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Morbidity costs associated with ambient air pollution exposure in Sao Paulo, Brazil

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ABSTRACT

In 2007 we conducted a contingent valuation survey in Sao Paulo, Brazil, to estimate the population's willingness–to–pay (WTP) to avoid one hospital admission (HA) and one emergency–room visit (ER) due to respiratory diseases in adults and children younger than 5 years old; and cardiovascular diseases in adults only; both associated with atmospheric air pollution. Our annual mean WTP estimates are €81.82 (adult) and €137.92 (child) for HA; €48.40 (adult) and €90.66 (child) for ER due to respiratory diseases; €53.57 (ER) and €90.08 (HA) for cardiovascular diseases. Our results suggest altruism towards children, and a strong income effect on WTP. Results will help analysts evaluating the health benefits of specific policies with potential air pollution impacts in Sao Paulo, Brazil.

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1. Introduction

The Brazilian government created PROCONVE (Programa de Controle da Poluicao do Ar por Veículos Automotores – *Motor Vehicles Air Pollution Control Program*) in 1986 aiming to reduce air pollution levels in urban areas. The programme, which was based on international experience, established emission standards for new vehicles produced in or imported to Brazil. It aimed to promote and develop technology for sampling and analysing pollutants; to create vehicles' inspection and maintenance programmes; to promote public awareness of the vehicular air pollution problem; and to establish a criterion for evaluation of the programme's results (Ferraz and Seroa da Motta, 2001). PROCONVE was fully implemented between 1988 and 1997 and the average emission levels decreased substantially in Brazil.

In the state of Sao Paulo[(1)], an additional significant air quality problem arises with the burning off of sugar–cane straw, after the crop has been harvested for sugar and ethanol production. Ethanol is a commodity facing increased demand worldwide due to its expected benefits in reducing greenhouse gas emissions from fossil fuels that would otherwise be consumed. Brazil is one of the main exporters of ethanol and a substantial consumer itself, while the state of Sao Paulo is the main area of sugar cane cropping and ethanol production in Brazil. However, the health impact of increased pollution due to the use of fire in the sugar cane cropping can potentially be high and at least partially offset the environmental benefits of the use of ethanol.

This research is part of two projects co–ordinated by the Brazilian Ministry for the Environment (MMA) that aim (i) to evaluate the health benefits of the PROCONVE programme associated with the reduced ambient air pollution in six metropolitan areas of Sao Paulo; and (ii) to estimate the health costs associated with increased air pollution due to the use of fire in the agricultural sector in five cities of Sao Paulo state. The physical impacts of air pollution (mortality and morbidity cases) are estimated in separate studies within the projects[(2)]. However, in order to estimate the total health benefits (PROCONVE) and health costs (sugar cane straw burning), the number of avoided or additional cases of certain health conditions estimated in epidemiological studies need to be multiplied by unit values of the respective health outcome.

[(1)] The state of Sao Paulo has approximately 249 000 km^2, representing 2.9% of the national territory. It is the state of the federation with greater terri–torial occupation, population (around 42 million inhabitants), the largest economic development (agricultural – highlighting the ethanol activity, industrial and services) and the largest fleet of automobiles (19.9 million cars). As a consequence, the state has serious air quality problems, especially in the metropolitan areas of Sao Paulo and Campinas and the municipality of Cubatao. Table 1 shows the key indicators for the Metropolitan Region of Sao Paulo (CETESB, 2010).

[(2)] For example, the number of avoided cases of respiratory hospital admissions and deaths between 1991 and 2000 that can be attributable to the PROCONVE programme in Sao Paulo was estimated and shown in Table 2.

This paper aims to present estimates of the economic value of specific morbidity endpoints associated with air pollution in Sao Paulo, Brazil. It was the first time that an original contingent valuation study of morbidity endpoints was conducted in Brazil. We estimate average willingness to pay to avoid one hospital admission (HA) and one emergency–room visit (ER) for respiratory and cardiovascular diseases, the major health consequences associated with air pollution in Sao Paulo (e.g., Braga et al., 1999; Gouveia and Fletcher, 2000; Braga et al., 2001; Ribeiro and Cardoso, 2003; Bell et al., 2006). These average estimates can be used in evaluation of part of the health benefit[3] from the PROCONVE programme and for evaluating part of the health costs associated with increased air pollution due to the use of fire in sugar cane cropping for ethanol production in Sao Paulo.

The paper is organised as follows: a literature review is undertaken in Section 2. Section 3 presents the methodology used and the main characteristics of the contingent valuation survey, while Section 4 shows our results. Conclusions and discussions are presented in Section 5.

2. Literature Review

The theoretical basis for economically measuring morbidity effects of air pollution is given by the health production and choice model and its variations (e.g., Cropper, 1981; Harrington and Portney, 1987; Dickie and Gerking, 1991; Freeman, 2003). The economic costs of the health impacts of air pollution can be given by the sum of three different categories: (i) Resource costs: represented by the direct medical and non–medical costs associated with treatment for the adverse health impact of air pollution; i.e. all the expenses the individual faces with visiting a doctor, ambulance, buying medicines and other treatments, plus any related non–medical cost such as the cost of childcare and housekeeping due to the impossibility of the affected person in doing so; (ii) Opportunity costs: associated with the indirect costs related to loss of productivity and/or leisure time due to the health impact; (iii) Dis–utility *costs*: refer to the pain, suffering, discomfort and anxiety linked to the illness.

