

Willingness to Pay for Opt-In Offsets in the Voluntary Carbon Market

Abstract

This thesis examined the consumer market for voluntary carbon offsets and sought to answer two questions: How much are airline passengers willing to pay to offset harmful emissions from their travel? And, how do various market attributes affect willingness-to-pay?

This study used contingent valuation to elicit airline passengers' willingness-to-pay (WTP) for voluntary, opt-in offsets. Survey respondents were asked to state WTP based on three variables: tax deductibility of the offset, market participation rate, and market transparency. In an offset market with low participation, little transparency, and no option of tax deductibility, 49% of respondents were willing to buy offsets. Mean WTP in this market was \$11.78 per ton of CO₂ equivalent. Tax deductibility and market participation had the most significant impact on demand, together raising WTP to \$32.00. The latter price is considerably higher than the current offset price of \$10.00 per tCO₂e, suggesting that there are significant opportunities for growth in the opt-in offset market.

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TABLE OF CONTENTS

LIST OF TABLES	iv
LIST OF FIGURES	v
CHAPTER 1: INTRODUCTION	1
1.1 Aviation: An Opportunity for the Voluntary Carbon Market?.....	1
1.2 What is a Carbon Market?	3
1.2.1 <i>Project Based vs. Allowance Based Markets</i>	4
1.2.2 <i>Voluntary vs. Mandatory Markets</i>	5
1.2.3 <i>U.S. Markets</i>	5
1.3 Research Question.....	6
CHAPTER 2: LITERATURE REVIEW	8
2.1 Demand in the Voluntary Carbon Market	8
2.2 Offsets: Describing the Good	10
2.3 Offsets: Describing the Market	11
2.4 Offsets in the Context of Aviation.....	12
CHAPTER 3: ECONOMIC THEORY	16
3.1 Theory of Externalities	16
3.2 Excludability and Rivalry.....	19
3.3 Non-Use Values	20
3.4 Non-Market Valuation	21
3.5 Contingent Valuation Biases.....	22
CHAPTER 4: METHODOLOGY.....	24
4.1 Survey Design.....	24

4.2 Survey Distribution.....	26
CHAPTER 5: RESULTS.....	27
5.1 Demographic Overview.....	27
5.2 Proportion and Mean WTP.....	29
5.3 Data: Regression Analysis.....	32
5.4 Data: Hypothesis Tests.....	33
5.5 Tax Deductibility.....	34
5.6 Participation.....	35
5.7 Story.....	35
5.8 Demographic Variables.....	36
5.8.1 <i>Male vs. Female</i>	36
5.8.2 <i>Student vs. Non-Student</i>	36
5.8.3 <i>Expert vs. Non-Expert</i>	37
CHAPTER 6: ANALYSIS.....	38
6.1 Willingness to Pay: A Closer Look.....	38
6.2 Market Participation and Game Theory.....	39
6.3 Tax Deductibility and Policy Implications.....	41
CHAPTER 7: CONCLUSION.....	43
APPENDIX A: SURVEYS.....	45
APPENDIX B: LINEAR REGRESSION DATA.....	48
APPENDIX C: HYPOTHESIS TEST FORMULAS AND DATA.....	49
REFERENCES.....	52

LIST OF TABLES

Table 1.1: Categories of Carbon Markets.....	4
Table 3.1: Welfare Calculations with a Negative Externality.....	18
Table 5.1: Variables.....	28
Table 5.2: Summary Statistics.....	28
Table 5.3: Variables by Survey.....	31
Table 5.4: Linear Probability Regression of Pay.....	33
Table 5.5: Linear Regression of WTP.....	33
Table 5.6: Hypothesis Test Difference in Proportions.....	34
Table 5.7: Hypothesis Test Difference in Means.....	34
Table 5.8: Critical Values for One-Sided T-Test.....	35
Table 6.1: Coordination Game for an Opt-In Offset.....	40
Table A1: Survey Questions on Demographic Information.....	45
Table A2: WTP Question in Survey #3.....	46
Table A3: WTP Question in Survey #7.....	47
Table C1: Variables.....	51
Table C2: Difference in Means.....	51
Table C3: Difference in Proportions.....	51

LIST OF FIGURES

Figure 2.1: Selecting an Offset Supplier.....	9
Figure 3.1: The Negative Externality of Air Travel.....	17
Figure 5.1: Proportion WTP Across Variables.....	29
Figure 5.2: Mean WTP Across Variables.....	30
Figure 5.3: Proportion WTP by Survey.....	31
Figure 5.4: Mean WTP by Survey.....	32

Chapter 1 - Introduction

1.1 Aviation - An Opportunity for the Voluntary Carbon Market?

Over the past decade, The Kyoto Protocol has encouraged environmentalists, policymakers, and economists to collaborate in emissions reductions on a global scale. Ratified in 1997 by over 30 countries, the protocol challenges participants to reduce greenhouse gas emissions to 5.2% below 1990 levels by the year 2012. This milestone treaty has spurred the development of today's \$120 billion greenhouse gas abatement markets, more commonly known as the carbon markets (Marcello and Sjardin 2009).

In recent years, carbon markets have focused on the reduction of ground-level emissions. Few efforts have targeted the aviation industry; in fact, the most frequently cited study on aviation and air quality was conducted nearly two decades ago. In 1992, the Intergovernmental Panel on Climate Change estimated that global aircraft emissions account for 3.5% of anthropogenic warming (Lister and Penner 1992). While this figure may appear low, carbon markets have since restricted emissions from major ground-level sources, leaving the aviation industry virtually untouched. In addition, air-traffic has experienced an unprecedented boom over the past two decades. Worldwide emissions from aviation grew by 50% between 1990 and 2000, and current estimates indicate a 5% annual growth rate (Brouwer et al. 2008). If carbon markets continue to focus exclusively on ground sources of emissions, aviation will soon become the industry with the fastest growing contribution to climate change (Sewill 2008).

While carbon markets do not presently address emissions from aviation, environmentalists as well as policymakers have expressed concern for this uncapped industry. In December of 2008, the Council of the European Union and the European

Parliament released a plan to include the aviation industry in its emissions trading scheme. This proposal has provoked much controversy among legal and political authorities. Most notably, the proposal may be considered a breach of the 1944 Chicago Convention on International Civil Aviation, which places tax exemption on aviation fuel. In addition to legal obstacles, economists have argued that the plan would lead to drastic distortions in the fuel prices (Rock and Baines 2008). The E.U. scheme would likely result in a sharp increase in fuel prices which would in turn shift demand outside of European borders. While the E.U. has taken the necessary first steps in confronting aviation emissions, it appears that the international nature of aviation emissions will demand an international solution.

As policymakers tackle these obstacles, the scientific community has also expedited efforts to control emissions from aviation. Studies have shown that emissions in the upper atmosphere have a greater warming effect than those released in equal amounts on the ground (US Government Affairs Office 2005). This finding further intensifies the threat of pollution. The scientific and economic concerns surrounding air pollution demand consideration, and while this industry may prove too problematic for traditional political or economic schemes, niche sectors of the carbon market offer new solutions.

In recent years, society has shown an increasing interest in compensating for environmentally harmful behaviors. The carbon markets have responded with a variety of products, including carbon offsets, or certifications of emissions reductions. Offset consumers pay to reduce emissions elsewhere and then take credit for this reduction. Offsets come in many shapes and sizes; one such package is the *opt-in offset*.

Several online travel companies including car rental and airline agencies sell opt-in offsets, or the option to buy an offset as part of a related purchase (Blachford, 2009). The economic reasoning behind the opt-in offset is clear: customers buying offsets not only pay for the utility of their car rental or flight, but also for the environmental costs of travel. Since customers independently elect to purchase opt-in offsets, this activity is classified under the voluntary carbon market.

In the context of the global carbon market, opt-in offsetting represents a small portion of activity. It is nevertheless important to explore this market because it offers an alternative to existing abatement schemes that have failed to address the aviation industry. The following section will situate the niche opt-in offset market within the global carbon market.

1.2 - What is a Carbon Market?

A carbon market is a network of buyers and sellers who trade the right to emit harmful greenhouse gases. Participants gain this “right” by engaging in emissions reduction projects. In 2008, the global carbon market was valued at approximately \$118 billion, up 84% from 2007 (Marcello and Sjardin, 2009). Voluntary transactions were valued at \$705 million, an 87% jump from 2007 (Hamilton et al. 2009). This section will situate the latter market within the context of the global carbon market.

As the global carbon market continues to expand, it is often difficult to distinguish activity in its various sub-markets. This section will untangle these various activities by categorizing the markets along two dimensions: project based vs. allowance-based and compliance/mandatory vs. voluntary. It is also important to consider the geographical boundaries of greenhouse gas (GHG) abatement schemes. While some such as the E.U.

Emissions Trading Scheme (ETS) span an entire continent, others such as the U.S. Regional Greenhouse Gas Initiative (RGGI) cover just one region. Table 1.1 shows possible intersections of carbon market features, highlighting the voluntary, offset-based market.

Table 1.1: Categories of Carbon Markets

	<i>Mandatory/compliance</i>	<i>Voluntary</i>
<i>Allowance cap-and-trade</i>	European Emissions Trading System U.S. Regional Greenhouse Gas Initiative	Chicago Climate Exchange Japanese Voluntary Emissions Trading
<i>Offset project-based</i>	Offset purchase never mandatory	U.S. Over The Counter Markets

1.2.1 - Project Based vs. Allowance Based Markets

In project-based markets, participants buy *offsets*, or certifications for emissions reduction projects. In 2008, renewable energy and landfill gas capture projects were the most popular for offset buyers, accounting for 66% of all transactions (Hamilton et al. 2009). Project-based transactions accounted for approximately 17.5% of the value traded in 2008 (Ambrosi and Capoor 2009). While many participants in mandatory schemes buy project-based offsets in lieu of allowances, it is important to recognize that participation in the project-based market is always voluntary.

