x_i\beta + u_i$$

where x_i corresponds to the control variables: socioeconomic characteristics, air quality perception, health concerns and civic engagement, β are the estimated parameters and u_i is the error term.

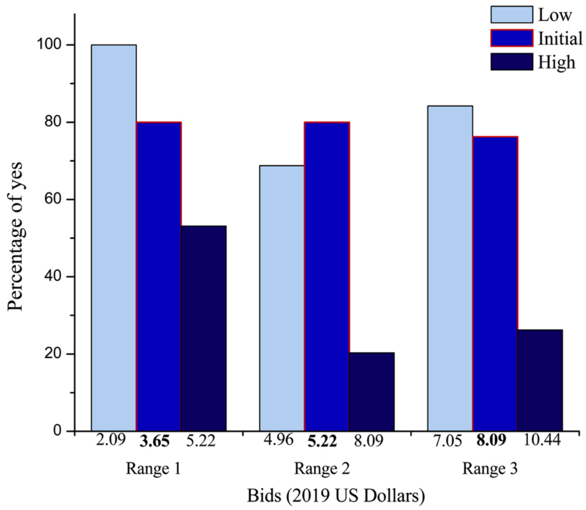

Fig. 3. Percentage of yes responses to bids presented to respondents.

among zero response and non-zero response for all the variables do not show statistically significant differences. Also, maintaining the assumption of normality, Fisher's exact tests suggest that non-zero WTP respondents are reasonably similar to respondents in the entire sample. The exceptions are age and perception of air quality at the neighborhood level. For the case of age, the non-zero WTP sample is composed of 55 % of people older than 38, which is the median age in the entire sample. For the perception of air quality, the non-zero WTP sample is comprises of 52 % of people perceiving poor or very poor air quality at the neighborhood level –versus 48 % in the entire sample. A slightly higher percentage of non-zero WTP respondents are older and have poor or very poor perceptions about air quality at the neighborhood level.

Otherwise, the non-zero WTP subsample closely replicates the relative frequencies of the entire sample when it comes to i) percentage of female respondents (61 %); ii) percentage of respondents within category of education –3% *(no school attendance), 9% (elementary school), 18 % (middle school), 26 % (high school), 35 % (bachelor), and 9% (graduate); iii) percentage of respondents within self-reported monthly income range –9% (< USD 136), 30 % (between USD 136 and USD 355), 27 % (between USD 355 and USD 605), 20 % (between USD 605 and USD 1,352), 5% (between USD 1,352 and USD 1,826), 6% (between USD 1,826 and USD 2,347), and 3% (> USD 2,347); iv) percentage of households that own their house (70 %); v) percentage of households with more than 3 members (50 %); vi) percentage of household with at least one household member suffering respiratory symptoms (45 %); vii) percentage of respondents perceiving air quality at city level as poor or very poor (70 %); viii) percentage of respondents participating in neighborhood meetings (25 %); and ix) percentage of respondents visiting public parks (73 %).

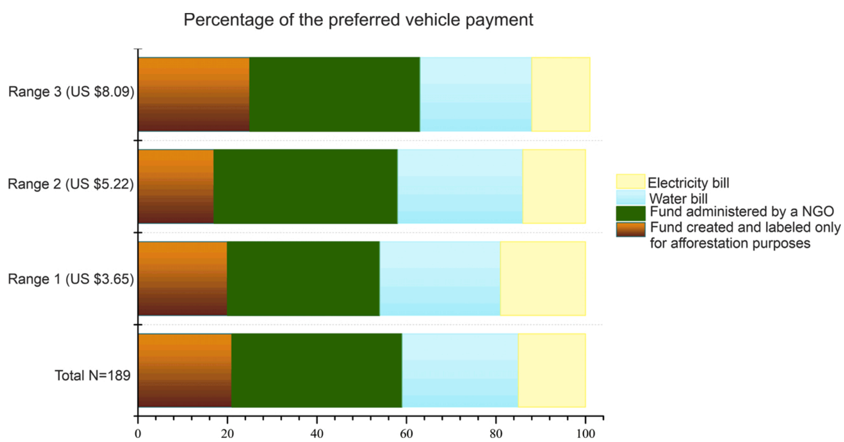

Fig. 4. Relative frequencies of the preferred vehicles of payment for non-zero responses.

