Climatic Change (2008) 90:299–313
DOI 10.1007/s10584-008-9414-0

OpenAccess

"A convenient truth": air travel passengers' willingness to pay to offset their CO_2 emissions

R. Brouwer · L. Brander · P. Van Beukering

Received: 7 February 2007 / Accepted: 20 February 2008 / Published online: 22 April 2008

Abstract Several economic reviews demonstrate the substantial costs related to climate change and consequently call for early action. These reviews, however, have been limited to measuring 'objective' risks and expected material damage related to climate change. The 'subjective' perceived risk of climate change and society's willingness to pay (WTP) to avoid these risks are expected to provide an important additional motivation for direct action. We investigate whether and why air travel passengers—an increasingly important source of greenhouse gas emissions—are supportive of measures that increase the cost of their travel based on the polluter pays principle and compensate the damage caused by their flight. Compared to the results of the few previous studies that have elicited WTP estimates for climate policy more generally, our results appear to be at the lower end of the scale, while a comparison to estimates of the social cost of carbon shows that the average WTP estimate in this study is close to the estimated marginal damage cost. Although significant differences are found between travellers from Europe, North America, Asia and the rest of the world, we show that there exists a substantial demand for climate change mitigation action. The positive risk premium over and above the expected property damage cost assessments should be accounted for more explicitly in economic reviews as it will add to the burden of proof of direct action. Measurements of passenger WTP will help policy makers to design effective financial instruments aimed at discouraging climate-unfriendly travel activities as well as to generate funds for the measures directed at climate change mitigation and adaptation. Based on stated WTP by travellers to offset their greenhouse gas emissions, funds in the order of magnitude of €23 billion could be generated annually to finance climate change mitigation activities.

R. Brouwer (✉) · L. Brander · P. Van Beukering
Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands
e-mail: roy.brouwer@ivm.vu.nl

1 Introduction

Climate change has evolved from an “inconvenient hypothesis” to an “inconvenient truth”. The scientific evidence for anthropogenic global warming is overwhelming (Gore 2006). Also further down the cause–effect chain, on the impact-side of climate change, evidence is accumulating rapidly. Although estimates of the social costs of greenhouse gas (GHG) emissions are highly sensitive to the assumptions made (e.g. the choice of discount rate, equity weighting, corrections for risk aversion and adaptive behaviour), various reviews demonstrate the substantial expected economic costs related to climate change (e.g. Tol 1999; Pearce 2003; Stern 2006). All reviews point in the same direction: ‘the benefits of strong and early action far outweigh the economic cost of not acting’ (Stern 2006)[1].

These reviews raise two important issues. First, there is the question as to whether the estimated costs of climate change are accurate. It can be argued that the estimates are in fact incomplete in that they are based on expected property damage costs determined through ‘objective’ measurements of the risks involved, not the theoretically correct ‘subjective’ expected utility values. The benefit-cost ratios based on property damage costs alone may substantially underestimate the total benefits since it does not account for public risk aversion. Tol (1999) presents estimates of marginal damage costs that are adjusted to reflect risk aversion, which are around three times higher than the unadjusted costs. These latter well-being effects, measured in economics through the concept of society’s willingness to pay (WTP) to avoid a specific risk when people are not entitled to risk protection, should be added to the expected damage costs (e.g. Jones-Lee 1989; Pearce and Smale 2005). Since the 1970s it has become generally accepted that effective risk and natural hazard management should not be informed by objective measures only, but should also include subjective risk assessments that reflect people’s social cognition of risk (Slovic 1987; Cvetkovich and Earle 1992; Beck 1992).

Second, despite consensus within the academic community on the need to act now, it remains to be seen whether policy makers and polluters are truly willing to take the necessary steps to avoid further climate change and related economic costs. There is currently very limited evidence whether or not people perceive climate change as a threat worth avoiding (e.g. Cameron 2001, 2005; Layton and Brown 2000; Layton and Levine 2002).

The main objective of this study is to investigate whether there is a demand for climate change mitigation action and examine what motivations underlie this demand. More specifically, we aim to reveal whether air travel passengers as polluters are supportive of measures that increase the cost of their travel and compensate the damage caused by their flights, and to quantify the benefits they obtain from mitigating their emissions. This provides an indication of the before mentioned economic welfare measure currently missing in economic reviews in support of direct action to avoid the future risks of climate change. We compare this with the existing cost and benefit estimates. Moreover, such measurements of passenger WTP helps policy makers to design effective financial instruments aimed at discouraging climate-unfriendly travel activities as well as to generate funds for the measures directed at climate change mitigation and adaptation.

To meet these objectives, we conducted a survey of air travel passengers at Amsterdam Schiphol airport, one of the largest airports in Europe. By focusing specifically on air travel

[1] The Stern Review has been criticised for its choice of assumptions and the resulting high estimate of damage costs. Adjusting these assumptions towards more generally acceptable values, however, still results in estimates of damage costs that warrant extensive greenhouse gas mitigation (Arrow 2007).

passengers we also aim to contribute to current policy developments regarding the control of GHG emissions from aviation. Driven by the polluter-pays-principle, governments are currently considering the implementation of various policy instruments to extract funds for climate change mitigation from the aviation industry and its passengers. For example, in early December 2006 UK chancellor Gordon Brown announced a doubling of air passenger duty on flights. Two weeks later, the European Commission announced that internal EU flights would be included within the EU emissions trading scheme from 2011.

