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Consumer Perspectives on Battery Electric Vehicles: An Analysis of Battery Information and Knowledge

David Webb
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Abstract

Battery electric vehicles (BEVs) adoption in the United States and around the world is increasing rapidly, so understanding consumer preferences and perspectives surrounding BEV adoption is increasingly important. Additionally, most BEVs that have been purchased by consumers have been new vehicles, however the pre-owned market is beginning to develop and take shape. The consumer perspectives and considerations for purchasing a pre-owned BEV may vary significantly from a consumers decision making process when buying a new BEV. This report analyzes survey data on consumer's preferences for information on the longevity and health of a battery of a used BEV. The survey was conducted in 2023 and includes 1490 individuals of which 490 are current BEV owners. Battery information including expected lifetime and range are viewed as very useful in making vehicle purchasing decisions and BEV owners and potential vehicles purchasers have similar preferences for battery information.

Keywords

Battery Electric Vehicles; Battery Information; Decision Science; Statistical Analysis; Survey Instrument; Sustainability

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Acknowledgments

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1. Introduction

Electric vehicle (EV) is a general term that includes both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs are all-electric vehicles powered by plugging into a specialized outlet and using electricity to charge a battery pack, with no gasoline engine (e.g., Tesla 3 or Nissan Leaf). PHEVs use a combination of a gasoline engine and battery power that can be plugged in to charge the battery component, which tends to have limited range (e.g., Toyota Prius Prime or Jeep Wrangler 4xe). Both BEVs and PHEVs are distinctly different than hybrid vehicles, which uses gasoline and battery power (e.g., Toyota Prius) with the battery being re-charged by driving the vehicle and cannot be charged by plugging it in.

Figure 1 shows that cumulative U.S. BEV and PHEV sales have been increasing significantly from nearly zero in 2010 to over 4.7 million in 2023, most of which (3.4 million or 72.6 %) were BEVs [1]. As the U.S. stock of EVs has grown, pre-owned EV sales have also increased, with approximately 190 000 sold in the first half of 2023 (140 000 BEVs and 50 000 PHEVs) [2]. Additionally, pre-owned EV sales are projected to increase by approximately 40 % year-over-year from 2023 to 2024 [2].

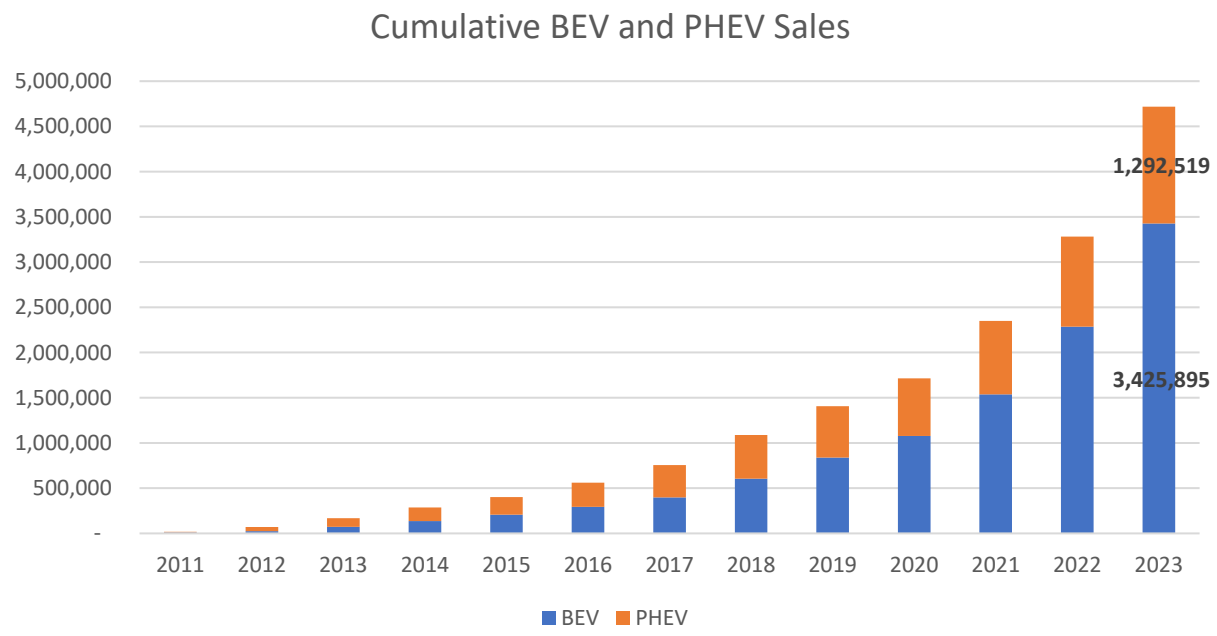

Figure 1. Cumulative BEV and PHEV Sales in the U.S. (2011-2023)

EVs have become a key part of carbon emission reduction strategies at the federal and state levels. On March 20, 2024, the Environmental Protection Agency (EPA) finalized the Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles that requires a dramatic increase in the number of new low emissions vehicles, including BEVs and PHEVs to reach the nearly 50 % reduction in projected fleet average emissions target levels relative to previous standards [3].