4. Results

4.1. Description of respondents' characteristics

Table 2 reports descriptive statistics of respondents' characteristics and perceptions. As 51 out the 240 respondents (21 %) reported a zero WTP,[6] statistics are reported for both the entire sample (n = 240) and the non-zero WTP subsample (n = 189). Fisher's exact tests are reported to explore whether the relative frequencies differ systematically across the entire sample and the non-zero WTP subsample. Nonparametric Kruskal-Wallis H tests are also presented to compare if the included variables significantly differ between zero and non-zero responses within the categories of each variable.[7]

In general, the results of the Kruskal-Wallis H test for differences

4.2. Description of zero responses

Table 3 reports reasons for zero WTP by category of perception of air quality at neighborhood level. The general message from Table 3 is that the majority (69 %) of zero responses are protest responses. Reasons for a protest response include lack of trust on institutions (29 %); the belief that those that pollute should be charged (16 %); that clean air is a human right (14 %), and the opinion that more green areas are not necessary for Mexicali (4%).

4.3. Description of answers to bids

As illustrated in Fig. 3, three bid ranges were randomly presented to respondents –covering the range from US 2.1 to US 10.4 (2019 US dollars). The first range includes US 2.1, US 3.6, and US 5.2; the second,

[6] The percentage of zero responses in our sample (21%) falls in the lower bound of values reported in previous studies –from 20% to 30% (Carlsson and Johansson-Stenman, 2000; Wang et al., 2015; Sun et al., 2016; Ardakani et al., 2017; Dong and Zeng, 2018).

[7] The Fischer's exact test allows testing whether there is an association between two categorical variables, under the hypothesis that the row and column effects are independent in an r ×c contingency table. This test is considered more accurate when the entries in each cell are small (Mehta and Patel, 1983). Kruskal Wallis H test, based on ranks rather than the trait values themselves and relaxes the assumption of normality (Vargha and Delaney, 1998).

Table 4
Double bounded dichotomous choice models on respondents with non-zero WTP (n = 189).

Variables	Intercept (I)	Socioeconomics attributes (II)	Family concerns (III)	Air quality perception (IV)	Civic engagement (V)	Significant variables (VI)
Socioeconomic variables						
38 or older[a]		−0.921 (0.443) **	−0.903 (0.447) **	−0.871 (0.445) **	−0.843 (0.445) *	−0.999 (0.418) **
Male[b]		0.446 (0.442)	0.415 (0.433)	0.488 (0.431)	0.478 (0.430)	0.485 (0.430)
High education level[c]		0.030 (0.451)	0.157 (0.446)	0.295 (0.445)	0.265 (0.453)	
House ownership[d]		0.238 (0.479)	0.122 (0.471)	0.022 (0.467)	0.044 (0.468)	
Family concerns						
Household with more than three members[e]			0.625 (0.442)	0.538 (0.439)	0.528 (0.440)	
Household with members experiencing frequent respiratory symptoms[f]			0.801 (0.442) *	0.865 (0.439) **	0.874 (0.438) **	1.032 (0.420) **
Air quality perception by geographical context[g]						
Poor or very poor air quality at the neighbourhood level				−0.888 (0.456) *	−0.902 (0.419) **	−0.931 (0.415) **
Poor or very poor air quality at the city level				−0.060 (0.504)		
Proxies of civic engagement						
Visits to public parks[h]					0.140 (0.470)	
Participation in neighbourhood meetings[i]					−0.231 (0.476)	
Intercept	7.444 (0.217) ***	7.535 (0.445) ***	6.877 (0.509) ***	7.363 (0.634) ***	7.272 (0.648) ***	7.740 (0.407) ***
Sigma	2.640 (0.179) ***	2.607 (0.178) ***	2.543 (0.173) ***	2.509 (0.171) ***	2.507 (0.171) ***	2.527 (0.172) ***
LR chi2		5.26 0.261	12.73 0.047	17.56 0.025	17.87 (0.037)	15.60 (0.003)
Log-likelihood	−260.809	−258.176	−254.518	−252.162	−252.011	−253.062
AIC	525.617	528.352	525.036	524.325	526.022	518.12

Standard errors in parenthesis; *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.
[a] 1 if the respondent is older than 38 (which is the sample median); 0, otherwise.
[b] 1 if the respondent is male; 0, female.
[c] 1 if respondent attended high school or equivalent; 0, otherwise.
[d] 1 if the respondent has his/her own house; 0, otherwise.
[e] 1 if respondent's household has more than three members (which is the sample median); 0, otherwise.
[f] Cough, phlegm and difficulties of sleeping caused by coughing or wheezing mainly in children or some household member.
[g] if respondent perceives that air quality is poor or very poor; 0, if respondent perceives good that air quality is good or regular.
[h] 1 if respondent visits public parks frequently or rarely; 0 if respondent never visits public parks.
[i] 1 if respondent participates in neighborhood meetings; 0 if respondent has never participated in neighborhood meetings.