The remainder of this paper is organized as follows. Section 2 introduces the relationship between aviation and climate change, and touches upon the issue of carbon offsetting initiatives. Section 3 presents the research methodology, including the introduction of a carbon travel tax for air travellers to offset their contribution to climate change. The main results are presented in Section 4 and Section 5 concludes.

2 Aviation growth and greenhouse gas emissions

Aviation traffic has increased dramatically over the past 40 years, with passenger traffic growing at approximately 9% per year since the 1960s (IPCC 1999). Although this level of growth is anticipated to slow down to some extent as markets in North America and Europe mature, the number of passenger kilometres flown is projected to continue to grow at 5% per year globally. In 2002, global civil aviation clocked up roughly 33 billion kilometres, and this is set to double over the next 20 years (Eyers et al. 2004). This level of aviation activity and the associated increase in emissions of GHG has raised concerns over the impact of aviation on the global climate, and the compatibility of aviation expansion with policies to address climate change.

Aviation uses fossil fuels and consequentially emits carbon dioxide (CO_2) and other GHG including methane and nitrous oxide. Fuel use in aviation is projected to increase at 3% per year—this is lower than the projected growth in passenger kilometres due to continuing improvements in aircraft efficiency. In comparison to terrestrial sources of emissions, however, aviation is recognized as having an enhanced global warming effect due to the altitude at which aircraft fly (IPCC 1999). This enhanced effect is estimated to be between two and four times the global warming potential of the CO_2 emissions from aviation. The best estimate of the contribution of aircraft emissions to human induced global warming is that aviation accounted for 3.5% of the total radiative forcing by all anthropogenic activities in 1992. This is not a high figure, but due to the projected growth in aviation, this could rise to 15% by 2050 (IPCC 1999).

Given the anticipated rise in GHG emissions from aviation there is a recognized need to control and compensate for these emissions. An international agreement on the control of emissions from aviation has, however, been impeded by the international nature of the industry and the lack of agreement on how emissions should be allocated (Oberthur 2003). GHG from aviation are currently only included in national emissions inventories under the UN Framework Convention on Climate Change for informational purposes and are not restricted by the emissions targets agreed under the Kyoto Protocol. Article 2.2 of the Kyoto Protocol merely asks industrialized countries to pursue the reduction of GHG from aviation through the International Civil Aviation Organisation (ICAO), which is still considering a range of technical, air traffic management, and market based instruments. The European Commission has recommended that intra-EU and international aviation should be included within the EU emissions trading scheme (ETS), but this proposal faces difficulties in terms of international legality and compatibility with the Kyoto Protocol (Cairns and

Newson 2006). It should be noted that the U.S. Government does levy a tax on aviation fuel used for domestic flights by U.S. commercial aircraft. This tax is not applied to fuel purchased by non-U.S. airlines or to fuel used for international flights (Cairns and Newson 2006). There is some doubt, however, over whether policy instruments such as tax and emissions trading that simply raise the cost of aviation would result in any significant decrease in fuel use and GHG emissions. Boon et al. (2007) find that around 100% of the costs of the EU ETS would be passed directly on to customers. Olsthoorn (2001) finds evidence that the price elasticity of demand for fuel is low, which suggests that a tax set at around the level of marginal external costs of CO2 emissions would only result in negligible reductions in emissions.

An alternative policy option for controlling the climate change impact of aviation, which conforms to the polluter pays principle, is a hypothecated tax on aviation, with the revenue being spent on carbon offsets. Carbon or GHG offsets are certified emissions reductions or sequestration that can be purchased by an individual, business or government to offset the emissions resulting from their activities. Offsetting essentially involves balancing GHG emissions from one activity with purposeful GHG reductions or sequestration from another activity in order to maintain "carbon neutrality". For example, as hosts of the 31^{st} G8 summit in July 2005 in Scotland, the UK government purchased offsets for the GHG emitted from air travel to the summit.

Carbon offsetting activities may include reforestation, renewable energy, and energy efficiency projects. Uncertainties regarding the measurement and permanence of GHG emission reductions, particularly with respect to carbon sequestration, have resulted in concerns over the credibility of offsets. There are now many commercial and non-profit providers of carbon offsets. A survey of 16 offset providers, covering the gamut of project types, locations, and commercial status, indicates a range of offset prices from €3.30 to €23 per ton (t) CO_2-equivalent (eq), with an average of €11.80 tCO_2-eq (prices are for December 2nd 2006—www.ecobusinesslinks.com 04/12/2006). Given the fact that most of these schemes depend on voluntary compliance, the main question is whether, in the current situation of high airport taxes and fuel surcharges, airline passengers are willing to pay for their CO_2 emissions.

3 Valuation methodology

The economic valuation method applied in this study is called contingent valuation (CV). CV is a social survey method where individuals are presented with information about specific environmental changes, the values of which are not accounted for in economic markets or fully captured through market-based instruments. In the survey, individual perception, attitudes and preferences regarding these changes and their non-market values are elicited. In order to measure the effect of the suggested changes on people's welfare, respondents are typically asked for either their willingness to pay (WTP) or their willingness to accept (WTA) compensation for the gains or losses involved (Mitchell and Carson 1989; Bateman et al. 2002). Of these options the WTP approach has become the most frequently applied and has been given peer review endorsement through a variety of studies (e.g. Arrow et al. 1993).