Considering the increasing public demand, domestic production, and regulatory push for more BEVs, it is increasingly important to understand the public's understanding of these vehicles, what guides their perceptions, and what information sources and tools they use to make their decisions on new or pre-owned vehicle purchases. Additionally, as the market for BEVs matures, an increasing number of vehicles will end up on the market as pre-owned vehicles and purchasers on the pre-owned market may have differing concerns on the nature of BEVs. In particular, perspectives on BEV battery performance over time is of interest to assess what type of information is desired and in what form that information should be provided to consumers to assist in making informed decisions.

This study seeks to understand the attitudes of potential vehicle purchasers in the U.S. regarding BEVs in general and specific interest in battery performance concerns and information preferences. Consumer perspectives have been collected through a survey instrument with questions on demographics, personal preferences, and vehicle ownership. The survey also collects information on BEV battery performance concerns and information needs for a BEV purchase decision.

This study analyzes the data collected through the survey and summarizes the findings, with a focus on the following research questions:

- What factors drive (e.g., concern about climate change) or hinder (e.g., range anxiety) adoption of BEVs?
- Are there differences in these factors for new versus pre-owned BEV adoption?
- Do these factors differ between current BEV owners and non-BEV owners?
- What concerns do consumers have related to BEV battery performance?
- What types of battery performance information do consumers find useful in their purchase decision?

2. Literature Review

A thorough literature review was performed as part of a companion document to this study. In lieu of a full recounting of the literature review paper, this section will instead present the key findings from that document. The literature focused on Adoption and Ownership and Resale and Battery End-Of-Life Decision as well as providing general background on the current state of BEV market and supporting infrastructure. The complete literature review is published in NIST Technical Note 2306 [4].

The literature survey found that North America is trailing Europe and China in terms of BEV and plug in hybrid vehicle (PHEV) sales by a wide margin with Europe having twice the total sales and China over five and a half times as of 2022 [5]. The US market is growing [1], though it still lags behind the global average [6]. The pre-owned market is still in nascent stages, only recently existing at a meaningful economic scale. Still, pre-owned vehicles are beginning to make up a sizeable portion of the BEV market, accounting for roughly one third of sales in the first quarter of 2022, while pre-owned stock is also increasing [2]. Tax credits, recently updated by the Inflation Reduction Act of 2022, have been implemented to assist buyers by offsetting the higher costs of BEVs and PHEVs provided they meet certain criteria. As of the writing of this paper there are 15 BEV and 6 PHEV models that qualify for the tax credits with 13 receiving the full credit [7].

BEV charging infrastructure is a key component in terms of BEV adoption. Large areas of the central US have fewer than 3 chargers per county with 36.2 % having none, and 80.2 % have 25 or less. Most chargers are concentrated on the US coasts, with urban areas showing the highest density of charging stations [8]. Many of these stations have two or fewer charging outlets, limiting volume [9].

Demographic factors have been shown to impact EV purchases. Survey work has found that men are more likely to purchase EVs, while the likelihood of purchase decreases as age increases. Carley et al. also found no linear relationship between number of cars owned and adoption likelihood, however Peters and Dütschke found that a relationship does exist if the number of cars owned is treated as a binary (Multicar versus Single Car) [10, 11].

Carley et al. also found that concern for the environment increased adoption intent. This finding was also present in work by Gore, finding that people were willing to pay more for a BEV that reduces emissions more than a BEV that reduces emissions less [10, 12]. A weaker correlation was found in work by Krupa et al., however this survey was conducted much earlier in the timeline of BEV adoption and attitudes on BEVs has likely evolved since then [13].

Krupa et al. found that the highest level of concern revolved around battery failure, be it replacement cost, engine servicing or overall battery lifetime, while Carley et al. noted charging time as decreasing adoption intent [10, 13]. Numerous sources have found that access to charging infrastructure is a key factor and, relatedly, much of the literature focuses on the range of the battery including Franke et al. and Yuan et al. [14, 15]. Willingness to pay studies are quite common. Pedrosa and Nobre find that consumer willingness to buy a pre-owned BEV increases if the pre-owned BEV comes with a new battery [16].