US 4.9, US 5.2, and US 8.1; and the third, US 7.1, US 8.1, and 10.4. We would expect that for each range, the percentage of yes responses monotonically decreases when the bid increases. This pattern is observed for the first and third ranges –with around 100 % of yes to US 2.1, 80 % to US 3.6, and 50 % to US 5.2; and 80 % to US 7.1, 70 % to US 8.1, and around 25 % to US 10.4. Answers to the second bid follow a non-monotonic decreasing pattern –with 70 % yes to US 4.9 and 20 % to US 8.1 but around 80 % to US 5.2.

Fig. 4 reports the relative frequencies of the preferred vehicle payment by range of bids presented to the respondents and also for the entire non-zero subsample. When focused on the entire subsample, around 20 % of the respondents prefer to contribute through a fund created and labeled as only for afforestation purposes; around 38 % of respondents prefer to contribute to funds administered by a NGO; around 26 % prefer to pay via their water bill,and 15 % prefer to pay via their electricity bill. Fig. 4 illustrates that these percentages remain relatively similar across the ranges of bids presented to respondents.

4.4. Econometric estimations

Table 4 reports coefficients obtained via six different specifications of our double-bounded dichotomous choice (DBDC) model on the subsample of non-zero WTP respondents (n = 189) –we deem this appropriate as excluding the zero WTP respondents does not substantially change the composition of the sample. Specification (I) only includes the intercept, which is the (unconditional on control variables) average monthly household's WTP estimated at USD 7.44 (2019 USD).[3] Specification (II) controls for respondents' socioeconomic variables, such as age, gender, education, and whether respondent's house is owned by the household.[8] The coefficient associated with the respondent's age is statistically significant and negative. Given that this variable is dichotomous and identifies 38 years old respondents (the sample median) or older, the estimated value of its coefficient implies that respondents of 38 years old or older report a WTP that is USD 0.92 lower than respondents younger than 38. Education is not statistically significant in our specifications.[9]

[8] Income is not included in our final specification due to three reasons: i) due to missing values in reported income; ii) the potential collinearity with education, and iii) income yielded insignificant coefficients when included as a control variable. We report in Table 1.A (see Supplementary Material) specifications including income –DBDC, bivariate probit, and logit specifications. In these specifications, income remains insignificant, and the coefficient associated with the bidding amount remains significant and with a negative sign.

[9] Previous authors have documented a lack of statistical significance for the coefficient associated with education (e.g. Wang and Zhang, 2009; Achtnicht, 2012). An explanation is that a high formal education does not necessarily imply greater environmental awareness. Torgler and Garcia-Valiñas (2007) postulated the relevance of non-formal education. The inclusion in the formal programs and diffusion of topics with orientation in the care of the environment, air pollution, and health effects can have a more considerable influence.