Aggregated across those who benefit from the services provided by ecosystems and natural resources, the aggregated WTP or WTA amount provides an indicator of the total economic value (TEV) of any change in their provision, including their quality level. Environmental economists have introduced a taxonomy of this TEV, distinguishing between use and non-use values, in order to account for the various reasons and motives people may have to value environmental change. Stated preference methods like CV are the only economic methods that are able to account for possible non-use motivations underlying people's value statements. Whereas use values refer to the values associated with the actual use of the various goods and services provided by ecosystems and natural resources, non-use values are unrelated to any actual or potential use, and may refer for example to the value people attach to preserving ecosystems or species (existence values) or the value they attach to leaving a healthy environment behind for future generations (bequest value).

In a two-day CV survey, carried out in the beginning of November 2006 at Amsterdam Schiphol airport, the fourth largest airport in Europe after London Heathrow, Paris Charles de Gaulle and Frankfurt with over 44 million passengers and more than 420 thousand flights in 2005 (Schiphol Group 2006), more than 400 air travel passengers from around the world were interviewed face-to-face about their travel behaviour, awareness of the environmental impacts of their travel behaviour and their WTP for a carbon travel tax to offset their contribution to the emission of GHG. Together these passengers travelled 1.6 million kilometres, emitting 375 tCO_2-eq (one-way). Passengers either arriving or departing on 8 or 9 November from Schiphol airport were interviewed for about 10 to 15 min using a thoroughly pre-tested questionnaire consisting of 35 questions. Passengers were selected randomly at a next-to-pass basis[2]. Three quarters of the questions are closed-ended in order to minimize the necessary interview time. The WTP questions are reproduced in the Appendix to this paper.

4 Results

4.1 Passenger characteristics and awareness of the impacts of flying

Most interviewed passengers are male (60%), ranging in age between 18 and 83 years, with an average age of 38 years. Forty percent of the passengers interviewed travel by plane for business, the rest for pleasure or a combination of business and pleasure. Almost 80% flies alone, 20% with one or more family members. The variety of passenger nationalities is presented in Fig. 1. The sample population is close to the inter-regional passenger movements from Schiphol airport. A high share of the interviewed passengers has the Dutch nationality (27%), followed by the United Kingdom (18%) and other Europeans (20%) (including Belgium, France, Germany, Norway, Sweden, Finland, Spain, Italy, Greece, Hungary, Romania, Slovenia). Almost 20% of the interviewed passengers come from Asia (China, Japan, India, Philippines, Thailand, Malaysia, Indonesia), and 12% from the United States and Canada. A small number of passengers (<5%) come from Australia, Africa (Tanzania, Mozambique, South-Africa) or South-America (Ecuador, Colombia, Uruguay, Brazil).

Besides income, significant differences are found between these nationalities in terms of (continental and intercontinental) travel frequency and the price paid for airplane tickets. Europeans and North Americans travel most frequently: about ten times per year. Passengers from the rest of the world travel half as much. North Americans paid most for their plane ticket (€950 including taxes and other services), followed by the rest of the world (€780) and Asians (€735).

[2] An important selection criterion was that travellers speak and understand English. Three questionnaire versions were used: a Dutch version for Dutch passengers (WTP questions in euros), an English version for other European passengers (WTP questions in euros), and an English version for the rest of the world with WTP questions in both euros and US dollars. Where necessary interviewers were instructed to help respondents to convert the money amounts in the questionnaire into their own currency.

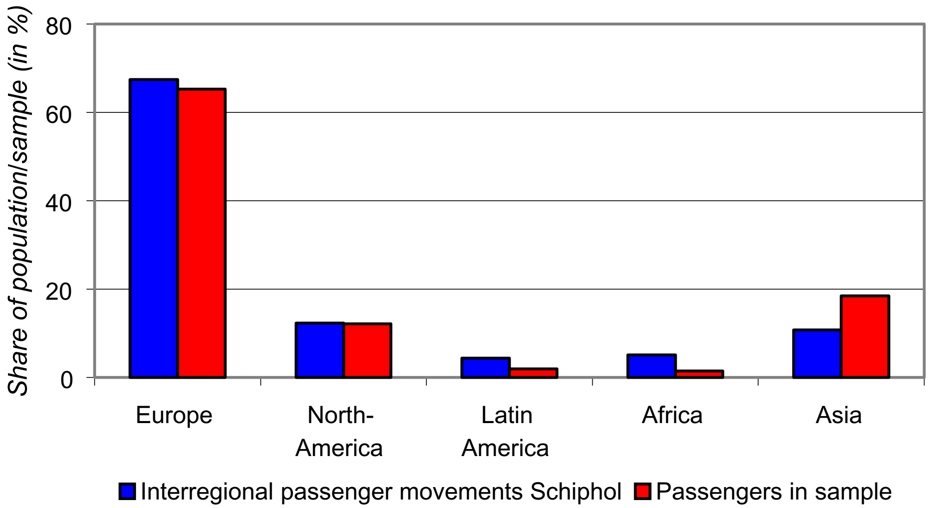

Fig. 1 Share of interregional passenger movements at Schiphol airport compared with the nationalities included in the sample

Interesting differences are found when investigating passenger *knowledge and awareness* of the impacts of flying on the environment and the link with climate change. UK and Dutch travellers are significantly more aware of the relationship between flying and climate change than other nationalities. The awareness level is lowest for passengers living in Asia. Significant differences are also found when investigating the *level of concern* regarding climate change, with UK passengers again being significantly more concerned than other passengers. No significant differences can be detected between North Americans and other (non-UK) Europeans, but concern is significantly lower in Asia, Latin America and Africa. UK residents also attach significantly more importance to the environment compared to other important public issues like employment, health and safety or economic growth. On the same scale, US citizens value the environment significantly less than any other group of passengers. Europeans and Asians also feel more responsible for climate change than North-Americans.

