Title
The Value of Green in Transportation Decisions

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Publication Date
2013

Peer reviewed|Thesis/dissertation

The Value of Green in Transportation Decisions

By

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A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Engineering – Civil and Environmental Engineering

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Joan Walker, Chair

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Fall 2013

Abstract

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To address issues of climate change, information about greenhouse gas emissions is more and more often being presented to people. For example, labels and signs displaying pounds and kilograms of CO_2 are showing up in trip planners, in car advertisements, and even in restaurant menus. This is being done under the assumption that the information about the environmental impacts of different alternatives will encourage more sustainable behavior. However, little is known about whether or not this strategy affects the choices people make. In order for people to change their behavior for the benefit of reduced emissions, they first need to place positive value on those reductions. This research aims to answer three questions regarding the efficacy of presenting people with this information: first, do people place significant value on reducing their greenhouse gas emissions, second, can people consistently value a pound of CO_2, and third, how does this value of green vary across the population? To answer these questions, five experiments were designed and conducted using discrete choice experiments, a framework typically used to investigate how people value reducing their travel time. UC Berkeley students and residents of the San Francisco Bay Area made stated and revealed preference transportation choices from a set of alternatives. With knowledge of the attributes of their chosen alternative as well as those of their available alternates, their choices were analyzed using logit, mixed logit, and hybrid choice models. The findings include that not only can people consistently interpret and place value on the pounds of CO_2 associated with their transportation alternatives, but also that there exists a discrete distribution in the value of green. For all except one experiment, the best models indicate that while a majority of the population does not act as though they care about reducing their greenhouse gas emissions, there is a small group with a willingness to pay of \$2.68 per pound of CO_2.

Acknowledgements

I would like to thank the University of California Transportation Commission (UCTC), the UC Berkeley Center for Future of Urban Transport, a VOLVO Center of Excellence, and the National Science Foundation for their generous funding.

I would like to thank my adviser, Joan Walker, my committee members Shachar Kariv and Samer Madanat, and my coauthors Yanding Zheng, David Vautin, and Akshay Vij for their help and guidance.

I would like to thank the Experimental Social Sciences Laboratory (XLAB) and the Qualtrics staff for their help with the experiments.

Most of all, I would like to acknowledge my loving and supportive family: Mom, Jen, and Emily. Thank you.

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Chapter 1

Introduction

Information is presented to decision makers in an effort to encourage certain decisions. Whether the intention is to sell more value meals at a fast food restaurant or to enroll more students in a training program, the marketing industry relies on broadcasting information to the public to boost consumption. While this is most often done in the name of benefits realized by a company, it can also be used to encourage people to make better personal decisions such as the campaigns to quit smoking or to exercise more, and it has recently been used to promote actions with societal benefits such as reducing littering and increasing recycling. In particular, people are more and more often being presented with information about the environmental impacts of their actions in the form of greenhouse gas emissions.

GREENHOUSE GAS EMISSIONS

The importance of greenhouse gas emissions has become popular recently as is indicated by the existence of markets in which to trade allowances for emitting carbon dioxide (Emissions, 2010) and by the passage of the Global Warming Solutions Act of 2006 by the California State Legislature, more popularly known as Assembly Bill 32 (California Assembly, 2006). This bill mandates that California reduce its emissions of carbon dioxide (CO_2) to the amount that was emitted in 1990 by 2020. Technological improvements such as hybrid vehicles contribute to reducing emissions, but encouraging more environmentally friendly behavior is also an important strategy for attaining this goal. In fact, Hoffert (2010) argues that technological improvements alone are insufficient to reach carbon emissions reductions goals.

Emissions information is becoming more prevalent under the assumption that it will encourage more sustainable behavior. However, little is known about whether or not people are willing to make personal sacrifices for a global benefit. In the research presented in this dissertation, this tradeoff between personal costs and societal benefits is studied in the transportation decisions people make. The transport of people and goods is responsible for up to 40 percent of greenhouse gas emissions (ARB, 2009). Also, many people have competitive alternative modes for their trips that they could use to save time, save money, get exercise, and/or reduce emissions.

UNCONVENTIONAL INFLUENCES

The methods used in transportation demand forecasting typically assume that people are only concerned with personal costs and benefits that occur immediately, such as the amount of time and the amount of money it will take to reach a destination. However, just as behavioral economists have been uncovering unconventional influences in our behaviors (Ariely, 2008), there are certainly other factors that people consider when making transportation decisions.

Beyond influences that involve personal immediate costs and benefits, people also consider what will happen in the future, what will happen to other people, and the riskiness of the outcomes. For example, some people might place value on the environmental friendliness of biking and walking while others could enjoy the perception of increased social status that comes with driving certain vehicles. One tradeoff that strongly indicates preference for future benefits to other people is the willingness to make personal sacrifices for the benefit of reduced CO_2 emissions. The purpose of this research is to investigate whether and how much people care about reducing the greenhouse gas emissions associated with their transportation behavior.

The experiments presented here use the framework that is typically utilized to study tradeoffs such as the value of time, which is well established and summarized by Mackie et al. (2003). This framework involves presenting people with several alternatives and observing which one they choose. Because the researcher knows the attributes of what could have been chosen as well as the attributes of the chosen alternative, this choice provides some insight into how the decision maker values the set of attributes. By including some variation across the choice sets, the researcher can form estimates of how each attribute is valued individually. This is often done to study how people value their travel time relative to their money, and in this research these tools are used to study how people value the emissions associated with their transportation decisions.

CONTRIBUTIONS

This research adds to the existing literature by quantifying the tradeoff people make between monetary costs in dollars and environmental costs in pounds of CO_2. Existing relevant literature finds that people are willing to pay a fractional premium for products and services marketed as "green" (Saphores et al., 2007) (Schubert et al., 2010). It has also been found that people are willing to pay more for a car with lower relative emissions than a car with similar levels of emissions as currently available vehicles (Bunch et al., 1993). Achtnicht (2009) found that people are willing to pay the equivalent of $0.22 per pound of CO2 reduced when purchasing a car. This value stands alone in the space of quantifying the tradeoff between personal monetary costs and public environmental benefits.

The research presented here also contributes by investigating different populations making different types of decisions as well as by investigating how this value of green varies across the population. The last contribution is distinguished from findings of related research such as that environmental beliefs are highly correlated with owning an efficient car and driving less (Daziano and Bolduc, 2011) by allowing willingness to pay for emissions reductions to vary randomly.

Five discrete choice transportation experiments were designed and conducted to investigate three research questions.

1. Is information about greenhouse gas emissions a significant influence in the transportation decisions people make?
2. Can people consistently value a pound of $C0_2$ relative to other attributes of their transportation alternatives such as time and cost across a wide variety of decisions and with different amounts of information?
3. How is this value willingness to pay for emissions reductions distributed across the population?

LAYOUT OF CHAPTERS

The five experiments that were designed to answer these questions are presented here in the form of three academic papers. The first paper is titled "Experimental Economics in Transportation: Focus on Social Influences and Provision of Information" (Gaker, et al., 2010). While several experiments are described that investigate non-standard influences in transportation decisions, this paper presents two experiments that are relevant to the value of green; a route choice for a day-trip to a park and a decision of which car to buy upon graduation. The subjects were undergraduate students at UC Berkeley.

The second paper is titled "The Power and Value of Green in Promoting Sustainable Transport Behavior" (Gaker, et al., 2011). This paper presents two additional experiments regarding the value of geen; a route choice for a commute trip and a recreational trip and mode choice for a commute trip. The auto purchase experiment from the previous paper is also revisited. This paper investigates systematic and random continuous heterogeneity in the willingness to pay for emissions reductions and for the value of time. The subjects were undergraduate students at UC Berkeley.

The third paper is titled "Revealing the Value of Green and the Small Group with a Big Heart in Transportation Mode Choice" (Gaker and Walker, 2013). It presents a transportation mode choice experiment that incorporates both stated and revealed preferences of residents of the San Francisco bay area. This paper investigates random discrete heterogeneity in the willingness to pay for emissions reductions. This paper also revisits the data from the first two papers to further investigate the heterogeneity of the value of green.

All three papers have their own individual focus, and each makes its own contributions to the literature that are relevant to our understanding of whether and how much value people place on their environmental impacts. The first shows that emissions information is a significant influence in the transportation decisions people make. The second shows that people can consistently place value on these emissions across a variety of types of decisions and with a broad range of information available. The third shows that this value of green also exists in revealed preferences and that while most people have no desire to reduce emissions there is a small group with a big heart that has a very high value of green. These three academic papers follow as the three chapters of this dissertation.

Chapter 2

Experimental Economics in Transportation: A Focus on Social Influences and the Provision of Information

Originally published in Transportation Research Record: Journal of the Transportation Research Board, 2156, pp 47-55, 2010.

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ABSTRACT

A major aspect of transportation planning is understanding behavior: how to predict it and how to influence it over the long term. Behavioral models in transportation are predominantly rooted in the classic microeconomic paradigm of rationality. However, there is a long history in behavioral economics of raising serious questions about rationality. Behavioral economics has made inroads in transportation in the areas of survey design, prospect theory, and attitudinal variables. Further infusion into transportation could lead to significant benefits in terms of increased ability to both predict and influence behavior. The aim of this research is to investigate the transferability of findings in behavioral economics to transportation, with a focus on lessons regarding personalized information and social influences. We designed and conducted three computer experiments using UC Berkeley students: one on personalized-information and route choice, one on social influences and auto ownership, and one combining information and social influences and pedestrian safety. Our findings suggest high transferability of lessons from behavioral economics and great potential for influencing transport behavior. We found that person- and trip-specific information regarding greenhouse gas emissions has significant potential for increasing sustainable behavior, and we are able to quantify this ***Value of Green*** at around $0.24/pound of greenhouse gas avoided. Congruent with lessons from behavioral economics, we found that information on peer compliance of pedestrian laws had a stronger influence on pedestrian safety behavior than information on the law, citation rates, or accident statistics. We also found that social influences positively impact the decision to buy a hybrid car over a conventional car or forgo a car altogether.

INTRODUCTION

Behavioral economics draws influences from both psychology and economics with an objective to "figure out what really influences our decisions in daily life (as opposed to what we think, often with great confidence, influences them)" (Ariely, 2008). The powerful tool of the field is its use of simple and cleverly designed experiments. These experiments are aimed at understanding behavior and often at exposing the irrationality of humans, and they are frequently successful. Even with high stakes and greater complexity (for example, marriage or entrepreneurs), behavioral economics uncovers many common biases (Thaler and Sunstein, 2008).

Despite decades of research raising serious questions about rationality (Kahneman and Krueger, 2006), the transportation profession is still too largely entrenched in the rational human paradigm. While there is ample evidence that people are irrational, behavioral economists have been successful at uncovering principles guiding these lapses. Armed with the knowledge of these techniques and principles, we can improve transportation planning, and this is the goal of this research. Note that we are not so much interested in proving so-called irrationality (which is debatable terminology), but in capturing significant drivers of transport behavior be they traditional or non-traditional factors.

INROADS OF BEHAVIORAL ECONOMICS IN TRANSPORTATION

Considering the volume of transport behavior literature, the infusion of behavioral economics into transportation has been relatively minimal. Further, the infusion has happened via a few primary avenues. One impact has been in the insights into survey research (for example, stated preference surveys), and in particular issues such as anchoring and framing (i.e., how responses are sensitive to how a situation is presented). See, for example, Gärling et al. (2000), Louviere et al. (2000), de Palma and Picard (2005), Bonsall et al. (2007), Ben-Elia et al. (2008), and Rose et al. (2008). Another avenue that has received considerable attention in transportation is prospect theory (Kahneman and Tversky, 1979) (Kahneman and Tversky, 2000), which focuses on decision-makers' behavior under risk, including asymmetric perceptions of gains, losses, and probabilities. Example applications in transportation include Venter and Hansen (1998), Nakayama and Kitamura (2000), Avineri and Prashker (2004), Zhang et al. (2004), Han et al. (2005), Avineri (2006), Cantillo et al. (2006), Elgar and Miller (1977), Liu and Polak (2007), and Puckett and Hensher (2009). The final area of influence is a bit more indirect, but involves bringing the psychological (as well as sociological) theories that influence behavioral economics into transport behavioral studies. This includes theories regarding decision-making processes and the influences of factors such as attitudes, perceptions, and social influences. Examples of work in this area include Fuji and Gärling (2003), Dugundji and Walker (2005), Handy et al. (2005), de Palma and Picard (2006), Páez et al. (2008), Schwanen and Mokhtarian (2007), Axhausen (2008), and Karash et al. (2008). Despite these inroads, much more can be learned. Indeed, McFadden (2008) emphasized the value of increased emphasis on behavioral science in transportation.

OBJECTIVES AND APPROACH

The aim of this research is to investigate the transferability of findings from behavioral economics to transportation, beyond the areas that have thus far been emphasized in the transportation literature as described above. While there are potentially dozens of other themes in behavioral economics from which the transport domain could benefit, we began this research by focusing on 2 themes: (1) information and feedback and (2) social influences. These two themes were selected as they are two of the most important drivers for behavioral modification mentioned by behavioral economists and they are highly relevant to transport behaviors.

Here we describe three experiments that focus on transportation issues, each inspired by research in behavioral economics. The methodological approach is to use behavioral economics as a driver for technique (experiments) and behavioral theories (irrationality), but do so with a strong eye on the needs for transportation. The transportation application areas we study are route choice, auto ownership, and pedestrian safety. The questions addressed in this paper are whether themes found in the experiments of behavioral economics hold under more realistic transportation choice environments, and whether we can learn valuable insights for transportation.

Employing one of behavioral economists' most common experimental techniques, we conducted our experiments in Xlab (the "Experimental Social Science Laboratory") at UC Berkeley. This is a computer laboratory for conducting human-subject experiments. The lab maintains a subject pool of over 2500 members, all of whom are UC Berkeley affiliates and most are undergraduate students. Xlab administration handles the recruiting and requires that researchers provide subjects with participation fees of around $15/hour.

We programmed and conducted the experiments using the experimental economics software z-Tree (Fischbacher, 2007), and we used the experimental design routines in SAS to develop the profiles presented to the subjects.

BEHAVIORAL ECONOMICS THEMES OF INFORMATION AND SOCIAL INFLUENCES

As discussed above, we focus on the two themes of information and social influences due to their prevalence in the behavioral economics literature as well as their potential for influencing behavior. Thaler and Sunstein (2008) in their popular press review of behavioral economics, state that they have found "one of the most effective ways to nudge (for good or evil) is via social influence". Here we highlight a few experiments particularly relevant to the task at hand.

One strong theme is the power of information and feedback. Schultz et al. (2007) report a residential energy use study in California in which households were given information about their energy use relative to the average energy use for households in their neighborhood. They found that above average users reduced their energy consumption. However, below average users actually increased their energy use. To counteract this "boomerang" effect, above average users were given a frowning face emoticon with their report (causing them to decrease use even further), and below average users were given a smiley face emoticon (causing them to maintain their low level of energy use).

In the transport domain, Taniguchi et al. (2007) examine the impact of a host of “travel feedback programs” instigated in Japan. These programs focus on working directly with households regarding goal setting (to more sustainable behaviors) and in providing personalized recommendations for modifying travel habits. Their meta-analysis indicates that these programs reduced car use by 7.3% to 19.1% and increased public transport use by 30.0% to 68.9% on average in residential areas of Japan. Gärling and Fuji (2009) also conclude that programs focusing on personalized education and feedback can have large effects on transportation demand.

While personalized feedback is powerful, it is difficult for people to understand the direct and/or long-term implications of their actions. Therefore, anything that can be done to make the impacts more transparent helps. Thomson (2007) reports an experiment with Southern California Edison customers aimed at reducing residential energy consumption. They provided two types of personalized feedback (to different groups). One was timely emails and text messages regarding energy use. The second was an ambient orb, which was placed in the house and glowed red during high energy use and green during low energy use. While the former did not lead to significant change in energy use, the latter led to a 40% reduction during peak periods.