3. Survey Design

This survey received approvals from the National Institute of Standards and Technology Institutional Review Board as well as approval from the Office of Management and Budget under the Paperwork Reduction Act prior to responses being collected[1]. The survey instrument was developed to answer the following questions:

- What information do consumers want to know about the battery health of a used electric vehicle?
- What sources of information are the most valuable to consumers?
- What are consumers' general perceptions surrounding battery related characteristics including range anxiety and resale anxiety?

Additionally, we collected data on current BEV owners' experiences including battery degradation to evaluate post-purchase issues and perspectives, and how they impact responses to the above questions. The survey also includes demographic and behavioral variables to use as control variables.

The survey consisted of the following sections: screening demographics, vehicle ownership questions, BEV owner specific questions, future vehicle ownership plans, BEV knowledge questions, attention checks, future expectations, information used for decision making, perceptions of BEV risks, additional demographics, and one open ended response. The only demographic used for screening was age, and participants who were under the age of 18 were screened out of our sample.

The survey flow logic is provided in Figure 2The survey begins with a few demographic questions used as filtering questions. The survey includes several additional questions for BEV owners including the range of their BEV as well as driving and charging patterns. The survey then asks about plans to purchase a new or preowned vehicle and the likelihood of that vehicle being a BEV. We include measures of risk aversion and environmental preferences as well. The survey also includes a few matrices of questions to understand how useful different information on battery performance would be in the buying process and range anxiety.

[1] Institutional Review Board reference: #EL-2022-0397
Office of Management and Budget control number: 0693-0089

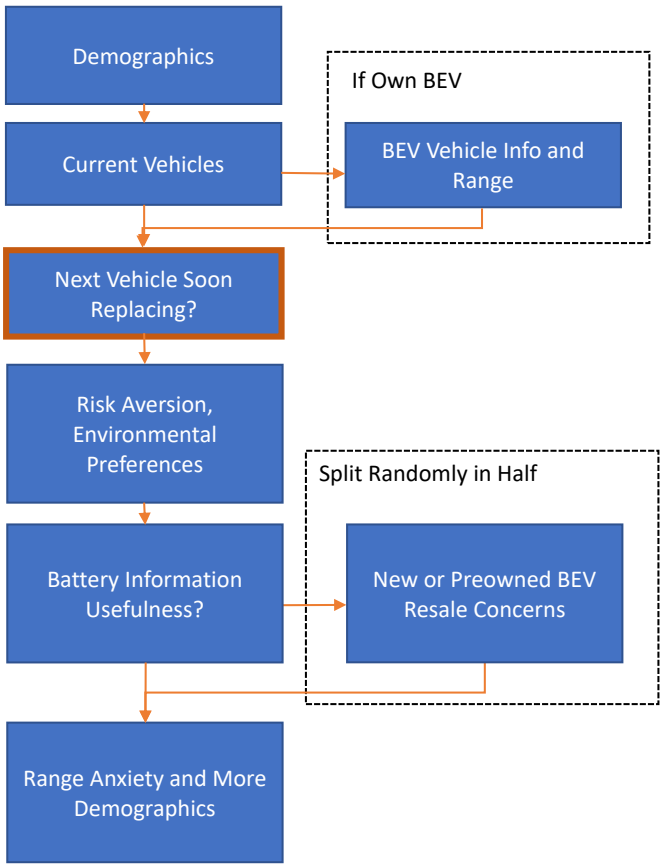

Figure 2. Survey Flow Logic Diagram. Adapted from [9,10]

Although there are more questions, for the purposes of this study only the questions in Table 3-1 were included in the analysis[2].

Table 3-1. Relevant survey questions for preliminary analysis

Question Label	Question	Response Type
q2	How old are you?	16 options starting from "Under 18" to "Over 85". Age groups are not uniform in range.
q3	What is your sex?	Optional, "Male" or "Female"
q4	How many passenger vehicles (not including motorcycles) are in use by your household? Your household includes all the persons who occupy the housing unit as their usual place of residence.	7 options starting from "0" going to "6 or more"
q39	Think about your household's **next** vehicle choice. How likely are you to select a BEV (Battery Electric Vehicle)?	7-point scale ranging from "Extremely Unlikely" to "Extremely Likely"