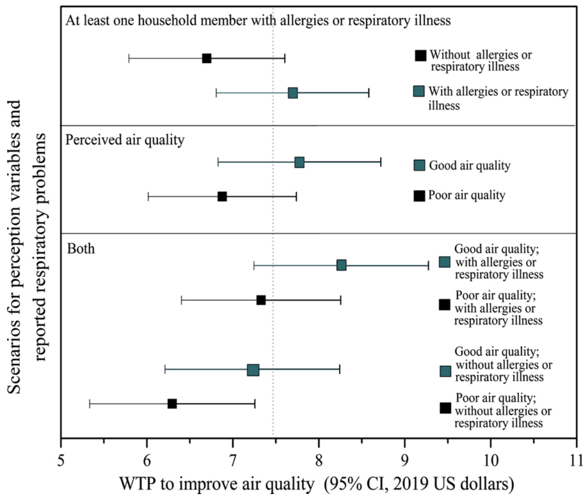

Fig. 5. Estimated monthly WTP (in 2019 USD) to improve air quality by air quality perception and household members with reported respiratory problems. The dotted line corresponds to the WTP without control variables (7.44 in 2019 USD). Green color refers to the categories with a positive effect on the WTP (Good air quality perceived and household members with reported allergies or respiratory illness). Black color relates to the perception of poor air quality (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Specification (III) in Table 4 builds upon the second model by adding variables capturing family concerns. These variables include a dichotomous variable identifying the households with more than three members which is the sample median, and a dummy identifier of the households affected by frequent respiratory symptoms such as cough, phlegm, or sleeping problems due to respiratory complications. Specification (III) yields no significant coefficients associated with the household size. However, the self-report of the households with members experiencing respiratory symptoms yields a significant coefficient. The significance of these variables remains in specifications (IV) to (VI), with coefficients around 0.86, 0.87, and 1.03, respectively.

Specification (IV) builds upon specification (III) by controlling for the respondent's air quality perception at the neighborhood and city levels. The variables controlling perception take different values. If the respondent perceives a poor or very poor air quality at the neighborhood level, his/her WTP is smaller by around USD 0.88 (2019 USD).

Specification (V) in Table 4 adds civic engagement proxies –a dichotomous variable identifying the respondents that visited public parks (the year previous to the survey) and a dichotomous variable identifying those participating in neighborhood meetings. Both variables yield insignificant coefficients.

Specification (VI) keeps the variables that are significant in the previous specifications and the gender variable –which is kept because, in logit and bivariate probit specifications that check for robustness, gender yields statistically significant coefficients (see Table 2.A and Table 3.A in Supplementary Material). Given that statistical significance and magnitude of coefficients remain similar than in the previous five specifications, specification (VI) is our preferred one based on its overall statistical performance, as measured by the Akaike Information Criterion (AIC) –which is the smallest for specification (VI) at 518 versus values ranging 524–528 for the other.

The estimated intercept remains fairly similar across the six specifications reported in Table 4, which we interpret as evidence that the estimated average of WTP is robust. We have also carried out an alternative specification to check the robustness of the relationship between the dichotomous responses and the bids presented to the respondents. These specifications include logit models (that only model the latest response of the double-bounded dichotomous answers) and biprobit models (that model both dichotomous responses as dichotomous

Table 5
Monthly and annual WTP per household (2019 USD) for scenarios considering perception of air quality at the neighborhood level, and respiratory symptoms in the household.

Specification		Monthly WTP per household (in 2019 USD)	95 % Confidence Interval	Annual WTP (in 2019 USD)
I. At least one household member with frequently respiratory symptoms related to allergies or respiratory diseases	1.With frequently respiratory symptoms	7.69	6.81 – 8.58	92.28
	2. Without frequently respiratory symptoms	6.69	5.79 – 7.60	80.28
II. Perceived air quality	1. Good air quality	7.77	6.83 – 8.72	93.24
	2. Poor air quality	6.88	6.02 – 7.74	82.56
II. Perceived air quality and at least one household member with frequently respiratory symptoms	1. Good air quality; with frequent respiratory symptoms	8.26	7.24 – 9.27	99.12
	2. Poor air quality; with frequent respiratory symptoms	7.33	6.40 – 8.25	87.96
III. Perceived air quality and without a household member with frequently respiratory symptoms	1. Good air quality; without frequently respiratory symptoms	7.23	6.21 - 8.24	86.76
	2. Poor air quality; without frequently respiratory symptoms	6.29	5.33 – 7.26	75.48

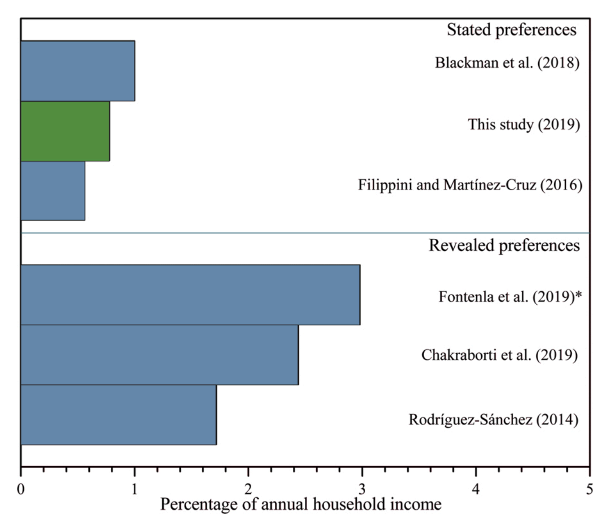

Fig. 6. Willingness to pay estimates as a percentage of annual household income to improve air quality in Mexico. * Fontenla et al. (2019) reports willingness to accept estimates.