Two general approaches for valuing the benefits of reduced morbidity associated with environmental programmes are the cost of illness approach (COI) and the willingness–to–pay (WTP) approach. The first approach measures direct costs of morbidity such as the values of goods and services used to treat the illness; plus indirect costs of morbidity such as the value of forgone productivity. The cost of illness approach in general reflects the societal costs of illness and is often based on aggregated data. The WTP approach, instead, is based on individual data and assumes that the preferences of individuals can be characterised by substitutability between income and good health, that is, individuals make trade–offs between consumption of goods or services and factors that increase the consumer's health status. These trade–offs reveal the values individuals place on their health.

One of the pioneering valuation studies dedicated to morbidity effects of air pollution was developed by Tolley et al. (1986), who conducted a contingent valuation study in Chicago and Denver to elicit the WTP for light symptoms reductions and angina relief related to clean air programs in the US. The seven symptoms investigated were nausea, headaches, sinus problems, drowsiness, throat congestion, itchy eyes, and coughing. Tolley et al. (1986) observed that the standard assumption of decreasing marginal utility of health (or increasing marginal dis–utility of illness) held, that is, respondents tended to pay more when they had experienced more days with the symptoms. Other relevant studies include Alberini et al. (1997), Johnson et al. (2000), Navrud (2001); Stieb et al. (2002), Ready et al. (2004a), Ready et al. (2004b) and Hammitt and Zhou (2006).

Chestnut et al. (2006) estimated the WTP to prevent or reduce respiratory and cardiovascular hospitalizations by combining the cost of illness and the WTP approaches. It included a survey of patients who have been hospitalized for respiratory or cardiovascular illnesses, which allowed the authors to obtain individual cost of illness information which are not available in hospital usage databases, and the traditional WTP estimates. The study was designed to obtain the individual COI and WTP measures, and a societal COI measure based on hospital databases.

Chestnut et al. (2006) identified a significant downward bias in the WTP responses because many respondents believed that their health insurance should pay for the expenses to prevent or reduce future hospitalizations. A particular important result regards the individual medical costs estimates that were much smaller than those obtained in the social COI perspective (that obtained from aggregated databases). The authors argue that this result refers to the fact that most respondents had both health insurance and some paid sick leave, which reduced the perceived medical costs. However, when accounting for individual opportunity costs of time; individual COI estimates were significantly higher. This is primarily a consequence of the social COI perspective not accounting for post–hospitalization recovery periods.

The perspective of the analysis of morbidity effects is, thus, an important consideration since COI measures cannot account for the total economic costs (pain, suffering, etc.) and the WTP approach may not reflect medical expenditures and lost productivity which are important when market or social mechanisms that reduce the private costs for the patient are in place. Stieb et al. (2002)[4], Rozan (2001) and Chestnut et al. (2006) suggested that the WTP approach should be used to estimate only the dis–utility share of the total economic costs of morbidity, and obtain individual COI estimates using the same survey questionnaire used to elicit WTP[5]. However, both procedures are problematic: estimating WTP measures that do not account for consequences other than the dis–utility share proved to be a difficult task (e.g. Rozan, 2001; Stieb et al., 2002); and individual COI data necessarily requires a sample of individuals who have actually experienced the symptoms or endpoints. Otherwise, the costs of illness for those who had not been hospitalized are always zero. This means that the individual COI approach is essentially an ex–post approach, while the WTP approach is, instead, an ex–ante approach.

[3] The economic impacts of air pollution can be observed as reduced productivity in the agricultural sector, as the deterioration of buildings and materials, and, more importantly, as negative health outcomes for the population exposed to air pollutants. In this paper we focus on the health impacts only. In addition, the mortality effect of air pollution accounts for a significant share of the health costs of air pollution, but this paper is concerned only with the morbidity effect since the economic costs of mortality were the subject of another study (Ortiz, 2009; Ortiz et al., 2009). Finally, there are other morbidity effects than hospital admission and emergency room visit (e.g. cough, wheeze and other symptoms occurrences; asthma cases etc.), but we restrict this paper to those outcomes of higher economic significance.

[4] Stieb et al (2002) actually aggregate results of two different surveys into a single average total economic cost of specific endpoints. The authors assume that the WTP estimate obtained in one of these surveys (Johnson et al., 2000) would not reflect the value of lost productivity and the cost of treatment since most respondents in that study declared having health insurance and sick leave payment schemes.

[5] Rozan (2001) used the Delphi method to question medical experts about their standard medicine prescription, number of days of sick leave, additional examinations and special treatment necessary to treat each illness episode for each group of patients. Market prices were assigned to the convergent standard prescriptions to estimate the average individual COI.

Table 1. *Key indicators for the Metropolitan Region of Sao Paulo (CETESB, 2010)*

Shares of emission (%) per type of source in the Sao Paulo Metropolitan Region, 2009					
Source/Pollutant	CO	HC	NO_x	SO_x	PM_{10}
Light vehicles	71	80	16	16	11
Heavy vehicles	26	17	80	16	29
Industry	3	3	4	68	10
Suspension	0	0	0	0	25
Aerosol	0	0	0	0	25
Total	100	100	100	100	100

Annual average concentrations of main air pollutants in the Sao Paulo Metropolitan Region, 2009								
Pollutant	$PM_{2.5}$	PM_{10}	Smoke	TSP	SO_2	CO	NO_2	O_3
Unit	$\mu g/m^3$	$\mu g/m^3$	µg/m3	$\mu g/m^3$	$\mu g/m^3$	ppm	$\mu g/m^3$	$\mu g/m^3$
Concentration	16	34	34	59	5	2.1	75	91

Table 2. *The number of avoided cases of respiratory hospital admissions and deaths between 1991 and 2000 that can be attributable to the PROCONVE programme in Sao Paulo*