[2] Some variables of interest were dropped from the regressions and do not appear in this list due to multicollinearity

q42	Do you have access to an electrical outlet where your vehicle is parked at your primary residence	"Yes", "No" or "Unsure"
q43	Consider how frequently your household uses a vehicle for long trips. In the last year, including work-related trips, weekends, holidays and vacations, approximately how many times did you use your own vehicle for a trip that took **more than 2.5 hours one direction?**	6-point scale ranging from "Never" to "12 or more". Intermediate values all cover a range of 3 i.e., "1-3 times"
q60	What type of information would be useful in your decision-making process to buy a pre-owned BEV? q60_1 – Expected remaining lifetime of the battery q60_2 – Expected remaining driving range of the battery for a specific number of years q60_3 – Current remaining driving range of the battery	7-point scale ranging from "Extremely Unuseful" to "Extremely Useful"
q61	What source of information would be useful in your decision-making process to buy a pre-owned BEV? q61_1 – The battery is guaranteed to last for a specific number of years q61_2 – The battery is federally rated to last for a specific number of years q61_3 – The battery is under manufacturer warranty for a specific number of years q61_4 – The battery is industry rated to last for a specific number of years	7-point scale ranging from "Extremely Unuseful" to "Extremely Useful"
q62	Please indicate the extent to which you agree or disagree with the following statements. q62_1 – If I owned a BEV, I would often worry about running out of charge q62_2 – If I owned a BEV, I would worry about finding places to charge it if I wanted to drive somewhere new q62_3 – Range is a major disadvantage of owning a BEV q62_4 – Please select "Strongly Disagree" as your response to this item[a]	7-point scale ranging from "Strongly Disagree" to "Strongly Agree"
q63	Please indicate the extent to which you agree or disagree with the following statements. q63_1 – If I bought a **new** BEV, I would worry that I would not get a good price when I wanted to sell it q63_2 – BEVs are less valuable than gasoline cars on the resale market, because the technology is always advancing q63_3 – If I bought a **new** BEV, I would worry about fast depreciation because of battery technology (relative to gasoline vehicles)	7-point scale ranging from "Strongly Disagree" to "Strongly Agree"
q64	Please indicate the extent to which you agree or disagree with the following statements. q64_1 – If I bought a **pre-owned** BEV, I would worry that I would not get a good price when I wanted to sell it q64_2 – BEVs are less valuable than gasoline cars on the resale market, because the technology is always advancing q64_3 – If I bought a **pre-owned** BEV, I would worry about fast depreciation because of battery technology (relative to gasoline vehicles)	7-point scale ranging from "Strongly Disagree" to "Strongly Agree"

q65	How do you see yourself: Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please answer in general – these can be risks in any realm of life.	10-pont scale with lower values corresponding to less risk taking
q68	Do you own or rent this residence?	"Own", "Rent" or "Other", with an input text box for "Other" to describe situation.
q69	Do you have solar panels installed on your residence?	"Yes" or "No"
q70	Do you own or lease your solar panels?	"Lease", "Own" or "Other". "Other" has a text box to input other states of ownership.
q71	What is your annual household income?	26-point scale ranging from "Less than $10,000" to "$250,000 or more". A 27th option is available for "Prefer not to answer
q72	Including yourself, how many people live in your household?	6-point scale ranging from "1" to "6 or more"
q73	Including yourself, how many people in your household drive a vehicle.	6 categories ranging from "1" to "6 or more"
q75	What is your race? Please check all that apply.	May check all that apply: "White", "Black or African American", "Native American or Alaska Native", "Asian (including Asian Indian)", "Native Hawaiian or Pacific Islander"
q76	Are you Hispanic, Latino, or Spanish in origin?	Selection of one of the following: "No, not of Hispanic, Latino, or Spanish origin", "Yes, Mexican, Mexican American, Chicano", "Yes, Puerto Rican", "Yes, Cuban", "Yes, another Hispanic, Latino, or Spanish origin"
q77	Please indicate your highest level of education (include degree you are currently working on if applicable)	Selection of one of the following: "Some high school", "High school", "GED", "Some college", "Associate's Degree (2-year degree)", "4-year college degree", "Masters degree", "Doctoral degree/advanced degree", "Other". "Other" has a text box to input other education levels
q78	How much do you, personally, worry about the issue of global climate change?	5-point scale ranging from "None at all" to "A great deal"
group	Not a question answered by the respondent, assigned by whether the respondent owns a BEV.	"BEV" if respondent owns a BEV, general population (coded as "genpop") if not

[a] This question was used to ensure survey takers were paying attention to question wording

The survey was executed from March 22nd to June 13th in 2023 by a third-party company, Qualtrics. Qualtrics is a company that specializes in survey design and implementation, although their participation was limited to the implementation of the survey in this instance. They were responsible for locating the appropriate sample and ensuring the desired number of responses were obtained with NIST thoroughly reviewing responses for quality.

