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California Households' Willingness to Pay for "Green" Electronics♣

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ABSTRACT

Concerns about rapid increases in the volume of electronic waste (e-waste) and its potential toxicity have sharpened policymakers' interest for extended producer responsibility to encourage manufacturers of consumer electronic devices (CEDs) to "design for the environment." This paper examines consumer willingness to pay for "green" electronics based on a 2004 mail survey of California households. Using ordered logit models, we find that significant predictors of willingness to pay for "greener" computers and cell phones include age, income, education, beliefs about the role of government for improving environmental quality, as well as environmental attitudes and behaviors, but neither gender nor political affiliation. Although most respondents are willing to pay only a 1% premium for "greener" CEDs, innovation and E.U. directives may soon make them competitive with conventional CEDs.

1. INTRODUCTION

Consumer electronics devices (CEDs) contain numerous toxic materials, including mercury, lead, zinc, and cadmium, that pose a threat to public and environmental health if CEDs are improperly discarded. As a result, California classifies discarded small electronics as "universal waste" and bans them from landfills, along with batteries, fluorescent lights, and thermostats (Cal/EPA, 2006). This measure makes recycling CEDs more costly for households and for municipalities, who must now accept some CEDs in household hazardous waste recycling facilities, without giving manufacturers incentives to improve the environmental performance of their products.

Several policies have been proposed to address low recycling rates and limitations of the recycling infrastructure for electronic waste (e-waste). We focus here on extended producer responsibility (EPR), which is increasingly attractive to policymakers and environmentalists because it gives manufacturers incentives to "design for the environment" (DfE; Calcott & Walls, 2005). Indeed, if CEDs had little or no toxic materials, e-waste could be treated like ordinary municipal waste, which would decrease its handling and disposal costs.

EPR shifts the end-of-life product management burden from consumers and municipalities to manufacturers, which motivates profit-maximizing firms to reduce the amount of toxic materials in their products and to make them easier to recycle (OECD, 2001). EPR was initially intended as a mechanism to manage the large volume of product packaging entering the waste stream, but it is increasingly being applied to consumer electronics (OECD, 2001). Municipalities in California expressed strong support for EPR programs in part because of the financial burden e-waste recycling places on local governments (CIWMB, 2004). Because they contain toxic materials, the costs of collecting, transportation, and processing e-waste for recycling are far higher than for traditional household products, with estimates ranging from $200-1,000 per ton (Walls, 2003). Although some municipalities have imposed disposal fees on electronics, these fees do not cover the full recycling costs and often lead to increased illegal dumping (CIWMB, 2004).

The European Union (EU) enacted two EPR policies for consumer electronics in 2002: the WEEE directive (2002/96/EC) and the RoHS directive (2002/95/EC). The former requires manufacturers to take back and to recycle waste electrical and electronic equipment while the latter restricts the use of some hazardous materials in electrical and electronic equipment. In addition, the EU has proposed the *Registration, Evaluation and Authorization of Chemicals* (REACH) initiative that would restrict the use of approximately 1,400 chemicals and make industry responsible for managing the health and safety risks associated with their use (European Commission, 2006).

By comparison, the U.S. is lagging. In California, a recent report by Wilson et al. (2006) emphasizes the need for the state to adopt a “green” chemicals policy that will encourage the design, manufacture, and use of chemicals that are safer for the environment and for human health. Assembly Bill 2202, introduced in February 2006, is the first U.S. law to consider banning toxic substances in CEDs. It appears to just be a start.

It may be argued that legislation mandating “greener” electronics is not needed in the U.S. because electronics manufacturers participating in global markets are likely to adopt stringent requirements legislated in Europe and elsewhere (including Japan). However, some manufacturers may decide to keep producing CEDs containing hazardous materials for some markets, including the U.S. This would increase the cost of recycling CEDs in the U.S. because it would be necessary to distinguish between environmentally friendly and “conventional CEDs” to limit the contamination of the waste stream by hazardous materials.

Although environmentally friendly (“green”) CEDs (i.e., CEDs free of regulated hazardous materials) would not be subject to disposal restrictions, they may be more expensive. Unfortunately, little is known about consumers’ willingness to pay higher prices for “green” electronics. This paper starts filling this gap by studying how much more, if anything, Californian households are willing to pay for “greening” two popular categories of electronic products: cell phones and desktop computers.

Our findings indicate that the majority of Californian households are willing to pay only a small premium for “green” electronics (between 1% and 5% of their current cost). Demographic characteristics such as age, income, and education influence support for such a premium, as well as environmental attitudes and behaviors. Our survey reveals that one-half of our respondents are unaware of California’s landfill ban on CRTs and one-quarter did not know that CEDs contain toxic materials, so more public education may expand households’ willingness to pay for "green" CEDs. It is likely, however, that innovation will need to play an important role and several electronics manufacturers have already made progress towards producing "green" CEDs following new regulations in the E.U. and in Japan.

We organize our paper as follows. In the next section, we briefly review recent papers on willingness to pay for "green" products and discuss some key papers on pro-environmental behavior from the environmental psychology literature. Our survey and data are summarized in Section 3. This is followed by a presentation of our modeling methodology and a discussion of our results. Finally, we conclude and present some policy recommendations.

2. LITERATURE REVIEW

Consumer willingness to pay for "green" products (e.g. organic foods, as well as biodegradable or toxic-free products) simply reflects that consumers make trade-offs between product attributes, including environmental quality. Willingness to pay for "green" products has been widely studied; yet identifying the "typical" green consumer is not a simple task. Demographic profiles of "green" consumers often conflict across studies (e.g., see Laroche et al., 2001 and references therein). In fact, Menges et al. (2005) and Roe et al. (2001) find that regardless of demographic characteristics or geographic location, most respondents appear willing to pay for improved environmental quality, although not necessarily at the socially optimum level.

In their literature review Laroche et al. (2001) classify key factors that determine willingness to pay for "green" products into five groups: 1) demographic characteristics such as age, gender, income, and education; 2) knowledge of environmental issues; 3) attitudes toward the environment; 4) individual values; and 5) actual environmental behaviors. It is noteworthy that, although most studies focus on demographic characteristics to predict willingness to pay, environmental knowledge, attitudes, and personal values are often more important predictors of environmentally friendly behavior. Another excellent literature review can be found in Diamantopoulos et al. (2003). They examine the relationship between six socio-demographic variables (gender, martial status, age, number of children, education, and social class) and environmental knowledge, attitudes and behavior. Their findings suggest that the relationship between socio-economic features, demographic characteristics, and pro-environmental behaviors is complex. Depending on the product in question, different variables may be more or less influential. While individual characteristics may explain environmental attitudes, it is much more difficult to predict a general propensity toward pro-environmental behavior. Given the large body of literature on willingness to pay for "green" products, we focus on stated preference studies published since 2000.