Allowance-based markets are synonymous with cap-and-trade schemes. Under these regulatory schemes, participants are restricted to an emissions volume or cap. If they emit above this cap, they must buy allowances from other participants. This market mechanism ensures that participants undertake reduction measures at their lowest possible cost. Allowance-based markets were valued at \$93 billion in 2008 (Ambrosi and Capoor 2009). The largest allowance-based market by far is the European Emissions Trading System (ETS).

1.2.2 - Voluntary vs. Mandatory Markets

Voluntary markets can be divided into two components: allowance-based markets such as the Chicago Climate Exchange (CCX) and the over-the-counter (OTC) market. The CCX is a cap-and-trade program where firms voluntarily set a limit on their emissions and then trade allowances. In the OTC market, participants trade project-based offsets. As implied by the term “voluntary,” transactions in this market occur outside of state or federal regulation. Several studies have explored the motivation for participation in the voluntary carbon market, and leading factors include corporate social responsibility, marketing, and pre-compliance investment (Hamilton et al. 2009).

The terms mandatory and compliance are synonymous in the context of carbon markets and are generally associated with cap-and-trade schemes. In mandatory systems, participants are required by law to reduce or offset emissions. Participants generally find the least-cost method of reducing emissions by using a combination of cap-and-trade allowances and project-based offsets. These schemes, however, restrict the number of offsets allowed to satisfy reduction requirements, encouraging participants to reduce their personal emissions rather than pay for emissions reductions elsewhere.

1.2.3 - U.S. Markets

The Chicago Climate Exchange (CCX) is the United States’ premier voluntary market. The CCX is a structured, cap-and-trade system that organizations join voluntarily. While membership is voluntary, reductions made through the CCX are legally binding. The CCX trades both allowances and offsets; the vast majority of trades are allowance-based however, as offset based credits satisfy only 4.5% of total emissions reductions.

The OTC market is the catchall phrase for voluntary trading that takes place outside of the CCX. This market is also referred to as the voluntary offset market. In 2008, private companies dominated demand in the OTC market, accounting for 66% of traded volume (Hamilton et al. 2009). Purchases by individuals dropped to just 1%, and it is this niche market that opt-in enthusiasts hopes to expand.

1.3 - Research Question

The market for opt-in offsets is relatively new, and little data therefore addresses consumer demand. This study will contribute to the literature surrounding offsets by answering two questions: How much are airline customers willing to pay to offset harmful emissions from air travel? And, how does the context of the offset purchase affect willingness-to-pay?

This thesis will explore both current demand and growth opportunities in the opt-in offset market. Previous studies have examined how offset attributes such as price, project-type, and location affect demand. This study will contribute by determining how three market attributes affect demand. Each of the three variables will describe the structure of the market rather than the offset itself: “tax” will determine whether tax deductibility affects willingness-to-pay (WTP); “participation” will test how knowledge of others’ offsetting behavior affects WTP; and “story” will test how the story behind the offset, or market transparency, affects WTP.

The option of tax deductibility has not yet been explored in the context of carbon offsets. If tax deductibility were to incentivize participation in the offset market, this policy would have the advantage of easy implementation and monitoring. Because most

people understand tax incentives, this deduction has the potential to quickly reshape the voluntary offset market.

This thesis predicts that market participation rate also has a significant impact on WTP. If faced with the decision of purchasing an offset, most people will consider the offsetting behavior of their peers; no one wants to be the only person paying to mitigate climate change. This study will explore the extent to which others' offsetting behavior affects WTP.

The third market attribute of this study will be market transparency. Existing studies of demand in the voluntary carbon market have shown that consumers often take into consideration the “story behind the offset” (Hamilton et al, 2008). This study will explore how varying levels of market transparency affect WTP.

By understanding how tax deductibility, participation rate, and market transparency affect offset demand, market participants as well as policymakers will be better situated to leverage opportunities in the opt-in offset market.

Chapter 2 - Literature Review

This literature review will provide an overview of two distinct bodies of research relating to the voluntary carbon market. The first describes offset demand, including motivations for voluntary participation. The second examines two existing studies of willingness-to-pay (WTP) for offsets in the context of the aviation industry.

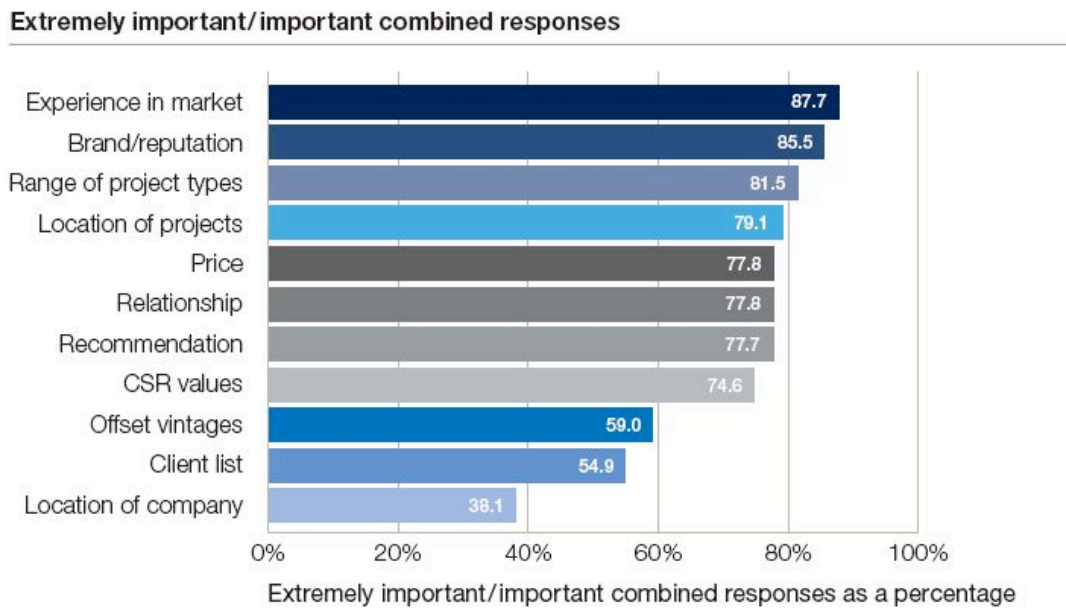
2.1 - Demand in the Voluntary Carbon Market

Participants in the voluntary market are forced to make several decisions before purchasing an offset: Should I participate in the voluntary market? From which supplier should I purchase offsets? What offset projects should I support? The existing literature on voluntary carbon markets begins to address these questions among many others. Two existing studies on the voluntary carbon provide particularly useful insights: “Fortifying the Foundation: State of the Voluntary Carbon Markets 2009” (Hamilton et al.) and “Carbon Offsetting Trends 2008 (Ashford et al.).

Hamilton et al.’s 2009 study revealed that “corporate social responsibility and public relations/branding” were among the primary motivators for voluntary market participation (Hamilton et al. 2009). Weaker motivations included anticipation of regulation and investment. While the 2009 report did not discuss any preference for project location, its predecessor “State of the Voluntary Carbon Markets 2008” revealed that OTC customers prefer offset projects that are originated close to home (Hamilton et al. 2008). The authors explain that this trend reflects the desire of businesses to publicly demonstrate the results of their offsetting behavior. In other words, a business is more likely to support a local offset project so that its customers and competitors can experience first-hand the effect of that project.

The publication of “Carbon Offsetting Trends 2008” (Ashford et al.) supplements this foundation by investigating the voluntary market from the perspective of the buyer rather than the seller. This survey revealed many motivations behind the offset purchaser’s behavior, including the criteria used to select an offset provider. This survey also assessed the desirability of offset projects based on various factors, including standard, project-type, and price. When asked the question, “What would be most important to you when selecting a carbon offset supplier?” respondents identified the following factors as extremely important or important:

Figure 2.1: Selecting an Offset Supplier



Source: Carbon Offsetting Trends Survey 2008

As evidences by this survey, carbon offsets come in many shapes and sizes. The following section will explore a few factors that distinguish offsets, including standard, project-type, and project location.

2.2 - Offsets: Describing the Good

According to recent market analysis, standards are the number one factor driving demand and pricing in the voluntary carbon market (Hamilton et al. 2008, Marcello and Sjardin 2009, Ashford et al. 2008). Standards evaluate offsets based on several criteria, including project type, location, project size, additionality testing methods, and co-benefits (Kollmuss et al. 2008). Standards establish requirements for both project development as well as the final offset product. As opposed to compliance schemes, which generally accept only one standard for offsets, the voluntary market uses dozens of standards. As of 2008, the Voluntary Carbon Standard and Gold Standard are the most popular, with CDM a close third (Ashford et al. 2008). In 2009, it is expected that the California Climate Action Registry (CCAR) will become increasingly popular as California continues to move towards a regulated carbon market.

Consumers typically buy offsets based not only on standard but also project-type. In 2008, the largest share of the offset market was occupied by renewable energy and landfill gas capture (Hamilton et al. 2009). Preferences for certain project types often reflect the motivation for offsetting. As discussed earlier, many voluntary market participants are motivated by corporate social responsibility or green marketing initiatives. These participants are therefore interested in “sexy” projects, or those most suitable for public relations. While certain project types may be more or less attractive to different buyers, renewable energy projects are perhaps the most easily understood and therefore the most appealing to many buyers.

2.3 - Offsets: Describing the Market

As evidenced by previous studies, analysis of demand in the voluntary market has focused on offset attributes. It is important to recognize, however, that several market characteristics may also affect demand. This thesis will contribute to the voluntary carbon market literature by exploring a new set of variables, those describing the *context* in which consumers buy offsets.

Tax deductibility, market participation, and market transparency all describe the market context for offset purchases. While the tax and participation variables have not yet been explored in this context, studies of unrelated markets have suggested that these two variables have a significant impact on consumer behavior. A large body of literature on tax deductibility and charitable donations, for example, shows that donations have high elasticity with respect to tax (Greene and McClelland, 2001). In other words, the option of tax deductibility increases the number of charitable donations by a quantity high enough to compensate for the loss of payments to the Treasury. If this high elasticity exists in the market for offsets, it may be economically efficient to make offsets tax deductible.