When asked how much passengers know about the Kyoto protocol, we find that Europeans are more knowledgeable than other nationalities. Half of all European passengers know the protocol's objectives. This is the case for 44% of the North-American passengers and 35% of the Asian travellers. Forty-one percent of the latter never heard of the Kyoto protocol. These percentages are lower for European (24%) and North-American (30%) passengers. About a quarter of all passengers has heard of the protocol, but has no idea what it aims to achieve. North-Americans and Europeans are more convinced than Asians that the introduction of a carbon travel tax will be effective in tackling climate change.

4.2 Testing the passenger pays principle

After introducing the idea of a carbon travel tax to passengers, they are asked if they would be willing to pay in principle for such a tax over and above the plane ticket for their current flight (see the Appendix to this paper). Three quarters of all travellers are willing to pay a carbon travel tax in addition to the price of their current airplane ticket[3]. Differences are found between continents, however, with slightly more Europeans (80%) than North-Americans (75%) willing to pay in principle, and Asian travellers (59%) being least willing to pay for a carbon travel tax. Protest against the imposition of a new carbon travel tax is limited to 14%, which is considered acceptable in this study. The most important reason for travellers to protest against paying is passenger disbelief that the carbon travel tax and the proposed (trees for travel) program will have any real impact.

Passengers who are willing to pay are primarily motivated by a sense of moral obligation and responsibility to pay for their contribution to climate change, concern about the environment in general and future generations (Fig. 2). Hence, 'existence values' and 'bequest values' seem to dominate the stated WTP responses. We find little to no evidence of what has been labelled 'warm glow' in the valuation literature (e.g. Nunes and Schokkaert 2003), meaning that travellers agree to pay because they like to give to good causes or charity. A considerable share of travellers wants to avoid future natural and economic disasters, which is interpreted as evidence of a positive risk premium. As said, these types of values are usually not included in any of the existing economic reviews related to global warming.

Respondents who are willing to pay in principle are subsequently asked whether they are willing to pay a specific amount of money. A start bid is varied across respondents, ranging between 5 and 100 euros per flight, and depending on their reply (yes or no), they are asked for their WTP for a second follow-up bid to which they can again answer either yes or no. If respondents answer 'no' ('yes') to the start bid, the follow-up bid is a lower (higher) amount. This is referred to as a double bounded (DB) dichotomous choice CV question (Hanemann and Kanninen 1999). This procedure yields an interval WTP value for each individual respondent in which respondents' maximum WTP value lies. The DB CV results are analyzed using the Turnbull estimation method (Haab and McConnell 1997), and presented in Table 1. The Turnbull estimator is based on a grouping of binary responses in bid intervals. To guarantee non-negative outcomes for WTP, the probability of WTP responses is constrained to be positive and sum to unity across bid intervals. The Turnbull estimator provides a lower bound for average WTP. Standard errors of the Turnbull WTP values are calculated based on bootstrap procedures (Efron and Tibshirani 1993).

Based on the *t*-test, no significant differences can be found between Europeans and North-Americans or North Americans and Asians. Europeans are, however, willing to pay significantly more than air travellers from Asia (t-value=2.059; p<0.040). Given the relatively low number of observations for North-Americans and Asians, these results have to be interpreted with the necessary care. The estimated average WTP results per flight presented in Table 1 are also related to the calculated average one-way travel distance and the emission of GHG per flight expressed in CO_2-eq. Travel distance and corresponding emission of CO_2 and total GHG are computed based on travellers' travel itinerary with the help of the calculator at www.greenseat.nl. Relating the estimated mean WTP values to the mean values found for travel distance and corresponding GHG emissions, average WTP ranges between 20 eurocents per 100 km for air travellers from Asia and 1 euro per 100 km

[3] This finding is supported by the results of a recent survey of 22,182 individuals in 20 countries conducted for the BBC on attitudes to climate change policies and taxes (BBC 2007). This survey found that 77% of the respondents were supportive of raising taxes on energy sources that contribute to climate change if the tax revenues were devoted only to increasing energy efficiency and developing energy sources that do not contribute to climate change.

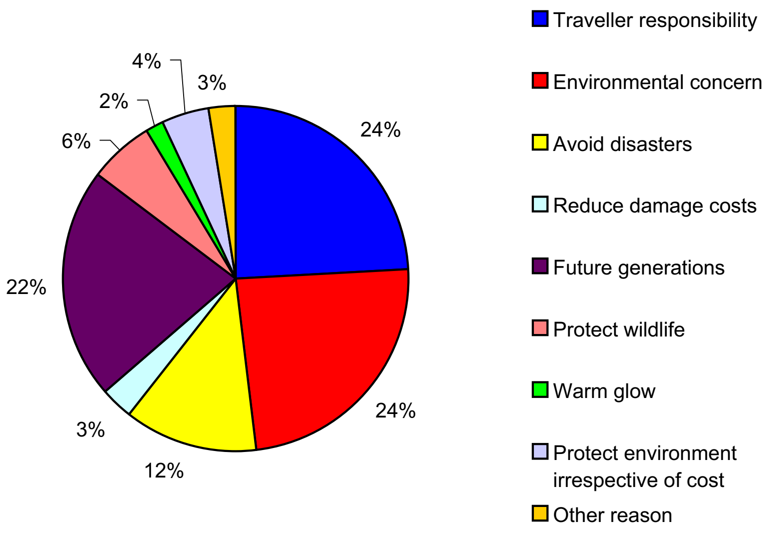

Fig. 2 Motivations for air traveller WTP for a carbon travel tax

for air travellers from Europe. In the whole sample, passengers are willing to pay on average 60 eurocents per 100 km they fly. This corresponds with an average WTP of about 25 euros per tonne tCO_2-eq.