In total, 1490 completed and validated responses were received. Of those responses, 752 were presented the matrix of questions related to resale of new vehicles[3] while 738 were presented the matrix of questions related to the resale of preowned vehicles. 490 respondents were BEV owners while the remainder (1000 responses) were non-BEV owners labeled as general population (**genpop**). For the purposes of this report, non-BEV owners and general population will be used to refer to the survey respondents who do not own a BEV. To be considered a complete and valid response, the respondent had to pass the two attention check questions contained in the survey and complete all the survey questions. Additionally, BEV owners had to select a match for the make and model of the BEV from the possible make and model answers.

An error in coding the survey resulted in the survey not allowing ZIP codes to be input with leading zeros. This resulted in no responses from the New England region to show up in the results. Latitude and Longitude coordinates were provided, however these appeared to be based on IP address and, when geolocated, resulted in only around 30 % matching with the reported ZIP code. Excluding New England, the geographic coverage achieved at least one result in every state though not all states had a response from a BEV owner. Figure 3 presents a map of the geographic coverage by ZIP code. Responses with ZIP codes outside the United States were kept (18 total) for the analysis in this document as no spatial component was done and the results were assumed to still represent genuine attitudes.

[3] "New" here refers to the state of vehicle at the time of the respondent's purchase.

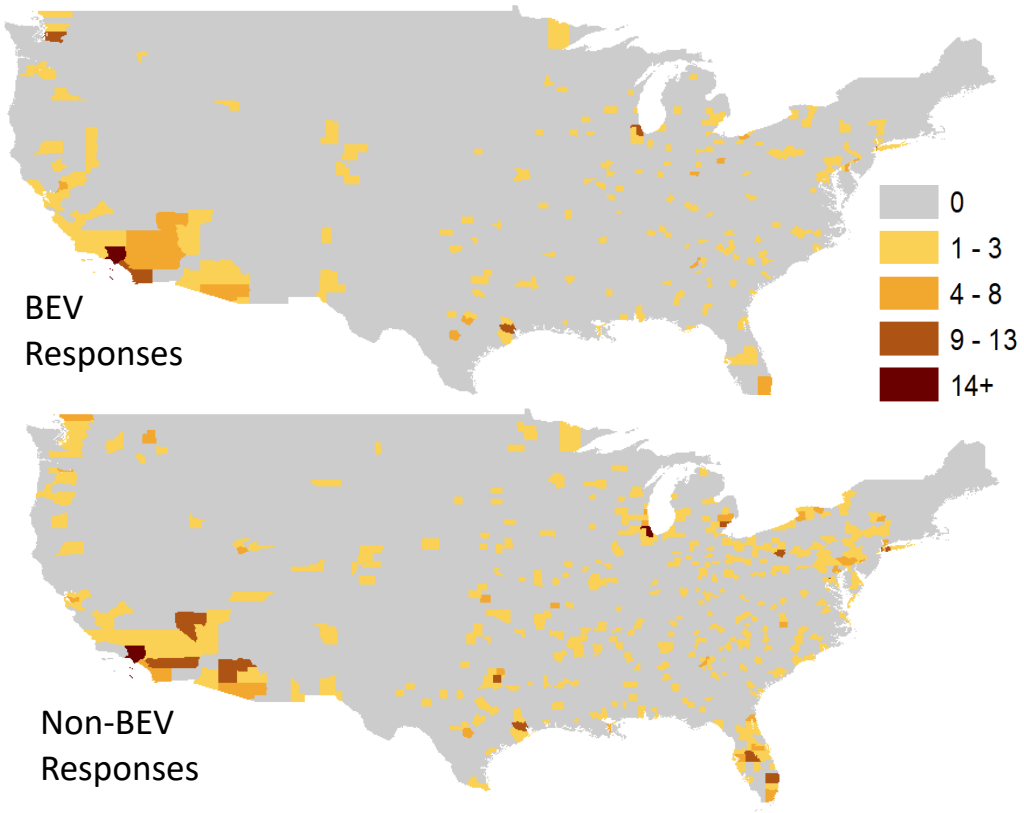

Figure 3. Survey Responses by County

4. Analysis of Survey Data

The raw data from the survey was examined, cross-tabulations were developed and analyzed, and preliminary tests were run before any regression analysis was performed. The purpose of the initial review was to highlight any interesting results in the cross-tabulations and ensure that key variables were not collinear with other dependent variables. Also, for the questions that were comprised of multiple sub-questions, the results were averaged to create an aggregated variable. Cross-tabulations were performed on the data from all questions of the survey, but only those that provided important insights are provided in this section. Variables that contained text input from the users were also reviewed, although no analysis has been done using them to date.