Unlike the tax variable, market transparency has been discussed in the context of the offset market. Hamilton et al. explain that “the story behind a credit is becoming and increasingly relevant component of its value” (Hamilton et al. 2008). This study tests this finding by including a “story” variable; the market is considered transparent only when the respondent is aware of the story behind the offset. These variables will be further described in the methodology chapter.

2.4 Offsets in the Context of Aviation

Only two existing studies have examined consumer willingness-to-pay for offsets in the context of air-travel. Brouwer et al. (2008) used contingent valuation to survey 400 travelers at Amsterdam Schiphol International airport. This study sought to uncover passenger willingness-to-pay to offset harmful emissions from air-travel. MacKerron et al. (2009) used contingent valuation as well as choice experiments to estimate willingness-to-pay for offsets with or without specific co-benefits such as the promotion of biodiversity and poverty alleviation.

The 2008 study by Brouwer et al. most closely resembles the purpose and design of this thesis. Brouwer et al. were the first to pose three research questions: What percentage of air-travel passengers would pay to offset emissions? How much are these passengers willing to pay? And what motivates their willingness-to-pay? Face-to-face interviews were conducted where each respondent answered 35 questions, 7 of which used the contingent valuation method to assess WTP. This method will be further examined in chapter four.

Brouwer et al. found that “75% of the passengers are willing to pay on average 25 euros per tCO₂-eq emitted using the conservative lower bound WTP estimate” (Brouwer et al. 2008, 310). This study also revealed the highest participation rates for Europeans with 80% willing to pay, as opposed to 75% of North Americans and 59% of Asians. These figures may in part reflect varying levels of awareness and concern surrounding climate change; the study found that UK and Dutch travelers are much more aware of the relationship between air-travel and climate change. Finally, the survey revealed that

passengers who were willing to pay were motivated by moral obligation and concern about the environment in future generations.

This study provides a solid model for surveys of the opt-in offset market. One potential error, however, was the choice to ask for willingness-to-pay “in principle,” introducing an additional level of ambiguity to an already hypothetical situation. It is often difficult to deduce true willingness-to-pay in the absence of real financial commitment; the language of this survey only augments this hurdle. Future surveys should attempt to elicit willingness-to-pay “in reality” rather than stressing the hypothetical.

In addition, Brouwer et al. do not clearly distinguish between the mandatory and voluntary carbon markets. Their study found that only 47% of European and 37% of North American travelers would be willing to pay for offsets in a purely voluntary scheme (Brouwer et al. 2008). If the tax was not mandatory, only 35% of respondents were “fairly sure” they would pay, and only 10% “very sure” (Brouwer et al. 2008). These findings undermine the earlier results that 80% of Europeans and 75% of Americans are willing to pay.

Despite this confusion, the study did uncover trends relating to market participation rate and market transparency. Brouwer et al. found that “passengers appear to be willing to participate if and only if other passengers do so too” (p. 311). This study also found that “respondent belief in the effectiveness of the proposed tree plantation program on climate change mitigation has a highly significant positive impact on the self-reported likelihood of paying” (p. 305). These two findings relate directly to the market

participation and market transparency variables, respectively, which this thesis will further examine.

MacKerron et al (2009) expand on Brouwer et al.'s work by estimating WTP for offsets with or without specific co-benefits. Many carbon offsets offer co-benefits, meaning that they not only reduce greenhouse gas emissions levels, but also create value in areas such as biodiversity, human development, and low-carbon market/technology development. Projects with these co-benefits often incur higher costs and weaker monitoring and are therefore less attractive to larger, mandatory markets. This study suggests that such offsets should be marketed in the voluntary sector where participants are most interested in maximizing social welfare.

This study used online surveys to reach UK adults aged 18-34 with higher education. These results therefore cannot be extrapolated to the general population. The survey consisted of two distinct sections: the first used contingent valuation to determine WTP for offsetting emissions from a flight from New York to London. The second used choice experiments to determine how price, government verification, and co-benefits affect WTP. The study found that respondents were willing to pay substantially more for offsets with all three co-benefits presented.

The results also revealed that the survey underestimated the WTP range. The results for mean WTP indicate a "fat-tail", suggesting that maximum bid levels were set too low. This error was unfortunately not apparent in the pilot phase of this survey, which suggests that WTP may be extremely volatile. This thesis will therefore use open-ended responses to assess WTP. While dichotomous choice methods often produce more

“reliable” results, it is clear that the market for voluntary offsets is still in its early stages, and it is important to anticipate this volatility.

Chapter 3 - Economic Theory

3.1 - Theory of Externalities

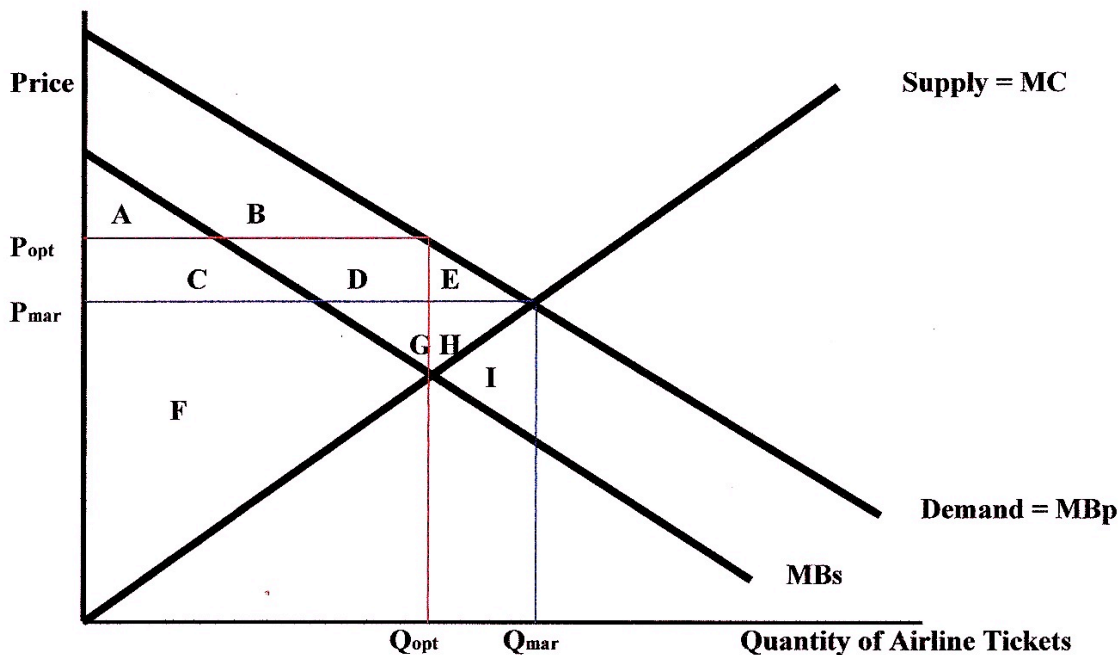
Market inefficiencies occur frequently in the context of goods and services provided by the environment. These inefficiencies are often the result of externalities, or the effects of production and consumption activities not directly reflected in price.

Externalities can be both positive and negative. A positive externality occurs when the full benefit of a good or service is not captured by its price. One person's decision to install energy efficient light bulbs, for example, would generate an additional benefit to the surrounding community in the form of increased electric supply. While the market equilibrium ignores this benefit, the optimal equilibrium would account for this social benefit, supporting a higher quantity of light bulb purchases at a lower price.

Pollution from air travel exemplifies a negative externality. Aviation generates a cost to society because one person's decision to fly increases the level of carbon dioxide in the atmosphere utilized by everyone. Because true cost of preventing or ameliorating this pollution is not included in the ticket price, the number of flights taken is inefficiently high. An efficient market would support fewer flights at a higher price level. In summary, an externality occurs when the private cost or benefit of consumption or production does not equal the cost or benefit to society.

Figure 3.1 illustrates the effects of a negative externality in the market for airline tickets:

Figure 3.1 – The Negative Externality of Air Travel



At the market equilibrium (Q_{mar}, P_{mar}), the marginal benefit to society (MBs) is less than the marginal benefit to the consumer MBp. This discrepancy occurs because there is an external cost (pollution) associated with the purchase of each airline ticket; the precise external cost is represented by the vertical distance between MBp and MBs.

In order to find the socially optimal equilibrium, we must first find the point where the MBs intersects supply. We then draw a vertical line through this point from the x-axis to the MBp curve. This end point represents the socially optimal equilibrium, (Q_{opt}, P_{opt}) which occurs at a lower quantity and a higher price level than the market equilibrium.

The calculations in *Table 3.1* summarize how a movement from the market equilibrium to the optimal equilibrium affects consumer surplus, producer surplus,

external cost, and total welfare. Each welfare measurement can be represented by an area in the graph: consumer surplus is the triangle bound by y-axis, the demand curve and price; producer surplus is bound by the y-axis, the supply curve and price; external cost is the area between MBp and MBs; and finally, total welfare is calculated by adding all three areas.

Table 3.1 – Welfare Calculations with a Negative Externality

	market equilibrium	optimal equilibrium	change (market – optimal)
consumer surplus	A+B+C+D+E	A+B	C+D+E
producer surplus	F+G+H	C+D+F+G	H-C-D
external cost	-B-D-E-G-H-I	-B-D-G	-H-E-I
Total Welfare	A+C+F-I	A+C+F	-I

The last column of Table 1 shows the change that occurs when moving from market to optimal equilibrium. Because we are subtracting the optimal equilibrium values from the market equilibrium values, losses in this last column are positive and benefits are negative. The change in total welfare amounts to $-I$, or a benefit equal to the area I. This area is known as the deadweight loss of the externality.