Compared to the results of other studies that have elicited WTP estimates for climate policy based on stated preference methods (converted into 2006 prices), our results appear to be at the lower end of the scale, although it is noted that the literature in this field is still very limited. Li et al. (2004) analyze the WTP of American citizens for climate policy and find that half of the sample are willing to pay about 3 euros per tCO_2-eq. Hersch and Viscusi (2006) report that Europeans are willing to pay up to 3.7% more for petrol to combat climate change, which translates to around 156 euros per tCO_2-eq. Viscusi and Zeckhauser (2006) find that Harvard students are willing to pay an extra $0.50 per gallon of petrol (a 25% increase) for GHG emission reduction (263 euros per tCO_2-eq). In comparison to estimates of the social cost of carbon as reviewed by Tol (1999), which vary between 8 and 35 euros per tCO_2-eq at 2006 prices, we find that our WTP estimate is close to the estimated marginal damage cost, if somewhat at the higher end of the scale.

Following the DB WTP question, respondents are asked in an open-ended (OE) follow-up question what the maximum amount of money is they are willing to pay over and above their current airplane ticket to compensate for their contribution to the emission of CO_2 of their specific travel distance that day. Although the OE WTP values are significantly higher than the DB WTP values, again no significant differences can be found between Europeans and North-Americans and North-Americans and Asians. A significant difference exists between Europeans and Asians[4]. In order to avoid overestimation, we only present the lower bound Turnbull results in Table 1.

When linking these individual OE WTP values to individual travel distances and GHG emissions, significant differences are found between all groups. Europeans are in this case

[4] Test results are available from the authors on request.

Table 1 Average WTP results

	Europe	North-America	Asia	All passengers[a]
Mean WTP (€) per flight	26.6	20.2	16.1	23.1
95% conf. interval	21.7–31.5	9.1–31.2	10.4–21.7	19.4–26.9
Mean WTP (€) per km travelled[b]	0.010	0.004	0.002	0.006
Mean WTP (€) per emitted ton GHG in CO_2-equivalents	41.0	17.1	10.0	25.0
Maximum WTP per ton GHG expressed as income share (%)[c]	6.5 (0.7)	2.9 (0.6)	2.3 (0.7)	5.5 (0.5)
N	233	42	59	349

Explanatory notes:

[a] Including respondents from other regions in the world.

[b] One-way travel distance.

[c] Based on significantly higher OE WTP values. Standard errors between brackets.

willing to pay significantly more per travel distance and GHG emission than North-Americans and North-Americans are willing to pay significantly more than Asians. Interestingly, when relating the stated OE WTP values to respondent household income, the average share of WTP in household income is statistically the same across all air traveller groups (2.4% for the sample as a whole) even though Europeans and North-Americans earn significantly more than travellers from Asia (no significant difference exists in disposable household income between European and North-American travellers). Correcting for travel distance and GHG emissions, the relative results change however. Europeans are now relatively willing to pay significantly more than North-American and Asian travellers, while no significant difference can be detected between the latter two groups. Mean WTP per ton GHG equals 6.5% of disposable household income for European travellers compared to 2.9% and 2.3% for North-American and Asian air travellers respectively.

Finally, when asked how likely it is that air travellers will actually pay the stated maximum WTP if the carbon travel tax is voluntary, the results are not very convincing. Forty percent of the North-Americans consider it unlikely that they would pay in that case against 35% of the Europeans and 14% of the Asians. Fifty percent of the Asian travellers, 47% of the European and 37% of the North-American air travellers believe it is likely that they would pay.

4.3 Factors determining air travel passenger WTP for a carbon travel tax

Factors that have a significant impact on the WTP results per flight presented in Table 1 are analyzed through interval regression techniques using the statistical software Stata. The determinants of stated WTP can be derived from the conventional WTP function:

$$\mathrm{WTP}_i^* = x_i'\beta + \varepsilon_i$$

where WTP* is the unobserved variable of willingness to pay and x_i is a vector of individual respondent characteristics, β the corresponding vector of coefficients and ε_i is a normally distributed error term with zero mean and variance σ^2.

Having used a DB dichotomous choice CV approach, we have information on WTP intervals. Respondents are asked two questions: do you accept the start bid and do you accept the follow-up bid. Based on these two questions, four possible intervals can be constructed for WTP (e.g. Hanemann et al. 1991; Alberini 1995):

$WTP^*>b_i$	accept both start bid (a_i) and follow-up bid (b_i)
$a_i<WTP^*<b_i$	accept the start bid (a_i) and reject the follow-up bid (b_i)
$c_i<WTP^*<a_i$	reject the start bid (a_i) and accept the follow-up bid (c_i)
$WTP^*<c_i$	reject both start bid (a_i) and follow-up bid (c_i)

The interval regression model is estimated using maximum likelihood regression techniques (e.g. Maddala 1983). In view of the fact that the interval categories are ordered, the response variable represents the probability of selecting each response category. The multivariate regression results are presented in Table 2. All effects presented in Table 2, except for two of the three dummies representing air travellers' place of residence, are statistically significant at the 10% level. The significance of the overall model fit is confirmed by the outcome of the Wald test. The total number of observations is lower than the original number of interviews because of the exclusion of missing values. The calculated pseudo R-squared is used here as a rough indicator of overall model fit. The statistic is not very high (almost 25%), but lacks the straightforward interpretation of explanatory power (McFadden 1994). Standard errors are corrected for possible heteroscedasticity using the Huber–White estimator of variance.