A major theme in behavioral economics is the desire to conform to social norms. This is reflected in the studies above where comparison to ones neighbors influence behavior. There are also many other examples along these lines. For example, Coleman (1996) reports a study aimed at increasing income tax compliance rates in Minnesota. Several strategies were used to attempt to increase voluntary tax compliance: (i) threats of increased examination and audit rates, (ii) redesign of the standard tax form, (iii) enhanced customer service, (iv) descriptions of the good works that taxes go towards, and (v) a statement that 90% of Minnesotans have already complied with the tax law. In this experiment, only the latter had a significant effect, demonstrating the power of informing people about what other people are doing.

Sometimes social influences are so strong that people blindly follow others without thinking on their own. The rationale is that others must know what they are doing or have some sort of private information. Behavioral economists talk of *information cascades* (Bikhchandani, et al., 1992) and *social herding* (Banerjee, 1992), which is “a situation in which every subsequent actor, based on the observations of others, makes the same choice independent of his/her private signal”, possibly leading to “erroneous mass behavior” (Bikhchandani, et al., 1996). This literature focuses on how such a phenomenon can lead to irrational or erroneous decisions, and there are many laboratory experiments along these lines. For example, using a simple gambling experiment, Çelen and Kariv (2004) and Gale and Kariv (2003) were able to show how subjects’ perceptions of probabilities were distorted away from reality when they were informed of others bets.

DESCRIPTION OF OUR EXPERIMENTS

As described above, our focus is on the themes of information and social influences. Therefore, we designed three experiments: the first focuses on information, the second on social influences, and the third combines the two.

The behavioral economics literature emphasizes the power of personalized feedback to impact one's behavior. To test this, we designed a stated preference route choice experiment in which the relatively standard attributes of time and cost were provided for each alternative route. However, we also provided information on green-house gas emissions. While Ortúzar and Rodríguez (2002) sought to find the willingness to pay for being exposed to less air pollution, we seek to find how people value reducing their own emissions. What we are testing is whether we can nudge people to more sustainable behavior if we provided trip-specific, personalized information on environmental impacts.

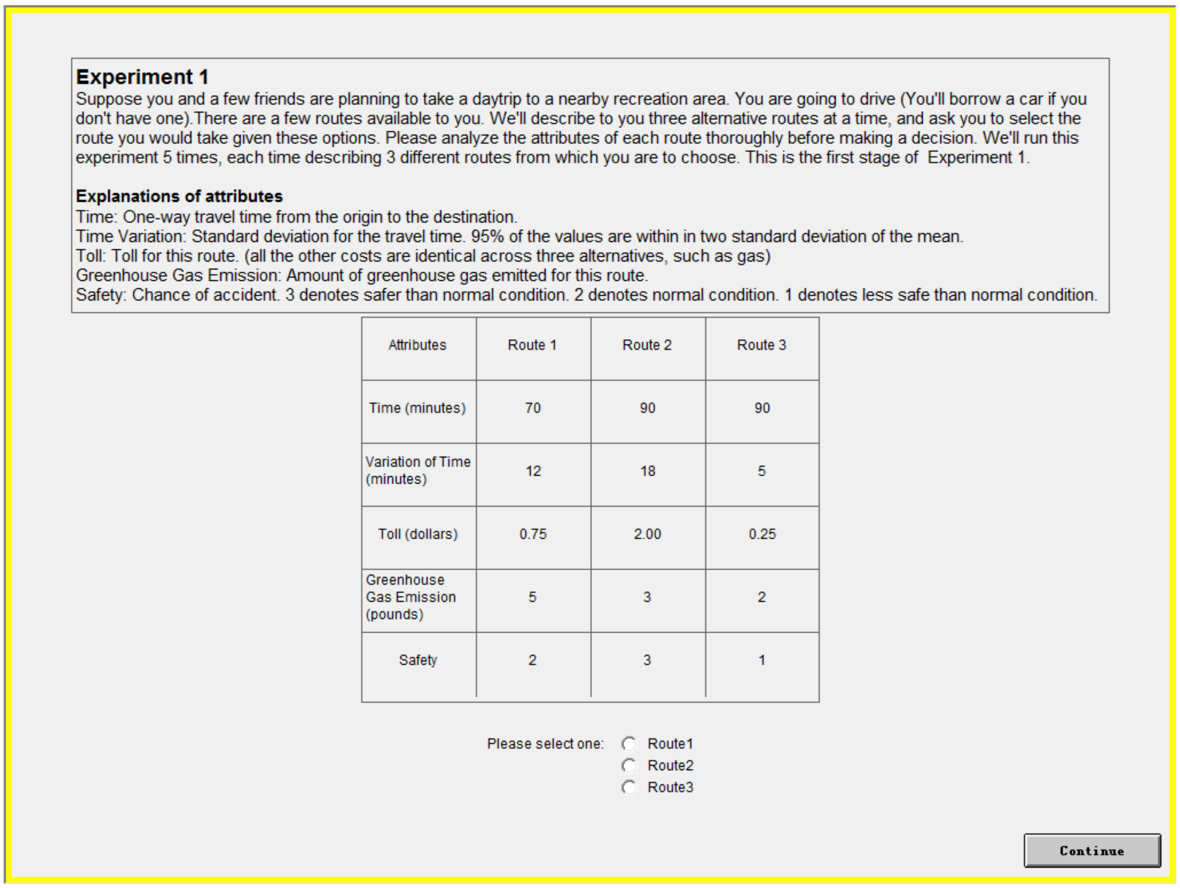
To test the social influences theme, we developed an "information cascade" experiment in an auto ownership setting. In an information cascade experiment in the lab, subjects make decisions in pre-determined order and their choices are broadcast to decision-makers who follow. Therefore, everyone but the first subject knows the decision of some of the other people in the experiment before making their own decisions. Subjects were given a scenario involving a future job, a residential setting, a commute, and attributes of a conventional car and a hybrid car. They were then asked whether they would buy one of the cars or forgo owning a car. However, before making the decision, they were told the distribution of choices (buy conventional, buy hybrid, not have a car) of a certain number of other subjects participating in the experiment at the same time. We varied the scenario presented to each person and tested whether people were influenced by the reported decisions of others in the lab.

To test a combination of the themes of information provision and social influences, our third experiment mimicked the Minnesota tax experiment described above (36), but in a pedestrian safety context. We devised different types of information aimed to influence pedestrian jaywalking behavior, including information based on the law, based on accident and citation rates, and based on behavior of peers. We then presented each subject with only one of these pieces of information, and asked whether the subject felt that in the coming week he/she would cross against red lights more frequently, less frequently, or the same as the previous week. We tested whether, like the Minnesota tax experience, people are most impacted by the behavior of their peers or whether more traditional methods emphasizing the law or accidents would be more significant.

The details of each of the three experiments are described below. The results are presented in the next section.

Figure 1 provides an example screen from the route choice experiment. All subjects were given the same scenario, which was taking a trip with friends to a recreational area. They were presented three routes, each described by travel time, variation in travel time, toll cost, greenhouse gas emissions, and safety. Each respondent was presented 5 different sets of route choices and asked each time to select one of three provided routes.

FIGURE 1 Example screen from Experiment 1 (Route Choice).



Experiment 1

Suppose you and a few friends are planning to take a daytrip to a nearby recreation area. You are going to drive (You'll borrow a car if you don't have one).There are a few routes available to you. We'll describe to you three alternative routes at a time, and ask you to select the route you would take given these options. Please analyze the attributes of each route thoroughly before making a decision. We'll run this experiment 5 times, each time describing 3 different routes from which you are to choose. This is the first stage of Experiment 1.

Explanations of attributes

Time: One-way travel time from the origin to the destination.
Time Variation: Standard deviation for the travel time. 95% of the values are within in two standard deviation of the mean.
Toll: Toll for this route. (all the other costs are identical across three alternatives, such as gas)
Greenhouse Gas Emission: Amount of greenhouse gas emitted for this route.
Safety: Chance of accident. 3 denotes safer than normal condition. 2 denotes normal condition. 1 denotes less safe than normal condition.

Attributes	Route 1	Route 2	Route 3
Time (minutes)	70	90	90
Variation of Time (minutes)	12	18	5
Toll (dollars)	0.75	2.00	0.25
Greenhouse Gas Emission (pounds)	5	3	2
Safety	2	3	1

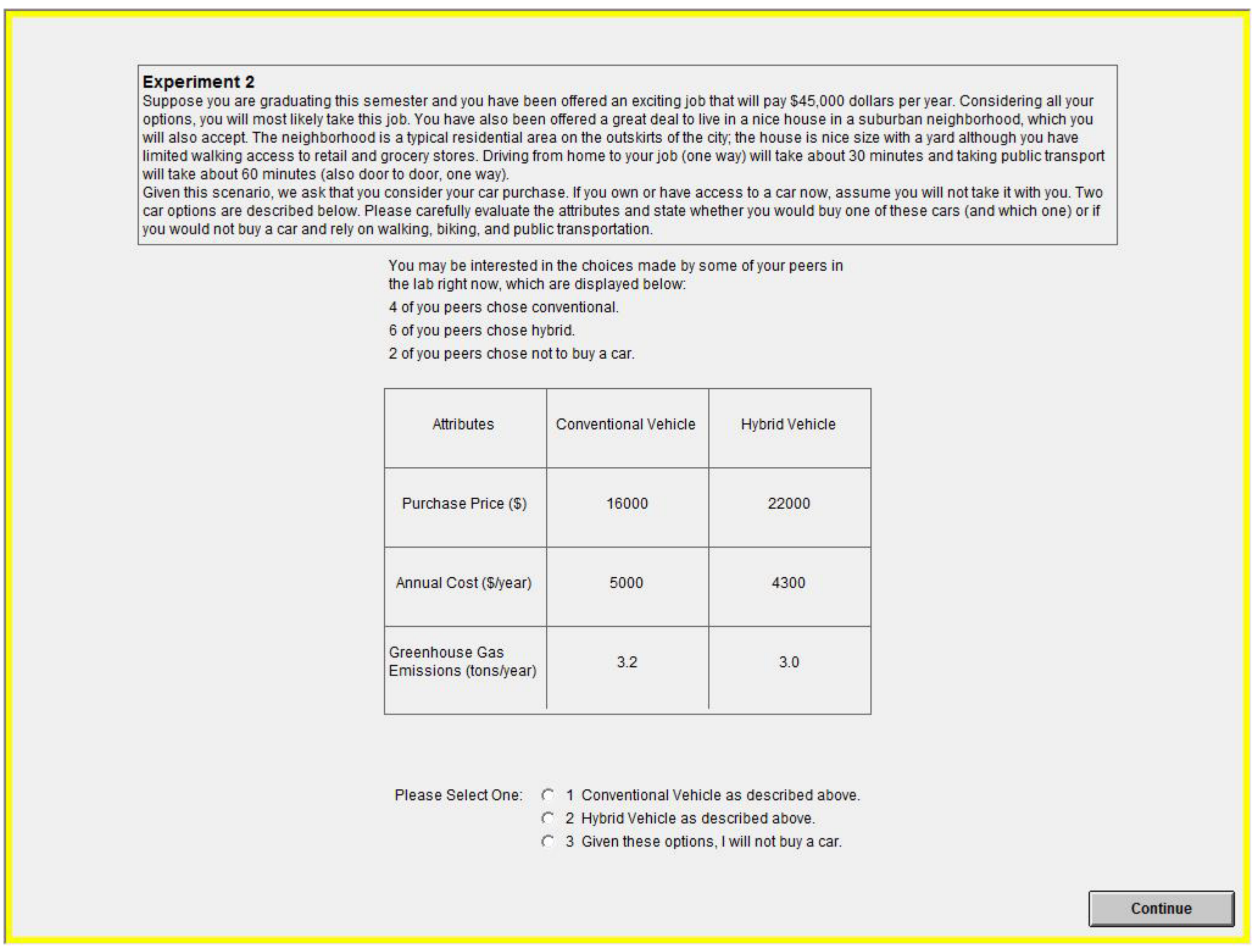
Please select one: Route1
Route2
Route3

Continue

Figure 2 provides an example screen from the auto ownership experiment. The setup described a future job and housing scenario. All respondents were presented the same job scenario, which is shown in Figure 2, where the key information is the salary of $45,000/year. There were two residential land use scenarios: one suburban and one mixed-use. We were interested in seeing whether the social influences would override fairly strong initial land use triggers. Figure 2 displays the suburban scenario, and the mixed-use scenario is as follows:

> Suppose you are graduating this semester and you have been offered an exciting job that will pay $45,000 dollars per year. Considering all your options, you will most likely take this job. You have also been offered a great deal to live in an apartment in a mixed use neighborhood. The apartment is nice, although small. The neighborhood is fairly dense with retail and entertainment nearby and decent access to public transit. Driving from home to your job (one way) will take about 20 minutes and taking public transport will take about 35 minutes (also door to door, one way).

FIGURE 2 Example screen from Experiment 2 (Auto Ownership).



Experiment 2

Suppose you are graduating this semester and you have been offered an exciting job that will pay $45,000 dollars per year. Considering all your options, you will most likely take this job. You have also been offered a great deal to live in a nice house in a suburban neighborhood, which you will also accept. The neighborhood is a typical residential area on the outskirts of the city; the house is nice size with a yard although you have limited walking access to retail and grocery stores. Driving from home to your job (one way) will take about 30 minutes and taking public transport will take about 60 minutes (also door to door, one way).

Given this scenario, we ask that you consider your car purchase. If you own or have access to a car now, assume you will not take it with you. Two car options are described below. Please carefully evaluate the attributes and state whether you would buy one of these cars (and which one) or if you would not buy a car and rely on walking, biking, and public transportation.

You may be interested in the choices made by some of your peers in the lab right now, which are displayed below:

4 of you peers chose conventional.

6 of you peers chose hybrid.

2 of you peers chose not to buy a car.

Attributes	Conventional Vehicle	Hybrid Vehicle
Purchase Price ($)	16000	22000
Annual Cost ($/year)	5000	4300
Greenhouse Gas Emissions (tons/year)	3.2	3.0

Please Select One:
- 1 Conventional Vehicle as described above.
- 2 Hybrid Vehicle as described above.
- 3 Given these options, I will not buy a car.

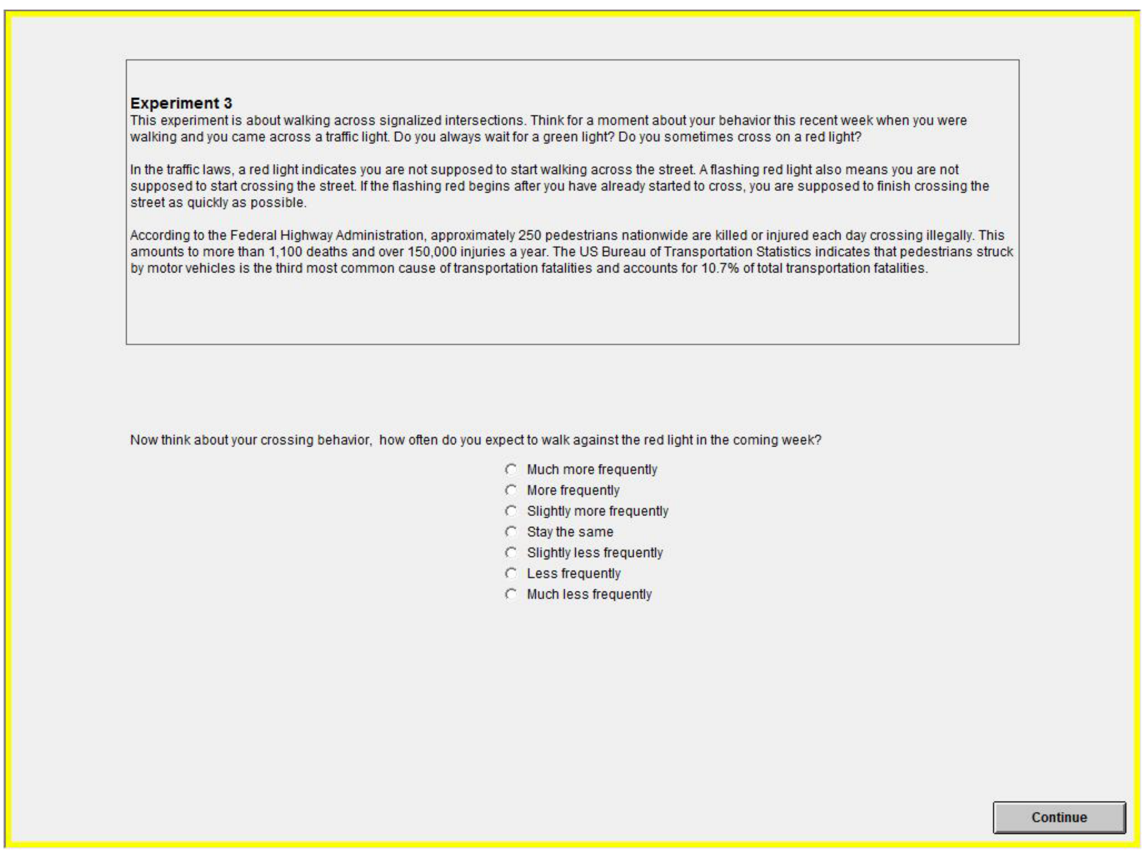
Continue

After the description of the job and residential scenario, we presented two auto purchase alternatives, one describing a conventional car and one describing a hybrid car. We provided attributes for each including purchase price, annual operating cost, and annual greenhouse gas emissions. The information cascade is presented with the auto descriptions, where respondents were told the choices of a certain number of their peers in the lab. We divided the subjects in any one lab (each lab had about 30 participants) into 4 groups, the first group had no information on peer decisions, and each following group had information on all preceding groups. The peer information did not roll over into the other lab sessions. Finally, the respondent was then asked to choose either to buy the conventional, to buy the hybrid, or to go without a car and rely on biking, walking and public transportation.