Unfortunately, consumers will not move independently from the market equilibrium to the social equilibrium. Policymakers typically rely on market mechanisms such as taxation to close the gap between private and optimal levels of consumption. A tax on airline tickets, for example, would change the equilibrium price and quantity (Pindyck and Rubinfeld 2005). Offsets, however, would not affect this equilibrium because they do not impose any mandatory changes. Instead, the offset would provide some compensation for the deadweight loss (area I) of the externality.

3.2 - Excludability and Rivalry

Economists often associate externalities with public goods. A public good is one that exhibits neither excludability nor rivalry. This section will further explore these definitions and simultaneously discuss the properties of the atmosphere as an economic good.

Excludability exists when a person can be prevented from consuming a good. Rivalry exists when one person's consumption occurs at the expense of another's (Perman et al. 2003). A private good, for example an airline ticket, is both excludable and rival. It is excludable because consumption is limited to those willing to purchase the ticket, and it is rival because one person's purchase decreases the total number of available tickets. Public goods, on the other hand, exhibit neither rivalry nor excludability. The atmosphere is non-excludable because no one can be prevented from "consuming" the air. This good is non-rival because one person's consumption does not impede another's. While these examples may appear straightforward, there is one catch: most public goods, including the atmosphere, have the potential for both excludability and rivalry.

Earth's limited ability to sustain a polluted atmosphere has put into question its rivalry and excludability. The atmosphere will always be non-excludable in the sense that no one can be prevented from breathing the air. Airlines, however, could easily be prevented from flying if their emissions continue to degrade the atmosphere. Furthermore, cap-and-trade systems limiting the total number of emissions make the atmosphere a rival good; in this case, one person's decision to emit decreases the remaining number of allowable emissions.

Recent emissions regulations threaten the definition of the atmosphere as a public good. As the atmosphere becomes increasingly rival and excludable, it is important to be able to quantify its value. Because markets do not exist for public goods such as the atmosphere, economists must use alternative valuation methods. The following section will provide an overview of values associated with public goods.

3.3 - Non-Use Values

Natural resource economists typically divide value into two categories: use value and non-use value. Use value refers to the planned use of the service or good by an individual. The use value of our atmosphere, for example, can be attributed to our ability to travel by aircraft. Non-use values are slightly more complicated, however, and involve a more abstract concept of valuation.

There are several non-use values, three of which relate directly to the example of aviation and the atmosphere. Altruism is a non-use value derived from the welfare of other individuals or groups. In this case, altruism might motivate a passenger to offset emissions because it will improve the air quality for others (Perman et al., 2003). Bequest value is associated with the welfare of future generations. An elderly airline passenger may choose to buy offsets because she wants her grandchildren to live in a world with cleaner air. Finally, existence value refers to the value derived from merely knowing that some aspect of the environment exists. We might be willing to pay for clean air, for example, just for the sake of knowing that it is clean.

Since environmental goods such as our atmosphere do not have a price tag, economists have developed several valuation methods that incorporate both use and non-

use values. The following section will describe these methods and focus on the contingent valuation method, the survey method used in this thesis.

3.4 - Non-Market Valuation

Non-market valuation methods can be broadly divided into two categories: direct and indirect methods. Direct methods use surveys to assess the willingness-to-pay (WTP) for an environmental good in a hypothetical market scenario. Indirect methods use the prices of related goods to estimate the value of environmental goods. This thesis will focus on direct methods and specifically contingent valuation.

Contingent valuation (CV) is a non-market valuation technique that uses economic theory and survey methods to elicit directly from consumers their willingness-to-pay (WTP) for a good (Carson and Mitchell 1989). In most CV studies, survey respondents are asked to state WTP for specific improvements in a public good. The survey typically presents hypothetical markets in which the respondent has the opportunity to buy the good in question at varying price levels.

The advantage of CV surveys is that they capture non-use values such as altruism, bequest, and existence values. Non-use values are also helpful in capturing uncertainty about the future. The increasing uncertainty surrounding climate change, for example, may increase the bequest or altruistic values of conservative respondents. One disadvantage of CV surveys is that they rely heavily on hypothetical situations to assess WTP. The hypothetical nature of this valuation technique often generates biases (Perman et al., 2003).

While most CV surveys assess willingness-to-pay for a public good or service in a hypothetical market, the voluntary offset market is in fact well established. This

application of CV therefore differs from most previous studies. The hypothetical component of this survey is the market context rather than the good itself. This study seeks to uncover how market characteristics including tax deductibility and participation rate affect consumers' WTP for an opt-in offset.

3.5 Contingent Valuation Biases

The hypothetical nature of CV surveys often results in several biases. Careful survey design, however, can minimize these effects. The two major biases are amenity specification bias and strategic bias. Amenity specification bias occurs when respondents do not correctly realize their WTP. In other words, this bias reflects a lack of clarity in the survey. It is therefore critical for the researcher to thoroughly describe the environmental good or service. Strategic bias occurs when respondents correctly realize their WTP but do not respond honestly. For example, someone who supports carbon offsetting but feels no commitment to her response might state a high WTP in hopes of affecting the overall awareness and demand for offsets.

Much literature surrounds the discussion of survey design for CV studies (Carson and Mitchell 1989). Two common survey formats are open-ended response, where respondents are simply asked to state their WTP, and dichotomous choice, where an initial amount is proposed and respondents are then asked to bid up or down. The dichotomous choice format has become the most widely accepted despite its many pitfalls (Carson and Mitchell 1989). One such shortcoming is the inevitable compliance bias, which pressures respondents to state more than their actual WTP. Another disadvantage of dichotomous choice is that it forces survey designers to make often-faulty estimates of the value of a good. The MacKerron et al. study, for example,

discovered a mean WTP that was higher than their highest payment bracket. Lastly, price brackets may undermine the very purpose of CV surveys, which is to uncover the value of a good with an unknown price.

Until recently, the most popular methods for acquiring responses were face-to-face interviews, mail surveys, and telephone interviewing. Today, online surveys are gaining popularity. This distribution method not only increases efficiency, but also reduces compliance bias. The following chapter on methodology will further describe the survey design and distribution for this study.

Chapter 4 – Methodology

4.1 - Survey Design

This study aimed to uncover both the proportion and mean willingness-to-pay (WTP) for opt-in offsets. WTP was dependent on three dichotomous variables: tax deductibility or “tax”, market participation or “participation”, and market transparency or “story”. The offset was either tax-deductible or non tax-deductible. Market participation rate was either 50% or 0%. And respondents either received a description of the offset project or received no description. Because each of the three variables had two possible values, there were eight permutations, and therefore eight different surveys. In order to produce statistically significant results, the target number of responses was fifty per survey, or four hundred total.

This survey had two parts: the first collected demographic information, and the second determined WTP. The demographic variables included gender, age, and zip code. Because many targeted respondents were students, the survey asked for employment status rather than income. Finally, respondents were asked whether or not they worked in carbon markets. The survey was distributed among a number of carbon experts in order to determine whether or not experience and knowledge of the markets affects WTP.

In the second part of the survey, respondents were asked to state their WTP for a carbon offset. This section consisted of two questions: the first question required a yes/no answer. If the respondent answered “yes” to the first question, the second question asked for WTP in dollars.

There were many design possibilities for the latter part of the survey. While most CV surveys use bidding games or price brackets to elicit WTP (see 3.5: Contingent

Valuation Biases), this survey deliberately used an open-ended question. While bidding games and price brackets may produce more consistent results (Carson and Mitchell 1989), this approach undermines the central objective of this study: to determine the true market demand for offsets. Furthermore, many respondents unfamiliar with offset prices may determine WTP based on the recommended values. If offset prices ranged from \$0 to \$10, for example, many respondents would pay \$5 but if the prices ranged from \$10 to \$20, many respondents would pay \$15.

The language of this survey was carefully planned in order to reduce bias. Each survey presented the following scenario:

You are planning a vacation and have decided to purchase airline tickets through expedia.com, an online travel service. You plan to travel 5,000 miles roundtrip and decide to spend \$400 on tickets. Before clicking “confirm purchase,” however, you are asked whether you are interested in offsetting emissions from your flight. In other words, you are asked to pay an additional fee to compensate for your portion of the flight’s harmful fuel emissions.

This scenario specified that the flight apply to a vacation; those flying on business may have had the option of paying with company money and therefore would not be accountable for their decision of whether or not to offset. This situation also controlled for the ticket price and the distance of the flight. Using online carbon emission calculators provided by Terrapass and The Carbon Neutral Company, it was determined that a flight traveling 5,000 miles emits approximately 1 ton of CO₂ equivalent per passenger. By specifying this distance, WTP is automatically expressed in dollars per 1 ton of CO₂ equivalent.

This survey design inevitably demanded a tradeoff between the level of specificity and the level of bias. The above scenario attempted to reconcile the two objectives, although the specific mention of expedia.com and Terrapass Inc. undeniably

introduced new biases. These names were included in hopes of presenting as realistic as possible a scenario. Contingent valuation surveys often suffer from their hypothetical nature, and while these specific company names may have introduced additional biases, they also provided a more concrete description of the opt-in offset market.

4.2 - Survey Distribution

This study used SurveyMonkey, an online survey design service, to format and distribute the survey. Images of the survey as it appeared on SurveyMonkey can be found in Appendix A.

Potential respondents were contacted directly via email and indirectly through LinkedIn and Facebook, public networking websites. The sample population for this survey was not random. All responses were collected over the week of March 3 to March 10, 2009.

One difficulty of using SurveyMonkey was ensuring that an equal number of respondents completed each survey. To address this dilemma, a table was utilized that indicated the proportion of the population with last names beginning with each letter of the alphabet. These frequencies were used to create eight groups of letters, each containing approximately 12.5% of the population. Each letter group was then assigned to a survey, and respondents were asked to take the survey corresponding to the first letter of their last name.