Significant demographic predictors of willingness to pay for "green" products include income, education, and age. To a lesser extent, gender and ethnicity are also found to be statistically significant variables.

As expected, income is often positively correlated with willingness to pay for environmentally friendly products, as illustrated by studies of participation in "green" electricity programs (Menges et al., 2005; Roe et al., 2001; Zarnikau, 2003).

Likewise, many studies find that more education leads to more interest in "green" electricity programs (Zarnikau, 2003), but also organic and locally produced food (Brown, 2003; Loureiro & Hine, 2004; Radman, 2005), "green" cars (Mourato et al., 2004), or certified forest products (Jensen et al., 2003).

De Pelsmacker et al. (2005), Gossling et al. (2005), and Zarnikau (2003) report that older adults tend to be less willing to pay higher prices for environmentally friendly products. However, Radman (2005) suggests that willingness to pay for organic food is higher for older adults. Safety and health concerns are commonly cited as a reason for purchasing organics (see, e.g. Krystallis & Chryssohoidis, 2005; Harris et al., 2000), which may explain these seemingly contradictory results.

Gender appears to influence consumer preferences, particularly for organic food. Recent findings indicate that women are willing to pay higher prices than men (Brown, 2003; Lockie et al., 2004; Loureiro et al., 2002), although our study of willingness to pay an advanced recycling fee (Nixon & Saphores, 2006) suggests this conclusion does not apply to CEDs.

Ethnicity has not been widely studied in the literature on "green" buying. Zarnikau (2003) does find, however, that Caucasians are more willing to pay for renewable energy than other groups.

Increasingly, researchers are interested in the roles of attitudes and values in predicting willingness to pay for "green" products. Loureiro et al. (2002) and Harris et al. (2000) report that attitudes toward the environment and personal values play key roles in understanding consumer preferences for organic food. Krystallis & Chryssohoidis (2005) and Lockie et al. (2004) find similar results. Wiser et al. (2002) also suggest that altruism is far more important than financial issues to motivate participating in "green" energy programs for businesses.

Environmental knowledge is another key factor that impacts willingness to pay for environmentally friendly products. Nomura & Akai (2004) find that willingness to pay for "green" electricity in Japan is heavily influenced by environmental knowledge, specifically awareness of renewable energy technologies. While financial considerations drive willingness to pay for a fuel cell taxi in London, knowledge and environmental concerns also come into play (Mourato et al., 2004).

Empirical evidence suggests links between people's willingness to pay higher prices for one "green" product and other "green" consumption behaviors. For example, according to Lockie et al. (2004), organic food consumption is positively correlated with other pro-environmental behaviors such as recycling. In addition, while political affiliation and environmental values have only a small impact on organic food purchases, there is a much stronger association between these factors and other "green" consumption activities including recycling and using environmentally friendly cleaning products. Jensen et al. (2003) also report a strong link between willingness to pay for certified forest products and other "green" consumption and pro-environmental behaviors.

Even though public opinion surveys consistently report that consumers are willing to pay higher prices for environmentally friendly products (Paulos, 1998), there is often a difference between stated willingness to pay and actual behavior (Ek, 2005). A recurring concern is the presence of a "socially desirable response bias" where respondents indicate their willingness to pay higher prices because it is socially-responsible, yet in reality, they do not pay premium prices (Paulos, 1998). Garrod & Willis (1999) discuss the pros and cons of stated versus revealed preference methods used in environmental valuation studies. Although revealed preference methods are clearly very useful, they have several limitations (Calfee et al., 2001; Freeman, 2003): first, market data may not be available; second, even if market data are available, they may not exhibit much variation, which hinders empirical work; and third, revealed preferences data do not allow estimating non-use values. By contrast, stated preference techniques allow researchers to explore preferences for hypothetical goods or scenarios, and to generate data for a wide range of respondents.

Research on pro-environmental behavior (PEB) is another important body of literature for this paper. Economic studies tend to focus on external variables such as prices, income, education, or other demographic and socio-economic characteristics to explain PEB (e.g., see Bergstrom et al., 1986; Choe & Fraser, 1999; Jenkins et al., 2003; Judge & Becker, 1993; or Weaver, 1996). Social-psychology, on the other hand, emphasizes internal variables such as personal attitudes, beliefs, or moral values (see Fransson & Garling, 1999, for a review of this literature). There have also been efforts to adopt an interdisciplinary approach to examine the factors that influence PEB (Van Liere & Dunlap, 1980; Messick & Brewer, 1983; Guagnano et al., 1995; Clark et al., 2003). We follow the same path and combine internal variables on environmental attitudes with external demographic and socioeconomic characteristics in order to investigate willingness to pay a premium for "green" cell phones and PCs.

3. SURVEY INSTRUMENT AND DATA

Data for this study were collected between January and April 2004 through a mail survey of 3,000 randomly selected California households stratified by county. To reflect the diversity of California's population, we geographically stratified our sample. We split the state in two (north versus south) and randomly picked two rural (Mono in Northern California and Kern in the south) and four urban counties (Alameda and Contra Costa in the north; Orange and San Diego in Southern California) to capture systematic geographic differences in our target population. We then hired Fox's Data Services (Oakland, California) to randomly selected 500 household addresses in each of these six counties from their most recent (end of 2003) database.

Our survey instrument focused on respondents' environmental attitudes and pro-environmental behavior. We inquired about e-waste recycling preferences, quantity of e-waste stored in homes, as well as awareness of environmental issues and regulations related to consumer electronics. In addition to collecting demographic and socio-economic information, we asked respondents about their willingness to pay higher prices for environmentally friendly cell phones and desktop computers.[1]

Mail surveys offer several key advantages over telephone or in-person surveys such as lower cost, access to a widely dispersed population, and the elimination of interviewer bias. Disadvantages include lower response rates and the need for respondents to have strong literacy skills. These factors could introduce bias into our sample so we followed recommendations by Alreck & Settle (1995) and Fowler Jr. (1988) to increase response rates.

Our overall response rate (12.4%) is low but typical of some other general population mail surveys (Alreck & Settle, 1995). Comparing our respondents' characteristics to 2000 Census data for the same geographic areas, we find that our respondents tend to be older and better educated. In addition, they have a higher household income and are less ethnically diverse. Due to these differences, it is necessary to be careful when extrapolating our results to various subgroups of Californians or to the whole state. More details about our survey methodology and results are available in Saphores et al. (2006).

4. MODELING HOUSEHOLDS' WILLINGNESS TO PAY FOR "GREEN" ELECTRONICS

We develop two models to estimate willingness to pay for "green" electronics. Our first model explores willingness to pay for "green" cell phones; our second model focuses on "green" desktop computers. In each case, respondents select their willingness to pay from among four alternatives: 1) Not willing to pay a premium; 2) Willing to pay a 1% premium; 3) Willing to pay a 5% premium; and 4) Willing to pay a 10% premium.