In this experiment we examine how various types of information impact pedestrian behavior, in particular crossing against a red-light.

Figure 3 shows a sample screen from the experiment. Each person was provided the introductory clarification of the subject area, shown at the top of the screen: “In the traffic laws, a red light indicates you are not supposed to start walking across the street. A flashing red light also means you are not supposed to start crossing the street. If the flashing red begins after you have already started to cross, you are supposed to finish crossing the street as quickly as possible.” The control group (approximately 1/6th of the subjects) was only provided this introductory information.

FIGURE 3 Example screen from Experiment 3 (Pedestrian Safety).



The remaining subjects were equally divided into five groups and each group was given one of the following five pieces of information (each is a true statement):

> **Accident statistics:** "According to the Federal Highway Administration, approximately 250 pedestrians nationwide are killed or injured each day crossing illegally. This amounts to more than 1,100 deaths and over 150,000 injuries a year. The US Bureau of Transportation Statistics indicates that pedestrians struck by motor vehicles is the third most common cause of transportation fatalities and accounts for 10.7% of total transportation fatalities."
>
> **The law, including the amount of a fine:** "According to 2009 California Vehicle Code: Unless otherwise directed by a pedestrian control signal as provided in Section 21456, a pedestrian facing a steady circular red or red arrow signal shall not enter the roadway. By violating the red light, a pedestrian convicted of an infraction for a violation shall be punished by a fine not exceeding fifty dollars ($50)."
>
> **Citation rates, including the amount of the fine**: "According to the data from UC Berkeley Police Department, in Jan 2009, five students were convicted of a red light infraction and were punished by a fine of $50 by the campus police around the campus."
>
> **Peer behavior, positively stated:** "An informal survey of students at Berkeley found that UC Berkeley students and staff cross legally at intersections 71.9% of the time."
>
> **Peer behavior, negatively stated:** "An informal survey of students at Berkeley found that UC Berkeley students and staff walk against the traffic signal 28.1% of the time."

The peer behavior statistic was obtained simply by counting red-light violations at a variety of intersections around the campus.

RESULTS

We report here results from experiments conducted on 312 subjects in UC Berkeley's Xlab between July and November, 2009. The demographics of our sample are as follows:

Number of respondents: 312
Age: Median 20 (92% between 18-22)
Gender: 57% female
Have an auto in Berkeley: 22%
Not in the US for most of high school: 11% (82% of these were in Asia)
Vegetarian/Vegan: 6%

For the experimental results described below, we first state the key hypothesis being tested, then summarize our finding, and then present the details. After results on the key hypotheses from each experiment are described, we present some other interesting findings such as the ***Value of Green***.

Results from Experiment 1: Personalized-Information & Route Choice

Hypothesis: ***We can nudge people towards more sustainable behavior by providing context- and person-specific information on the environmental impacts of their actions.***

Findings: ***Results suggest this has great potential.***

Recall in this experiment that each subject was presented three potential routes to take on a recreational trip with friends. The estimation results for the route choice model are shown in Table 1. These are panel data with 5 responses per person. We did not consider the panel in the estimation, and therefore the estimates are consistent but inefficient. Robust standard errors are used to obtain consistent estimates of the standard errors. The signs for all variables are correct and their significance high. In particular, to address the primary hypothesis of this experiment, the subjects were significantly swayed by the provision of information regarding greenhouse gases emitted for the route. As discussed more under "other findings" below, this model suggests a ***Value of Green*** of $0.50 per pound. This and other statistics from the model (for example, an estimated value of time of $6.51 per hour) are presented in Table 4 and will be discussed further after all estimation results are presented.

Our subjects are likely on the younger and more idealistic end of society (although they also, temporarily at least, are on the poorer side). However, the results are strong enough that they are worth pursuing on a broader scale. The results suggest that if people have better understanding of alternatives available and their relative impacts on the environment, they will take this into account and make choices that are more sustainable. With mobile-phone apps and greater understanding of related issues such as life-cycle costs and emissions modeling, the possibility of providing such personalized information (for example, in response to queries to a direction/mapping search engine) is real.

TABLE 1 Estimation results from Experiment 1 (Route Choice)

Parameter	**Estimate**	**t-test**	**p-value**
Travel time (minutes)	-0.0596	-17.4	0.00
Standard deviation of travel time (minutes)	-0.0232	-3.9	0.00
Toll ($)	-0.549	-14.9	0.00
Dummy variable if toll = $0	0.393	3.7	0.00
Greenhouse gases (pounds)	-0.275	-10.1	0.00
Safety: below average (relative to average)	-1.44	-14.2	0.00
Safety: above average (relative to average)	0.236	3.8	0.00
Number of observations	312 subjects * 5 responses/subject		
Adjusted rho-square	0.308		

Results from Experiment 2: Social Influences & Auto Ownership

Hypothesis: ***Social influence in the form of an information cascade will impact whether a person buys a conventional car, buys a hybrid car, or forgoes having a car.***

Findings: ***Our subjects were indeed influenced by the decisions of their peers.***

Recall that in this experiment, the subjects were given a job and housing scenario, and then presented with a hypothetical conventional car and a hypothetical hybrid car. The choice was whether to buy one of the two cars or to forgo owning a car. Each subject had a different set of attributes presented to them (determined through experimental design); 17% of our subjects chose the conventional car, 49% chose the hybrid car, and 34% chose to go without a car. The social cascade twist was that subjects were told what other subjects in the same lab experiment chose to do.

The estimation results are shown in Table 2. The traditionally hypothesized and modeled influences of residential scenario (suburban versus mixed use) and costs (purchase price and operating cost) are highly significant with correct signs. Greenhouse gas emissions are significant (suggesting a ***Value of GREEN*** of \$0.37/annual pound when purchasing the vehicle and \$0.08/pound on an annual operating cost basis), and this is beyond the benefit of fuel cost savings as that is captured by the annual operating costs. The peer influence variable is the last parameter in the table where we include in each utility the fraction of peers reported to choose each of the three alternatives. It suggests that providing information on peer decisions impacts auto purchasing decisions. In terms of influencing sustainable behavior, it will depend on what the relative peer behavior is in terms of driving conventional or hybrid cars or not owning a car.

TABLE 2 Estimation results from Experiment 2 (Auto Ownership)

Parameter (& alternative to which it applies at right)	**Conventional**	**Hybrid**	**No Car**	**Estimate**	**t-test**	**p-value**
Constant (hybrid)		x		0.990	2.2	0.03
Constant (no car)			x	-10.1	-3.4	0.00
Suburban residential scenario (vs mixed use)			x	-1.76	-6.1	0.00
Purchase price (\$1000s)	x	x		-0.258	-4.7	0.00
Annual operating cost (\$1000s)	x	x		-1.27	-2.2	0.03
Greenhouse gas emissions (tons/year)	x	x		-0.192	-1.7	0.08
Fraction of peers who chose alternative	x	x	x	1.41	2.6	0.01
Number of observations				312		
Adjusted rho-square				0.173		

Results from Experiment 3: Information and Social Influences & Pedestrian Safety

Hypothesis: ***Providing information on social norms has a greater influence on pedestrian safety behavior than traditional information regarding accidents, citations, and fines.***

Finding: ***Our results suggest that social norms do, indeed, have the most significant impact on behavior. Unfortunately, providing such behavioral statistics can degrade pedestrian safety due to the large percentage of the population that does not comply with the law.***

Recall that in this experiment subjects were given varying types of information related to pedestrian safety. We had six different treatments and divided the subjects equally among them. After seeing one piece of information, the subjects were asked to state whether in the coming week they thought they would more frequently, less frequently, or not change their rate of walking against a red light relative to the previous week. Not surprisingly, most of our sample (66%) said our information would not influence their behavior. However, 27% stated they thought they would improve their pedestrian safety behavior. Unfortunately, 7% stated they would worsen their behavior.

The estimation results are shown in Table 3. The subjects provided their response in the form of a 7 point scale as shown in Figure 3. However due to the small percentage who reported a change in behavior, we modeled only 3 levels: change for the worse (more law breaking), no change, and change for the better (less law breaking). The first thing to note in the estimation results is that socio-demographics seemed to have the largest influence on the stated responses. In particular, we found that females were more likely to state they would improve their behavior, and subjects who spent most of their high school years outside the US were more likely to state they would change their behavior, either for the better or (more weakly) the worse. In terms of the effects of the information we provided, we estimated two parameters for each type of information: one for influencing a positive change in behavior, one for influencing a negative change in behavior. Both of these parameters are relative to no change and relative to the control group, which did not receive special information. The only significant parameter at the 95% level (or close to it) is that providing information on the percent of peers that cross illegally influences people to state they intend to worsen their pedestrian safety behavior. None of the other pieces of information were found to have a significant effect, either positive or negative.

Recall that the idea for this experiment came from the Minnesota tax compliance experiment where they found the social influence information to be the most effective in nudging desirable behavior. In our case there are indications that it could be influential (at least more so than accident rates and statements of the law), however it is influencing these subjects in the wrong direction: towards less desirable behavior. This is likely because our statistic is that their peers walk against red lights 28% of the time, which is high enough to make people feel it is okay to do. In the tax experiment, the compliance rate was 90%. Our result is along the lines of the "boomerang" effect described above in the context of the energy experiment. The lesson is that you don't want to let people know they are behaving better than the norm.

TABLE 3 Estimation results from Experiment 3 (Pedestrian Safety)

Parameter	**improve**	**no change**	**worsen**	**Estimate**	**t-test**	**p-value**
Constant - improve pedestrian safety behavior	x			-1.59	-4.0	0.00
Constant - do not change pedestrian safety behavior		x		0	fixed	
Constant - worsen pedestrian safety behavior			x	-3.56	-3.4	0.00
Female dummy - improve behavior	x			0.793	2.8	0.01
Female dummy - worsen behavior			x	-0.0530	-0.1	0.91
Outside US most of high school - improve behavior	x			0.940	2.3	0.02
Outside US most of high school - worsen behavior			x	0.928	1.4	0.15
Information provided – improve behavior						
Accident statistics	x			0.335	0.7	0.47
The law, including the amount of the fine	x			0.224	0.5	0.61
Citation rates, including the amount of the fine	x			0.378	0.8	0.42
Peer behavior, positively stated (X% obey law)	x			-0.495	-0.9	0.35
Peer behavior, negatively stated (X% break law)	x			-0.257	-0.5	0.63
Control group (no additional info given)	x			0	fixed	
Information provided – worsen behavior						
Accident statistics			x	0.716	0.6	0.57
The law, including the amount of the fine			x	1.38	1.3	0.21
Citation rates, including the amount of the fine			x	0.0749	0.1	0.96
Peer behavior, positively stated (X% obey law)			x	0.586	0.5	0.64
Peer behavior, negatively stated (X% break law)			x	2.57	2.4	0.02
Control group (no additional info given)			x	0	fixed	
Number of observations				312		
Adjusted rho-square				0.265		

Other findings: *Value of Green*, Power of Free!, & Gains versus Losses

Other interesting findings from these results are presented in Table 4. The first is that because we have both price attributes and greenhouse gas attributes, we can estimate the ***Value of Green***, and we can do so from both the route choice experiment and the auto ownership experiment. What is interesting and comforting is that the values of green from the two experiments are on the same order of magnitude: $0.50/pound from route choice versus $0.37/annual pound (purchase price) and $0.08/annual pound (operating cost) in auto ownership. To test the hypothesis that the ***Value of Green*** does not significantly differ across the experiments, we used a joint estimator and applied a likelihood ratio test. This required assumptions as the auto ownership value is calculated in terms of annual pounds saved and the route choice experiment involves a trip with several friends so there may be cost sharing. We assume that two people in a car share the cost in the route choice experiment and purchasers of new cars expect to own the car 5.5 years. Making the appropriate unit conversions and estimating a single ***Value of GREEN*** using the data from both experiments, we found that our subjects value reducing their environmental impact at $0.24/pound of greenhouse gas. Further, there was no statistical evidence to reject our null hypothesis (p-value of 0.63). We do not report the estimation results from the joint model; however, none of the other parameter estimates were significantly different from the separate models. Our evidence suggests that our respondents are able to understand and fairly consistently process their preferences in relation to greenhouse gas emissions in pounds, even though one experiment involved *tons per year* and one *pounds per trip*. The importance of these results in terms of sustainable behaviors is that there *is* a ***Value of GREEN*** and people (well, our young, poor, and idealistic undergraduates, at least) are willing to pay to reduce their impact on the environment.

Other interesting findings involve corroborating results from the behavioral economics literature. The first of these is the "power of FREE!" concept coined by Ariely (2008), who points out that FREE! is an "emotional hot point… a source of irrational excitement… zero is not just another discount, it is a different place". We test this by including a dummy variable in the route choice experiment when there was no toll on the route. This parameter is significant and suggests that people are willing to (irrationally) pay $0.72 in order to avoid a toll or, equivalently, spend 8 more minutes traveling. In our experiment, this could partially be due to the desire to avoid stopping at a toll booth. The second behavioral phenomenon is at the heart of prospect theory which is that people are more risk averse than gain seeking. We see this in our results with the safety attribute in the route choice experiment. The results suggest subjects are willing to pay $2.62 to avoid a route with below average safety, although they are only willing to pay $0.43 to take a route with above average safety: a difference of over a factor of 6.