Age group	Hospital admission	Mortality
0 – 2	11 098	1 420
64+	1 337	184
TOTAL	12 435	1 604

Children form a group particularly susceptible to air pollutants (e.g., Braga et al., 1999; Braga et al., 2001). Although the epidemiological literature seems to be clear in identifying the morbidity effects of air pollution in children, the valuation of such effects still forms a grey area in economics since the WTP approach is based on the individualistic principle of welfare economics, which states that the individual is the best judge of his or her preferences. In the case of children, however, they do not have the necessary level of discernment to evaluate their preferences for changes in health states, neither the necessary knowledge to engage in economic decisions. Therefore, the usual practice in valuing children's health is to observe parents' behavior towards their children's health and safety, which introduces the issue of the role of altruism in cost–benefit analysis. Experimental evidence supports the idea that altruism is compatible with rational behavior. The impact of altruism on individuals' behavior and choices towards the provision of public goods should be addressed within cost–benefit analyses, but an open question regards which type of altruism drives consumers' behavior (Chanel et al., 2005)[(6)]. Examples of studies addressing this issue include Dickie and Ulery (2002) and Kohlova and Scasny (2006).

Studies that have used stated preference methods to evaluate health episodes tend to be vague in the survey instrument about the cause of the illness that causes the endpoints; how the illness would be avoided or how the improvement would be paid for. The resulting WTP values are then assumed to be applicable for policy analysis of any program that results in changes in numbers of that type of episode. This approach follows the standard purchase model in which utility and welfare are assumed to be determined only by policy outcomes, and not dependant on the policy process leading to the policy outcomes (Johnston and Duke, 2007).

However, the NOAA (The U.S. National Oceanic and Atmospheric Administration) expert panel on contingent valuation concluded that respondents could not reliably answer contingent valuation questions about environmental goods unless the hypothetical program to provide the good is described in detail. In fact, Johnston and Duke (2007) examined relationships between WTP for land preservation outcomes and attributes of the policy process. The authors showed that policy attributes may influence respondents' utility and WTP. Regarding health–related impacts of environmental programs, the cause of the ill health and the way it would be treated are inherent to the environmental program. For example, Bosworth et al. (2006) showed that WTP for mortality reductions varied regarding the way it would be achieved: whether using preventing or treatment mechanisms.

The risk involved in evaluating the illness endpoints in the context where the risks are generated is that the focus of respondents can be deviated from the endpoints themselves to the cause of the endpoints. For example, Rozan (2001) found that the main reason that respondents gave for refusing to engage in an air quality program that would prevent them to suffer some health symptoms was that respondents did not think they were polluters and should not suffer the financial consequences. Navrud (2001) claims that respondents are distracted in their valuation of the dis–utility of different symptoms once air pollution is mentioned as one of the possible causes for the increase in the frequency of symptoms. On the other hand, focusing on the endpoints in a context–free approach may cause respondents not to take the hypothetical scenario and WTP questions seriously enough to provide reliable estimates for policy analysis.

Ready et al. (2004a) found little evidence that the mention of the cause of the illness (air and water pollution) influenced respondents' stated WTP to avoid an illness episode, supporting the cost–saving practice of considering the cause of illness separately from its valuation. Rozan and Willinger (1999), in turn, showed that WTP for reducing symptoms caused by air pollution depends on the respondents being aware of the origin of the symptoms. The observed WTP of respondents who knew that air pollution was the origin of the bad health state was approximately 50% higher than WTP of respondents unaware of the origin of the symptoms. In summary, although there would be no theoretical basis for expecting a priori differences between WTP estimates generated by the alternative strategies, empirical results can either show a significant difference (Rozan and Willinger, 1999) or no difference at all (Ready et al. 2004a). This issue was investigated empirically in our pilot surveys, discussed below.

3. Materials and Methods

We conducted a face–to–face household survey in five cities in the Sao Paulo[(7)] state in Brazil between September and November 2007. The contingent valuation questionnaire elicited respondents' WTP for avoiding, during the following year, one hospital admission (HA) and one emergency–room visit (ER) due to respiratory diseases in one sample and due to cardiovascular diseases in another sample. The age groups investigated were

[(6)] Pure altruism, which in our case occurs when parents attach utility to the general utility level of their children; or paternalistic altruism, which occurs when parents´ utility depends only on their children´s health but not on their consumption of other goods. The reader can refer to Jones–Lee, (1991).

[(7)] Sao Paulo (capital), Araraquara, Ribeirao Preto, Taubate and Presidente Prudente.

those age groups most susceptible to these illnesses: adults older than 40 years and, for respiratory disease only, children aged between 0 and 5 years old, whose parents (of any age) were interviewed and elicited their WTP to avoid one HA and ER for one child picked randomly among the kids in the household. A representative sample of the population of the state of Sao Paulo was obtained following standard sampling procedures following age, gender and income quotas observed in official Census data for each city.

Prior to our final survey we conducted three pilot surveys in Sao Paulo capital in August 2007, with two hundred questionnaires in each pilot survey, in order to test different versions of the questionnaire. The main aspects tested in the pilot surveys regarded (i) the air pollution context versus a no–context scenario; (ii) the WTP elicitation format; and (iii) the payment vehicle to be used.