To motivate our discrete choice models, we assume that respondents maximize an

[1] A copy of the survey can be obtained directly from the authors.

unobserved utility function when they select between different alternatives. This utility function depends on the attributes of the choices under consideration and on the unique characteristics of each respondent. We therefore decompose the unobserved utility y_i^* of respondent *i* (*i*=1,…,*N*) into two parts: 1) a deterministic portion that depends on a vector of observations x_i of explanatory variables and a vector β of unknown parameters; 2) a random error component ε_i (the ε_is are assumed identically and independently distributed) that reflects the difference between true utility and what is actually observed. This can be written:

$$y_i^* = x_i^{'}\beta + \varepsilon_i. \qquad (1)$$

The actual choice of category *k* by respondent *i* (i.e., y_i =*k*) is related to his utility y_i^* by:

$$y_i = k, \quad \text{if } \tau_{k-1} \le y_i^* < \tau_k, \qquad (2)$$

with $\tau_0 = -\infty < \tau_1 < \tau_2 < \tau_3 = +\infty$; the $\tau_i s$ are unknown thresholds we jointly estimated with β. The probability of a given outcome, as shown by Long (1997), is then

$$\Pr(y_i = k) = F(\tau_k - x_i^{'}\beta) - F(\tau_{k-1} - x_i^{'}\beta), \qquad (3)$$

where *F*(.) is the cumulative distribution function of the error term ε. This multivariate approach allows us to examine the joint influence of several independent variables on our dependent variable, which is not possible through correlation or contingency table analysis.

We use ordered logit to estimate our model. This assumes that the error term ε has a standard logistic distribution (mean = 0; variance = $\pi^2/3$). An advantage of this approach is that choice probabilities are readily interpretable and a variety of specification tests are available to assess whether our model is correctly specified.

First, we check for multicollinearity between our explanatory variables as recommended by Stewart (1991). We then perform a battery of tests to assess the robustness of our results. We add quadratic and cubic transformations of our continuous variable to evaluate linearity and examine a variety of interaction terms. Likelihood ratio tests are used to check for their statistical significance. We also use a Wald test proposed by Brant (1990) to test the parallel regression assumption (i.e., the slope of the regression line does not vary across the different categories of our dependent variable). Finally, we test for influential observations using Pregibon's Delta-Beta influence statistic as recommended by Long & Freese (2006).

To condense survey data information on environmental attitudes and behavior into a small number of factors, we conduct a Principal Components Analysis (PCA) with varimax rotation. This linear transformation technique allows us to summarize most of the information from the original set of variables into a small set of factors (Dunteman, 1989). PCA is widely used in numerous disciplines including physical sciences as well as behavioral and social sciences (Dunteman, 1989). Rotation allows us to more easily interpret the newly created factors (Jackson, 1991). In order for this technique to work effectively, the intercorrelations between the original variables need to be large enough (otherwise too many factors will be generated), so we compute Bartlett's test for sphericity. However, excessive intercorrelations suggest a problem with multicollinearity. To detect whether intercorrelations are high enough to limit the number of factors, but not so high as to avoid multicollinearity, we calculate the Kaiser-Meyer-Olin (KMO) statistic. A KMO statistic of at least 0.6 is recommended to proceed with PCA. Lastly, we rely on Cronbach's alpha to measure the reliability of our factors.

5. RESULTS

A. Principal Components Analysis

We develop two factors, normalized between 0 and 1, to summarize answers to ten survey questions on environmental activism and attitudes (see Table 1).

<Insert Table 1 approximately here>

Our first factor (PC1) reflects a respondent's level of involvement in environmental activities; higher values indicate *less* involvement and *less* support for environmental protection. This "environmental inactivism" factor is based on four survey questions with fairly high intercorrelations (Cronbach's alpha = 0.695), and it accounts for 80.1% of their variance (see Table 1 for the text of the questions used to create the different factors).

The second factor (PC2) is based on six survey questions that ask respondents to rate environmental quality at the local, state, and national levels; to prioritize the environment over the economy; and to assess the adequacy of current spending on environmental protection. Higher factor values indicate beliefs that environmental quality has improved in recent years and a tendency to prioritize economic over environmental concerns, hence its name "Environmental quality and economic priorities." This factor accounts for 29.2% of the variance between the original variables (Cronbach's alpha = 0.782). Among our respondents, approximately two-thirds believe that environmental quality has worsened over the past 10 years. Respondents were also asked to rate the current environmental quality in the U.S., California, and their local community. Respondents are fairly equally divided between rating the current environmental quality across the U.S. and California as "good" or "fair" (approximately one-third for each). However, when it comes to rating their current local environmental quality, nearly 70% believe that it is only "poor" or "fair."

B. Willingness to Pay for "Green" Electronics

In each model, our survey respondents were given four options to indicate their willingness to pay for environmentally friendly electronics: 1) Not willing to pay a premium; 2) Willing to pay a 1% premium; 3) Willing to pay a 5% premium; and 4) Willing to pay a 10% premium.[2] Our range of categories is based on empirical evidence from previous studies on willingness to pay for "green" products. These studies suggest that consumers are generally not willing to pay more than 10% extra (De Pelsmacker et al., 2005; Harris & Burress, 2000).

Table 2 presents a breakdown of responses by category. It shows similarities between the willingness to pay for "green" cell phones and for "green" PCs: for the former, 8.8% of our respondents were ready to pay a 10% premium and 25.2% agreed on a 5% premium, versus 7.7% and 23.0% respectively for the later. These similarities do not suggest our respondents disagreed with our assumption that making these CEDs more environmentally friendly may roughly be proportional to their value and size.

<Insert Table 2 approximately here>

After checking for the absence of multicollinearity between our explanatory variables, we use Stata (StataCorp LP, College Station, TX) to estimate ordered logit models that explain willingness to pay a premium for "green" cell phones and desktop computers based on 251 valid answers (some respondents only provided incomplete information). Descriptive statistics for our two factors and statistically significant demographic and socioeconomics variables are summarized in Table 3.

<Insert Table 3 approximately here>

[2] Montgomery and Helvoigt (2006) also use broad categories for their research on salmon recovery, and so do Chung and Poon (1996) in a study of recycling attitudes in Hong Kong.

Using likelihood ratio (LR) tests, we find no significant polynomial contrasts, but three interaction terms turn out to be statistically significant. In addition, Pregibon's Delta-Beta influence statistic does not detect any influential observation. Finally, tests of the parallel regression assumption fail to reject this important assumption, which gives support to our choice of ordered logit models.