TABLE 4 *Value of GREEN*, Power of FREE!, Gains versus Losses

Value of GREEN				
From route choice experiment *(GHG savings presented in pounds/trip)*	$ 0.50	per pound		($ in terms of trip toll; per pound saved on the trip)
From auto ownership experiment *(GHG savings presented in tons/year)*	$ 0.37 $ 0.08	per pound per pound		($ in terms of purchase price; per annual pound saved) ($ in terms of operating cost; per annual pound saved)
Joint estimation: Constraining ***Value of GREEN*** to be equal across route choice and auto ownership experiments	$ 0.24	per pound		($ per pound saved) Assumptions: Own car 5.5 years; Toll shared among 2 in car. There is no evidence to reject the null hypothesis that the ***Value of GREEN*** is the same (p-value = 0.63)

Value of other things (all from the route choice experiment)				
Travel time	$ 6.51	per hour		
Travel time variance	$ 2.54	per hour		
Avoiding a toll	$ 0.72	- or -	7	minutes of travel time
Avoiding below average safety	$ 2.62	- or -	24	minutes of travel time
Gaining above average safety	$ 0.43	- or -	4	minutes of travel time

CONCLUSION

By applying simple lessons from behavioral economics to transportation, we have obtained several useful pieces of information regarding transportation behaviors. The strongest is that there is a ***Value of Green*** (estimated here to be $0.24/pound); individual- and trip- (or choice-) specific information on environmental impact has the potential to significantly influence people towards more sustainable travel patterns. We also confirmed that social norms are amongst the most powerful influences of transport behavior. Whereas social norms have worked effectively in other settings to nudge behavior in a positive direction (such as the tax compliance example), they actually backfired in our pedestrian safety experiment because of the relatively high rate of jaywalking in the peer group. We also saw strong evidence that social influences impact auto ownership decisions, including whether to buy a car and what type (hybrid or conventional). In general, the results from our experiments are promising in terms of understanding and influencing transport behaviors. There is a lot more to learn by transferring lessons from behavioral economics to transportation, particularly in these areas of social influences and personalized-information. Critical questions include how other segments of society behave in these scenarios (we studied UC Berkeley students), how these transfer to real market situations (i.e., revealed preference settings), and whether the result is long-term behavioral shifts or merely short-term blips in behavior. We also need to think more comprehensively in terms of useful ways to nudge people towards more sustainable and safer behaviors and the implications that these behavioral findings have on our modeling and forecasting methods.

Chapter 3

The Power and Value of Green in Promoting Sustainable Transport Behavior

Originally published in Environmental Research Letters, 6, pp 1-10, 2011.

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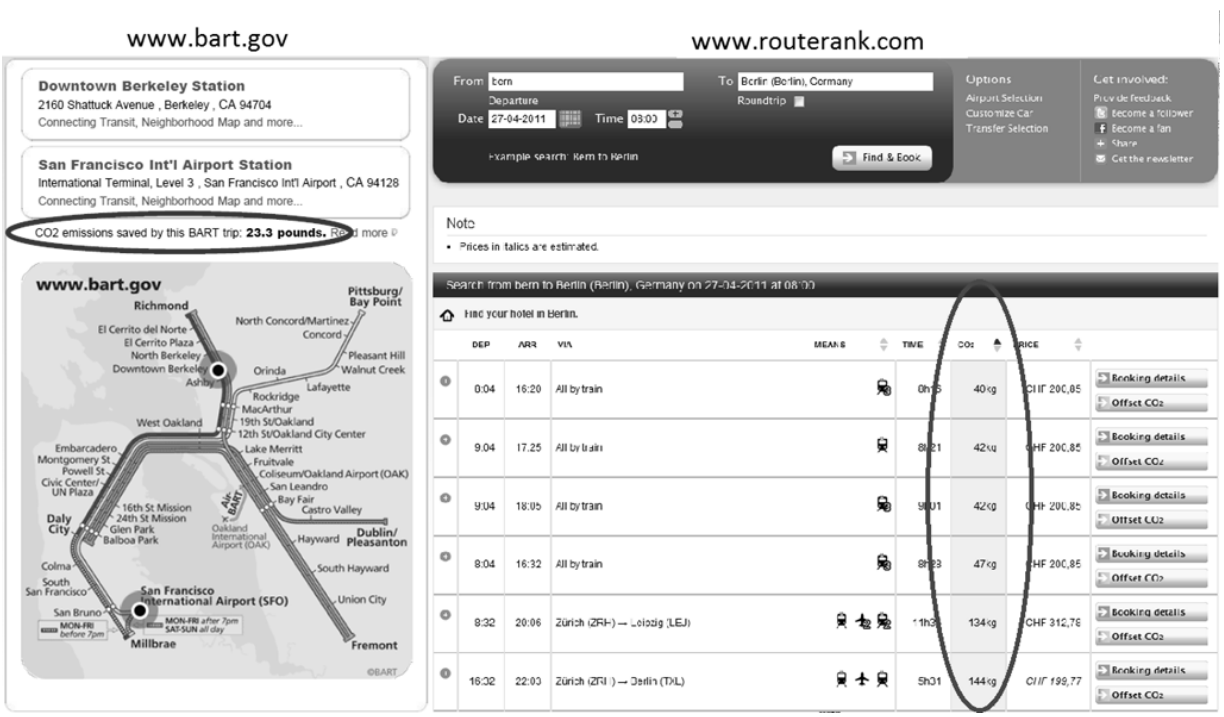
ABSTRACT

While it is increasingly popular to broadcast information regarding environmental impact, little is known regarding the effects this information has on human behavior. This research aims to provide insight on whether, and to what extent, presenting environmental attributes of transport alternatives influences individual transport decisions. We designed and conducted three experiments in which subjects (UC Berkeley undergraduates) were presented with hypothetical scenarios of transport decisions, including auto purchase choice, mode choice, and route choice. We analyzed their decisions via a choice model to determine how they value reducing their emissions relative to other attributes. We found that our subjects are willing to adjust their behavior to reduce emissions, exhibiting an average willingness to pay for emissions reduction, or *value of green (VoG)*, of 15 cents per pound of CO_2 saved. Despite concern that people cannot meaningfully process quantities of CO_2, we found evidence to the contrary in that the estimated VoG was consistent across context (the wide range of transport decisions we presented) and presentation (e.g., whether the information was presented in tons or pounds or whether a social reference point of the emissions of an average person was provided). We also found significant heterogeneity in VoG, with most of the respondents valuing it somewhere between 0 and 70 cents per pound and with women, on average, willing to pay 7 cents more per saved pound than men.

INTRODUCTION

The key issue with understanding any sort of behavior is in knowing how the decision maker values and reacts to the information that is available. Not only do people make tradeoffs regarding the readily available personal costs and benefits of their actions, but less blatant externalities may also be considered. One externality that has become a popular topic is the damage associated with greenhouse gas emissions. In the realm of transport behavior, information regarding environmental impact has begun appearing on numerous websites, including mode specific websites such as the Bay Area Rapid Transit trip planner and trip planning sites such as routeRANK (see Figure 4). However, little is known regarding what impact, if any, such information has on transport decisions. The large contribution of passenger transport to overall emissions makes this critical to understand; direct emissions from motor vehicles are the largest contributor to total household emissions (Jones and Kammen, 2011), and passenger transport is responsible for approximately 20% of greenhouse gas emissions in the US (Chester, 2008) and as high as 40% in California (ARB, 2009).

FIGURE 4 Emissions information displayed on transport websites



This research builds on a large body of literature that investigates drivers' response to travel information (see Chorus, 2007, for a review) and that investigates travelers' values of travel time savings in making transport decisions (see Hess et al., 2005, for a review). Whereas the focus in such literature has been on time and cost and reliability of travel alternatives, we use similar methods and add environmental factors to the mix. We have several objectives. The first is to determine whether and to what extent travelers are willing to modify their behavior to save emissions. The second is to investigate whether people can process "pounds" of CO_2 in a meaningful way. The third is to investigate heterogeneity in response to emissions information.

The fourth is to determine the sensitivity of response to presentation style of the emissions information. The policy implication of this work is that, if influential, emissions information could be used to encourage more sustainable transport choices.

LITERATURE

Despite the increasing awareness of the consequences of greenhouse gas emissions, there is a distinct gap in the research to answer the questions of if and how this type of environmental information influences transport decisions (Avineri and Waygood, 2011). There have been several studies involving the tradeoffs people are willing to make in order to reduce emissions, but many are specific to certain decisions and are not easily generalized to transport behavior. For example, Saphores et al. (2007) asked households whether or not they were willing to pay nothing, 1%, 5%, or 10% more for green cell phones and computers relative to conventional. They found the average household willing to pay only a 1% premium. Schubert et al. (2010) investigated willingness to pay for green restaurants and found that 65% of people stated they were willing to pay at least a 10% premium over standard restaurants, whereas 15% were not willing to pay anything. Choudhury et al. (2008) estimated willingness to pay for a variety of environmental improvement scenarios and found that while people with higher income have a higher willingness to pay for environmental improvement, this is mostly caused by their lower cost sensitivity rather than their environmentalism. While primarily focused on electricity and water, they also investigated driver behavior under various emissions fee scenarios. They were unable to estimate significant willingness to pay for increased fuel efficiency, but found socio-demographic influences such as that younger people or people with higher incomes were more likely to purchase clean vehicles.

Our specific interest is the impact that the presentation of equivalent pounds of CO_2 has on individual transport decisions. There have been limited studies in this area, and similar to the literature above (and our work presented in this paper), stated preference techniques are used in which subjects are presented with hypothetical transport alternatives (described by relevant attributes) and then asked which they would select. Achtnicht (2009) studied car purchase behavior in Germany, and from this estimated a willingness to pay of $0.22 per pound of CO_2 savings (€349 per tonne). Further, he found that willingness to pay was higher for females (relative to males), younger persons (under 45 relative to older than 45), and those with higher education. In our earlier work (Gaker et al., 2010), we estimated a willingness to pay of $0.24 per pound of CO_2 savings in auto purchase and route choice behaviors. Interestingly, while the Achtnicht (2009) and Gaker et al. (2010) estimates are similar in magnitude, they are much higher than the $0.01 per pound (€15 per ton) common on the European Climate Exchange (Emissions, 2010). Waygood and Avineri (2011) focus on how travelers perceive the sustainability of travel alternatives and found differences based on how emissions are presented, such as whether emissions are described in pounds or trees and whether the reference alternative is a bus or SUV.

RESEARCH APPROACH AND OUTLINE OF THE PAPER

In this paper, we retain the focus on pounds of CO_2 due to its prevalence, for better or for worse, as the dominant metric for reporting greenhouse gas emissions (Avineri and Waygood, 2010). We build on the initial findings from Achtnicht (2009) and Gaker et al. (2010) by investigating the consistency of VoG across context (meaning different transport decisions) and presentation (e.g., including a social reference or presenting yearly rather than daily emissions), and we further explore the distribution of VoG across subjects.

Here we present experimental results in which our subjects (UC Berkeley undergraduates) are presented hypothetical scenarios regarding various transport decisions and asked to state their preferences. The choice contexts include transport decisions ranging from longer-term auto ownership decisions to shorter-term route choice decisions. We also vary the manner in which the CO_2 is presented (e.g., pounds versus tons) to study the sensitivity of presentation. In stating their preferences, the subjects reveal information regarding the trade-offs they are willing to make among attributes such as cost, time, and emissions. We then estimate logit and mixed logit models to infer the sensitivity of our subjects to the attributes. From these models we estimate a willingness to pay for greenhouse gas reduction, which we call *value of green (*and heretofore denote as *VoG)*, and test whether VoG is significant and whether it varies across context, presentation, and individuals.

The next section describes the experiments. This is followed by a presentation of the estimation results. First we present the key findings regarding the estimated average VoG and its consistency across the choice contexts. Then we present estimation results aimed to explore the heterogeneity of VoG in the population. We then conclude with a discussion of our findings.

EXPERIMENTS

Our experiments were conducted on UC Berkeley undergraduates in the Experimental Social Sciences Laboratory (XLAB) in the Haas Business School. The subjects are recruited by the lab and paid $15 per hour. We conducted three primary experiments: an *auto-ownership* question of whether to buy a car (and what type), a *mode choice* question of whether to use the car or some other mode on a given trip, and a *route choice* question regarding which route to take on a specific auto trip. Each is described below. Note that while these experiments were designed to investigate a multitude of questions, our discussion here focuses on the influence of emissions information on the subjects' decisions.

Auto-Ownership Experiment

In this experiment subjects were presented with a hypothetical scenario in which they had graduated, found a job, and had a place to live in a described urban environment. They were then asked whether they were most likely to buy a hybrid vehicle, a conventional vehicle, or not to own a car. The two vehicle options were characterized by purchase price, annual operating cost, and annual greenhouse gas emissions. This experiment had a social norm focus, and so they were also given information on decisions made by their peers. Figure 5 provides an example screenshot from the experiment. The scenario shown is that of a suburban living situation, which was presented to half of the subjects; the other half was given a mixed-use neighborhood scenario. As with all of our experiments, we employed experimental design methods (see Louviere et al., 2000) to generate different profiles, which varied over respondents. This experiment was conducted on 312 subjects in the summer and fall of 2009.

FIGURE 5 Example screenshot from the Auto Ownership Experiment

Suppose you are graduating this semester and you have been offered an exciting job that will pay $45,000 per year. Considering all your options, you will most likely take this job. You have also been offered a great deal to live in a nice house in a suburban neighborhood, which you will also accept. The neighborhood is a typical residential area on the outskirts of the city, the house is nice size with a yard although you have limited walking access to retail and grocery stores. Driving from home to your job (one way) will take about 30 minutes and taking public transport will take about 60 minutes (also door to door, one way).

Given this scenario, we ask that you consider your car purchase. If you own or have access to a car now, assume you will not take it with you. Two car options are described below. Please carefully evaluate the attributes and state whether you would buy one of these cars (and which one) or if you would not buy a car and rely on walking, biking, and public transportation.

You may be interested in the choices made by some of your peers in the lab right now, which are displayed below:

4 of your peers chose a conventionally fueled vehicle.
6 of your peers chose a hybrid vehicle.
2 of your peers chose not to buy a car.

	Alternatives	
Attributes	**Conventional Vehicle**	**Hybrid Vehicle**
Purchase Price ($)	16,000	22,000
Annual Cost ($/year)	5,000	4,300
Greenhouse Gas Emissions (tons/year)	3.2	3

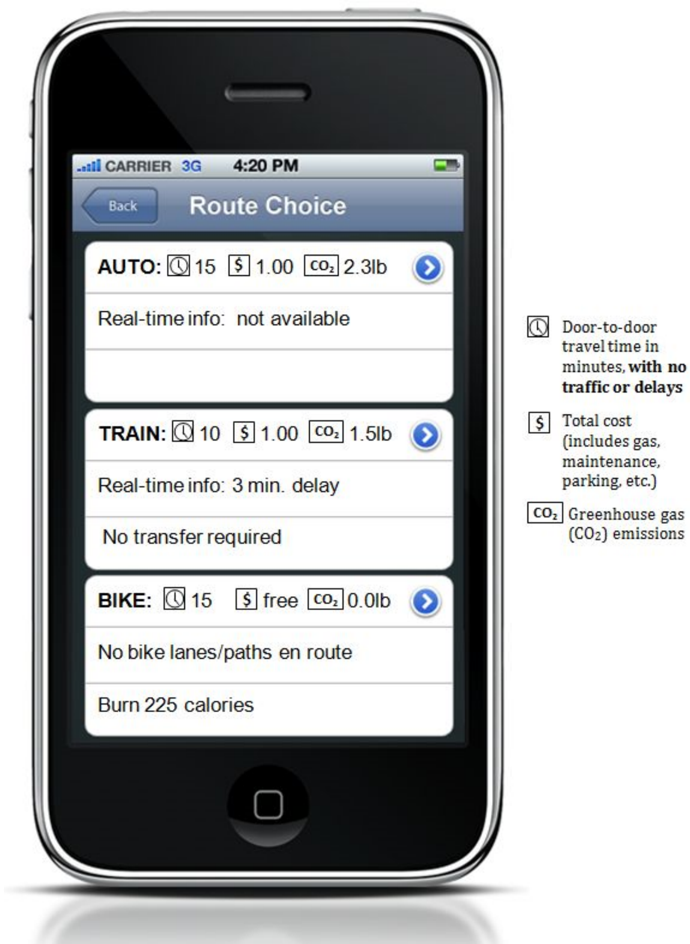
Please Select One:

O Conventional Vehicle
O Hybrid Vehicle
O No Vehicle

Mode Choice Experiment

In this experiment subjects were again presented with a post-graduation scenario and were asked questions regarding what mode they would select for their daily commute. They were provided with the results from a smartphone application that displayed three alternative transport modes and their attributes for their work commute, such as that shown in Figure 6. Varying combinations of auto, train, bus, bike and walk alternatives were provided. All modes included information on time, cost, and greenhouse gas emissions. This experiment had an information provision focus, and so some auto and transit alternatives included real-time information, and some biking and walking alternatives included calories burned and information on facilities. The subjects were asked to select which mode they would select for their daily commute after graduation. This experiment was conducted on 334 subjects in the summer of 2010 (different from the 312 in the auto choice experiment), with each subject making a selection from a unique choice set 5 times.