Table 2 Interval regression results for WTP per flight

Explanatory factor	Values	Parameter estimate
Constant	–	−66.233*** (25.314)
North-American air travellers	Dummy (1=respondent is North-American)	3.593 (7.998)
Asian air travellers	Dummy (1=respondent is Asian)	−10.005* (5.799)
Rest of the world air travellers	Dummy (1=respondent is from the rest of the world)	−12.000 (10.400)
Start bid	Linear (€5–100)	0.455*** (0.072)
Flying frequency continental	Linear (1–60 times/year)	0.584*** 0.228
Current price ticket	Linear (natural logarithm €10–3915/ticket)	3.887* (2.154)
Household disposable income	Linear (natural logarithm €450–5000/month)	6.164** (3.092)
Air traveller awareness impact flying on environment	Dummy (1=respondent is aware and is able to list the impact of flying on the environment)	7.996* (4.531)
Air traveller perceived responsibility for Climate Change	Linear (0—not responsible at all–4—very responsible)	4.818** (2.280)
Air traveller perceived effectiveness carbon travel tax	Linear (0—not effective at all–4—very effective)	4.120** (2.063)
Log-likelihood		−407.329
Wald χ^2		97.77 ($p<0.001$)
Pseudo R-squared		24.0
N		292

Explanatory notes:

Standard errors of the parameter estimates between brackets.

*** $p<0.01$; ** $p<0.05$; * $p<0.10$.

Whilst accounting for a variety of influencing factors, including disposable household income, no significant differences can be detected between air travellers except for Asian travellers when European travellers are used as the baseline category in the regression model[5]. As before in Table 1—but this time accounting for income differences and other influencing factors—the probability that Asian air travellers end up in a higher ordered WTP interval is significantly lower than for European air travellers, whereas no significant differences can be found between European and North American passengers or the rest of the world.

As expected based on economic theory, WTP is significantly influenced by disposable household income and the intensity of use of the good for which travellers are asked to pay. The more someone is able to pay, the higher the probability that someone replies positively to the presented bid amounts, all other things being equal. The same positive relationship is found between stated WTP for the carbon travel tax and the number of times respondents fly. We find a significant relationship for continental flights, but not for intercontinental flights (or the aggregate of both). A possible explanation for this finding may be that a number of respondents commented that they believe that a carbon travel tax is justified for continental flights in view of the fact that travellers can choose alternative modes of transportation for continental travel, but not for intercontinental travel.

Travellers' perception of their own responsibility for climate change and the effectiveness of the proposed carbon travel tax also have a significant positive impact on stated WTP. The more someone feels personally responsible for climate change or the higher the perceived effectiveness of taxing people for their contribution to climate change when flying, the higher the probability that someone says 'yes' to the presented bids.

The finding that passenger awareness of the impact of flying on climate change has a significant positive impact on stated WTP supports our confidence in the WTP results. The more informed the respondent, the higher our confidence in general in the stated WTP responses. Overall confidence in the survey findings is furthermore founded on the fact that the survey meets important application recommendations that respondents should understand and be familiar with the good valued and have had or be allowed to obtain prior valuation and choice experience with respect to consumption levels of that good (e.g. Cummings et al. 1986; Mitchell and Carson 1989). All respondents in the sample had flown before, only 1% flew for the first time.

As expected based on previous CV research (e.g. Mitchell and Carson 1989; Bateman et al. 2005), significant positive anchoring is found of stated WTP on the start bid and the current price travellers pay for their airplane ticket. The higher the start bid or the airfare, the higher the likelihood of falling in a higher ordered bid interval. Given the probabilistic nature of the estimated model, it is difficult to say how much the starting bid influences average WTP in absolute terms[6]. Both the start bid and the current price paid for the good in question provide an important psychological value cue to the respondent.

[5] The correlation between the explanatory factors does not exceed 30 percent. The highest correlation between the place of residence and disposable household income is found for Asian travellers (r=-0.253; p< 0.001).

[6] Regressing the OE WTP values against disposable household income and start bid using OLS and a double log functional form results in a marginal effect of start bid on stated maximum WTP of 0.326 (p<0.001). This suggests that—all other things being equal—a one percent increase in the start bid results in a 0.3 percent increase in stated maximum WTP.

The price paid for the airplane ticket is highly correlated with the distance flown (r= 0.610; p<0.001). Including both is therefore not possible as this would result in multicolinearity. Travel distance has a significant positive impact on the response variable, but including this variable instead of the price variable makes the awareness factor become statistically insignificant, and this model is therefore not presented here.

Finally, no significant impact can be detected of any of the other standard demographic and socio-economic respondent characteristic variables included in CV research. Whether the flight was for business or pleasure and the respondent flew business or economy class with or without family members did not have any influence on stated WTP either.

5 Conclusions

The willingness of the general public to invest in climate change mitigation may be much higher than is generally assumed. The main motivation for this positive WTP is not so much the general desire of people to give to charities and good causes, but rather stems from the recognition of responsibility and accountability for climate change as well as the genuine belief in the detrimental effects of climate change on future generations. We find that awareness and demand for climate change mitigation vary across aviation passengers depending on their place of origin. Europeans are most aware and willing to pay for carbon offsets when controlling for the distances flown and associated GHG emission using the higher OE WTP results, whereas North Americans and Asians are less informed and less willing to act, also not when accounting for income differences (i.e. ability to pay). The lack of awareness in Asian travellers is a concern given the projected growth in the aviation industry in Asia.