Our results using the air pollution context scenario (pilot 1) were better than the no–context scenario (pilot 2) in terms of respondents' acceptance, understanding and credibility of the main characteristics of the scenarios, given their answers to a number of debriefing questions in both questionnaires. In addition, several interviewers reported that respondents demonstrated far more interest during the interviews when the air pollution context was used. Consequently, we followed Johnston and Duke (2007) and assumed that explicitly informing the respondent of the origin of the reduced morbidity – reduction in air pollution levels due to the PROCONVE programme and the reduction in the use of fire in sugar cane crops – would result in WTP values that most precisely fit into the specific local context of the cost–benefit analyses. However, in order to avoid the potential risk of deviating attention of respondents from the health endpoints themselves to other impacts of air pollution, we informed respondents in our final survey that we were interested in evaluating only the health impact of air pollution; that one occurrence of each health endpoint could be avoided by air quality improvement or medical treatments; and that this (private) treatment is what we were interested in evaluating.

The WTP elicitation format chosen was the payment ladder, which allows for a range of uncertainty over the value respondents place on the commodity being valued (Hanley et al., 2003). Its advantage to the dichotomous choice format[8] for a relatively unfamiliar good such as health outcomes is that respondents may know for sure the values they would pay and those values they would not pay, but still have values that they are not sure about. In addition, with a payment ladder respondents are faced with a larger range of values to say "yes" or "no" to, it is likely that respondents will give more consistent answers since they spend more time thinking about the decision. The potential disadvantage of the payment ladder in comparison with other elicitation formats is that respondents are not familiar to the payment instrument and may make mistakes when eliciting their answers. However, pilot tests showed that respondents easily understood the mechanism, which was confirmed by interviewers who have undertaken the final survey.

The typical payment vehicles used in contingent valuation studies on the morbidity effects of air pollution, when they happen to be clearly specified in the questionnaires, are general daily expenses, taxes, household bills, or products such as medicines or treatments. We followed Hammitt and Zhou (2006) and proposed a personal treatment or medicine that would reduce, with certainty, one episode of respiratory/cardiovascular disease that requires a visit to an emergency room/an admission to hospital. By suggesting that, we make sure that respondents think about their own risks and make the valuation exercise similar to the more familiar exercise of buying goods in a pharmacy. In addition, we solve the problem on how the benefit would be delivered: buying the medicine/treatment would avoid with certainty one episode of the endpoint. The acceptance of the proposed medicine was high during the pilot surveys and, similar to other aspects of the questionnaire, was accepted by a greater percentage of the sample when the air pollution scenario was used. In addition, our confidence in the appropriateness of the delivery good also comes from interviewers reporting that several respondents inquired about the name of these medicines and when they would be available for purchase.

Another issue addressed in our study is the potential ordering effect commonly identified in contingent valuation studies (e.g., Bateman et al., 2006). In our first pilot survey we identified that respondents tended to show higher WTP to the health endpoint (HA or ER) elicited first. In our pilot 3 we tested questionnaires that elicited one health endpoint only and the mean and median WTP estimates were not significantly different from the results in the pilot survey where both endpoints were elicited together. Given that eliciting only one health endpoint per questionnaire would reduce our sample size with no observed significant benefits, in the final survey instrument we returned to the format where we elicited both health endpoints in each questionnaire, but split the samples into different orders: first hospital admission (HA) then emergency–room visit (ER); and; first ER then HA. We generate results combining observations in both formats (orders) to minimize potential ordering effects.

The general structure of the survey questionnaire includes: (i) a set of questions (filter) in order to check whether there is a potential eligible respondent in the household, according to the pre–defined sample stratification in terms of gender, education and income. It also describes the objectives of the survey, its non–commercial aspect and confidentiality; (ii) household composition; (iii) health status and attitudes towards health; (iv) perceptions about air pollution and health; (v) the scenario; (vi) WTP questions; (vii) debriefing questions; and (viii) socio–demographic questions.

4. Results

Our final sample consists of 1 200 households in the state of Sao Paulo, distributed in five cities. It was evenly divided among the age groups and diseases investigated, as detailed in Table 3. We identified protesters as those respondents, who stated WTP equal to zero for both health endpoints and, additionally, gave a non–economic reason[9] for doing so in an open question following the WTP question. For respiratory diseases, 11.12% of respondents stated WTP equal to zero to both endpoints, of which 49.4% were protesters; totaling 44 respondents protesting or 5.5% of the sample. For cardiovascular diseases, protesters were 8.75% (35 respondents).

The results shown below exclude protesters. As Table 4 shows, general socio–economic characteristics of our sample are not far away from the population's characteristics obtained in official Census data. The average individual and household incomes observed in our sample are lower than the population's averages, although the sample's education profile is slightly higher than the population's. The percentages of female in our samples match with the population of Sao Paulo.

[8] The dichotomous–choice format is recommended in most contingent valuation manuals (see for example Bateman et al., 2002 for a discussion on WTP question formats) because it better approximates the usual procedure of a market transaction, where the consumer faces a price tag and decides whether or not to buy the good.

[9] The most frequent explanation for WTP equal to zero which we considered protest was "It should be provided by the government, for free, via the public health system".

Table 3. *Total Samples (one adult per household)*

	Respiratory diseases		Cardiovascular diseases		Total
	HA ; ER	ER ; HA	HA ; ER	ER ; HA	
Adults 40+ (own WTP)	198	202	199	201	800
Parent´s WTP for children 0–5 years	200	200	——	——	400
Total	800		400		1 200

Table 4. *Socio–economic characteristics*

	Sample Respiratory diseases	Sample Cardiovascular diseases	Sao Paulo population[a] above 40 years (census data)
Mean individual income[b]	R$ 1 053 (€ 528.76)	R$ 1 123 (€ 563.91)	R$ 1 375 (€ 690.45)
Mean household income[b]	R$ 1 569 (€ 787.86)	R$ 1997 (€ 1 002.78)	R$ 2 296 (€ 1 152.92)
Average years of schooling	7.63	6.98	6.71
% female	51.06	50.68	51.51
% single, divorced or widowed	19.18	29.59	——
% own house	68.92	83.84	——