4.1. Demographic and Personal Preferences Questions

Of the demographic characteristics, several stood out as key factors in BEV adoption decisions: age, educational attainment, and income. BEV owners are skewed younger (Figure 4) with higher incomes (Figure 5) and more have higher levels of education (Figure 6), all of which are consistent with previous studies of BEV owners [4]. BEV owners are predominantly between 25 to 50 years of age. For non-BEV owner respondents, 54 % are below $90 000 in annual household income while for BEV owner respondent, only 26 % are below $90 000. Similarly, 18 % of non-BEV owner respondents have a high school diploma, GED, or some high school education while 7 % of BEV owner respondents have that same education level. One interesting result in educational level is that a significant portion of BEV owners have an Associate's degree (23 %) while only 11 % of non-BEV owners have that level of education. Typically, BEV ownership has been increasing with increasing educational attainment, however in our sample the largest difference in educational attainment is in the percentage of the population with an associate's degree.

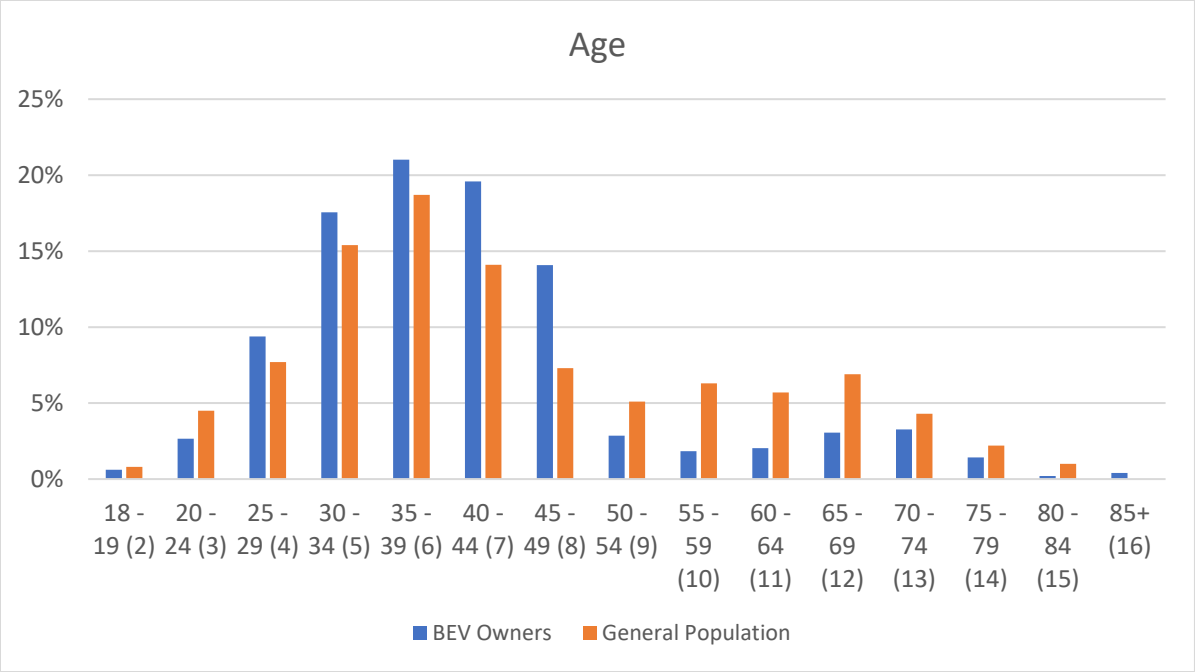

Figure 4. Age of Respondents - BEV owner versus non-BEV owner

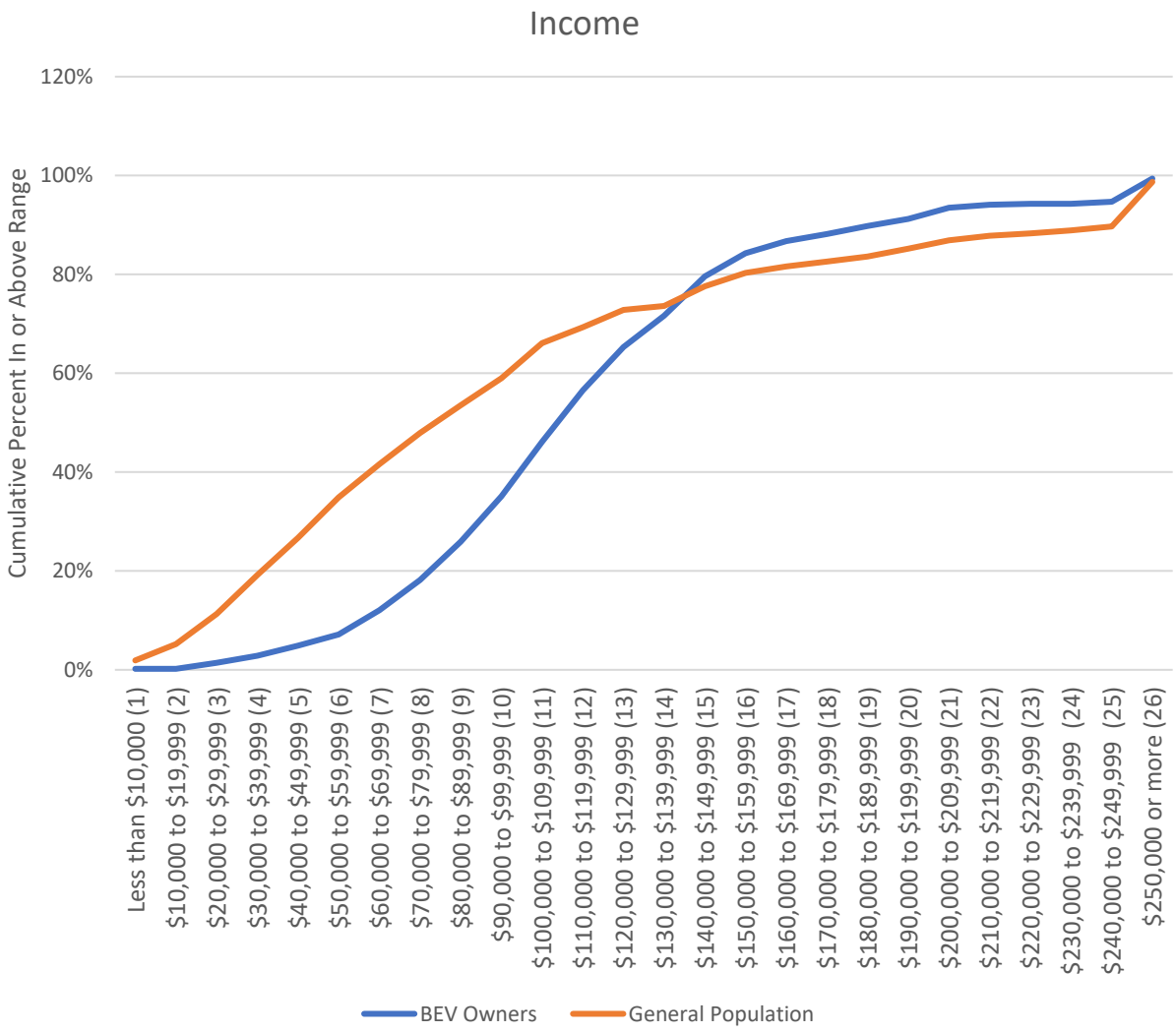

Figure 5. Income distribution – BEV owner versus non-BEV owner

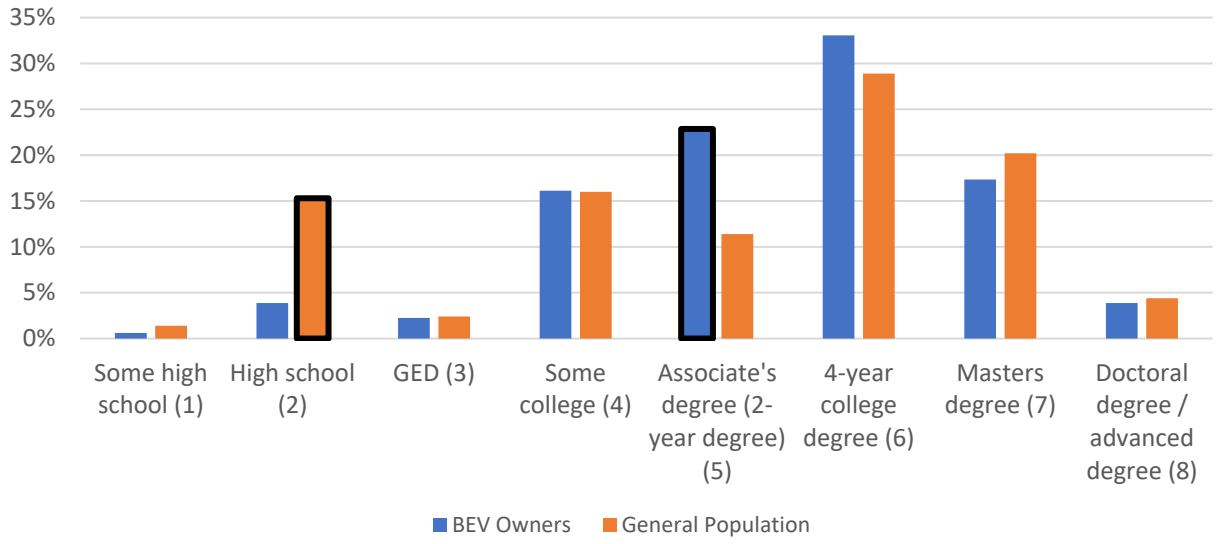

Figure 6. Educational Attainment – BEV owner versus non-BEV owner. Outlined results indicate education levels that have large gaps between BEV and non-BEV owners.

Some additional questions relate to personal preferences provided interesting results. First, BEV owners view themselves as more willing to take risks, with 60 % identifying themselves as greater than neutral (Table 4-1). This compares to only 45 % of non-BEV owners viewing themselves as greater than neutral. Second, there is a correlation between BEV owners and having solar panels installed on their home, the ability to charge at home, and greater concerns about climate change. BEV owners are nearly twice as likely to have solar installed on their home (46 % versus 25 %) (Table 4-2); however, it is unclear if they had solar panels installed before their BEV purchase or after the purchase. Nearly