variables whose errors terms are correlated). The results of these models are reported in Table 2.A and Table 3.A (Supplementary Material), respectively. In general, our respondents are found to be responsive to the bids presented to them and the WTP estimates resulting from these alternative models fall within the range reported in Fig. 5.

4.5. Estimation of the WTP

In order to compare different scenarios, WTP was estimated based on specification (VI) and significant coefficients, including air quality perception variable and the variable of households with members frequently affected by respiratory symptoms. Fig. 4 presents the WTP to improve air quality through urban afforestation under eight scenarios and take as base the estimated WTP without control variables (approximately USD 7.44). As we seek to estimate variations due to perception and health concerns, the other variables were maintained in their reference values.

Results in Fig. 5 illustrate how point WTP estimates vary depending on air quality perception. Keep in mind that the unconditional WTP is represented with the dotted line in Fig. 4. In all scenarios, a larger WTP prevails for the respondents who perceive air quality between good and regular in their neighborhood. Among the respondents who reported at least one member with frequent respiratory symptoms related to allergies and respiratory diseases, the estimated WTP was higher, USD 7.79. At the same time, WTP decreases to USD 6.69 if the respondent reports that no household member has frequent respiratory symptoms. On the other hand, both variables lead to the higher WTP among the respondents who perceived good air quality and a household member affected by frequent respiratory symptoms (USD 8.26). In contrast, the lower WTP corresponded to respondents without household members affected by frequent respiratory symptoms and who perceived poor air quality USD 6.29, as shown by line 1 and line 4 in the bottom box in Fig. 4. Estimated WTP and 95 % confidence intervals are presented in Table 5. These scenarios suggest the importance of air quality perception in the knowledge of health effects for the design of strategies to improve air quality. The aggregate annual value is calculated for these significant variables in the proposed scenarios in Table 5.

Table 5 reports an average annual WTP per household of USD 87.96. We can interpret this number as the average stated benefits derived from the air-filtering service that trees would provide in Mexicali –particularly concerning PM_{10}. Heterogeneity in the WTP is associated with perceptions of air quality and respiratory symptoms at home. Respondents that perceive poor air quality in their neighborhood and without household members affected by frequent respiratory symptoms report USD 75.48. In contrast, those perceiving good air quality and with household members with frequent respiratory symptoms report USD 99.12.

5. Discussion and policy implications

5.1. Determinants of the willingness to pay

Results in Section 4 imply that residents of Mexicali are willing to contribute monetarily to an urban afforestation program. This WTP varies with age –younger respondents report a higher WTP than older respondents. This direction in the effect from age has also been documented by Carlsson and Johansson-Stenman (2000); Wang and Zhang (2009); Yu et al. (2015); Wei and Wu (2017); Pu et al. (2019) and Zahedi et al. (2019).

A respondent in a household with someone suffering frequent respiratory symptoms reports higher WTP than those whose household have no members suffering from respiratory symptoms. This positive effect is in line with results reported by Filippini and Martínez-Cruz (2016) for Mexico City. Also, Zhang et al. (2019); Wang et al. (2015), and Akhtar et al. (2017) documented a positive and significant effect in Shanghai (China) and Lahore (Pakistan) for the willingness to pay to improve air quality. We suggest that this higher WTP is due to that the respondents in a household with a member suffering respiratory symptoms are more aware of the private costs of air pollution, and they are more altruistic towards those members suffering such symptoms.

A third component relevant to our results is air quality perception. We document a negative effect on WTP from poor air quality perception at the neighborhood level. The direction of this effect has been previously documented by Yu et al. (2015) and Sun et al. (2016) in China for the WTP to reduce the days when air pollution and poor visibility occurs. Bickerstaff (2004) associated this effect with a disconnection determined by people's perception of their ability to act, their attachment to the place, and their commitment to neighborhood problems.