[a] *The population of the state of Sao Paulo equals 41 163 818, of which 35.06% is over 40 years old (IBGE, 2006)*
[b] *PPP–adjusted in parenthesis; last PPP US$ available for 2005 (US$ 1 = R$ 1.4; World Bank); exchange rate: €/US$ = 0.703 (http://www.xe.com/ict).*

Table 5 shows a variety of statistics regarding respondents' health status, history and attitudes towards health. It can be seen that a high percentage of the sample consider their own health relatively good. At the same time, respondents are familiar with the health endpoints being investigated as a high percentage of respondents themselves had at least one experience in emergency rooms or hospital admission, their relatives and/or their children. An important result shown in Table 5 refers to the percentage of respondents who have private health insurance[10]. This indicates that those respondents do not actually pay for most of the resource (medical) costs involved in a hospital admission and emergency–room visit. As discussed later, this influences which components of welfare costs the WTP stated preferences refer to.

Before the scenario information was given to respondents and the WTP questions posed, respondents were asked about their previous knowledge of air pollution issues and the relationship between air pollution and their health, and whether they had heard about the programmes being valued in our study. The results shown in Table 6 suggest that the relationship between air pollution and respiratory and cardiovascular diseases is a well known subject for respondents.

In order to enable us to infer how credible the scenario was to respondents, and their WTP responses, a number of debriefing questions were asked after the scenario information was given and the WTP questions posed. Results about the acceptance of the scenario and delivering instrument (medicines), shown in Table 7, are very good and positive; that is, the vast majority of respondents believed that air pollution can cause respiratory/ cardiovascular diseases for themselves; that the medicines can prevent cases and the impact of respiratory/cardiovascular diseases on themselves; and that the medicines can prevent cases of HA and ER for themselves. Other positive results refer to whether respondents considered their budget when stating their WTP, and that they considered their suffering, pain and work–day losses. This issue is discussed further below.

[10] The health system in Brazil is universal in a sense that every citizen has the right to obtain medical assistance in the public health system. However, due to the poor quality of the public health assistance, a significant share of the population relies on private health insurances for their health treatments: 24.5% nationwide and 39% in Sao Paulo state (Kilsztajn et al., 2001), These estimates refer to year 1998 but the most recent national census available (IBGE, 2003) presents similar percentages.

However, a relatively high number of respondents considered side effects of the medicine and other effects of air pollution than HA and ER, although the questionnaire stressed our interest in the human health effects only. Two–sample mean–comparison tests (t–tests) were performed to investigate whether the mean WTP of those who did not consider other effects of air pollution was statistically different (at the 95% level) from the mean WTP of those respondents who did. As seen below, we did not perform any arbitrary adjustment in our estimates on the basis of these results.

As a result of the payment card being used in our study, we do not observe the respondents' WTP directly but instead observe the interval in which the WTP is. The responses to the payment card were combined to generate intervals in which the respondents' WTP are to be found. In our econometric analysis we used accelerated failure–time (survival) models, which are appropriate for dealing with dependent variables that are in the form of interval data, assuming the non–negative distributions (Weibull, exponential, lognormal and log–logistic). We used the software STATA v.10 in all analyses. Table 8 shows our mean and median WTP estimates using all non–negative models in a constant–only format, that is, with no regressors explaining WTP as suggested in Bateman et al. (2002). As expected, WTP to avoid one hospital admission was consistently higher than WTP for avoiding one emergency–room visit given that the costs and the severity of the illness should be higher if the patient needs to be admitted in hospital. In order to select the best–fit probability distribution to each sample data, the Akaike information criterion was used (Akaike, 1974) and, as a result, the log–logistic model is assumed in our subsequent analyses, being the best–fit distribution in the majority of samples.

One issue that can be observed in our results in Table 8 is the potential altruism of parents towards their children reflected in their WTP to avoid one occurrence of a health outcome for their children. Due to limited resources and the fact that this was not the central objective of our study, we did not elicit WTP values for avoiding one heath outcome for parent and for son/daughter in the same questionnaire. Instead, we interviewed adults older than 40, in order to elicit their WTP to avoid one health outcome

Table 5. *Subjective health status; life–style; attitudes towards health and family health history*

Percentage of respondents who:	Respiratory	Cardiovascular
Consider own health status good or very good [a]	71.7	66.0
Avoid unhealthy food	54.6	64.4
Smoke	26.5	23.6
Have medicine or vitamins regularly	36.9	54.0
Exercise or go to a gym regularly	27.8	32.6
Avoid smoky areas	68.4	76.2
Drink alcohol [c]	15.6	11.0
Have a private health insurance	55.4	64.1
Have or had asthma/angina [b]	21.2	11.5
Have or had bronchitis/high blood pressure [b]	43.8	80.8
Have or had other respiratory/cardiovascular disease [b]	42.2	36.2
Have or had an emergency–room visit for resp./card. Diseases [b]	47.9	35.6
Have or had a hospital admission for resp./card. diseases [b]	21.4	21.9
Have or had an emergency–room visit for other diseases [b]	93.8	89.6
Have or had a hospital admission for other diseases [b]	85.7	83.8

[a] *Subjective health status as compared to other individuals at the same age.*
[b] *Occurrence observed in the respondent and/or his/her parents and children.*
[c] *The question did not specify a frequency for drinking alcohol; the possible answers were ´yes´; ´no´ or ´sometimes´. The percentages shown correspond to the ´yes´ answers only*