Our final models are presented in Table 4. Other variables considered, but not statistically significant include political affiliation and gender (by itself, and interacted with either knowledge of the toxicity of e-waste or knowledge of California's CRT law). The lack of significance of gender may seem surprising given that Saphores et al. (2006) find that women are more willing to recycle e-waste using data from the same survey. In fact, the literature on gender differences in pro-environmental behavior is split. In their extensive review of the demographic profile of "green" consumers, Diamantopoulos et al. (2003) find that women are generally more likely than men to engage in pro-environmental consumerism, but Gamba & Oskamp (1994) or Werner & Makela (1998), for example, detect no relationship between gender and recycling. This illustrates that gender differences in pro-environmental behavior are neither uniform nor systematic.

We also examined the role of environmental knowledge related to CEDs, but it was not found to be statistically significant. This contrasts with several other papers (Nomura & Akai, 2004; Mourato et al., 2004) where environmental knowledge has been shown to be a significant predictor of willingness to pay for other environmentally friendly products. This result cannot be attributed to a lack of variation, however, as one-quarter of our respondents were unaware that CEDs contain toxic materials and more than one-half did not know about California's landfill ban on CRTs. Instead, we suggest that consumers may have a strong expectation of falling prices for CEDs.

Finally, we tested dummy variables reflecting the geographic distribution of our respondents within California, but they were also not found to be statistically significant.

<Insert Table 4 approximately here>

The Adjusted Count R^2 for our "green" cell phone and "green" desktop computer models is 0.284 and 0.215, respectively. Unlike the Count R^2, which simply reports the proportion of correct predictions, the Adjusted Count R^2 represents the proportion of correct predictions beyond what would have been guessed by choosing the largest marginal category (Long, 1997). In both cases, our models best predict the 1% category (as high as 77% accuracy for "green" PCs) and are least successful at predicting the 10% category (3 out of 23 for "green" cell phones and only 1 out of 20 for "green" PCs).

a. Sensitivity Analysis - General

Because they are nonlinear, the interpretation of ordered models is somewhat more involved than the discussion of linear regressions. Following Long (1997), we analyze two ways the predicted probabilities of being in one of the four categories characterizing willingness to pay a premium for "green" electronics: first, we examine the impact of discrete changes in our binary variables on predicted probabilities; and second, we plot predicted probabilities as a function of our two continuous explanatory variables, PC1 and PC2.

We begin with defining a baseline respondent characterized by mean values of our independent variables. For the "green" cell phone model, he/she (gender is not relevant here) is

36 to 65 years old, Caucasian, college educated, and with an annual household income under $80,000. He/she also believes that government plays a major role in protecting the environment. Finally, he/she scores 0.77 on PC1 ("Environmental inactivism") and 0.44 on PC2 ("Environmental quality & economic priorities"). Our baseline respondent for "green" PCs is similar, except that ethnicity is irrelevant and his/her age ranges from 18 to 65 years.

Our final models explaining willingness to pay for "green" cell phones and for "green" computers are quite similar so, for conciseness, we focus on the former and we highlight differences between the two models when appropriate.

b. Discrete Variables

To explore the specific influence of our binary dependent variables on a respondent's willingness to pay higher prices for "green" cell phones, we change each binary variable sequentially, holding all others at their baseline value (Long, 1997). Table 5 summarizes our results.

<Insert Tables 5 and 6 approximately here>

The highest baseline probability (44.5%) is for a 1% price premium on "green" cell phones suggesting that, while most respondents are willing to pay more for environmentally friendly electronics, they would only support a small price increase. We find very similar results for our "green" PC model (shown in Table 6).

Only young adults and households earning more than $80,000 per year are willing to pay a higher price premium (5% to 10%) than our baseline respondent. The impact of income is not unexpected. Wealthier households tend to have more disposable income and thus may be more willing to pay higher prices for "green" electronics. This result is similar to previous research by

Menges et al. (2005), Roe et al. (2001), and Zarnikau (2003) who find that income is positively correlated with willingness to pay for "green" electricity.

Young adults (under 36 years) are more willing to pay 5% to 10% extra (+12.4% and +5.8% respectively) for "green" cell phones, whereas older adults (over 65 years) are less likely to support these price premiums (-10.6% and -2.8% respectively). According to CEA Market Research (2004), seniors tend to have lower than average ownership of some CEDs and they express less interest in consumer technology, so these results are not surprising.[3]

Interestingly, the young adult variable is significant only for "green" cell phones and not for "green" PCs. Although they now outnumber PCs, cell phones are a more recent addition to the consumer electronics market. The idea of cellular communications dates back to the late 1940s, but the first modern portable handset was not invented until 1973 and commercial cellular service was first authorized by the Federal Communications Commission in 1982 (Agar, 2003). Wireless subscriptions soared from approximately 200,000 in 1985 to more than 190 million in 2005 (CTIA, 2005). Although huge, the growth of the PC market was not as large: nearly 7 million U.S. households already owned a personal computer in 1984, versus 113 million in 2003 (U.S. Census, 1988; 2005). Young adults are a niche market for CEDs; in particular, they follow trends and are more likely than other age groups to upgrade to the latest technology (Mintel USA, 2005). In 2005, eighty-five percent of adults aged 18 to 24 owned a cell phone, the highest rate of any age group and 30% more than the ownership rates for seniors (Enpocket, 2005).

Ethnicity is also statistically significant in our "green" cell phone model as non-Caucasians appear less likely to support higher prices (by 12.5%). Research on the influence of ethnicity is limited, but these findings are similar to Zarnikau's (2003).

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[3] Our survey indicates, however, than seniors tend to have just as much e-waste as others (see footnote 4). Two reasons may be invoked: first, electronics is now ubiquitous, and second, casual observations suggest that many seniors tend to accumulate objects over time.

Education intervenes in our model through interactions with both PC1 and PC2. The net effect of education is quite small across all levels of the dependent variable. The largest effect is for the “not willing to pay higher prices” category where a lack of a college education increases the predicted probability by 1.7%.

Finally, we find that political ideology is important. Respondents who believe government does not play an important role in protecting the environment are more likely to oppose higher prices for “green” cell phones (+14%) than our baseline respondent. Although our survey question did not suggest that such a technological change would be mandated by the government, respondents may have implicitly assumed that manufacturers would be required by law to reduce the hazardous material composition of electronics (as for the EU RoHS Directive).