FIGURE 6 Example screenshot from the Mode Choice Experiment



Route Choice Experiment

Our third experiment concerns which route to take to reach a destination for an auto trip. This was a redesign of our earlier experiment reported in Gaker et al. (2010), where in this case we honed in on issues related to greenhouse gas emissions. Subjects were told that they were going to make a trip by car and were asked to select a route from three alternatives. Each route was described by time, variation of time, cost (in terms of a toll), greenhouse gas emissions, and relative safety. We introduced several variations to test sensitivity to context and presentation. To test whether our subjects had a different VoG for different types of trips, some of the subjects were presented with a recreation trip and others were presented with a commute scenario. To determine whether the scale of the information impacted VoG, some of the commuters were given daily values as shown in Figure 7 and others were given yearly values. To provide more intuition on the meaning of a pound of CO_2, some received information regarding the emissions caused by the average American commute. Our final variation was an attempt to make the costs and benefits more real to the subjects. Therefore, while some of our subjects were paid the standard flat fee of $15/hour, others were told that their payout would be based on the decisions they made. Subjects who made more selfish selections were paid $18 and subjects who made more environmentally conscious selections were paid $12 and a donation was made to an on-campus fund to reduce emissions. The general structure of the payout (and donation) was described to subjects in the variable pay group; however, they were not told the specific values of the payouts. This experiment was conducted on the same 334 subjects as the mode choice experiment in the summer of 2010, with each subject making a selection from a unique choice set 5 times.

FIGURE 7 Example screenshot from the Route Choice Experiment

For all the following questions in Experiment 2, consider the following context.

Suppose you have graduated, you have a job which pays $45,000 per year, and you have a new place to live. You have three options for how to get to work. Keep in mind that this is a trip you will make 5 days per week. Given the following alternatives shown for a round-trip to work and home again, which route are you most likely to choose?

You will be asked the same question five times given the same scenario but with different numbers.

Explanations of attributes

Round Trip Time	Two-way travel time from the origin to the destination.
Time Variation	Standard deviation of the travel time. 95% of the values are within two standard deviations of the mean.
Toll	Toll for this route (all the other costs are identical across the three alternatives).
Greenhouse Gas Emissions	Amount of greenhouse gases emitted for this route.
Safety	Chance of an accident. 3 denotes safer than normal, 2 denotes normal, and 1 denotes less safe than normal.

	Alternatives		
Attributes	Route 1	Route 2	Route 3
Time (minutes/day)	80	90	100
Variation of Time (minutes)	± 5	± 18	± 12
Toll (dollars/day)	$4.00	$0.00	$2.00
Greenhouse Gas Emissions (pounds/day)	5	3	2
Safety	1	3	2

Please Select One: O O O

EMPIRICAL RESULTS

We employ logit and mixed logit (or random parameter) specifications to model the choices of the subjects and infer how they value different attributes relative to each other. In such models, the utility U that individual n associates with alternative i in choice context t is given by the equation $U_{int} = \boldsymbol{\beta}_n{}' \boldsymbol{x}_{i_t n} + \varepsilon_{i_t n}$, where $\boldsymbol{x}_{i_t n}$ is a column vector of explanatory variables (characteristics of the decision maker and attributes of the alternative and context), $\boldsymbol{\beta}_n$ is a column vector of taste parameters, and $\varepsilon_{i_t n}$ is an error that is extreme value iid across alternatives and choice contexts and individuals. If the taste parameters do not vary across the population (i.e., $\boldsymbol{\beta}_n = \boldsymbol{\beta}$ for all n) and assuming that the alternative with maximum utility is chosen, then the probability with which person n chooses alternative i from choice set C_{nt} in context t is logit:

$$P_n(i_t) = \frac{\exp\,(\boldsymbol{\beta}' \boldsymbol{x}_{i_t n})}{\sum_{j \in C_{nt}} \exp\,(\boldsymbol{\beta}' \boldsymbol{x}_{j_t n})}\,.$$

If the taste parameters vary randomly across the population with density $f(\boldsymbol{\beta})$, then the probability with which person n chooses a sequence of choices $\boldsymbol{i}$=($i_1, \ldots, i_T$) is mixed logit:

$$P_n(\boldsymbol{i}) = \int_{\boldsymbol{\beta}} \prod_{t=1}^{T} \frac{\exp\,(\boldsymbol{\beta}' \boldsymbol{x}_{i_t n})}{\sum_{j \in C_{nt}} \exp\,(\boldsymbol{\beta}' \boldsymbol{x}_{j_t n})} f(\boldsymbol{\beta}) d\boldsymbol{\beta}.$$

We use the mixed logit specification to capture both unobserved correlations across alternatives as well as random taste heterogeneity. The unknown parameters are the fixed parameters $\boldsymbol{\beta}$ and parameters of $f(\boldsymbol{\beta})$, and these are estimated via maximum (simulated) likelihood estimation using the free discrete choice estimation software Biogeme (Bierlaire, 2003). Ben-Akiva and Lerman (1985) and Train (2009) provide further information on logit and mixed logit models.

In this section, we present and discuss results estimated from basic models that do not incorporate random taste heterogeneity. The next section discusses models with both systematic and random taste heterogeneity of VoG.

The estimation results for the basic models are shown in Tables 5 to 7, one table for each experiment. For each model, we include as explanatory variables all of the attributes that were presented to the respondents. The auto ownership and route choice models are logit. The mode choice model is mixed logit to capture unobserved correlation among the walk and bike alternative (all other correlations across alternatives were insignificant). The first thing to note is that the models perform well in that all attributes have expected signs and most are highly significant. Here we will focus our discussion on the key estimates of value of green (VoG) and value of time (VoT). VoT is of interest because we have some intuition as to what is a reasonable VoT, and so we can use this to judge the quality of the responses.

VoG and VoT are both marginal rates of substitution (MRS), equal to the trade-off that one can make between two attributes and maintain the same level of utility. These are both willingness' to pay and so the trade-off is between a non-price attribute (CO_2 for VoG and time for VoT) and the price. In a linear in parameters model where $U_{in} = \cdots \beta_k x_{ink} + \beta_p p_{in} + \cdots \varepsilon_{in}$, ($p_{in}$ is the price and x_{ink} is the quantity of attribute k) the marginal rate of substitution of x for p is $MRS_{xp} = \frac{\partial U}{\partial x_{ink}} / \frac{\partial U}{\partial p_{in}} = \frac{\beta_k}{\beta_p}$ and the units are in units of price per unit of the non-price attribute (e.g., \$/lb of CO_2 or \$/hr of time). As our models are linear in CO_2 (green), time, and price (cost), the VoG is the parameter on CO_2 divided by the parameter on cost and the VoT is the parameter of time divided by the parameter on cost. Note that in the estimation results, the VoT and VoG are estimated directly rather than estimating (and reporting) the individual parameters. This is a trivial manipulation, does not fundamentally change the model in any way, and is advantageous for interpretation and in estimating the distribution of VoG and VoT. The manipulation to estimate an MRS directly is as follows (Ben-Akiva et al., 1993):

$$U_{in} = \cdots \beta_k x_{ink} + \beta_p p_{in} + \cdots \varepsilon_{in} = \cdots \left(\frac{\beta_k}{\beta_p} x_{ink} + p_{in} \right) \beta_p + \cdots \varepsilon_{in}$$
$$= \cdots \left(\beta_{MRS_{xp}} x_{ink} + p_{in} \right) \beta_p + \cdots \varepsilon_{in}$$

On the right shows the specification that is estimated where $\beta_{MRS_{xp}}$ and β_p are estimated directly.

First, we discuss the VoT results. We can estimate VoT when we have cost and time data, which occurs in both the mode choice and route choice experiments. (For the auto experiment, time was part of the housing scenario and cannot be distinguished from the suburban dummy.) Our results indicate that our subjects had similar VoT in the mode choice and route choice experiments of \$7.78/hour and \$8.81/hour, respectively. These estimates appear within reason because both are lower than the \$15/hour that the subjects were paid to participate in the study and roughly equal to their expected wage rate (current California minimum wage is \$8.00/hour). This provides some assurance that our subjects were taking the choice tasks seriously and performing in a behaviorally realistic manner.

Turning to VoG, here we have much less to go on compared with VoT in terms of the expected value. We can estimate VoG from each of the three experiments because each involves cost and emissions information. As shown in the tables, our subjects had remarkably consistent VoG: 14 cents per pound for auto ownership, 16 cents per pound for the mode choice, and 14 cents per pound for route choice. A likelihood ratio test (see Ben-Akiva and Lerman, 1985, pp. 164) does not reject the null hypothesis that the VoG is the same across experiments with a p-value of 0.066. This is astonishing considering the diversity of information presented to the subjects: tons of emissions and thousands of dollars in the auto ownership experiment versus pounds of emissions and single digit dollars in the mode choice and route choice experiments.

TABLE 5 Estimation Results from Auto Ownership Experiment

Choice: Buy Conventional Vehicle, Buy Hybrid Vehicle, Don't Buy a Vehicle (i.e., No car)

Explanatory variable - Applicable alternatives	Estimate	Units	t-test	p-value
Alternative specific constant - Hybrid alternative	0.990		2.2	0.03
Alternative specific constant - No Car alternative	-1.010		-3.4	0.00
Dummy = 1 if suburban scenario (vs urban) - No car alternative	-1.760		-6.1	0.00
Percent of peers reported to choose alternative - All alternatives	1.410		2.6	0.01
Vehicle purchase price - Auto alternatives	-0.260	1/$1000	-4.7	0.00
Vehicle annual operating cost - Auto alternatives	-0.230	1/$1000	-2.2	0.00
Value of Green - Auto alternatives	0.140	$/pound CO_2	1.5	0.13
Number of Observations	312 subjects * 1 responses each			
Adjusted rho-square	0.173			

TABLE 6 Estimation Results from Mode Choice Experiment

Choice: Auto, Bus, Train, Bike, Walk

Explanatory variable - Applicable alternatives	Estimate	Units	t-test	p-value
Alternative specific constant - Bike	-3.090		-3.1	0.00
Alternative specific constant - Bus	0.370		2.7	0.01
Alternative specific constant - Train	0.415		3.2	0.00
Alternative specific constant - Walk	-0.705		-0.7	0.46
Reported cost of mode - Auto, Bus, Train	-0.706	1/$	-5.7	0.00
Value of Time - all alternatives	7.800	$/hour	7.5	0.00
Value of Green - Auto, Bus, Train	0.164	$/pound CO_2	2.8	0.01
Error correlation coefficient - Walk, Bike	9.400		4.7	0.00
Number of Observations	334 subjects * 5 responses each			
Adjusted rho-square	0.207			

TABLE 7 Estimation Results from Route Choice Experiment

Choice: Which of 3 auto routes to take

Explanatory variable (each enters all alternatives)	Estimate	Units	t-test	p-value
Variation of travel time	-0.040	1/min	-3.6	0.00
Reported cost (toll)	-0.490	1/$	-10.5	0.00
Free dummy = 1 if the route has no toll cost	0.640		4.8	0.00
Safety (1 below average, 2 average, 3 above average)	0.620		12.8	0.00
Value of Time	8.810	$/hr	-21.3	0.00
Value of Green	0.140	$/pound CO_2	8.0	0.00
Number of Observations	334 subjects * 5 responses each			
Adjusted rho-square	0.412			

Heterogeneity of VoG (and VoT)

In this section we investigate the heterogeneity of VoG across our subjects, first exploring random heterogeneity using a random parameter specification for VoG and second focusing on systematic heterogeneity by including demographic and experimental variables as modifiers to VoG.

Random Heterogeneity of VoG

While above we estimated a fixed parameter for VoG and VoT that applied to the entire population, here we use random parameter logit to explore how VoG and VoT are distributed in the population. Our approach follows closely the large body of literature on distribution of value of travel time savings (see Hess et al., 2005). We specify that VoG and VoT vary across subjects according to independent lognormal distributions (lognormal so that the values are strictly positive). Each lognormal distribution has two parameters, location and scale, which are estimated.

The results of the models with lognormally distributed VoG and VoT are shown in Tables 8 through 10. While the random parameter specification did not lead to a statistically significant improvement in the case of the auto choice model, it did significantly improve the fit of both the mode choice and the route choice experiments suggesting that there is taste heterogeneity in VoT and VoG. The auto ownership result is not too surprising given that we had only 1 auto choice response per person (rather than the 5 as in the other experiments), which makes it more difficult to capture heterogeneity.

TABLE 8 Estimation Results from Auto Ownership Experiment with Distributed VoG

Choice: Buy Conventional Vehicle, Buy Hybrid Vehicle, Don't Buy a Vehicle (i.e., No car)

Explanatory variable - Applicable alternatives	Estimate	Units	t-test	p-value	Distributional Parameters	
Alternative specific constant - Hybrid alternative	1.000		2.1	0.04		
Alternative specific constant - No Car alternative	-1.010		-3.5	0.00		
Dummy = 1 if suburban scenario (vs urban) - No car alternative	-1.780		-4.9	0.00		
Percent of peers reported to choose alternative - All alternatives	1.420		2.5	0.01		
Vehicle purchase price - Auto alternatives	-0.260	1/$1000	-4.6	0.00		
Vehicle annual operating cost - Auto alternatives	-0.230	1/$1000	-2.3	0.02		
Value of Green - Lognormal location parameter	-2.020		-1.7	0.09	Mean	0.14 $/lb
Value of Green - Lognormal scale parameter	0.410		0.2	0.87	Std Dev	0.06 $/lb
Number of Observations	312 subjects * 1 responses each					
Adjusted rho-square	0.170					

TABLE 9 Estimation Results from Mode Choice Experiment with Distributed VoG and VoT

Choice: Auto, Bus, Train, Bike, Walk

Explanatory variable - Applicable alternatives	Estimate	Units	t-test	p-value	Distributional Parameters	
Alternative Specific Constant - Bicycle	0.840		3.5	0.00		
Alternative Specific Constant - Bus	0.520		4.3	0.00		
Alternative Specific Constant - Train	0.620		5.5	0.00		
Alternative Specific Constant - Walk	2.120		4.3	0.00		
Reported cost of mode - Auto, Bus, Train	-0.470	1/$	-6.4	0.00		
Value of Time: Lognormal location parameter - all alternatives	-1.590		-10.5	0.00	Mean	16.21 $/hr
Value of Time: Lognormal scale parameter - all alternatives	0.750		10.3	0.00	Std Dev	14.09 $/hr
Value of Green: Lognormal location parameter - Auto, Bus, Train	-2.850		-3.8	0.00	Mean	0.42 $/lb
Value of Green: Lognormal scale parameter - Auto, Bus, Train	1.990		7.4	0.00	Std Dev	3.00 $/lb
Error correlation coefficient - Walk, Bike	1.220		4.3	0.00		
Number of Observations	334 subjects * 5 responses each					
Adjusted rho-square	0.242					

TABLE 10 Estimation Results from Route Choice Experiment with Distributed VoG and VoT

Choice: Which of 3 auto routes to take

Explanatory variable (each enters all alternatives)	Estimate	Units	t-test	p-value	Distributional Parameters	
Variation of travel time	-0.048	1/min	-4.5	0.00		
Reported cost (toll)	-0.647	1/$	-10.7	0.00		
Free dummy = 1 if the route has no toll cost	0.511		3.4	0.00		
Safety (1 below average, 2 average, 3 above average)	0.660		12.3	0.00		
Value of Time - Lognormal Location	-2.100		-20.5	0.00	Mean	8.21 $/hr
Value of Time - Lognormal Scale	-0.465		-5.2	0.00	Std Dev	4.08 $/hr
Value of Green - Lognormal Location	-2.360		-14.6	0.00	Mean	0.14 $/lb
Value of Green - Lognormal Scale	-0.895		-7.2	0.00	Std Dev	0.16 $/lb
Number of Observations	334 subjects * 5 responses each					
Adjusted rho-square	0.426					

Both the estimated location and scale parameters of the lognormal distribution as well as the calculated means and standard deviations of the distributions are reported in the estimation tables. The distributions are plotted for comparison in Figure 8 (for VoG) and Figure 9 (for VoT). Here we note significant heterogeneity of these parameters within each experiment, as well as differences in the distributions across experiments. This is consistent with the findings in the transport literature and accepted in practice that value of travel time savings varies across context such as work trips and non-work trips (see, for example, Bradley et al., 2010). However, despite the variability, there does seem to be some consistency in the range of VoG and VoT values where the majority of the population lies. The range for the VoT seems a bit high for these subjects; however, in most instances they were given a post-graduation scenario. In terms of the VoG distributions, the mode choice results show the greatest variability with a significant portion of the distribution concentrated near zero (people who don't consider CO_2) and a long right tail (people who care a lot about CO_2). However, 90% of the mode choice distribution is below $0.70/pound. For route choice, the 90^{th} percentile is at $0.30/pound, and for auto ownership the 90th percentile is at $0.22/pound. The 50th percentiles show less variability, with mode choice at $0.06/pound, auto choice at $0.13/pound, and route choice at $0.09/pound.