Table 6. *Previous information about health effects of air pollution*

Percentage of respondents who:	Respiratory	Cardiovascular
Think that air pollution affects their health	97.5	96.7
Think that air pollution affects their children's health	97.9	97.0
Think that air pollution can cause respiratory diseases	98.5	99.4
Know that air pollution can be caused by different sources (transport, industry, agriculture, cigarettes)	98.9	99.2
Heard about a programme that aims to reduce vehicles emissions	81.3	83.6
If yes, knew that this programme is called PROCONVE	20.8	24.3
Know that sugar cane residuals are burnt and it can cause air pollution	86.2	91.2

Table 7. *Debriefing questions*

Percentage of respondents who:	Respiratory	Cardiovascular
Believed that an improvement in air quality can reduce the cases of respiratory/cardiovascular diseases to themselves.	94.8	91.5
Believed that the proposed new medicines can prevent cases of respiratory/cardiovascular diseases to themselves.	66.4	62.5
Believed that the proposed new medicines can reduce the impact of respiratory/cardiovascular diseases to themselves.	70.1	66.0
Believed that the proposed new medicines can prevent HA and ER for themselves.	64.9	63.3
Considered any side effects of the new medicines.	53.6	51.5
Considered that they would have to give up other goods in order to buy the medicine.	79.2	78.6
Considered their pain and suffering involved in a HA and ER episode when stating WTP for the medicines.	90.1	85.2
Considered their work–day losses and/or school days losses when stating WTP for the medicines.	84.3	78.4
Considered other impacts of air pollution (other than HA and ER) when stating WTP for the medicines.	77.5	71.8
Considered their budget when stating WTP for the medicines.	88.2	89.6

Table 8. *Annual WTP for avoiding 1 hospital admission and 1 emergency–room visit (PPP–adjusted €2 007)*

	Respiratory				Cardiovascular	
	Adult 40+		Children 0–5		Adult 40+	
MEAN	**HA**	**ER**	**HA**	**ER**	**HA**	**ER**
Weibull	67.90	42.69	115.78	70.38	77.58	47.68
Exponential	77.70	48.08	125.59	73.41	91.36	54.55
Log–logistic	**81.82**	**48.40**	**137.92**	**90.66**	**90.08**	**53.57**
Log–normal	62.56	38.79	112.45	70.98	70.18	43.05
MEDIAN						
Weibull	29.73	20.09	54.54	37.20	31.18	21.21
Exponential	53.85	33.32	87.05	50.88	63.33	37.81
Log–logistic	**25.15**	**17.02**	**44.86**	**30.93**	**25.59**	**17.68**
Log–normal	25.75	17.67	46.36	31.44	26.82	18.50

Notes: PPP US$ 2005 (US$1 = R$ 1.4; World Bank); exchange rate: €/US$ = 0.703 (http://www.xe.com/ict).

for themselves and separately interviewed parents of any age but with children younger than six years old in the household[(11)].

However, we can compare WTP estimates for children and adults to have an insight to what extent there is a potential altruism in our estimates. Table 6 shows that mean and median annual WTP are consistently higher for children than for adults in every model used. In addition, t–tests comparing mean annual WTP values for adults and children confirmed that the latter were statistically higher (at the 95% level) than the former. The marginal rate of substitution between children and adults ranged between

[(11)] This fact characterizes the parental perspective, important to estimate social benefits of public policy since the underlying model adopts the unitary approach, in which parental decisions are guided by the expected utility function and perceived risks (e.g., Viscusi et al., 1988).

1.68 and 1.78 for hospital admissions and between 1.81 and 1.87 for emergency room. This result is similar to those found in the literature where the ratio between the WTP to avoid a certain health risk in children and that in parents is approximately 2 (e.g. Liu et al., 2000; Dickie and Gerking, 2007; Hunt and Ortiz, 2006). Our results tend to confirm that estimating willingness to pay for children's health by transferring estimates computed for adults on a one–to–one basis would appear likely to substantially understate children's health benefits.

Other results observed in the altruism literature include (i) mothers stating WTP 20% greater for sons than for daughters (Liu et al., 2000); (ii) parents' WTP to avoid own or child illness declining with fertility (Dickie and Ulery, 2002); (iii) single parents tending to state higher WTP for children than married parents (Dickie and Ulery, 2001; Kohlova and Scasny, 2006). We performed regression analyses (not reported in this paper) on those variables that, according to this literature, might explain the observed altruism between parents and children. Women stated higher WTP for children than men, but gender was not relevant in the analysis of WTP for reductions of own risks. Respondents who already experienced respiratory illnesses (in themselves, their parents or their children) and those who had to visit an emergency room or had to be admitted in a hospital (themselves, their parents or their children) expressed a higher WTP for their children, which is a result in accordance with Kohlova and Scasny (2006). In addition, our results suggest that if parents know that air pollution causes damages to their children's health, they state a higher WTP, which matches with results in the analysis of altruism undertaken by Chanel et al. (2005).

We estimated regression models of WTP against the usual socio–economic characteristics of the respondents and other attitudinal variables in order to test whether WTP responses varied according to respondents' income and other characteristics or, otherwise, were randomly assigned. Table 9 shows the results obtained for a general model (model 1) containing the main variables in our dataset that a priori we suspected could explain WTP responses. Given that the variable representing the household income consistently showed the highest level of significance, while other relevant socio–economic variables did not, we investigated the relationship between income and other socio–economic variables using regressions and correlation analysis. As expected, variables such as education and gender were highly correlated with income. We therefore estimated a reduced model (model 2) with only income as the socio–economic variable and those attitudinal variables that showed significance in at least one of the sub–samples in model 1.