5.2. This paper's estimates in comparison to estimates from previous studies

The estimated maximum annual WTP to improve air quality through native trees in Mexicali is (2019) USD 99, with a 95 % confidence interval between USD 86 and USD 111. This amount is consistent with previous contingent studies applied to air quality improvements in Mexico. In Mexico City, the study of Filippini and Martínez-Cruz (2016) proposed regulatory and technological measures to improve air quality, and the estimated annual average WTP per household was (2019) USD 92.14. Blackman et al. (2018), also focusing on Mexico City, reported an annual WTP of (2019) USD 108.7 to be exempted from a regulation imposing one day without driving weekly. Estimates from Blackman et al. (2018) can be interpreted as reflecting costs that the regulation imposes on car drivers, and our USD 99 can be seen as reflecting a lower bound to private costs due to respiratory symptoms.

Fig. 6 presents the annual WTP as a percentage of annual average household income from studies using both stated preferences and revealed preference methods in Mexico. In Baja California, the annual average household income is (2019) USD 12,685 (INEGI, 2019), and therefore our highest annual WTP estimate (USD 99) represents 0.78 % of the annual average household income. The upper part of Fig. 5 shows that our estimates fall within those reported

by Filippini and Martínez-Cruz (2016) and Blackman et al. (2018) –0.58 % and 1.00 %, respectively. Studies based on hedonic price functions report a higher WTP as a percentage of annual average household income. Rodríguez-Sánchez (2014) reports a WTP of around 1.4 % of annual household income. Chakraborti et al. (2019) reported a WTP equivalent to 2.44 % of annual household income. Fontenla et al. (2019) documents that an average household is compensated with 2.8 % of their income for an increase of 1 $\mu g/m^3$ in PM_{10}.

5.3. Policy implications

Our results imply that Mexicali's residents are willing to contribute monetarily to an urban afforestation program on the grounds that it would improve air quality –PM_{10} concentrations in particular. Around 80 % of our respondents have reported a positive WTP. While there is heterogeneity in the WTP, the point estimates suggest a relatively small range of annual values per household –with a minimum of around (2019) USD 75 and a maximum of around (2019) USD 99. Extrapolating the 21 % that reports the highest annual WTP to the 61 thousand households in Mexicali, we estimate aggregated benefits from urban afforestation in Mexicali at (2019) USD 6.04 million.

To put our estimated benefits in context, it is useful to estimate the costs of providing a tree seedling in Mexicali. We have estimated these costs at USD 186.74 per seeding.[10] This number refers to a two-meter mesquite tree seedling, and results from adding three categories of

[10] The per tree cost may vary because planting costs can be reduced if multiple tree seedlings are planted at once. In addition, these costs are subject to the conditions of the soil, the location, and the size of the tree.

costs –i) market price of a tree seedling; ii) planting costs; and iii) per tree seedling administrative costs. The market price of a two-meter mesquite tree seedling is USD 104.38 in Mexicali –-this paper's main author has personally verified this value in nurseries located in Mexicali. Planting a tree seedling implies preparation of the location, renting of planting equipment, and labor costs. All together, these costs amount to USD 78.29 per tree seedling.[11] We have estimated administrative costs per tree seedling at USD 4.07. This number results from dividing the budget allocated to running an afforestation program in Baja California by the number of tree seedlings planned to be provided. Total annual budget is obtained by adding annual budget for nurseries and germplasm bank operating in Mexicali (USD 377,143.29) and the costs of georeferencing of sites where afforestation is carried out to monitor, and coordination meetings between NGOs and government (USD 29,702.71).[12] Thus administrative costs amount to USD 406,845.98. Nurseries are expected to provide 100,000 tree seedlings per year. Thus 406,845.98/100,000 = 4.07 is our estimation for per tree seedling administrative costs.

Thus our estimates of annual WTP per household, when extrapolated to and aggregated over the total number of households in Mexicali, suggest that benefits from afforestation justify the implementation of an urban afforestation program supplying 30 thousand tree seedlings per year.

We have motivated this study by highlighting that there is an urban afforestation program at the state level that Mexicali's residents could benefit from. However, there is a lack of awareness about the program due to a poor communication campaign –there is no readily information about it with the exception of a couple of news on internet that report the number of trees planted by the program at the state level and a short paragraph on how citizens can apply to become beneficiaries of the program.