The findings of this study supplement the existing economic literature on the costs of future climate change. Reviews of the costs of climate change such as those produced by Tol (1999), Pearce (2003), and the recent review by Stern (2006) have been limited to measuring 'objective' risks of expected material damage related to the impact of climate change on the economy and the environment. This study shows how the 'subjective' or perceived risk of climate change is an important additional motivation for tackling climate change. In our survey, people generally dislike being at risk and are willing to pay to reduce their exposure to risks associated with climate change. This reduced disamenity through mitigating climate change is an important economic benefit of action. Existence and bequest values and positive risk premiums over and above the 'objective' damage cost assessments should be accounted for more explicitly in existing economic reviews as it will add substantially to the burden of proof of direct action.

Regarding the demand and supply of carbon offsets for GHG emissions from aviation, the results of our survey suggest that airline passengers' demand for offsets may easily exceed the supply price of offsets. The survey results show that 75% of the passengers are willing to pay on average €25 per tCO_2-eq emitted using the conservative lower bound WTP estimate. On the supply side, the average price per tCO_2-eq is currently around €12. We therefore conclude that the market potential for carbon offsets is substantial. Given that the civil aviation industry currently emits approximately 1.3 billion tCO_2-eq per year (Eyers et al. 2004), the market for carbon offsets alone could account for more than €23 billion in climate change mitigation activities annually when simply aggregating the results found here at one of the largest European airports across the whole aviation industry under the rough assumption that the survey results are representative for airports worldwide. This leads us to conclude the 'convenient truth' that air travel passengers are willing to pay to offset their GHG emissions.

6 Epilogue

It has been exactly one year since the implementation of the survey and the revision of this paper. Several interesting developments took place in the context of passengers' WTP to offset their CO_2 emissions from which we can draw valuable lessons. First, numerous voluntary offset schemes were introduced by airlines and airports, which performed worse than expected by their initiators. An important reason seems to be that passengers appear to be willing to participate if and only if other passengers do so too. Free riders or better 'free flyers' in this case appear to have a negative influence on passengers' willingness to participate in offset schemes. Second, several governments in Europe are proposing and seem determined to push through a compulsory climate change tax for air travellers although there is strong resistance and opposition from airline companies and airports. Opponents of such a tax claim that such unilateral national schemes will only reduce the competitive position of the aviation industry and the airports in the countries where such a tax is to be introduced. Equally important is the counterargument that the tax revenues are not earmarked for climate change policies. Our study confirms that passenger belief in the effectiveness of the tax significantly influences WTP and that introducing a voluntary tax is expected to result in a high degree of non-participation.

Appendix

Suppose that *depending on your travel distance* an extra *carbon travel tax* would be introduced on your plane ticket to reduce and avoid further climate change by investing this carbon travel tax in a 'Trees for Travel' program managed and controlled by an independent international organization, who invests this money in trees to compensate for your contribution to climate change.

NOTE: if respondent is a business traveller whose ticket is paid for by the employer, ask him/her to answer the next questions as if he/she would have to pay the ticket him/herself

1 Would you be willing to pay such a carbon travel tax *in principle*, the height of which depends on travel distance, to compensate for your contribution to the emission of CO_2 and hence climate change?

Note: This money will be used exclusively for the funding of planting trees!

1 No → *GO TO QUESTION 2*
2 yes → *GO TO QUESTION 3*

2 If you are *not* willing to pay for this in principle, can you indicate why not?

[Try to circle only one answer if possible, namely the most important reason]

0 I don't believe in climate change
1 My income is too low
2 Climate change does not affect me or my family
3 I prefer to spend my money on other things
4 I don't believe that such a program would have any real impact
5 Other reason, namely. ....

SKIP THE NEXT QUESTIONS 3 TO 7

3 Suppose the extra carbon travel tax to offset your contribution to the emission of CO_2 of your specific travel distance today would be € X extra on top of your current airplane ticket. Would you be willing to pay this extra carbon travel tax?

0 No → *GO TO QUESTION 4*
1 yes → *GO TO QUESTION 5*

4 If not this amount, are you willing to pay € Y extra on top of your current airplane ticket to compensate for your contribution to the emission of CO_2 of your specific travel distance today?

0 No → *GO TO QUESTION 6*
1 yes → *GO TO QUESTION 6*

5 Are you in that case also willing to pay € Z extra on top of your current airplane ticket to compensate for your contribution to the emission of CO_2 of your specific travel distance today?

0 No → *GO TO QUESTION 6*
1 yes → *GO TO QUESTION 6*

6 What is the *MAXIMUM* amount of money are you willing to pay over and above your current airplane ticket to compensate for your contribution to the emission of CO_2 of your specific travel distance today?
€ ....

7 What is the most important reason why you are willing to pay this specific maximum amount of money?
[Try to circle only one answer if possible, namely the most important reason]

0 I feel responsible for my contribution to climate change
1 I care about the environment in general
2 To avoid future natural disasters
3 To reduce future economic damage costs
4 To protect future generations
5 To protect flora and fauna on this earth
6 I like to give to good causes
7 The environment has the right to be protected irrespective of the costs
8 Other reason, namely. ....