As can be seen in Table 9, in addition to income, variables that were consistently significant in explaining WTP for avoiding health outcomes due to respiratory diseases include (i) whether the respondent or any of his/her family members had asthma, bronchitis or other respiratory disease; (ii) whether respondents believed that air pollution could affect their health; (iii) how credible the proposed medicine was for the respondent; and (iv) whether respondents considered their pain, suffering and work–day losses when stating their WTP.

Regarding the variables that explain WTP for avoiding a health outcome due to cardiovascular diseases, in addition to income, others that are significant at 5% include (i) whether the respondent and his/her family have private health insurance; (ii) the degree of respondents' faith in one religion; (iii) whether there are children younger than 6 years in the household; and (iv) whether respondents smoke and/or drink alcohol.

5. Discussion and conclusions

This paper presents results of a contingent valuation survey used to estimate the WTP of the population for prevented health outcomes associated with air pollution in the context of the PROCONVE program and the use of fire in sugar cane crops in Sao Paulo, Brazil. It was the first time that such original contingent valuation study of morbidity effects associated with air pollution was undertaken in Brazil, and it contributes to the scarce literature of similar studies in developing countries. Our annual WTP estimates were obtained assuming the log–logistic distribution and results range between (PPP–adjusted) €81.82 and €90.08 for an adult's hospital admission due to respiratory and cardiovascular diseases, respectively (€48.40 – €53.57 for an adult's emergency–room visit due to respiratory and cardiovascular diseases, respectively). For children aged between 0 – 5 our central result is €137.92 (HA) and €90.66 (ER), suggesting some parent's altruism towards their children. In order to put our results in perspective, Ready et al. (2004b) report WTP estimates for these end–points in five European countries. The authors estimated annual WTP to avoid an adult's hospital admission due to respiratory diseases equal to €468, while annual WTP to avoid one emergency–room visit was €242. Our respective results were €81.82 and €48.40; approximately five times lower than the European results, a difference that may be partially explained by income differentials among the countries[12] (see also discussion below about WTP elasticity of income).

However, we suspect that our results present an upward bias, given that approximately 75% of respondents stated that they considered other effects of air pollution when stating their WTP. Global warming was the other effect of air pollution most mentioned by respondents (60%), followed by acidification (19%) and depreciation of building materials (7%). Whilst we have not attempted to adjust our results for the observed possible bias, it adds a further dimension of uncertainty in their use in policy analysis. The observed potential upward bias was a consequence of our decision in eliciting WTP for health outcomes in an explicit air pollution context. Given that air pollution and its consequences are well known problems to the population of Sao Paulo, it has proved difficult for respondents to disassociate other conse–quences of air pollution from their WTP. On the other hand, based on our pilot tests of a context–free scenario, we believe that using the air pollution scenario is preferable in terms of the trade–off between scenario credibility and potential biases. In addition, since WTP estimates can vary according to policy characteristics (e.g. Johnston and Duke, 2007) it is important for policy evaluation to obtain WTP estimates in the context of the programmes being analysed in our study.

Another important issue is the extent to which our results reflect the total economic cost of morbidity. We explicitly asked respondents to consider all costs involved in one hospital admission and emergency–room visit – resource or medical, opportunity, and dis–utility costs – when stating their WTP for the medicine that would avoid one HA and/or ER with certainty. However, our results suggest that WTP estimates refer only to the intangible share of the economic costs of health endpoints; that is, they represent the WTP to avoid the dis–utility (pain and suffering) of having a hospital admission and an emergency–room visit.

Separately, we used the (social) cost of illness approach to estimate the average medical and opportunity costs involved in one episode of our health outcomes in Sao Paulo. Government data (http://www.datasus.gov.br) on average medical costs of one adult hospital admission for respiratory and cardiovascular diseases in Sao Paulo are on average R$2 000 (approximately €1 004), not including the patient's medical costs such as medicines. The opportunity cost of one adult's hospital admission equalled R$300 (€151) based on average wages in Sao Paulo, and the average time an adult spends in hospital for respiratory and

[12] For example, in 2007 the PPP–adjusted GDP per capita in Germany was 3.5 higher than the equivalent in Brazil: US$ 34 181 / 9 695 (IMF, 2008).

Table 9. *Validity tests of WTP – accelerated failure–time models assuming the logistic distribution (log–logistic model)*