Table 6 presents the changes in predicted probabilities of a respondent’s willingness to pay extra for “green” PCs when we systematically change each discrete variable while holding others at their baseline value. Results are very similar to the discrete changes for the “green” cell phone model. Baseline probabilities are highest for a 1% premium (49.9%). Higher income households are more likely to support 5-10% higher prices, while older adults, those who believe government does not play a role in protecting the environment, and respondents without a college education are more likely to be unwilling to pay a premium for “green” PCs.

c. Continuous Variables

To examine the effect of our two factors (PC1 and PC2) over their range, we plot the predicted probability that a respondent is in any one of our willingness to pay categories as a function of each factor. We begin with our baseline respondent and sequentially change the value of our binary independent variables, holding all others at their baseline value.

Figure 1 graphs the predicted probability that an individual is unwilling to pay higher prices for a “green” cell phone as a function of PC1. A higher PC1 score indicates less direct involvement with environmental activities and organizations so we expect that higher factor scores will correspond to higher predicted probabilities of opposing a price premium for “green” electronics. Baseline probabilities increase from 13.9% to 26% over the range of PC1.

<Insert Figure 1 approximately here>

Older adults (≥ 65 years), non-Caucasians, and respondents who believe government does not play a major role in protecting the environment are consistently more likely to oppose a price increase than our baseline (the last two categories are not shown on Figure 1; they are very similar to older adults). As expected, young adults and higher income households (>$80,000/yr) have lower predicted probabilities for this category as they are more willing to pay a premium for “green” cell phones. These findings are consistent with our results for discrete changes.

Interestingly, the effect of education varies considerably over the range of PC1. Education enters our models through an interaction with both PC1 and PC2. Our results suggest that individuals without college education but with high levels of environmental activism (indicated by low PC1 scores) have lower predicted probabilities than our baseline, and they tend to support higher prices for “green” electronics. As PC1 increases, this relationship is reversed. Since PC1 reflects time-consuming involvement with environmental activities, this result may be better explained by a lack of free time than by environmental beliefs.

Figure 2 charts the change in predicted probability for support of a 1% price increase for “green” cell phones as a function of PC2. This figure allows us to examine the transition between support levels for different premium levels for our respondents. Older adults are initially more supportive of a 1% price premium than our baseline, but they become less supportive as PC2 increases. We obtained similar results for non-Caucasians and for respondents who believe government does not play a major role in protecting the environment.

<Insert Figure 2 approximately here>

As expected, we find that young adults and wealthier households are initially less willing to support a 1% premium for "green" cell phones than our baseline as these respondents are actually willing to support higher prices (+5% to 10%). As PC2 increases, these respondents become more willing to support a 1% increase. The influence of education is most apparent at extreme values of PC2; otherwise, the impact of education on the probability of supporting 1% higher prices does not vary much over the range of PC2.

Likewise, for mid-range values of PC2, individual characteristics do not significantly change support for a 1% premium. The mean value of PC2 is 0.44 and the distribution of scores is approximately normal suggesting that most respondents have "middle-of-the-road" opinions on how to prioritize environmental protection and economic growth; support for a small price increase for environmentally friendly electronics is widely acceptable.

Figure 3 illustrates the change in predicted probability that a respondent is willing to pay a 10% premium for "green" PCs as a function of PC1. Similar to our "green" cell phone model, wealthier households are consistently more willing to pay higher prices, while older adults and those who indicate *no government role* (not shown but similar to older adults) are less likely to support price increases. Also, the effect of education is consistent with our previous results, with a spike at close to 55% for environmental militants with a low education.

The rest of our comprehensive sensitivity analysis for both models supports these conclusions, so it is omitted.

<Insert Figure 3 approximately here>

6. POLICY CONSIDERATIONS AND CONCLUSIONS

Extended producer responsibility regulations and other policies that encourage "design for the environment" are increasingly popular for addressing the end-of-life management of obsolete consumer electronics. This paper expands the literature on consumer preferences for "green" products by analyzing how internal and external variables influence household willingness to pay for "greener" CEDs. Our research gives insights on consumer willingness to pay for "green" electronics in California that are likely to be of interest to policymakers, local governments, and electronics manufacturers.

Currently in the U.S., municipal governments are the primary agents responsible for e-waste management. As new e-waste regulations are enacted, local governments face additional burdens and in a recent survey (CIWMB, 2004), municipalities listed finance, the availability of end markets for recovered materials, and environmental issues as their top concerns with regard to e-waste. EPR programs are an attractive policy option as they shift these burdens away from municipalities and encourage environmentally friendly product design which may improve local environmental quality. We therefore recommend that policymakers seriously consider implementing EPR at the state or national level in the US to pre-empt the creation of a multitude of local regulations that would complicate the task of CED manufacturers and could increase the cost of CEDs.

Although empirical evidence suggests that consumers are willing to pay as much as 10% extra for environmentally friendly products, particularly organic foods (De Pelsmacker et al., 2005; Harris & Burress, 2000), our survey indicates that a majority of Californian households back only a 1% premium for "green" electronics; widespread support for higher premiums (5-10%) is generally limited to wealthier households. This is the bad news. This willingness to pay for "greener" electronics is somewhat low, although it appears similar to the interest for "green" electricity programs (Menges et al., 2005; Roe et al., 2001). We conjecture that consumers expect manufacturers to innovate to make their products more environmentally friendly without significantly increasing their prices as they may be accustomed to the falling prices and constant progress that characterizes electronics manufacturing.

The low willingness to pay for "green" electronics may also be caused by poor knowledge about the toxicity of e-waste. Indeed, more than half of our respondents were unaware of California's CRT landfill ban and one-quarter did not know that consumer electronics contain toxic materials, although this lack of knowledge did not turn out to be statistically significant in our models. Weak support for "green" CEDs is problematic if both "green" and "non-green" products are jointly available because it requires establishing separate recycling chains to avoid contaminating recycled materials by toxic substances. Higher prices for "green" CEDs would also entice some consumers to keep or buy used "non-green" products, which may then be longer in use. Better informing households about the potential environmental impacts of e-waste would then be useful not only to boost support for "greener" CEDs, but also to prevent the improper disposal of e-waste.

Our survey data thus clearly reveal the need to educate people about e-waste. Our models suggest that public information campaigns should target households earning less than

$80,000 annually and older adults as these groups are less likely to support higher prices for environmentally friendly CEDs.[4]

In any case, the availability of "greener" CEDs will increase significantly after the RoHS directive goes into effect on July 1, 2006. After resisting E.U. initiatives to eliminate some toxic substances from CEDs, a number of companies (mostly in Europe and Asia) have embraced the challenge of greener electronics.

The good news is that producing "greener" CEDs may not be much more costly than conventional ones. Fujitsu Siemens unveiled the RoHS-compliant Esprimo computer line in 2005 which retails for prices similar to non-"green" models. Likewise, Nokia, the world's largest cell phone manufacturer, introduced a RoHS-compliant phone in April 2005 with production costs comparable to non-compliant models (Wilson, 2006). More generally, research by Technology Forecasters indicates that suppliers and manufacturers will likely be able to meet RoHS requirements with a one-time investment of approximately 2-3% of overall manufacturing costs (Reed Business Information, 2005). In addition, as the CED industry is highly competitive and the price elasticity of demand for CEDs exceeds one (Cette et al., 2005; Stavins, 1997), electronics manufacturers will likely pass along only a fraction of these cost increases to consumers.