Chapter 5 - Results

Summary of Results

- In an offset market with low participation, little transparency, and no option of tax deductibility, 49% of respondents were willing to pay for offsets. Mean willingness-to-pay (WTP) in this market was \$11.78 per ton of CO₂ equivalent.
- Tax deductibility increased WTP by \$8.61. Tax deductibility had a more significant impact on the dollar amount WTP than the proportion of respondents WTP.
- Market participation had the strongest effect on males and non-students; these populations were more likely to purchase offsets if their friends and colleagues are also doing so.
- Market transparency had little effect on WTP.
- Female WTP exceeded that of males by \$8.58.

5.1 - Demographic Overview

This analysis aims to determine the willingness-to-pay (WTP) for opt-in carbon offsets in the context of airline tickets. WTP will be expressed both as a proportion and a mean, where the mean value indicates WTP per ton of CO₂ equivalent. Calculations of WTP tested the six variables described in *Table 5.1*. Three additional variables were excluded from the regression analysis: zip code, employment, and age. Zip code was omitted because of its lack of numerical significance. The vast majority of respondents (87%) were from the United States, and over 50% were from either New England or New York. International responses came from Australia, Canada, Denmark, India, and Tanzania, among other countries.

“Employment” and “age” were omitted because of imperfect multicollinearity, which occurs when two or more regressors are highly correlated. A respondent

answering “yes” to “student,” for example, is likely to also select “age 18-22” and “unemployed”. The inclusion of too many related variables would distort the regression coefficients.

Table 5.1 – Variables

<i>Dependent Variables</i>	
Pay	= 1 if respondent is willing to pay
WTP	Amount WTP (\$US) to offset 1 ton of CO ₂ equivalent
<i>Independent Variables</i>	
Tax	= 1 if offset is tax deductible
Participation	= 1 if market participation rate is 50%
Story	= 1 if market transparency exists
Gender	= 1 if male
Student	= 1 if student
Carbon Expert	= 1 if carbon expert

This study used a total of 397 responses, approximately fifty for each of the eight surveys. Seven surveys were excluded due to incomplete data. The data in *Table 5.2* reveal a high proportion of female and student respondents, a reflection of this author’s academic network. Because many respondents were targeted directly via email, this data cannot be considered a random sample and the results will therefore not be extrapolated to the general population.

Table 5.2 - Summary Statistics

Female	61%
Age 18-22	42%
Age 23-29	15%
Age 30-39	13%
Age 40-49	10%
Age 50-59	15%
Age 60+	5%
Student	49%
Carbon Expert	16%
Employed Full-Time	44%
Employed Part-Time	30%

5.2 - Proportion and Mean WTP

Figures 5.1 and 5.2 reveal the effects of the market variables on proportion and amount WTP, respectively. The blue bars represent the proportion or mean WTP when the market variable is equal to zero, and the red bars represent WTP when the market variable is equal to one.

Figure 5.1

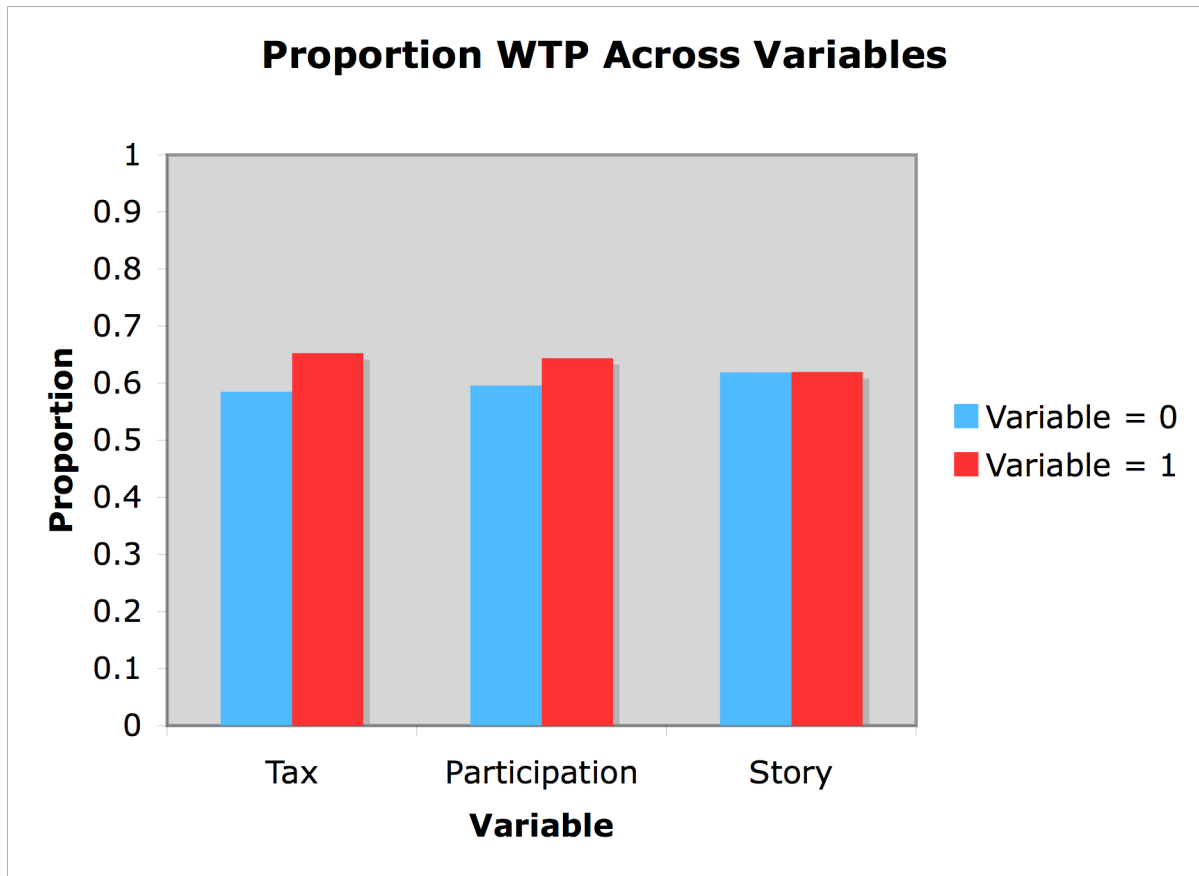
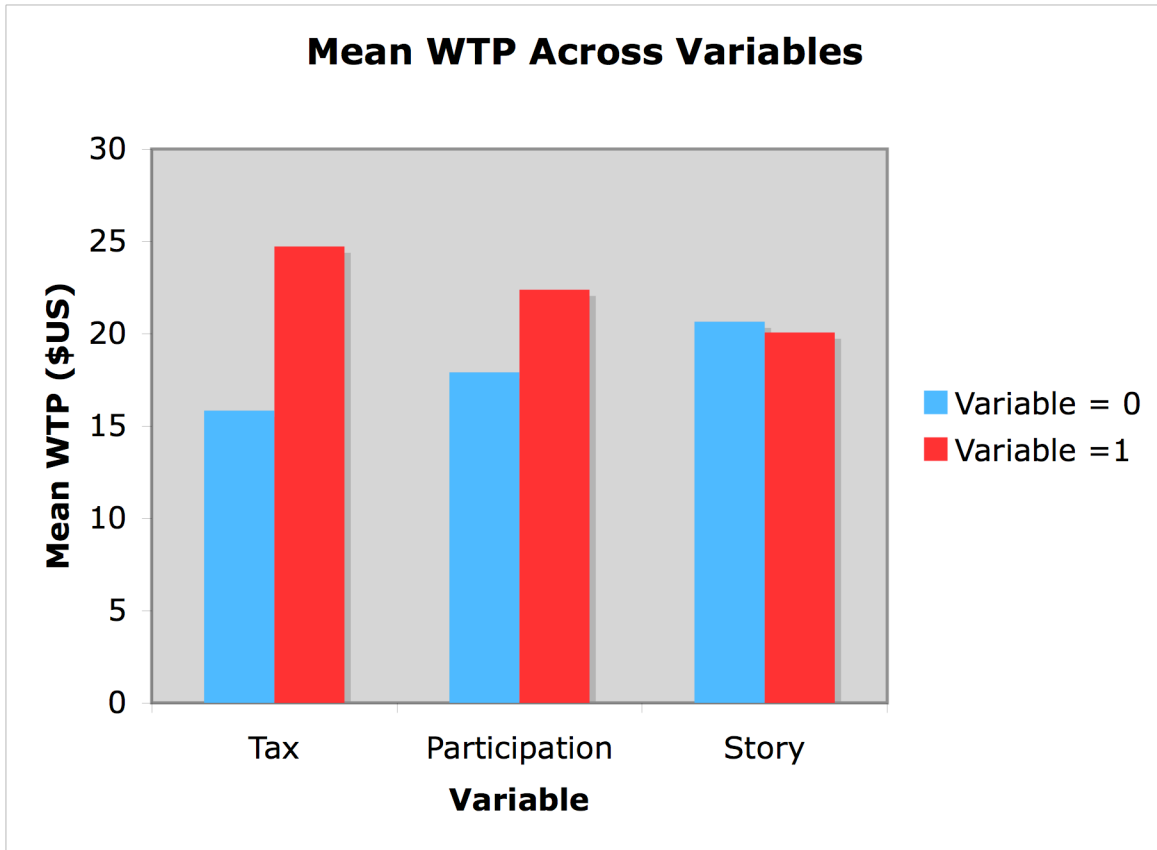


Figure 5.2



These graphs provide a visual for one of the key outcomes of this study: market conditions have a more significant impact on mean WTP than proportion WTP. In other words, these variables may not cause a significant increase in the number of buyers, but they could motivate existing customers to pay higher prices for offsets.

Below, *Figures 5.3* and *5.4* illustrate proportion and mean WTP by survey. *Table 5.3* serves as a key for the value of each variable in the eight surveys.