References

Alberini A (1995) Efficiency vs bias of willingness-to-pay estimates: bivariate and interval-data models. J Environ Econ Manage 29:169–180

Arrow KJ (2007) Global climate change: a challenge to policy. The Economists' Voice 4(3):2

Arrow KJ, Solow R, Portney PR, Leamer EE, Radner R, Schuman H (1993) Report of the NOAA panel on contingent valuation. Fed Regist 58(10):4601–4614 January 15

Bateman IJ, Carson RT, Day B, Hanemann M, Hanley N, Hett T, Jones-Lee M, Loomes G, Mourato S, Ozdemiroglu E, Pearce DW, Sugden R, Swanson J (2002) Economic valuation with stated preference techniques: a manual. Edward Elgar, Cheltenham, UK

Bateman IJ, Brouwer R, Hanley N, Georgiou S, Machado M, Mourato S, Saunders C (2005) A 'natural experiment' approach to contingent valuation of private and public UV health risk reduction strategies in low and high risk Countries. Environ Resour Econ 31:47–72

BBC (2007) Global public opinion survey on climate change. Web reference (10/12/2007): http://news.bbc.co.uk/2/shared/bsp/hi/pdfs/02_11_07bbcclimatesurvey.pdf

Beck U (1992) Risk Society: Towards a New Modernity. Sage London
Boon B, Davidson M, Faber J, van Velzen A (2007) Allocation of allowances for aviation in the EU ETS. CE Delft, Delft, The Netherlands
Cairns S, Newson C (2006) Predict and decide: aviation, climate change and UK policy. Environmental Change Institute, University of Oxford, UK
Cameron TA (2001) Updating subjective risks in the presence of conflicting information: an application to climate change. J Risk Uncertain 30(1):63–97
Cameron TA (2005) Individual option prices for climate change mitigation. J Public Econ 89:283–301
Cummings RG, Brookshire DS, Schulze WD (1986) Valuing environmental goods: an assessment of the contingent valuation method. Rowman and Allanheld, Totowa
Cvetkovich G, Earle TC (1992) Environmental hazards and the public. J Soc Issues 48(4):1–20
Efron B, Tibshirani RJ (1993) An introduction to the bootstrap. Chapman and Hall, New York
Eyers CJ, Norman P, Middel J, Plohr M, Michot S, Atkinson K, Christou RA (2004) AERO2k global aviation emissions inventories for 2002 and 2025. QinetiQ, Farnborough, UK
Gore A (2006) An inconvenient truth: the planetary emergency of global warming and what we can do about it. Rodale Books, New York, p 328
Haab TC, McConnell KE (1997) Referendum models and negative willingness to pay: alternative solutions. J Environ Econ Manage 32:251–270
Hanemann WM, Kanninen B (1999) The statistical analysis of discrete-response CV data. In: Bateman Willis IJKG (ed) Valuing environmental preferences: theory and practice of the contingent valuation method in the US, EU, and developing countries. Oxford University Press, Oxford, pp 302–441
Hanemann WM, Loomis JB, Kanninen B (1991) Statistical efficiency of double bounded dichotomous choice contingent valuation. Am J Agric Econ 73:1255–1263
Hersch J, Viscusi WK (2006) The generational divide in support for environmental policies: European evidence. Clim Change 77:121–136
Intergovernmental Panel on Climate Change (1999) Aviation and the global atmosphere. IPCC, Geneva, Switzerland
Jones-Lee MW (1989) The economics of safety and physical risk. Blackwell, Oxford
Layton DF, Brown G (2000) Heterogeneous preferences regarding global climate change. Rev Econ Stat 82:616–624
Layton DF, Levine RA (2002) How much does the far future matter? A hierarchical Bayesian analysis of the public's willingness to mitigate ecological impacts of climate change. Daniel J. Evans School of Public Affairs, University of Washington, Seattle, WA, p 29
Li H, Berrens RP, Bohara AK, Jenkins-Smith HC, Silva CL, Weimer DL (2004) Exploring the beta model using proportional budget information in a contingent valuation study. Ecol Econ 28:329–343
Maddala GS (1983) Limited-dependent and qualitative variables in econometrics. Cambridge University Press, Cambridge, England
McFadden D (1994) Contingent valuation and social choice. Am J Agric Econ 76:689–708
Mitchell RC, Carson RT (1989) Using surveys to value public goods: the contingent valuation method. Resources for the Future, Washington DC
Nunes PALD, Schokkaert E (2003) Identifying the warm glow effect in contingent valuation. J Environ Econ Manage 45:231–245
Oberthur S (2003) Institutional interaction to address greenhouse gas emissions from international transport: ICAO, IMO and the Kyoto Protocol. Climate Policy 3:191–205
Olsthoorn X (2001) Carbon dioxide emissions from international aviation: 1950–2050. J Air Transp Manag 7:87–93
Pearce D (2003) The social cost of carbon and its policy implications. Oxf Rev Econ Policy 19(3):362–384
Pearce DW, Smale R (2005) Appraising flood control investments in the UK. In: Brouwer R, Pearce DW (eds) Cost-benefit analysis and water resources management. Edward Elgar, Cheltenham
Schiphol Group (2006) Facts and figures 2005. Schiphol, The Netherlands. www.schipholgroup.com.
Slovic P (1987) Perception of risk. Science 236:280–285
Stern N (2006) The economics of climate change: the stern review. Cambridge University Press, Cambridge, UK
Tol R (1999) The marginal costs of greenhouse gas emissions. Energy J 20(1):61–81
Viscusi WK, Zeckhauser RJ (2006) The perception and valuation of the risks of climate change: a rational and behavioral blend. Clim Change 77:151–177