The lack of a communication campaign is, arguably, a deterrent to afforestation in Mexicali and the State of Baja California. Thus a low-hanging fruit action is to increase the information available to citizens. Also, administrators of the afforestation program may want to consider citizens' donations as an additional source to finance afforestation. Indeed, reaching out for donations implies an increase in the transparency on how resources are managed and the progress of the program. Administering donations via a government-NGO partnership is an option that may be well-received by residents of Mexicali –recall that around 40 % of those willing to contribute responded that they would trust an NGO in administering the contributions.

5.4. Limitations and further considerations

A concern may arise from excluding zero responses when implementing the double bounded dichotomous specifications. We have deemed appropriate to base our estimates on only non-zero respondents because the sample that excludes zero respondents looks similar to the entire sample. Despite this similarity, zero respondents may be genuinely not willing to contribute monetarily; if this was the case, then our exercise might overestimate the benefits from the afforestation scenario.

In responding to such concern, we highlight two features of our results. On one hand, around 70 % of our zero respondents can be classified as protest respondents –these respondents likely have a positive WTP but find the scenario either unrealistic or unreliable. Indeed, the 30 % of zero respondents that cannot be classified as protest zeros may truly be willing to pay zero, and the potential for overestimation remains. To explore for the possibility of overestimation, we have compared our results with previous contingent valuation studies that have obtained benefits from improvements in air quality in the Mexican context (see Section 5.2). Estimates from previous studies work as a baseline against which our estimates can be judged. To make the comparison stricter, we have compared the highest WTP estimated in this study against the average WTP estimates reported in Filippini and Martínez-Cruz (2016) and Blackman et al. (2018). These comparisons have been carried out in terms of WTP as a percentage of a household's annual income. Our highest estimates are equivalent to around 0.8 % which falls between the average values reported by Filippini and Martínez-Cruz (2016) (0.58 %) and Blackman et al. (2018) (1.00 %). Thus we believe that our estimates fall within a reasonable range despite arising from only non-zero answers.

A relevant issue that we have not considered in our afforestation scenario is that trees may also produce disservices associated with the potential allergenic, biogenic volatile organic compound emissions (Escobedo et al., 2011) and the water requirements (Vijayaraghavan, 2016; Azeñas et al., 2019). We leave an exploration of this issue to future research.

6. Conclusions

This study contributes to a nascent literature of contingent valuation studies valuing afforestation strategies to improve air quality in urban contexts –and, to the best of our knowledge, it represents the first attempt to do so in an arid city of an emerging economy. The scenario under analysis is an urban afforestation program with native trees in Mexicali, Baja California, Mexico. The estimated mean monthly WTP per household falls within the range of (2019) USD 6.29 and USD 8.26. The highest annual WTP estimated in this study is USD 99 and represents around 0.8 % of the annual household income. Residents' perception about air quality is an important determinant of their willingness to contribute monetarily to urban afforestation –with respondents perceiving poor air quality at their neighborhood reporting smaller willingness to contribute. Also, respondents with household members suffering frequent respiratory symptoms report a higher willingness to contribute monetarily.

The WTP estimates in this study suggest that the benefits from an urban afforestation program in Mexicali justifies the provision of at least 30 thousand mesquite trees at around (2019) USD 186 per two-meter tree seedling. Our results motivate the suggestion that policymakers in Mexicali and Baja California are missing out on two opportunities. On the one hand, they can initiate a communication campaign informing citizens about how to become beneficiaries of the State Urban Afforestation Program. On the other hand, they may want to consider a government-NGO partnership to administer potential citizens' contributions to the program.

CRediT authorship contribution statement

Dalia M. Muñoz-Pizza: Conceptualization, Funding acquisition, Investigation, Methodology, Software, Formal analysis, Writing - original draft. **Mariana Villada-Canela:** Conceptualization, Writing - review & editing. **Patricia Rivera-Castañeda:** Conceptualization, Writing - review & editing. **Marco A. Reyna-Carranza:** Conceptualization, Writing - review & editing. **Alvaro Osornio-Vargas:** Conceptualization, Writing - review & editing. **Adan L. Martínez-Cruz:** Conceptualization, Methodology, Writing - original draft.

Declaration of Competing Interest

The authors report no declarations of interest.

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[12] These numbers have kindly been provided by officials of the Environment Protection Agency of the State of Baja California, via personal communications, and complemented by consulting the Official Newspaper of the State.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2020.126854.

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