Table 5.3 - Variables by Survey

Survey	Tax	Participation	Story
1	1	1	1
2	0	1	1
3	1	0	1
4	0	0	1
5	1	1	0
6	0	1	0
7	1	0	0
8	0	0	0

Figure 5.3

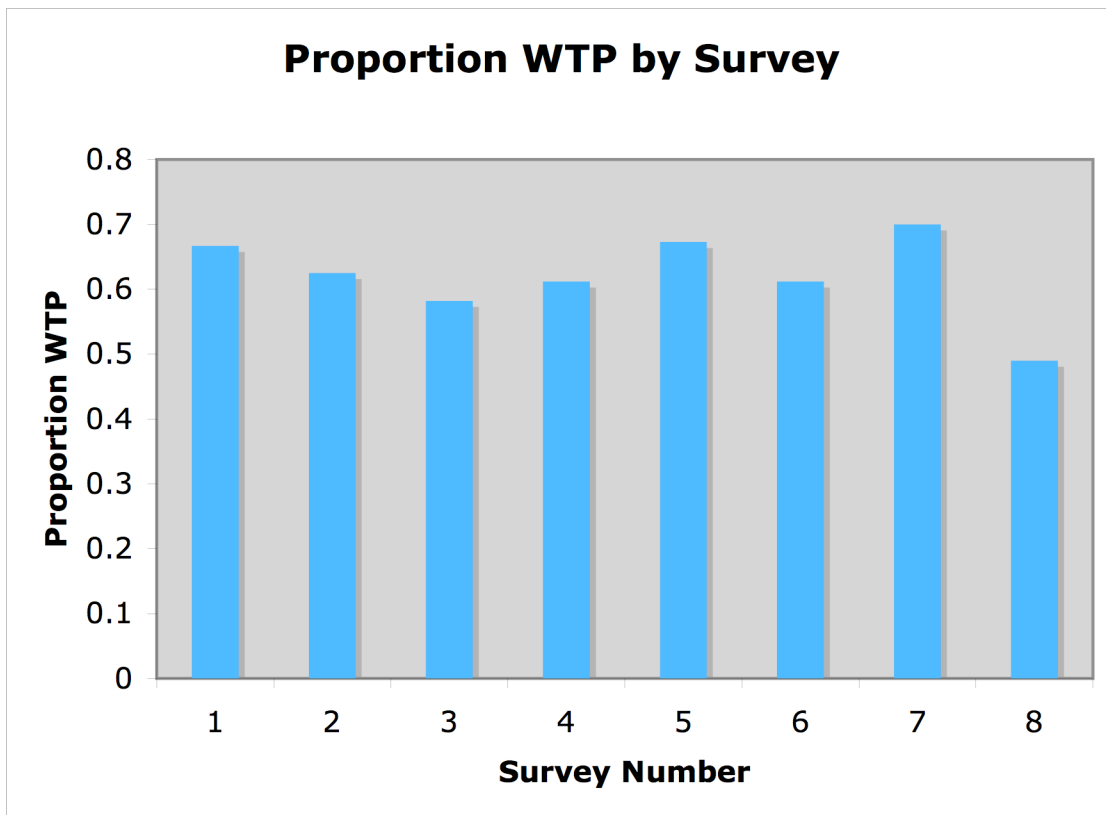
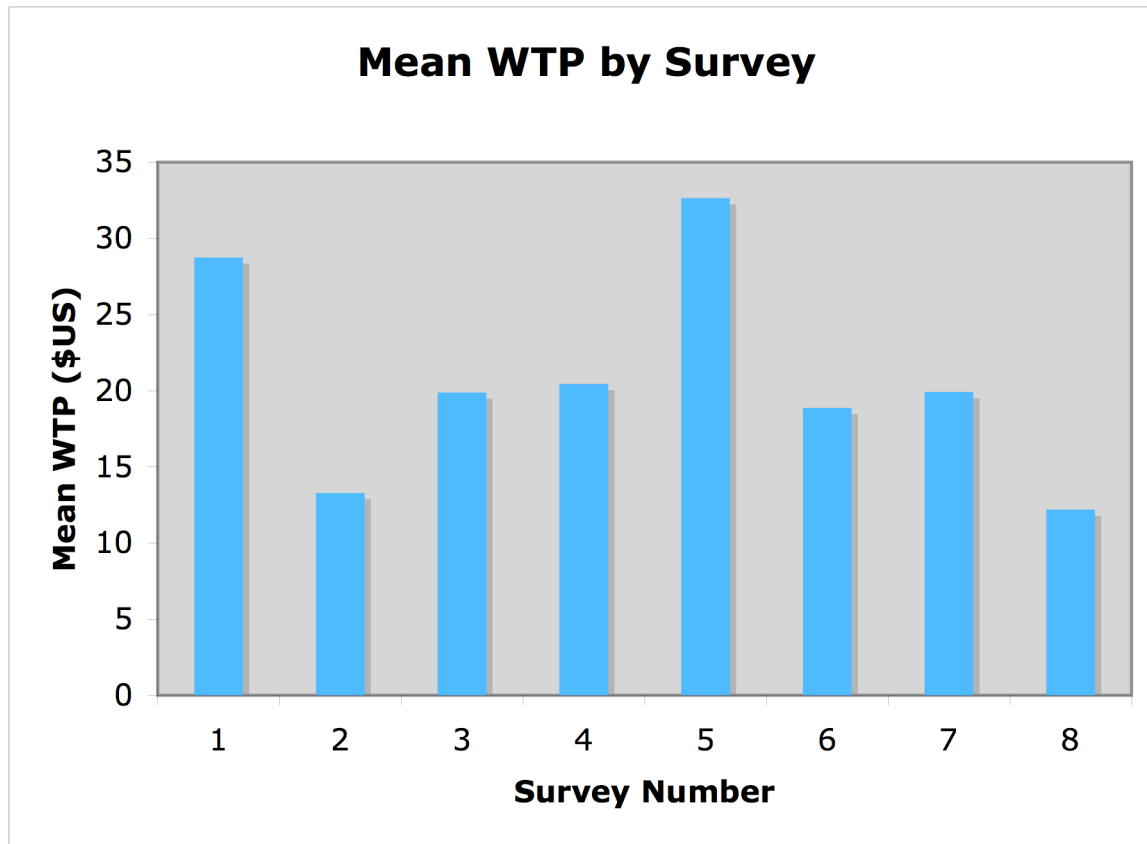


Figure 5.4



Proportion WTP ranged from 0.49 to 0.70 across the 8 surveys. The low value occurred in Survey 8, the only survey where all three variables reflected true market conditions. The high value occurred in survey number 7, where there was no market transparency or market participation but the offset was tax deductible.

Mean WTP reached its maximum in Survey 5 (\$32) where the offset was tax deductible, market participation was 50%, and there was no market transparency. The low value (\$11.78) occurred in Survey 8 where all three variables were equal to zero.

5.3 – Data: Regression Analysis

This study used STATA software to run a linear probability regression on the binary dependent variable “pay” and a linear regression on the continuous variable

“WTP.” These models generated the coefficients below (*Tables 5.4 and 5.5*). Complete results of the regression can be found in Appendix B.

Table 5.4 - Linear Probability Regression of Pay

pay	Coef.	Std. Err.	t	p-value
tax	0.067	0.049	1.36	0.174
participation	0.056	0.049	1.14	0.254
story	0.003	0.049	0.07	0.945
gender	-0.101	0.057	-1.73	0.084
student	0.025	0.056	0.44	0.66
carbon expert	0.035	0.076	0.46	0.643
constant	0.578	0.062	9.26	0

Table 5.5 - Linear Regression of WTP

pay	Coef.	Std. Err.	t	p-value
tax	8.611	3.732	2.31	0.022
participation	5.727	3.756	1.53	0.128
story	-0.1903	3.727	-0.05	0.959
gender	-8.584	4.440	-1.93	0.054
student	2.593	4.288	0.6	0.546
carbon expert	6.122	5.822	1.05	0.294
constant	14.700	4.765	3.08	0.002

5.4 – Data: Hypothesis Tests

While regression analysis provides many useful data points, hypothesis tests help to reinforce these outcomes. The following tables show the sample statistics for hypothesis tests on the three market variables. Proportion 1 and Mean 1 show the proportion and mean WTP when the market variable is equal to zero. Proportion 2 and Mean 2 apply to surveys where the market variable is equal to one. The following sections will analyze each variable in further detail using the results of both the regression analysis and hypothesis tests.

Table 5.6: Hypothesis Test Difference in Proportions

Variable	Prop. 1	Variance 1	Count 1	Prop. 2	Variance 2	Count 2	Test Statistic
Tax	0.585	0.244	195	0.653	0.228	202	-1.39
Participation	0.596	0.242	203	0.644	0.23	194	-0.98
Story	0.619	0.237	197	0.62	0.237	200	-0.02

Table 5.7: Hypothesis Test Difference in Means

Variable	Mean 1	Variance 1	Count 1	Mean 2	Variance 2	Count 2	Test Statistic
Tax	16.17	421.35	195	25.1	2304.15	202	-2.42
Participation	18.18	559.85	203	23.37	2264.39	194	-1.36
Story	20.86	1422.22	197	20.57	1377	200	0.07

5.5 - Tax Deductibility

Tax deductibility had a more significant impact on mean WTP than on proportion WTP. In the linear probability model for “pay”, tax had a marginally significant impact, with a coefficient of 0.067 and a p-value of 0.174. The linear regression for WTP, however, showed that consumers are willing to pay \$8.61 more for a tax deductible offset. This coefficient’s low p-value (0.022) confirms its significance.

The hypothesis test for tax deductibility reiterates these results. The difference in mean WTP between a tax deductible and a non-tax deductible offset was significant at the 1% level ($t = -2.45$). Those who did not receive the tax option were willing to pay just \$16.75 on average compared to the \$25.10 average for a tax deductible offset. The 95% confidence interval for this difference was (-\$2.92, -\$14.97), meaning that 95% of random samples from the true population would pay from \$2.92 to \$14.97 more for an offset that is tax deductible.