Worldwide, the trend is toward environmentally friendly electronics manufacturing. Although the U.S. has mostly lagged behind Europe and Japan, EPR appears to be a promising solution to tackle the increasing e-waste problem without unduly burdening consumers.

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[4] Although older adults may not be major consumers of some electronic products (e.g. MP3 players), our survey suggests that they own as much e-waste as the rest of the population. Our survey asked respondents to identify the number of obsolete CEDs they have for a wide range of products (small/large TVs, PCs, laptops, small/large monitors, and small/large general CEDs). The largest (in absolute value) correlation coefficients between age and the reported number of large, obsolete CEDs was only -0.22. Public information campaigns targeting older adults may

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thus also result in increased willingness to pay for “green” CEDs.

Table 1: Principal Components Analysis of Environmental Attitudes and Behaviors

Survey Items and Principal Components	Eigenvectors and scoring coefficients	% Variance explained v; Cronbach's α; KMO; Bartlett.
PC1 – Environmental inactivism		v = 80.1%
1. In the past 12 months, have you attended a meeting or signed a petition aimed at protecting the environment?	0.611	α = 0.695 KMO = 0.711
2. In the past 12 months, have you contributed to an environmental organization?	0.761	Bartlett: $p<0.001$
3. During the past 12 months, have you participated in local environmental activities such as Earth Day or Beach Clean-Ups?	0.295	
4. Are you an active, inactive, or not a member of an environmental organization?	0.744	
PC2 – Environmental quality and economic priorities		v = 29.2%
1. Do you believe that the environment (land, sea, air, rivers, lakes, climate, etc.) has become better or worse in the past 10 years?	0.513	α = 0.782 KMO = 0.772 Bartlett: $p<0.001$
2. How would you rate environmental quality in the U.S.?	0.698	
3. How would you rate environmental quality in California?	0.743	
4. How would you rate your local environmental quality?	0.500	
5. Indicate your level of agreement with the statement "environmental protection should be a priority, even if it slows economic growth and causes some job losses"	0.643	
6. Do you believe that we are spending too much money, the right amount, or too little money on improving and protecting the environment?	0.615	

Notes. A higher value of PC1 indicates less environmental involvement. A higher value of PC2 indicates less concern for the environment and a belief that environmental quality is improving. Cronbach's α assesses how well a set of variables measures an underlying construct; it is high when inter-item correlations are high. KMO measures sampling adequacy and tests whether partial correlations between variables are small; it should be >0.5 for a satisfactory factor model.

Bartlett's test of sphericity checks whether the correlation matrix of the variables considered differs significantly from the identity matrix; if not, the factor model is inappropriate.

Table 2: Breakdown of Survey Responses for Willingness to Pay Extra for "Green" Electronics

	"Green" Cell Phones	"Green" Desktop Computer
Not willing to pay extra	30.66 %	29.20 %
Willing to pay 1% extra	35.40 %	40.15 %
Willing to pay 5% extra	25.18 %	22.99 %
Willing to pay 10% extra	8.76 %	7.66 %

Table 3: Descriptive Statistics for Key Variables

Variable	Mean	S.D.	Minimum	Maximum
Willingness to pay extra for "green" cell phones	2.16	0.95	1	4
Willingness to pay extra for "green" desktop computers	2.12	0.91	1	4
PC1 – Environmental inactivism	0.77	0.32	0	1
PC2 – Environmental quality and economic priorities	0.44	0.20	0	1
Age between 18 and 35 years (yes = 1)	0.13	0.33	0	1
Age over 65 years (yes = 1)	0.19	0.39	0	1
Caucasian (yes = 1)	0.78	0.41	0	1
College (yes = 1)	0.87	0.34	0	1
Household income >$80,000 per year (yes = 1)	0.45	0.50	0	1
Interactions:				
PC1 * college (yes = 1)	0.68	0.38	0	1
PC2 * college (yes = 1)	0.40	0.24	0	1
PC2 * Role of government in protecting the environment (major role = 1)	0.36	0.24	0	1

Notes: PC1 and PC2 are both treated as continuous indexes. They are normalized to be between 0 and 1. All other independent variables are binary (0 or 1) indicator variables.

Table 4: Model Estimation Results Comparing WTP "Green" Cell phone vs. "Green" PC

Variable	Willingness to Pay for "Green" Cell Phones Coefficient	Robust standard error	Willingness to Pay for "Green" Personal Computers Coefficient	Robust standard error
PC1 – Environmental inactivism	-4.234	[.620]	-4.407	[0.614]
Age between 18 and 35 years (yes = 1)	0.757	[0.360]	—	—
Age over 65 years (yes = 1)	-0.711	[0.362]	-0.562	[0.345]
Caucasian (yes = 1)	0.616	[0.293]	—	—
Household income >$80,000/yr (yes = 1)	0.618	[0.263]	0.430	[0.263]
Interactions:				
PC1 * college	3.455	[0.627]	3.616	[0.612]
PC2 * college	-5.725	[0.948]	-5.639	[0.895]
PC2 * Gov't role	1.515	[0.610]	1.357	[0.553]
τ_1	-3.098	[0.627]	-3.874	[0.470]
τ_2	-1.153	[0.445]	-1.656	[0.387]
τ_3	0.925	[0.439]	0.355	[0.553]

Notes: 1) Number of observations = 251.

2) Results for willingness to pay for "green" cell phones: Log-likelihood = -280.902. Wald Chi-Square (with 8 degrees of freedom) = 67.26; the corresponding p-value is <0.0001. Count R^2 = 0.538; Adjusted Count R^2 = 0.284.

3) Results for willing to pay for "green" desktop computers: Log-likelihood = -275.656. Wald Chi-Square (with 6 degrees of freedom) = 66.10; the corresponding p-value is <0.0001. Count R^2 = 0.534. Adjusted Count R^2 = 0.215.

Table 5: Discrete Changes in the Willingness to Pay Extra for "Green" Cell Phones

Variable	0%	1%	5%	10%
Baseline probabilities:	*0.227*	*0.445*	*0.270*	*0.058*
Age 18-35 years (*no* → yes):	-0.106	-0.076	+0.124	+0.058
Age 65 years + (*no* → yes):	+0.147	-0.012	-0.106	-0.028
Caucasian (*yes* → no):	+0.125	-0.006	-0.094	-0.026
Household income >$80,000 per year (*no* → yes):	-0.090	-0.057	+0.103	+0.044
College education (*yes* → no):	+0.017	+0.004	-0.016	-0.005
Role of government in protecting the environment (*major role* → minor or no role):	+0.140	-0.010	-0.102	-0.028

Notes. To generate the results above, we change discrete variables one at a time while other variables stay at their baseline value (which is underlined and in italics in the left-most column). Baseline respondents score 0.77 on PC1 and 0.44 on PC2.