FIGURE 8 Estimated VoG probability density function (PDF) by experiment

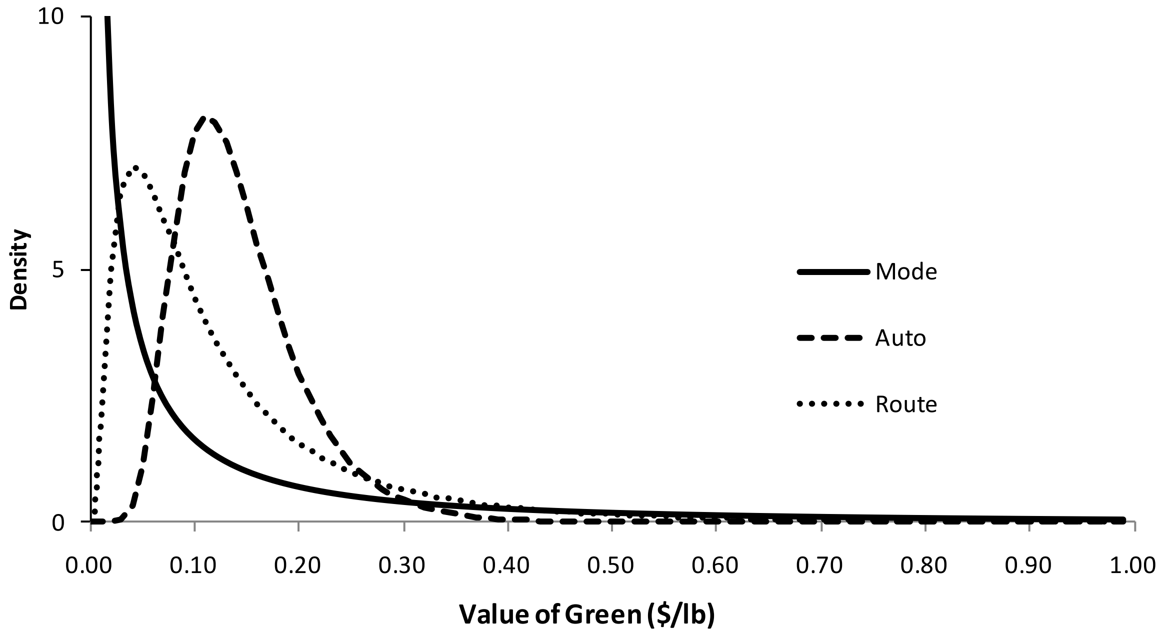
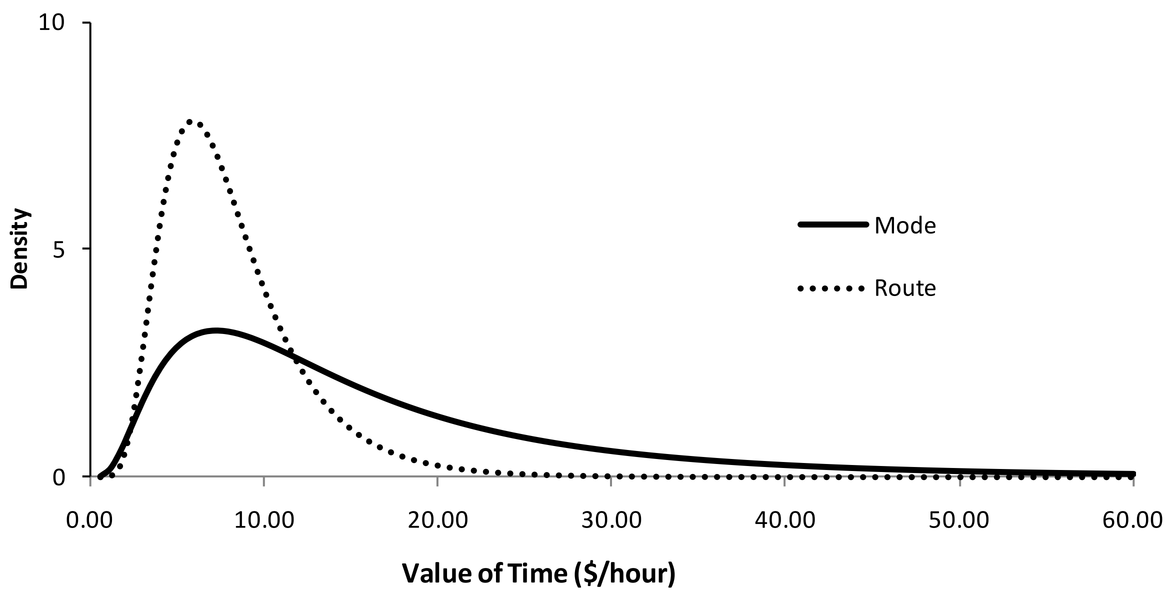


FIGURE 9 Estimated VoT probability density function (PDF) by experiment



Systematic Heterogeneity of VoG

While above we estimated random heterogeneity of VoG, we did not investigate the source of the heterogeneity. However, the design of our route choice experiment (described above) allows us to investigate specific sources of heterogeneity. The results are shown in Table 11 in which the baseline VoG and VoT are modified based on explanatory variables (all 0/1 dummies) related to demographics, context, and presentation of CO_2. According to this model, our female subjects significantly valued reducing their emissions more (7 cents more per pound) than their male counterparts (consistent with Achtnicht, 2009). Subjects who were presented with recreation trips did not have significantly different VoG than subjects who were faced with commutes. Similarly, presenting commuters with information on the emissions associated with the average American commute or presenting CO_2 on an annual basis rather than daily basis did not elicit a change in VoG. One interesting finding is that the attempt to make the costs more real to the subjects by paying them based on their decisions (and making a donation to an on-campus environmental fund), actually increased this group's VoG by 11 cents per pound relative to the group who received a fixed payout. This indicates that our subjects were more willing to undertake sustainable behaviors when there was a clear environmental benefit, even with additional personal cost.

TABLE 11 Estimation Results from Route Choice Experiment with Systematic VoT and VoG Modifiers

Choice: Which of 3 auto routes to take

Explanatory variable (each enters all alternatives)	Estimate	Units	t-test	p-value
Variation of travel time	-0.040	1/min	-4.0	0.00
Reported cost (toll)	-0.530	1/$	-9.8	0.00
Free dummy = 1 if the route has no toll cost	0.580		4.2	0.00
Safety (1 below average, 2 average, 3 above average)	0.630		11.7	0.00
Base Value of Time (VoT)	9.780	$/hr	-12.8	0.00
VoT Modifier - Recreational trip (versus commute trip)	-0.950	$/hr	0.9	0.39
VoT Modifier - Yearly travel time reported (versus daily)	-2.770	$/hr	2.9	0.00
Base Value of Green (VoG)	0.060	$/pound CO_2	2.2	0.03
VoG Modifier - Recreational trip (versus commute trip)	-0.020	$/pound CO_2	-0.6	0.58
VoG Modifier - Yearly travel time reported (versus daily)	-0.020	$/pound CO_2	-0.9	0.35
VoG Modifier - Female (versus Male)	0.070	$/pound CO_2	2.9	0.00
VoG Modifier - Average personal emissions provided (vs not)	-0.010	$/pound CO_2	-0.2	0.83
VoG Modifier - Payout a function of green behavior (vs not)	0.110	$/pound CO_2	4.9	0.00
Number of Observations	334 subjects * 5 responses each			
Adjusted rho-square	0.424			

DISCUSSION AND CONCLUSION

In this investigation into how people respond to the environmental feedback that they are already receiving, we found a surprising consistency in how our respondents (UC Berkeley undergraduates) value CO_2. Most seem to be willing to adjust their transport behavior to reduce CO_2 emissions. Our basic (homogeneous) models indicate a value of green (VoG) of \$0.15/pound of CO_2, regardless of context (auto, mode, route) or presentation (pounds versus tons, daily versus annual). Our random parameter models exhibit greater variability, suggesting a median VoG of \$0.06-\$0.13/pound with over 90% of the distribution falling between \$0.00 and \$0.70/pound. Further, we found that females have a higher VoG than males (by \$0.07/pound). Our results suggest that our subjects could meaningfully process the rather abstract notion of CO_2 and that they value CO_2 enough to vary their actions. This suggests that the wider provision of emissions information could be used to encourage more sustainable transport decisions. While our numerical results are of course influenced by the sample, UC Berkeley undergraduates, and by the simple fact that they were in a lab instead of making choices in their day-to-day lives, the significance lies in the consistency of the findings rather than in the absolute value, indicating that even if people don't consciously know what a pound of emissions is, they still know how to value it.

Chapter 4

Revealing the Value of "Green" and the Small Group with a Big Heart in Transportation Mode Choice

Originally published in Sustainability, 5, pp 2913-2927, 2013.

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ABSTRACT

To address issues of climate change, people are more and more being presented with the greenhouse gas emissions associated with their alternatives. Statements of pounds or kilograms of CO_2 are showing up in trip planners, car advertisements, and even restaurant menus under the assumption that this information influences behavior. This research contributes to the literature that investigates how travelers respond to such information. Our objective is to better understand the "value of green" or how much travelers are willing to pay in money in order to reduce the CO_2 associated with their travel. As with previous work, we designed and conducted a mode choice experiment using methods that have long been used to study value of time. The contributions of this paper are twofold. First, we employ revealed preference data, whereas previous studies have been based on stated preferences. Second, we provide new insight on how the value of green is distributed in the population. Whereas previous work has specified heterogeneity either systematically or with a continuous distribution, we find that a latent class choice model specification better fits the data and also is attractive behaviorally. The best fitting latent class model has two classes: one large class (76% of the sample) who are not willing to spend any time or money to reduce their CO_2 and a second class (24% of the sample) who value reducing their CO_2 at a very high rate of \$2.68 per pound of reduction – our so-called small group with a big heart. We reanalyzed three value of green datasets that we had previously collected and found considerable robustness of this two class result.

INTRODUCTION

Urban areas today go to great lengths to mitigate the damages associated with many people driving private vehicles. The three largest of these damages are economic losses due to compromised safety, added congestion, and air pollution. Dubner and Levitt (2008) estimate these cost the United States $220 billion, $78 billion, and $20 billion per year respectively. For the most part, these problems of the modern world are addressed independently rather than collectively. Lanes are often added to freeways that can temporarily alleviate some congestion, vehicle manufacturers are mandated to install specific safety features to reduce the frequency and severity of accidents, and fuels and on-board technologies are regulated to reduce the harmful pollutants in exhaust gasses. However, an improvement in one measure often means a decline in another; adding a lane to the freeway might reduce congestion but it will probably also increase air pollution, for example. Sometimes there is also an eventual decline in the measure of interest as is the case when better access to an area served by a new freeway induces greater travel demand which in turn leads to worse congestion than before the bottleneck was removed. Even if there was a desirable way to physically build a solution to the problems associated with so many people driving alone, the extraordinary cost of new infrastructure is often prohibitive, which leaves some type of mode shift as the preferred solution to the safety concerns, congestion, and environmental impacts associated with our current transportation network. Encouraging this type of a shift with a carrot such as a dramatically improved transit system is not as effective as the models predict (Flyvbjerg, 2005), and using a stick such as road pricing is politically impossible many places in the world. On the other hand, the provision of information to users of the transportation network is practically free, and while traveler response to information about time and cost has been heavily studied, there are currently a lot of unknowns about how people react to various types of information, such as the environmental footprint of a trip.

With all the talk of “green” products and actions, climate change, and carbon pricing, it is reasonable to believe that people might desire to reduce their environmental footprint and perhaps even that the simple act of giving people information about the emissions associated with their transportation decisions could be used to encourage some mode shift towards walking, biking, and transit and away from driving alone. However, it is not well understood how people value reducing their environmental impact or how they react to being informed of their emissions. This type of information is becoming more and more popular, as shown in Figure 10 on the online trip planner for San Francisco’s Bay Area Rapid Transit, which prominently displays the reduced emissions relative to making the trip by car.

FIGURE 10 Emissions savings displayed on BART trip planning online tool (bart.gov)

Using stated preference experiments, it has been shown that some people do make choices that indicate that they value reducing their emissions, and that there is substantial variation in how much value people place on these reductions. The aim of this research is to determine whether this willingness to pay for emissions reductions persists when peoples' decisions in their day-to-day lives (revealed preferences) are analyzed as well as to further investigate how the value of green is distributed in the population. While this desire to mitigate emissions cannot necessarily be extrapolated immediately to mode shifts as a response to information provision, it is an important first step to investigate the tradeoffs people make when choosing their daily actions.

LITERATURE REVIEW

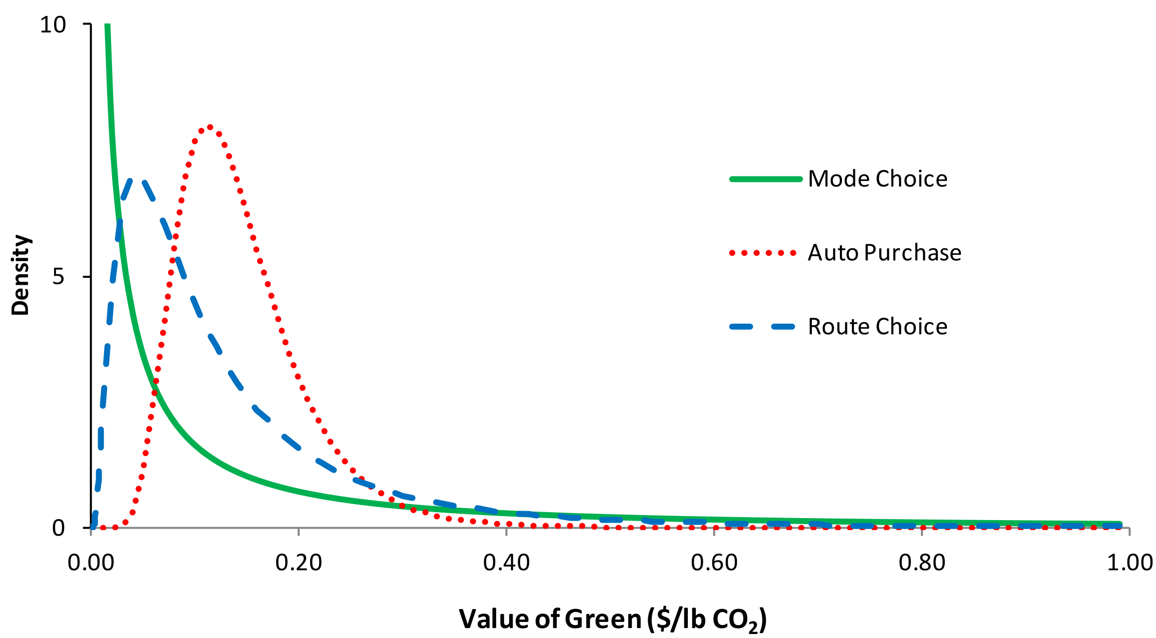
According to micro-economic theory, decision makers will be willing to trade one attribute for another without being any better or worse off. This is known as the marginal rate of substitution (MRS) between the two attributes. The common MRS in transportation decisions is between time and money, known as the value of time. This estimation is the average amount of one attribute (dollars in this case) the subjects would be willing to give up in order to gain a single unit of the other attribute (an hour of travel time). Value of time as well as other MRSs are commonly estimated from logit models. For example, if time and cost enter the utility linearly, then the value of time is the ratio of the time parameter divided by the cost parameter. Such analysis of the value of time has become standard and is well summarized by Mackie, et al. (2003). However, the willingness to pay for emissions reductions or the "value of green" has only recently been investigated. Here we review the literature in the transportation realm that has investigated how people value reducing their environmental footprint.