5.6 - Participation

Like the tax variable, changes in participation impacted mean WTP more significantly than proportion WTP. The linear probability regression produced a coefficient of 0.056, indicating that the proportion of people willing to pay for offsets increased by .056 when participation increased to 50%. The high p-value for this coefficient (0.254), however, undermines its significance.

The regression on mean WTP produced stronger results. According to the regression analysis, respondents were willing to pay \$5.73 more for an offset if other passengers were also buying. This coefficient produced a lower p-value (0.128), reinforcing the argument that market incentives have a stronger impact on mean WTP than on proportion WTP.

The hypothesis tests once again confirmed these results. Respondents in a market with 0% participation rate were willing to pay \$18.18 on average compared to a WTP of \$23.37 for those in a market with 50% participation. The difference in means was significant at the 10% level ($t = -1.37$), while the difference in proportions was insignificant ($t = -0.98$).

5.7 - Story

The very high p-values associated with the story variable suggest two possible outcomes: either market transparency truly has no effect on a customer's WTP, or this variable was not clearly defined in the survey. According to the latter possibility, also known as amenity specification bias, respondents failed to recognize the effect of market transparency because of poor survey design. In reality, transparency is not gained through a two-sentence description of the offset but rather through accumulated

knowledge and market experience. It was therefore difficult and perhaps overly ambitious to attempt to capture this effect through the use of a binary variable.

5.8 – Demographic Variables

5.8.1 - Male vs. Female

P-values for the gender variable were among the lowest across the two regressions. In other words, gender had a stronger impact on WTP than any other variable. In the linear probability regression, gender had a coefficient of -0.101 and a p-value of 0.084. These results tell us that the proportion of males willing to pay for offsets is .101 lower than that of females, all other factors equal. The regression on mean WTP showed that females are willing to pay \$8.58 more for opt-in offsets, with a p-value of 0.054.

Hypothesis tests add to this analysis by determining how each market variable affected WTP by gender. While the effect of tax deductibility did not differ by gender, the participation variable had a much stronger effect on males. 50% market participation increased both proportion and amount WTP for males at the 10% level with t-statistics of -1.39 and -1.47, respectively. The corresponding t-statistics for women were only -0.38 and -0.87.

5.8.2 - Student vs. Non-Student

The student population expressed a higher proportion and a higher mean WTP for offsets than non-student respondents, although the p-values for this coefficient were very high at 0.66 and 0.55, respectively. In addition, the variables “tax” and “participation” had different effects on WTP between two groups. Tax deductibility did not strongly influence proportion WTP for students ($t = -0.44$) while the difference for non-students

was significant at the 10% level ($t = -1.57$). In other words, tax deductibility is much more likely to influence the non-student population.

The variable “participation” generated even more drastic differences between the two groups. In the student group, the participation variable actually had the opposite effect as predicted; an increase in market participation decreased the proportion of students willing-to-pay to offset from 0.67 to 0.62. In the non-student sample, however, higher participation rates significantly increased the proportion of respondents willing to pay. The difference in both the means and proportions for the non-student group were significant at the 5% level. According to these results, the offsetting behavior of others has a stronger effect on non-students, suggesting that non-students are more likely to free ride than are students.

5.8.3 - Expert vs. Non-Expert

No significant difference was found between the WTP of carbon market experts and non-experts. Narrative data, however, reveals that the “story” variable likely had a different effect on those familiar with the markets. Multiple carbon markets experts wrote emails voicing their concern with the use of Terrapass in this survey. One carbon expert responded that she would not buy this offset regardless of the market conditions simply because she chooses to offset with a different supplier. An expansion of this study would benefit from the inclusion of narrative data.

Chapter 6 - Analysis

6.1 –Willingness to Pay: A Closer Look

This study reveals willingness-to-pay (WTP) for opt-in offsets in the context of the aviation industry. In analyzing the results of this study, it is important to realize that many if not all respondents were unaware of the actual price of reducing one ton of CO₂ equivalent. This lack of market awareness was a primary motivator for this study; the results of the previous chapter can be used to enhance market transparency, establish a demand curve for offsets, and ultimately increase efficiency in the market.

At the time of this survey, a Terrapass-certified offset for a 5,000-mile flight cost about \$10. The results of this study, however, indicate that 47% of all respondents were willing to pay an amount higher than \$10. Excluding those respondents not willing to pay at all, 80% were willing to pay higher than \$10. This data reveals that the demand curve for opt-in offsets may support higher prices than predicted by suppliers.

In examining the results of this survey, we must also take into consideration survey design. While most contingent valuation surveys use dichotomous choice to suggest potential values for the good, this survey deliberately refrained from revealing the market price. One of the drawbacks of the open-ended format is that respondents often overestimate WTP (Carson and Mitchell 1999). In addition, the spread of the data is inherently less consistent. For this reason, the ranges and standard deviations for amount WTP were very large; the standard deviation across all samples was \$37.36 and the range was \$425.

The proportion WTP for offsets was also surprisingly high. While precise participation rates in the actual opt-in offset market are unknown, Terrapass CEO Erik Blachford estimates that only 1% of expedia.com customers choose to buy offsets (Blachford, 2009). In this study, however, 49% of respondents were willing to pay even in the least desirable market scenario. This discrepancy may again reflect overestimation due to the hypothetical nature of the survey. Without further narrative data, it is difficult to determine the precise magnitude of this error. It is nevertheless important to note that the proportion of respondents willing to pay in this survey was significantly higher than that in the real world.

6.2 – Market Participation and Game Theory

This section will further analyze the effect of the participation variable and describe a basic application of this data to game theory. The coefficient on market participation was 5.73, meaning that respondents were willing to pay \$5.73 more for an offset if 50% of airline customers are also doing so. Market participation had a particularly strong impact on the WTP of males and non-students; game theory analysis may provide further insights into the decision-making processes of these populations.

Game theory explains how people use others' actions and responses to make strategic decisions (Pindyck and Rubinfeld 2005). The general objective of any game is to reach an equilibrium, or a set of strategies such that no unilateral deviation is profitable. While this equilibrium may be clear in some games, coordination games often have multiple equilibria, complicating the decisions of each player.

A coordination game with multiple equilibria can easily be applied to the market for opt-in offsets. Consider a scenario where two airline customers on expedia.com are

deciding whether or not to purchase an offset. Assume that both customers place a higher value on a clean atmosphere than a polluted one. If both customers then buy an offset, they both benefit. The customers know, however, that there is a potential for free riding if only one chooses to offset; if customer 1 does not offset, customer 2 does not want to offset either.

There are four possible outcomes to this game, outlined in *Table 6.1*. The top row represents the offset decision of customer 1 and the left column represents the offset decision of customer 2.

Table 6.1 - Coordination Game for an Opt-In Offset

	Yes	No
Yes	(yes, yes)	(yes, no)
No	(no, yes)	(no, no)

This game has four potential outcomes but only two equilibria: either both customers choose to offset (yes, yes) or neither customer chooses to offset (no, no). When both customers choose to offset, there is no unilateral benefit to changing strategies; both customers receive the maximum benefit. When neither customer chooses to offset, there is also no *unilateral* benefit in changing strategies because neither customer wants to be the only one offsetting. The former equilibrium is known as Pareto superior and the latter Pareto inferior (Cooper, 1998).

In this game, the market is more likely to reach the Pareto superior equilibrium if all customers choose to offset. Because very few people are currently offsetting, it is likely that the market is at the Pareto inferior equilibrium. This study reveals, however, that at least 49% of customers are willing to pay for offsets, and this percentage increases significantly under more desirable markets conditions. In future studies, a more detailed

game theory analysis could determine the participation threshold at which customers reach the Pareto superior equilibrium.

6.3 – Tax Deductibility: Policy Implications

Tax deductibility proved to be the most statistically significant market variable in this study. Respondents were willing to pay significantly more for tax-deductible offsets. A 95% confidence interval for the coefficient on WTP was (\$1.27, \$15.94) meaning that 95% of samples from similar populations would produce coefficients ranging from \$1.27 to \$15.94. In other words, it is likely that people are willing to pay anywhere from \$1.27 to \$15.94 more for a tax deductible offset. The magnitude of this difference has many policy implications.

Tax deductibility has the potential to expand the market for offsets. According to the results, the tax variable not only increased mean WTP but also proportion WTP by 0.067. Furthermore, the market participation variable illustrated somewhat of a snowball effect; if tax deductibility encouraged more people to participate, this effect could in turn motivate even more people to join the market. Simply put, the option of tax deductibility would have greater gains than just the tax revenue.

Future studies could expand on this hypothesis by testing the elasticity of charitable donations with respect to tax deductions. In an article concerning tax deductions and charitable giving, Greene and McClelland write, “one benchmark for viewing the responsiveness of charitable giving to tax incentives is whether or not the additional donations induced by the itemized deduction exceed the amount lost to the Treasury” (Greene and McClelland, 2001). In order to calculate elasticity, the authors

compare the change in the charitable contribution to the change in taxable income. If this elasticity exceeds 1 in absolute value, the tax incentive is economically efficient.

Unfortunately, this study did not collect data on income and therefore cannot complete similar calculations. Again, if the tax price elasticity were to exceed 1 in absolute value, the policy option of tax deductibility could create economic benefits.

Chapter 7 - Conclusion

Demand in the voluntary carbon market relies on a range of factors. Previous studies have shown how attributes of the offset itself, for example project-type or location, affect demand. This study addresses a new set of variables: those describing the context of the offset purchase, or the context in which consumers purchase offsets.

Respondents were asked to state their willingness-to-pay (WTP) for an opt-in offset under various market conditions. According to this study, WTP in the current offset market is \$11.78 per ton of CO₂ equivalent. Tax deductibility and participation rate had significant effects on demand, however, together raising WTP to \$32.00. The latter value is considerably higher than the current price (\$10.00), suggesting that there are significant opportunities for growth in the opt-in offset market.