Table 6: Discrete Change in the Willingness to Pay Extra for "Green" Personal Computers

Variable	0%	1%	5%	10%
Baseline probabilities:	*0.206*	*0.499*	*0.242*	*0.053*
Age 65 years + (*no* → yes):	+0.107	-0.004	-0.080	-0.022
Household income >$80,000 per year (*no* → yes):	-0.062	-0.035	+0.070	+0.026
College education (*yes* → no):	+0.046	+0.005	-0.039	-0.012
Role of government in protecting the environment (*major role* → minor or no role):	+0.117	-0.007	-0.086	-0.023

Notes. To generate the results above, we change discrete variables one at a time; other variables stay at their baseline value (underlined and in italics in the left-most column). Baseline respondents score 0.77 on PC1 and 0.44 on PC2.

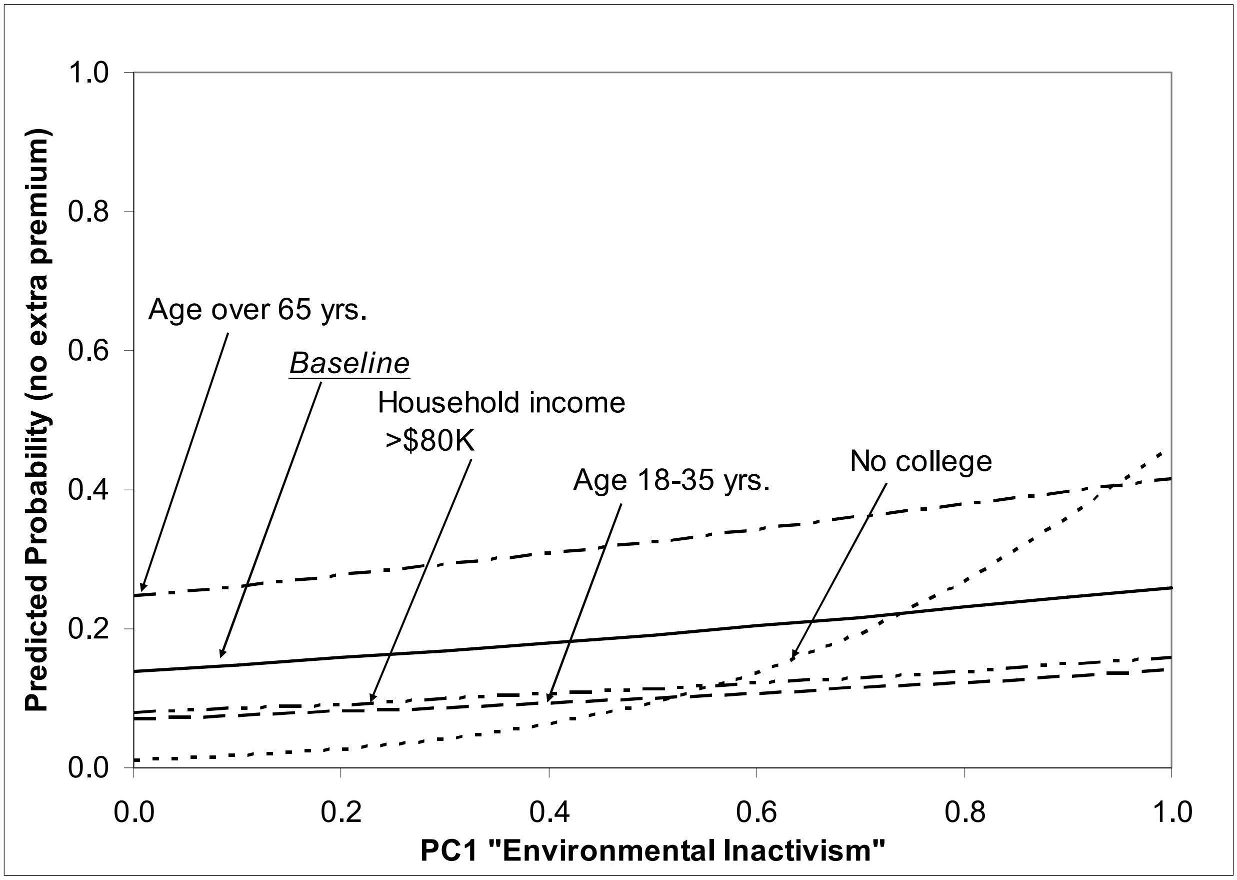

Figure 1: Predicted probability of the unwillingness to pay an extra premium for "green" cell phones versus PC1.

Note. PC1 reflects personal involvement in environmental activities, with higher values indicating less support for the environment; it is normalized to be between 0 and 1. Our baseline respondent is 36 to 65 years old, Caucasian, college educated, and with an annual household income under $80,000. In addition, he/she (gender is not relevant here) believes that government plays a major role in protecting the environment, scores 0.77 on PC1 ("Environmental inactivism") and 0.44 on PC2 ("Environmental quality & economic priorities").