As an effort to reduce air pollution especially in the South Coast Air Basin, in 1990 the California Air Resources Board passed requirements for the fuel use and emissions of new vehicles. In order to forecast how households in the area might decide which (not-yet-available) car to buy, Bunch et al. (1993) designed an experiment that presented households in Southern California with three hypothetical vehicles described by their purchase price, operating cost, range, emissions, and fuel availability. They found that their subjects value reducing the emissions associated with their next vehicle. In the trade-off between purchase price and emissions, a decrease of emissions from 100% to 50% of then-current (1991) vehicles would have to be paired with a purchase price increase of $4000 in order to maintain the same choice probability. This trade-off is not found to be linear, however; a decrease of emissions from 50% to 10% would require an additional price increase of $6000. The emissions of concern at the time were primarily local pollutants rather than those contributing to climate change, but this research shows that people are willing to incur personal costs for the benefit of society at large.

Also investigating the decision of which car to buy, Achtnicht (2009) estimated a marginal rate of substitution between carbon dioxide emissions and monetary cost by using a stated preference experiment. He found that German car buyers are willing to pay €349 per tonne ($0.22 per pound) of CO_2 mitigated, which is substantially higher than the typical price for carbon on the open market. He also found systematic heterogeneity in his sample; females, people younger than 45, and people with higher educational achievement have a higher willingness to pay for emissions reductions. To investigate the difference between environmentalists and non-environmentalists, Daziano and Bolduc (2011) used a hybrid choice model which include both latent variable and discrete choice models and showed that environmentally conscious consumers are more supportive than their counterparts of fossil fuel taxation and policies promoting green technologies, an explicit example of taste heterogeneity. In studying the revealed preferences of Californians, Martin (2009) found that while some households purchase efficient vehicles based on cost savings alone, others exhibit a willingness to pay personal costs for the reductions of emissions and other public costs when their expectations regarding life of a car, such as duration of ownership and discount rate, are included in the calculation. In identifying this frontier between those who value environmental benefits and those who do not, Martin illustrates that there are some people with zero willingness to pay for emissions reductions as well as some who place positive value on societal benefits. This finding of a discrete distribution for willingness to pay for public goods such as emissions reductions supports our research which aims to quantify how many people care as well as how much they care.

In our previous work (Gaker et al., 2010), we designed and conducted two experiments in the laboratory using UC Berkeley undergraduates as subjects. We found that they were willing to pay $0.24 per pound of emissions when buying a car and when choosing a route. The fact that the subjects were able to consistently place value on the pollution is particularly interesting because the emissions were presented in units of tons per year in the auto purchase choice and in units of pounds per trip in the route choice. Again using UC Berkeley undergraduate students as subjects, we further investigated the tradeoffs students make and found that their subjects were consistently willing to pay $0.15 per pound of greenhouse gas emissions across decisions such as which car to buy, which mode to use, and which route to take (Gaker et al., 2011). While we found systematic heterogeneity in that females have a higher value of green, we also found that a statistically superior model included a continuous distribution of willingness to pay for emissions reduction within the sample, as is shown in Figure 11. Because these distributions are log-normal, all subjects have a positive value of green, but the shape of the distribution in the mode choice experiment in particular indicates that there is a substantial proportion of the sample with zero willingness to pay for emissions reductions.

FIGURE 11 Distribution of the marginal rate of substitution between cost and emissions (Gaker, et al., 2011)



Building on this previous work, the objectives of this paper are twofold. First to investigate the value of green using revealed preference data, whereas the previous work uses only stated preference data. Second to further explore the heterogeneity of the value of green in the population, in particular the hypothesis that there may be a segment of the population that places zero value on green and will not change their transport behavior to reduce CO_2 emissions.

SURVEY AND EXPERIMENT DESIGN

While a primary objective of this work was to estimate value of green based on a revealed preference dataset, the classic issue in revealed preference mode choice data of time and cost being highly correlated is amplified in the value of green setting where CO_2 is highly (and sometimes perfectly) correlated with time and/or cost. Therefore, we designed and conducted a mode choice experiment in which we collected both stated and revealed mode choice decisions from our subjects.

The survey was conducted all online and via email and each subject participated in the experiment for two weeks. There were four parts to the survey: a stated preference questionnaire inquiring about mode choices for hypothetical trips, a set of survey questions related to their household characteristics and transportation profiles including common trips, delivery to the subjects of modal alternatives and their attributes for the subject's reported common trips, and a two-week travel diary to report revealed preferences on these common trips.

Subjects were first sent a link to an online survey that included both the stated preference questions and the questions regarding the household characteristics and transportation profile. In the stated preference portion, each subject was asked 5 hypothetical mode choice questions for 5 different trip purposes: to buy something small at a grocery store, to drop off a document at an office, to go to lunch, to buy a shirt, and to meet friends for coffee. An example survey question is shown in Figure 12. The available travel modes for these trips were walking, biking, driving, walking to a bus stop and taking a bus, walking to a train station and riding the Bay Area Rapid Transit (BART), and biking to a train station and riding BART. Each mode was described by access time, travel time, transfer time, cost, calories, and emissions. While the main benefit of stated preference experiments is that correlation between attributes, such as time and cost, can be eliminated, we chose to base our stated preference experiment on a more realistic set of alternatives and thus retained correlation between the attributes. This decision was based on feedback we got from our previous experiments that the alternatives we presented were too unrealistic. We based the hypothetical choices on estimated attributes of five actual trips in the San Francisco Bay Area.

The trip times and distances were estimated with Google Maps for each mode. Emissions, costs, and calories were then calculated based on travel mode and distance traveled. For the car alternative, we assume single occupancy and fuel economy of an average vehicle (20 miles per gallon) to calculate emissions and fuel costs (Staniford, 2011). Marginal costs and emissions were used for driving because our focus group felt that lifecycle calculations unfairly punished people who drive very little with very high per-mile emissions. For transit alternatives, we assume average occupancy with each rider sharing responsibility for the emissions associated with propulsion of the transit vehicle, and we use the estimates of Chester and Horvath (2008). For BART trips the greenhouse gas emissions associated with active vehicle operations are 39 grams per passenger kilometer traveled, and for bus trips they are 166 grams per passenger kilometer traveled. Transit costs were based on actual fares. We assumed average body size and physical intensity of walking and biking. An average person will burn 100 calories per mile walked (Ford, 2010) and 50 calories per mile biked (Schwartz, 2012). The marginal emissions associated with biking and walking are a result of the additional food a person will consume to replenish the calories burned. There are approximately 1.7 pounds of CO_2 associated with each 500 calories of a balanced diet (the.co2list.org, 2013).

The first estimate of these attributes had perfect correlation between attributes such as cost and emissions of driving because both are a linear function of the amount of fuel burned. We decreased the correlation by adjusting each attribute according to an orthogonal design of 125 choice sets divided into five blocks for the five trip types. This design included five levels for each attribute: 0.5, 0.7, 1, 1.5, or 2. The original estimates of the trip attributes were then multiplied by these levels to create 25 choice sets for each trip purpose. Each participant was randomly presented with one choice set for each of the five trip purposes, where each choice set was presented approximately the same number of times.

FIGURE 12 Stated preference mode choice

In this last scenario, please imagine that you are going to meet some friends for coffee.

You look up directions and are presented with these alternatives.
Please indicate which one you would choose.

Mode	**Total Time =** (minutes)	**(Travel +** (minutes)	**Access +** (minutes)	**Transfer)** (minutes)	**Cost**	**Calories**	**Emissions** (lbs CO_2)
Bicycle	30	30	0	0	$0.00	453	0.3
Bus	41	23	8	10	$2.67	35	3.8
BART	50	30	15	5	$4.00	70	1.5
Drive	22	18	4	0	$4.13	19	7.0

After the five stated preference mode decisions, the subjects answered a series of questions regarding their household characteristics and transportation profiles, including demographics, car ownership and type, car-share membership, bicycle ownership and operability, and transit pass availability. The subjects also outlined three of their common trips, providing information such as origin, destination, typical mode, time of day, and physical and schedule constraints. In particular, they were asked to provide details for their commute, their trip to their most-visited grocery store, and a common social trip. They were prompted to provide details for these trips in particular in order for us to observe the greatest number of mode decisions during the two week experiment. Lastly, the subjects entered their e-mail address in order to participate in the last part of the experiment.

The next stage of the experiment was to report to the subjects the available modes and their attributes for the common trips that each subject reported. Using Google Maps, we estimated the time and distance traveled for of the feasible and available alternatives for each of these trips and e-mailed these choice sets to the subjects. As with the stated preference choice sets, the attributes included access time, travel time, transfer time, cost, calories, and emissions. The specifics of the choice set were tailored to the specific situation of the subject. The only modes included in these choice sets were those that were both available to the subject and reasonably competitive with modes typically used. The calculations for transit emissions varied depending on whether the subject believed (as stated in response to a survey question) that a rider should be responsible for emissions based on vehicle ridership, based on the average of the entire transit system, or not at all. The shares of subjects with these beliefs are approximately 20%, 40%, and 40% respectively. This strategy of presenting transit emissions is different from the stated preference experiment because of our knowledge of each individual's belief about which method of emissions accounting is appropriate. The cost of transit was calculated based on the services used while controlling for the type of transit pass held by the subject. Tailpipe emissions as well as monetary costs for private vehicles were calculated based on the EPA estimated fuel economy of the subject's actual vehicle and occupancy for the trip (EPA, 2013). As in the stated preference experiment, calories burned were calculated using distance biked or walked and associated emissions were then estimated based on the calories burned. An example of the choice sets for the actual trips is displayed in Figure 13.

FIGURE 13 Choice sets for revealed preferences using subjects' origins, destinations, and mode availabilities

Commute Trip							
Mode	Total Time =	(Travel +	Access +	Transfer)	Cost	Calories	Emissions
Bicycle	15	15	0	0	$0.00	160	0.0
Bus	38	4	28	6	$2.35	20	2.1
BART	47	12	35	0	$1.75	160	1.8
Drive	12	10	2	0	$1.40	10	3.1

Grocery Trip							
Mode	Total Time =	(Travel +	Access +	Transfer)	Cost	Calories	Emissions
Walk	23	23	0	0	$0.00	90	0.0
Bicycle	7	7	0	0	$0.00	60	0.0
Bus	16	6	10	0	$2.10	20	0.9
Drive	7	6	1	0	$1.20	10	1.3

After participants were sent the attributes of the feasible alternatives for their personal trips, they were asked via e-mail on a daily basis about their mode decisions for these trips for two weeks in order to collect revealed preference data. This open interaction also provided a way for subjects to provide corrections regarding their choice sets or more details about their choices such as the inconvenience of needing correct change for the bus.

SUBJECTS

The subjects for this experiment were residents of the San Francisco bay area who made regular trips for which they had more than one feasible alternative. One-hundred twenty-two subjects were recruited through a variation of a snowball sampling technique; the authors asked their colleagues to ask a few of their colleagues to participate. It is possible that some of the subjects were familiar with the type of research done by the authors thereby inducing some bias in the results, but this sampling strategy was chosen because of the exploratory nature of this study.

Although not representative of the San Francisco Bay area, this sample provides us with insight into the decisions of people outside of the UC Berkeley community. Forty-eight percent of our subjects are male. Thirty-four percent are UC Berkeley graduate students, 13 percent are UC Berkeley faculty and staff, and the remainder are employed elsewhere. The non-students in our sample have a median annual income between $50,000 and $75,000. Seven percent of the sample have children living in their household. Sixty-nine percent have a bicycle to use that is in operable condition, and 83% have access to a vehicle.

Our 122 subjects collectively made 603 stated preference mode decisions, and the 46 who completed the experiment collectively made 583 revealed preference mode decisions.

MODEL SPECIFICATION AND RESULTS

Using the data as described above, we estimated a mode choice model from the combined dataset that included both the stated and revealed preferences from all subjects. We explored many model structures, including different specifications for the systematic utility, for the imposed constraints across the RP and SP models, and for the error structure, including the specification of the heterogeneity of the value of green. The final estimation results are shown in Table 12. First we will describe and motivate the model specification and likelihood function, and then we will discuss the estimation results.

The systematic utility includes alternative specific constants (ASC) and the cost, time, and calories of the alternatives, where each enters the utility function linearly. There were very few subjects who chose to utilize the combination of biking to BART in their actual trips, and therefore it was eliminated from the available modes in the revealed preference dataset. The time parameters are specified to be separate for each mode of travel and entered the utility equations for each leg of the trip rather than only for the primary mode of the trip. For example, time spent walking to a destination and time spent walking to access a car, bus stop, or train station are both included as walk time.

As a major objective of this work was to explore the heterogeneity of value of green, many different specifications were explored for the emissions parameters. These included both the systematic heterogeneity and continuous random distributions (for example, lognormal as in Figure 2) of our previous work as well as new specifications based on discrete mixtures. The discrete mixture is a form of latent class choice model in which there are different distinct segments of the population, each of which has a different value they place on emissions (i.e., a different emissions parameter). This specification is appealing because it is able to capture our hypothesized segment that does not place any value on emissions (i.e. has a $0 value of green). For each segment of the population (i.e., each class), an emissions parameter is estimated specific to the class, and a proportion parameter is estimated that represents the percent of the population that belongs to the class (i.e., a naïve class membership model). Based on our hypothesis of the 0 value of green group, we fixed the parameter on emissions to be equal to 0 for one of the classes. In estimating such a model, the number of classes is determined by estimating models with different numbers of classes and then using measures of fit such as the AIC to determine the best model (Akaike, 1974). Based on this exploration of systematic, continuous random (lognormal) and discrete mixtures, we found that the discrete mixture with 2 classes fit the data significantly better than all other specifications. The estimation results in the Table 1 report the resulting 2 emissions parameters (one for each class, one of which is fixed to 0) and the probability of belonging to the first class. We call the class whose decisions indicate a desire to reduce emissions "environmentalists." The emissions parameter for non-environmentalists is fixed at zero.

While the latent class model to capture heterogeneity in the value of green introduces a discrete mixture to the specification, we also include a continuous mixture to capture correlation across utility errors from a single individual. Conceptually, this captures the fact that while some people might view walking or biking as enjoyable activities for reasons other than those presented as attributes, other people generally prefer to avoid these options, and likewise for the transit alternatives or driving. This is introduced by specifying the alternative specific constants (ASC) with normal distributions, and estimating the means and standard deviations of these distributions. The mean is the ASC that is estimated in a logit model. The standard deviations of the distribution are reported just after each ASC. The value is held constant across responses from the same individual to build in correlation across their multiple responses.

The final wrinkles in the model have to do with the combination of the RP and SP data. First, some parameters are constrained to be the same across the RP and SP and some are not. In this case the mean and standard deviations of the ASC distribution are allowed to be different across the RP and SP. In contrast, the parameters associated with the attributes (time, cost, calories, and emissions) are constrained to be the same across the RP and SP. The model also included a scale parameter to allow the variance of the unobserved variables term to be estimated for stated preferences relative to the normalized revealed preferences (Ben-Akiva and Morikawa, 1990).