According to this study, the option of tax-deductibility increases offset value by \$8.61. Tax deductibility also increases the proportion of respondents willing-to-pay, although this difference was less significant than that in amount WTP. This study also concluded that airline passengers are more likely to purchase offsets if other passengers are doing so. The market participation variable had the strongest effect on the male and non-student populations. Finally, the survey found that the WTP of females exceeds that of males by \$8.58.

While this study succeeded in examining a new set of variables in the offset market, it was not without its flaws. Future studies could expand on this work by improving the survey design, particularly the description of the market transparency variable. This brief survey struggled to capture the market transparency and many

respondents expressed concern over this variable; a more comprehensive study may benefit from clarification.

Future studies may also benefit from adjusting the market scenario described in the survey. Possible variations on this survey abound. This scenario failed to state whether or not the 5,000 mile flight was direct, a factor that would significantly impact the quantity of emissions. Another variation might ask for WTP as a percentage of the ticket price, rather than an absolute dollar amount. One final option would be to examine whether corporations allow their employees to buy offsets to compensate for business-related travel.

The results of this study point to many growth opportunities for the voluntary, opt-in offset market. It is important to pursue research in this market because it offers an alternative to existing schemes that have failed to cover the aviation industry. Further exploration of the offset market will benefit both voluntary market participants and the broader population of those concerned by threats to our environment.

APPENDIX A - SURVEYS

Table A1 - Survey Questions on Demographic Information

*** 1. Gender**

- Male
 Female

*** 2. Age**

- 18-22 23-29 30-39 40-49 50-59 60+

*** 3. Please enter your zip code (US) or country residence (international).**

*** 4. Are you a student?**

- Yes
 No

*** 5. Are you employed?**

- Yes - full time
 Yes - part time
 No

*** 6. Do you have a job relating to carbon markets (i.e. carbon markets researcher, analyst, consultant, trader, policy expert)?**

- Yes
 No

Table A2 - WTP Question in Survey #3

*** 1. Consider the following scenario: You are planning a vacation and have decided to purchase airline tickets through expedia.com, an online travel service. You plan to travel 5000 miles roundtrip and decide to spend \$400 on tickets. Before clicking "confirm purchase," however, you are asked whether you are interested in offsetting emissions from your flight. In other words, you are asked to pay an additional fee to compensate for your portion of the flight's harmful fuel emissions.**

Before completing your purchase, consider that the following circumstances apply:

- **Your money will go towards Terrapass Inc., a company specializing in the reduction of carbon footprints. Terrapass will use your money to support fuel-efficient technologies, reducing a significant quantity of harmful emissions.**
- **None of your friends or colleagues has chosen to offset their emissions over the past year.**
- **Your contribution will be tax deductible.**

Will you pay to offset harmful emissions from your flight?

- Yes
- No

2. If yes, how much money (\$US) are you willing to pay? (please enter dollar amount with no symbols)

Table A3 - WTP Question in Survey #7

*** 1. Consider the following scenario: You are planning a vacation and have decided to purchase airline tickets through expedia.com, an online travel service. You plan to travel 5000 miles roundtrip and decide to spend \$400 on tickets. Before clicking "confirm purchase," however, you are asked whether you are interested in offsetting emissions from your flight. In other words, you are asked to pay an additional fee to compensate for your portion of the flight's harmful fuel emissions.**

Before completing your purchase, consider that the following circumstances apply:

- **Your money will go towards Terrapass Inc.**
- **None of your friends or colleagues has chosen to offset their emissions over the past year.**
- **Your contribution will be tax deductible.**

Will you pay to offset harmful emissions from your flight?

- Yes
- No

2. If yes, how much money (\$US) are you willing to pay? (please enter dollar amount with no symbols)

[Prev](#) [Next](#)

Appendix B – Linear Regression Data

Linear Probability Regression of “Pay”

Source	SS	df	MS	Number of obs = 397		
Model	1.72909743	6	.288182905	F(6, 390)	=	1.22
Residual	91.8376532	390	.235481162	Prob > F	=	0.2930
				R-squared	=	0.0185
				Adj R-squared	=	0.0034
Total	93.5667506	396	.236279673	Root MSE	=	.48526

pay	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
tax	.0665508	.0489073	1.36	0.174	-.0296042	.1627057
participat~n	.0562241	.049215	1.14	0.254	-.0405358	.152984
story	.0033694	.0488372	0.07	0.945	-.0926478	.0993866
gender_male	-.1009378	.0581812	-1.73	0.084	-.2153258	.0134502
student_yes	.0247268	.0561947	0.44	0.660	-.0857557	.1352093
carbon_exp~s	.0354064	.0762983	0.46	0.643	-.1146011	.1854139
_cons	.5780173	.0624492	9.26	0.000	.4552381	.7007966

Linear Regression of “WTP”

Source	SS	df	MS	Number of obs = 397		
Model	18016.7824	6	3002.79706	F(6, 390)	=	2.19
Residual	534770.756	390	1371.20707	Prob > F	=	0.0432
				R-squared	=	0.0326
				Adj R-squared	=	0.0177
Total	552787.539	396	1395.92813	Root MSE	=	37.03

wtpwithzeros	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
tax	8.610507	3.732048	2.31	0.022	1.273058	15.94796
participat~n	5.727429	3.755526	1.53	0.128	-1.656181	13.11104
story	-.1902666	3.7267	-0.05	0.959	-7.517202	7.136669
gender_male	-8.584481	4.439723	-1.93	0.054	-17.31327	.1443043
student_yes	2.59267	4.288141	0.60	0.546	-5.838096	11.02344
carbon_exp~s	6.121667	5.822217	1.05	0.294	-5.325193	17.56853
_cons	14.69804	4.765413	3.08	0.002	5.328928	24.06716

Appendix C – Difference in Means and Proportions

The following formulas were used to construct hypothesis tests of the difference in means and proportions for each of the three market variables (tax, participation, and story).

Formulas – Difference in Means

Large Sample Test of Hypothesis for $(\mu_1 - \mu_2)$: Independent Samples

- One- Tailed test

$$H_o : (\mu_1 - \mu_2) = D_o$$

$$H_A : (\mu_1 - \mu_2) < D_o$$

$$[\text{or } H_A : (\mu_1 - \mu_2) > D_o]$$

where D_o = Hypothesized difference between the means

$$\text{Test statistic: } z = \frac{(\bar{x}_1 - \bar{x}_2) - D_o}{\sigma_{(\bar{x}_1 - \bar{x}_2)}} \text{ where } \sigma_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

$$\text{Rejection region: } z < -z_\alpha [\text{or } z > z_\alpha \text{ when } H_A : (\mu_1 - \mu_2) > D_o]$$

Large Sample (1- α)% Confidence Interval for (p₁-p₂)

- Assumptions: - The two samples are randomly selected in an independent manner from the two target populations.
- The sample sizes, n₁ and n₂, are both large enough so that the sampling distribution of ($\hat{p}_1 - \hat{p}_2$) will be approximately normal.

$$\begin{aligned}(\hat{p}_1 - \hat{p}_2) \pm z_{\frac{\alpha}{2}} \sigma_{(\hat{p}_1 - \hat{p}_2)} &= (\hat{p}_1 - \hat{p}_2) \pm z_{\frac{\alpha}{2}} \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}} \\ &\approx (\hat{p}_1 - \hat{p}_2) \pm z_{\frac{\alpha}{2}} \sqrt{\frac{\hat{p}_1 \hat{q}_1}{n_1} + \frac{\hat{p}_2 \hat{q}_2}{n_2}}\end{aligned}$$

Formulas – Difference in Proportions

Large-Sample Test of Hypothesis about (p₁-p₂)

- One-Tailed Test

$$H_o : (p_1 - p_2) = 0$$

$$H_a : (p_1 - p_2) < 0$$

$$[or \quad H_a : (p_1 - p_2) > 0]$$

$$\text{Test statistic: } z = \frac{(\hat{p}_1 - \hat{p}_2)}{\sigma_{(\hat{p}_1 - \hat{p}_2)}}$$

$$\text{Rejection region: } z < -z_{\alpha}$$

$$[or z > z_{\alpha} \text{ when } H_a : (p_1 - p_2) > 0]$$

Large Sample Confidence Interval for ($\mu_1 - \mu_2$) : Independent Samples

$$(\bar{x}_1 - \bar{x}_2) \pm z_{\frac{\alpha}{2}} \sigma_{(\bar{x}_1 - \bar{x}_2)} = (\bar{x}_1 - \bar{x}_2) \pm z_{\frac{\alpha}{2}} \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

where s_1^2 and s_2^2 can be used instead of σ_1^2 and σ_2^2 if needed

The raw data from this study was applied to the formulas above in order to calculate the statistics for difference in means and proportions listed in Tables C2 and C3, respectively. Table C1 describes the notation used in these tests.

Table C1: Variables

Tax	= 0 when the offset is not tax deductible
	= 1 when the offset is tax deductible
Participation	= 0 when market participation is 0%
	= 1 when market participation is 50%
Story	= 0 when the market has low transparency
	= 1 when the market has high transparency
Mean 1	Mean WTP when variable = 0
Mean 2	Mean WTP when variable = 1
Proportion 1	Proportion WTP when variable = 0
Proportion 2	Proportion WTP when variable = 1

Table C2: Difference in Proportions

Variable	Prop. 1	Variance 1	Count 1	Prop. 2	Variance 2	Count 2	Test Statistic	P-value
Tax	0.585	0.244	195	0.653	0.228	202	-1.39	0.0823
Participation	0.596	0.242	203	0.644	0.23	194	-0.98	0.1635
Story	0.619	0.237	197	0.62	0.237	200	-0.02	0.496

Table C3: Difference in Means

Variable	Mean 1	Variance 1	Count 1	Mean 2	Variance 2	Count 2	Test Statistic	P-value
Tax	16.17	421.35	195	25.1	2304.15	202	-2.42	0.0078
Participation	18.18	559.85	203	23.37	2264.39	194	-1.36	0.0869
Story	20.86	1422.22	197	20.57	1377	200	0.07	0.5279

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