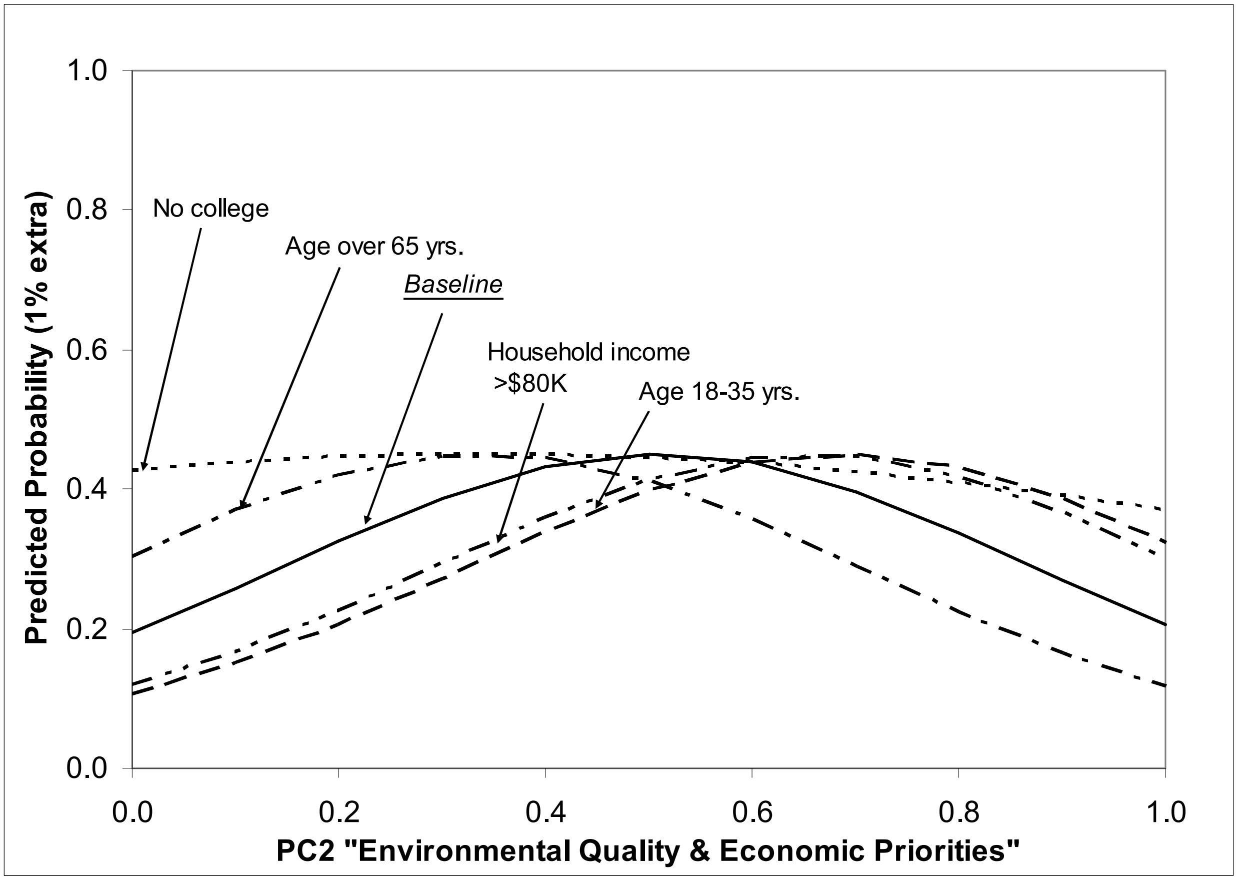

Figure 2: Predicted probability of the willingness to pay a 1% premium for "green" cell phones versus PC2.

Notes: PC2 reflects personal attitudes toward current environmental quality; a higher value for PC2 indicates a general belief that environmental quality has improved in recent years and a tendency to prioritize economic over environmental concerns; PC2 is normalized to be between 0 and 1.

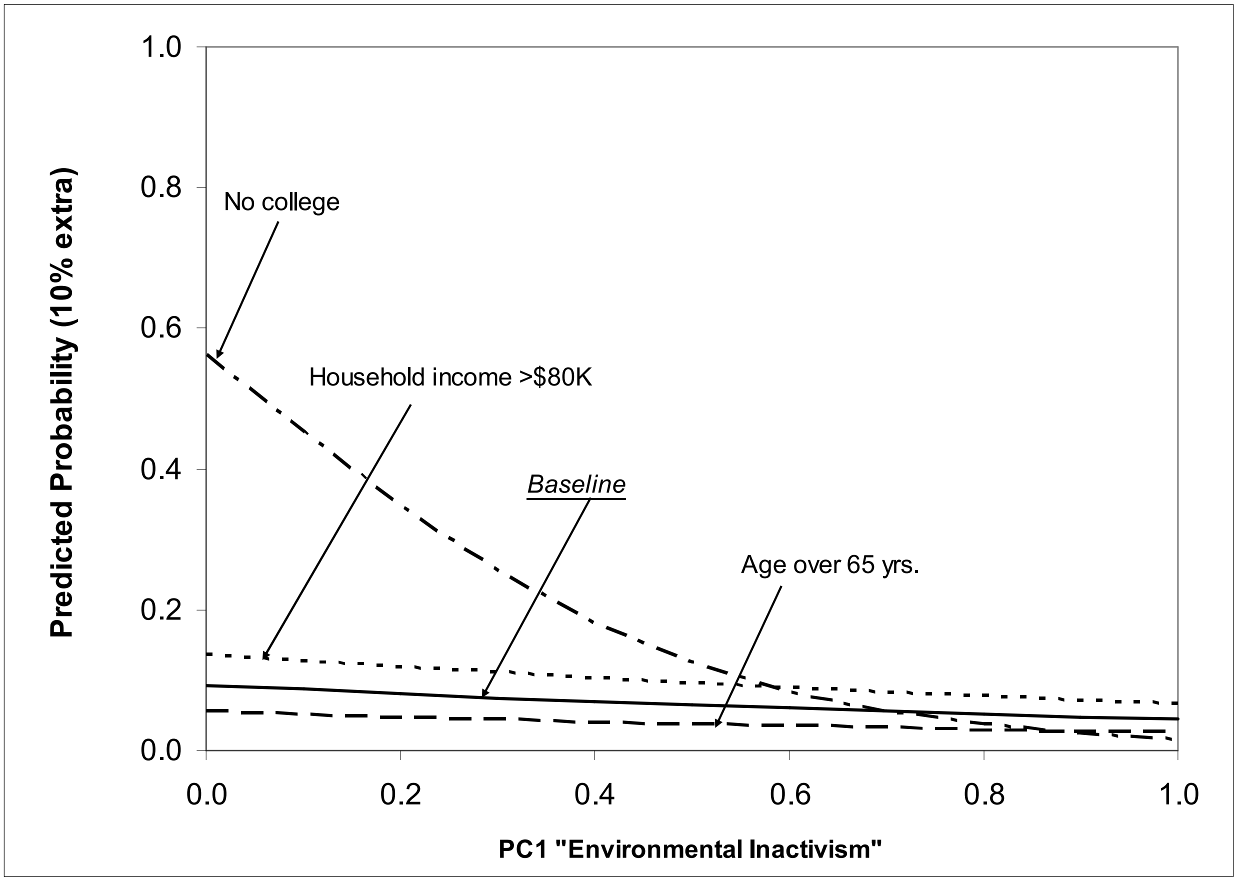

Figure 3: Predicted probability of the willingness to pay a 10% premium for "green" desktop computers versus PC1.

Notes. PC1 reflects personal involvement in environmental activities, with higher values indicating less support for the environmental; it is normalized to be between 0 and 1. Our baseline respondent is 36 to 65 years old, Caucasian, college educated, and with an annual household income under $80,000. In addition, he/she (gender is not relevant here) believes that government plays a major role in protecting the environment, scores 0.77 on PC1 ("Environmental inactivism") and 0.44 on PC2 ("Environmental quality & economic priorities").

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