The model was estimated by maximizing the following likelihood function, which reflects the specification described in more general terms above. The model takes the form of a Hybrid Choice Model (Ben-Akiva, et al., 2002) to capture the random continuous taste heterogeneity included in the alternative specific constants, the random discrete heterogeneity of the value of green, and the joint SP/RP specification.

$$Likelihood = \prod_{n=1}^{N}\sum_{s=1}^{S}\pi_s\left\{\int_{\boldsymbol{\alpha}^{RP}}\left(\prod_{t=1}^{T_n^{RP}}\prod_{j=1}^{J_{nt}}\left(\frac{\exp\left(\boldsymbol{\alpha}_j^{RP}+\boldsymbol{\beta X}_{ntj}^{RP}+\gamma_s E_{ntj}^{RP}\right)}{\sum_{j'=1}^{J_{nt}} exp\left(\boldsymbol{\alpha}_{j'}^{RP}+\boldsymbol{\beta X}_{ntj'}^{RP}+\gamma_s E_{ntj'}^{RP}\right)}\right)^{y_{ntj}^{RP}}\right) f(\boldsymbol{\alpha}^{RP})d\boldsymbol{\alpha}^{RP}\right\}$$
$$*\left\{\int_{\boldsymbol{\alpha}^{SP}}\left(\prod_{t=1}^{T_n^{SP}}\prod_{j=1}^{J_{nt}}\left(\frac{\exp\left(\mu\boldsymbol{\alpha}_j^{SP}+\mu\boldsymbol{\beta X}_{ntj}^{SP}+\mu\gamma_s E_{ntj}^{SP}\right)}{\sum_{j'=1}^{J_{nt}} exp\left(\mu\boldsymbol{\alpha}_{j'}^{SP}+\mu\boldsymbol{\beta X}_{ntj'}^{SP}+\mu\gamma_s E_{ntj'}^{SP}\right)}\right)^{y_{ntj}^{SP}}\right) f(\boldsymbol{\alpha}^{SP})d\boldsymbol{\alpha}^{SP}\right\}$$

The indicies are *n=1,…,N* for individual, *j=1,…,J* for alternative, *t=1,…,T* for choice instance, *s=1,…,S* for class, and an SP/RP designation for choice experiment. The likelihood function has two primary components: the likelihood that an individual chooses the observed set of stated preferences and the likelihood that an individual chooses the observed set of revealed preferences. Both of these likelihoods are conditioned on the individual belonging to a specific class *s*. y_{ntj} (with associated SP/RP designation) is the choice indicator, which is equal to one if person *n* chose alternative *j* in choice instance *t* of the SP/RP experiment and equal to zero otherwise. The product of these two likelihoods is the likelihood that an individual chooses the observed set of stated and revealed preferences, conditioned on the individual belonging to a specific class. To remove the conditionality on *s*, the conditional likelihoods are marginalized over the probabilities that the individual belongs to different classes (denoted by parameter π_s) to obtain the likelihood function for each individual. The likelihood function for the sample population then equals the product of the likelihood function for each individual taken over all individuals $n=1,\ldots,N$.

Within the utility specification, the explanatory variables are the scalar E_{ntj} for the emissions attribute and the column vector $\boldsymbol{X}_{ntj}$ for all of the other attributes, $\boldsymbol{\alpha}_j$ are the alternative specific constants, each of which is independently, normally distributed. $f(\boldsymbol{\alpha}^{RP/SP})$ are the products of these normal distributions, for which the mean and standard deviation of each are estimated. The SP and RP conditional likelihoods are integrated over this distribution. $\boldsymbol{\beta}$ is a row vector containing the parameters for all of the attributes except for the environmental variable. γ_s is the parameter for the emissions variable, which is estimated separately for each class *s*. Finally, μ is the scale parameter for the SP model (estimated relative to the RP scale which is fixed to 1).

ANALYSIS AND FINDINGS

The results of the joint model using both the stated and revealed preferences are shown in Table 12.

TABLE 12 Joint-estimation results for stated and revealed preferences

	Parameter		Walk	Bike	Bus	Drive	BART	Bike-BART	Estimate	Std Error	p-value
			Utility Equation								
Stated Preference	Alternative Specific Constant - Walk		X						0.00	-	-
	Std Dev		X						0.03	0.82	0.97
	ASC - Bike			X					-1.95	0.47	<0.01
	Std Dev			X					0.79	0.49	0.11
	ASC - Bus				X				-4.25	1.20	<0.01
	Std Dev				X				1.51	0.78	0.05
	ASC - Drive					X			-4.09	0.80	<0.01
	Std Dev					X			1.11	0.50	0.03
	ASC - BART						X		-2.59	0.84	<0.01
	Std Dev						X		0.34	1.61	0.83
	ASC - Bike BART							X	-1.71	0.78	0.03
	Std Dev							X	1.83	1.42	0.20
Revealed Preference	Alternative Specific Constant - Walk		X						0.00	-	-
	Std Dev		X						2.88	0.54	<0.01
	ASC - Bike			X					-2.53	0.89	<0.01
	Std Dev			X					2.96	0.98	<0.01
	ASC - Bus				X				-2.49	0.80	<0.01
	Std Dev				X				2.97	0.71	<0.01
	ASC - Drive					X			-2.93	0.81	<0.01
	Std Dev					X			0.52	0.59	0.38
	ASC - BART						X		-3.73	1.52	0.01
	Std Dev						X		3.45	1.65	0.04
Constrained across SP & RP	Cost	($)			X	X	X	X	-0.40	0.11	<0.01
	Calories	(100)	X	X	X	X	X	X	-2.86	1.64	0.08
	Walk Time	(minutes)	X		X	X	X		-0.15	0.03	<0.01
	Bike Time	(minutes)		X				X	-0.19	0.04	<0.01
	Bus Time	(minutes)			X				-0.11	0.03	<0.01
	Drive Time	(minutes)				X			-0.07	0.03	0.02
	BART Time	(minutes)					X	X	-0.10	0.03	<0.01
	Wait Time	(minutes)			X		X		-0.14	0.07	0.05
	Emissions - Environmentalist	(pounds)			X	X	X	X	-1.06	0.27	<0.01
	Emissions - Non Environmentalist	(pounds)			X	X	X	X	0.00	-	-
	Probability of Environmentalist								0.24	0.08	<0.01
	Scale for Stated Preferences		X	X	X	X	X	X	0.63	0.12	<0.01

Observations	1186
RP Choices	583
SP Choices	603
Individuals	122
Draws	7500
log-likelihood	-901.37

The first thing to notice is that all parameters have the expected sign; the negative time and cost parameters mean that relatively more expensive and longer duration modes have lower utility and therefore a lower probability of being chosen. Interestingly, the parameter for calories burned is negative, indicating that on average, people want to avoid transportation options that include a physical fitness component. This could also be interpreted as a desire not to be sweaty upon reaching one's destination because people likely make a connection between burning calories and working out, as was expressed by a subject in one of the daily e-mails.

Beyond checking to make sure that the signs are as expected, the relative magnitudes of the parameters provide further insight into the decisions the subjects make. The standard deviations for the alternative specific constants for the revealed preference modes have larger magnitudes than those for the revealed preference modes. This indicates that unobserved attributes of the modes have a greater influence in the revealed preference than in the stated preference mode decisions. The significant scale term for the stated preferences provides further support for the conclusion that the unobserved attributes are more influential in revealed preferences than in stated preferences. The ratio of two parameters that enter the utility equation linearly is the marginal rate of substitution of one attribute for another, so it is simple to investigate how our sample value one factor relative to another. For example, the value of time spent driving can be found by taking the ratio of the parameter for drive time and the parameter for cost and multiplying by 60 to convert dollars per minute to dollars per hour. As an indicator that our subjects were making reasonable decisions, their estimated value of time ranges from $10.42 per hour driving up to $28.18 per hour biking as can be seen in Table 13 below. Similarly, Björklund and Carlén (2012) found that the value of travel time for cycling far exceeds the value of travel time for other modes. These reasonable values of time indicate that the model performs well because these values of time are similar to the subjects' hourly pay.

TABLE 13 Estimated Marginal Rates of Substitution between Time and Cost

Value of Bike Time	$28.18 / hour
Value of Walk Time	$23.03 / hour
Value of Wait Time	$21.82 / hour
Value of Bus Time	$16.67 / hour
Value of BART Time	$14.94 / hour
Value of Drive Time	$10.42 / hour

By taking the ratio of the emissions parameter and the cost parameter, we find that our environmentalists, who constitute 24% of our sample, value reducing their greenhouse gas emissions at a rate of $2.68 per pound of carbon dioxide, and the non-environmentalists simply ignore this information when making transportation decisions. This makes intuitive sense in that while everybody cares about saving time and money, the desire to reduce environmental impact is not universal; some people care and some do not. This estimate is substantially higher than the previous estimations, but that is likely because in previous studies a single willingness to pay for emissions reductions was estimated for the entire sample rather than allowing for distinct groups with varying tastes (Gaker, et al., 2011), and that our current sample is both older and better educated than previous samples, factors which Achtnicht (2009) found are associated with a higher willingness to pay for emissions reductions.

In previous research we found that a random continuous distribution for the value of green explained transportation decisions better than systematic heterogeneity (Gaker, et al., 2011). By specifying a random discrete distribution for the value of green instead, we reanalyze the data from these earlier experiments using the latent class specification described and employed above. These previous datasets include an auto purchase experiment, a route choice experiment, and a mode choice experiment. With all except one of the data sets, we find that the model with two mass points describes the behavior of the subjects better than any other number of mass points, better than a model with random continuous heterogeneity, and better than a model with systematic heterogeneity that controls for trip purpose or demographics. Further, one of the mass points in each dataset is estimated to be at zero dollars per pound of emissions, rather than constrained to zero as in the analysis for the experiment above. Each of the class membership models is naïve, meaning that they include no explanatory variables such as demographics or environmental sentiment. We did not find that including demographics or other explanatory variables improved the fit of the models enough to justify the additional complexity. This is likely due to our small sample size and to the low variation in the education and age of our subjects. Results for models incorporating a random discrete distribution of the value of green are shown in Table 14.

TABLE 14 Random discrete distribution of the value of green for previous and current datasets

		Value of Green	Environmentalists
Auto Purchase	(Gaker et al., 2011)	$0.14	100%
Route Choice	(Gaker et al., 2011)	$0.51	11%
Mode Choice	(Gaker et al., 2011)	$2.44	20%
Mode Choice - SP Mode Choice - RP		$2.68	24%

The consistent finding that there exists a small group of people whose decisions show that they care a lot about reducing greenhouse gas emissions lends credibility to the results of the experiment presented in this paper. Further, the estimated parameters for the earlier mode choice experiment are remarkably close to the results of the RP/SP model, even though the old experiments had a considerably different design and were collected from undergraduate students rather than the broader demographic sample. Future research will be aimed at using demographics, political affiliation, and environmental sentiment to better explain what influences whether or not someone belongs in this group of people with a strong willingness to pay for reduce emissions as well as investigating whether there exist discrete distributions for other parameters such as the multiplier for calories burned.

CONCLUSIONS

The topics of sustainability and reducing environmental impacts are frequently discussed everywhere from academic institutions to dinner parties, and information about carbon is being presented to people facing a wide array of decisions. This information, however, remains substantially under-studied. While there have been several investigations into the amount people are willing to pay to reduce their environmental footprint, all known experiments attempting to quantify the value of "green" have relied on participants' stated preferences in decisions ranging from which car to buy to which route to take. The findings of this research are instead calculated including transportation mode decisions people actually face in their day-to-day lives. Our subjects both made stated preference decisions for which mode they would take for realistic trips and reported their revealed mode choice preferences for a period of two weeks after being presented with information about the feasible alternatives for their specific origins and destinations. In so choosing they made tradeoffs between attributes such as time spent, money spent, calories burned, and greenhouse gasses emitted. After a thorough exploration of the heterogeneity of the value of green, the best models indicate a discrete distribution in which some people do not care about emissions but there exists a small group that cares a lot. Using a mixed logit model we find that 24% of our subjects value reducing their emissions at a rate of $2.68 per pound both in their stated preferences and in their revealed preferences. Through their willingness to take on personal costs for the benefit of the public, this small group shows that they have a big heart. These findings are validated both by the reasonable values of time estimated and by the similar results from reanalyzing data (all stated preferences) from earlier experiments. This consistency represents a crucial step in understanding peoples' desires and the heterogeneity of the tradeoffs they make when faced with decisions involving personal and societal costs and benefits. These findings contribute to the existing literature by estimating the proportion of the sample that has a desire to reduce emissions and by quantifying how much they care in their revealed preferences.

Chapter 5

Conclusion

This dissertation presents three academic papers that each contribute to our understanding of how people value reducing the emissions associated with their transportation decisions.

In “Experimental Economics in Transportation: Focus on Social Influences and Provision of Information” (Gaker, et al., 2010) we presented subjects with two experiments that involved trading personal monetary costs and public environmental costs among other attributes. Both in the choice of which car to buy as well as in the choice of which route to take our subjects indicate a willingness to pay for emissions reductions. Further, it was found that the subjects valued reducing their emissions at a consistent rate ($0.24/pound) across the two experiments even though the emissions information was given to them in units of tons per year in one experiment and pounds per trip in the other.

In “The Power and Value of Green in Promoting Sustainable Transport Behavior” (Gaker, et al., 2011) we presented subjects with two experiments that involved trading personal monetary costs and public environmental costs among other attributes. The mode choice experiment focused on a commute trip and provided subjects with a variety of information such as real-time bus arrivals and calories burned by walking. The route choice experiment aimed to investigate whether people were sensitive to whether the trip was a commute trip or a recreation trip, whether or not they had information about average commutes, and whether the emissions information was in units of pounds per day or tons per year. We also reanalyzed the data from the auto purchase experiment above. Again we found that our subjects consistently valued reducing their emissions ($0.15/pound) across all versions of all experiments. Further, we found systematic heterogeneity in that, on average, women have a higher value of green than men do. By instead specifying random continuous heterogeneity, we found a median value of green of $0.06-$0.13/pound and over 90% of the distribution falling between $0.00 and $0.70/pound.

In “Revealing the Value of Green and the Small Group with a Big Heart in Transportation Mode Choice” (Gaker and Walker, 2013) we presented subjects with both stated preference mode choices as well as revealed preference mode choices. In choosing which mode to use, they traded attributes of travel time, access time, wait time, monetary costs, calories burned, and CO_2 emissions. After a thorough exploration of the form of the heterogeneity of the value of green, the best model includes a random discrete distribution for the emissions parameter. While 75% of the sample does not care about emissions, 25% have a value of green of $2.47/pound of CO_2. We observe similar distributions when analyzing the datasets from the experiments presented in “The Power and Value of Green in Promoting Sustainable Transport Behavior;” 20% of the subjects in the mode choice have a value of green of $2.44/pound and

11% of the subjects in the route choice have a value of green of $0.51/pound, and the rest show no desire to reduce the emissions associated with their transportation behavior.

People are more and more frequently being presented with information about the environmental impacts associated with the choices they make. This information is believed to have some influence over their decisions, but there has been little research conducted to investigate whether or how much people have a desire to reduce their impacts. In this dissertation I present three academic papers discussing five experiments aimed at answering three questions about the tradeoffs people make between emissions and other attributes associated with various transportation alternatives. I find that information on greenhouse gas emissions is influential in transportation decisions, that people consistently value reducing their emissions across a wide range of scenarios, and that there exists a discrete distribution in this value of green; most people don't care but some people indicate a strong willingness to pay for emissions reductions.

Avenues for future research exist in four directions. First, it would contribute significantly to this work to better explain who the people are that have such a high value of green. This could be done by maintaining the latent class framework and adding demographics and environmental attitudes and beliefs. Second, with this understanding that some people care a lot about reducing their emissions, research could be done to investigate how to motivate more people to care and how to use this value of green to promote behavior change. Third, this can be used to predict consumer response to new clean fuel vehicles or fleet replacement of a mass transit system. Lastly, it is unknown whether companies use green practices and materials simply because they can then market the products to consumers or whether these organizations have their own value of green.

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