	Respiratory				Respiratory				Cardiovascular			
	Model 1				Model 2				Model 1		Model 2	
	Adults HA	Adults ER	Children HA	Children ER	Adults HA	Adults ER	Children HA	Children ER	Adults HA	Adults ER	Adults HA	Adults ER
Household income	0.0003[c]	0.0003[c]	0.0002[c]	0.0002[c]	0.0003[c]	0.0003[c]	0.0003[c]	0.0003[c]	0.0001[b]	0.0001[c]	0.0001[b]	0.0001[c]
Years of education	0.0068	0.010	0.037[a]	0.028					0.018	0.015		
Age	–0.143[a]	–0.113	0.026	0.004					0.055	0.082		
Age square	0.001	0.0008	–0.0005	–0.0002					–0.0005	–0.001		
Female	–0.160	–0.031	–0.122	–0.185					–0.186	–0.017		
Subjective health status	0.011	–0.013	–0.069	0.004					–0.057	–0.137		
Nr children 0 – 5 years in the household	0.166	0.160	0.095	0.149					–0.247[b]	0.046	–0.236[b]	0.041
Nr children 6 – 18 years in the household	–0.102	0.021	–0.041	–0.078					–0.011	–0.074		
Married or cohabiting	–0.118	0.024	–0.037	–0.174					0.026	0.244		
Religious	0.124	0.053	–0.071	–0.079					–0.298[b]	–0.255[b]	–0.390[c]	–0.318[c]
Health insurance	0.124	0.014	–0.024	0.171					0.371[b]	0.322[b]	0.437[c]	0.475[c]
Considered side effects of medicine	–0.179	–0.196	–0.062	0.051					0.089	0.082		
Positive attitudes towards health	0.099	0.198	0.093	0.189					–0.134	–0.096		
Negative attitudes towards health (smoking and/or drinking)	–0.097	–0.212	0.107	–0.059					0.276	0.515[c]	0.273	0.511[b]
Occurrence of resp/card diseases in the family	0.335[b]	0.371[b]	0.298[b]	0.157	0.311[b]	0.351[b]	0.300[c]	0.203	–0.189	0.016		
Occurrence of HA and/or ER in the family	–0.145	0.222	–0.191	0.542					0.423	0.223		
Believed that air pollution can affect own and family's health	–0.513	–0.853[b]	–2.080[a]	–2.338[b]	–0.237	–0.645[b]	–2.130[b]	–1.905[c]	0.538[b]	–0.101	0.613[b]	0.051
Believed that the medicine can prevent health outcomes	0.375[b]	0.312[b]	0.311[a]	0.402[b]	0.357[b]	0.272[b]	0.301[a]	0.424[b]	–0.041	0.168		
Considered pain and suffering; and work–day loss	0.668[c]	0.407[a]	0.687[a]	0.556[a]	0.697[c]	0.446[b]	0.568	0.438	–0.023	–0.086		
Previous knowledge about the PROCONVE and sugar cane fires	–0.068	0.257	0.111	–0.068					0.045	0.208		
Constant	8.019[c]	6.266	5.169[c]	5.09[c]	2.757[c]	3.06[c]	5.221[c]	4.734[c]	2.643	1.188	3.985[c]	3.658[c]
Observations	301	296	351	342	301	296	351	342	308	300	308	300
log pseudo–likelihood	–468.6	–444.5	–550.0	–527.3	–478.4	–455.0	–560.8	–540.6	–510.1	–469.3	–515.6	–478.9

Notes: Robust standard error in parentheses; [a] significant at 10%; [b] significant at 5%; [c] significant at 1%.

cardiovascular diseases. Comparing our WTP results (ex–ante approach) with these official statistics (ex–post approach) make it difficult to believe that the resource and opportunity costs were included in the WTP stated by the majority of the respondents.

We argue that there are two reasons for our results representing the intangible share of the economic costs only: (i) over half the respondents have private health insurance, which covers 100% of their medical costs – 55% in the respiratory sample and 64% in the cardiovascular; (ii) respondents in a formal job (approximately 30% for respiratory disease and 15% for cardiovascular) have sick leave schemes and so do not lose all their wage while they are at hospital – other 30% of our samples were self–employed and 40% retired, unemployed or students in the respiratory dataset; in the cardiovascular disease dataset 25% of respondents were self–employed and 60% retired, unemployed or house–keepers. This issue has been raised by Freeman (2003), who states that WTP estimates may not be higher than those obtained using the cost–of–illness approach in countries where well established social security schemes are in place. Other studies (e.g. Stieb et al., 2002) assume that the WTP estimates obtained did not reflect the value of lost productivity and the cost of treatment since most respondents in these studies declare having health insurance and sick leave payment schemes. In addition, as discussed in Section 2, the ex–ante characteristic of the WTP measures adds another difficulty for respondents eliciting their true WTP value, since those respondents who did not experience an emergency–room visit or a hospital admission may not know the magnitude of their actual medical costs and their opportunity cost of work.

In the light of the potential biases discussed above, our annual WTP estimates should be seen with caution when used for policy analyses in Brazil or elsewhere (e.g. benefit transfer). However, analysts interested in developing contingent valuation studies of morbidity endpoints related to air pollution, especially in developing countries, can benefit from our experience and the problems that we faced in undertaking this study. Our main lessons learned refer to the difficulty that respondents have to dissociate the health endpoint from the cause of illness that causes the endpoint; and how respondents can better consider their medical (resource) costs and the opportunity cost of their time when stating WTP measures for avoiding health endpoints. These points definitively deserve further research and empirical tests.

Finally, household income was the main determinant of WTP estimates in our study, a result in line with economic theory and other contingent valuation studies in Brazil and other developing countries. This suggests that income plays an important role in stated WTP in developing countries, dominating all other socio–economic variables. In order to further investigate the effect of income in our WTP estimates we calculate the marginal effect of income on WTP, per income level of respondents, using our most robust regression model (model 2 in Table 9).

As can be seen in Table 10, we divide our sample into those with household income lower, and higher, than R$2 000 (€1 004) because our median household income lies in that income range. It shows the estimated income elasticities of WTP in our sample. If we assume different scenarios for annual GDP increase in Brazil (say, 1%, 3% and the current 5%), and that the disposable income of households will increase at the same pace, we could expect WTP estimates to increase according to the elasticities in Table 10. These estimates are relevant for future benefit transfer exercises that would include income adjustments with income–elasticity of WTP in Brazil.

Table 10. *Income elasticity of WTP ($\partial \log(\text{WTP}) / \partial \log(\text{income})$) – accelerated failure–time model – Log–logistic distribution*

	Respiratory				Cardiovascular	
	Adult 40+		Children 0–5		Adult 40+	
	HA	ER	HA	ER	HA	ER
Household income lower than R$2 000	0.554	0.501	0.630	0.679	0.783	0.793
Household income higher than R$2 000	0.928	0.823	0.505	0.488	0.089	0.191
Total sample	0.473	0.475	0.446	0.429	0.218	0.236

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