all BEV owners (92 %) have an electrical outlet available their primary residence while only 58 % of non-BEV owners have one available (Table 4-3). Although it is unclear whether the outlet already existed at the time of or installed after BEV purchase. BEV owners worry about climate change “a lot” or “a great deal” at 53 % while non-BEV owners are at 42 % (Figure 7). Third, BEV owners are much more likely to purchase a BEV as their next vehicle (54 % are “extremely likely” and 93 % at least “slightly likely”) than a non-BEV owner (22 % are “extremely likely” and 64 % at least “slightly likely”) (Figure 8).

Table 4-1. Risk Preferences

Risk Taker (1 low, 11 high)	BEV Owners	General Population
<6	29%	44%
6 (neutral)	11%	11%
>6	60%	45%

Table 4-2. Solar Installed on Residence

Solar	BEV Owners	General Population
No (1)	54%	75%
Yes (2)	46%	25%

Table 4-3. Electrical Outlet Available Outside their primary residence

Electric Outlet	BEV Owners	General Population
Yes (1)	92%	58%
No (2)	7%	38%
Unsure (3)	1%	4%

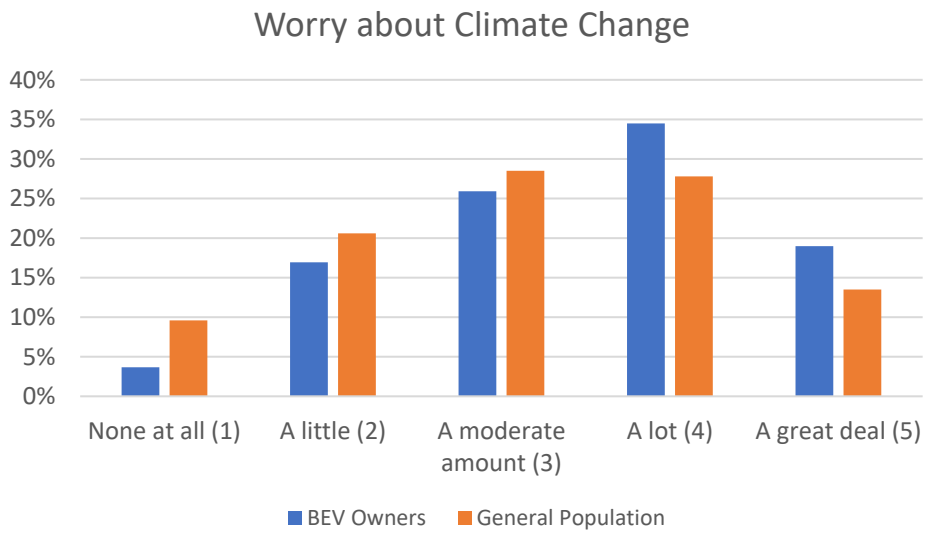

Figure 7. Worries about Climate change – BEV owner versus non-BEV owner

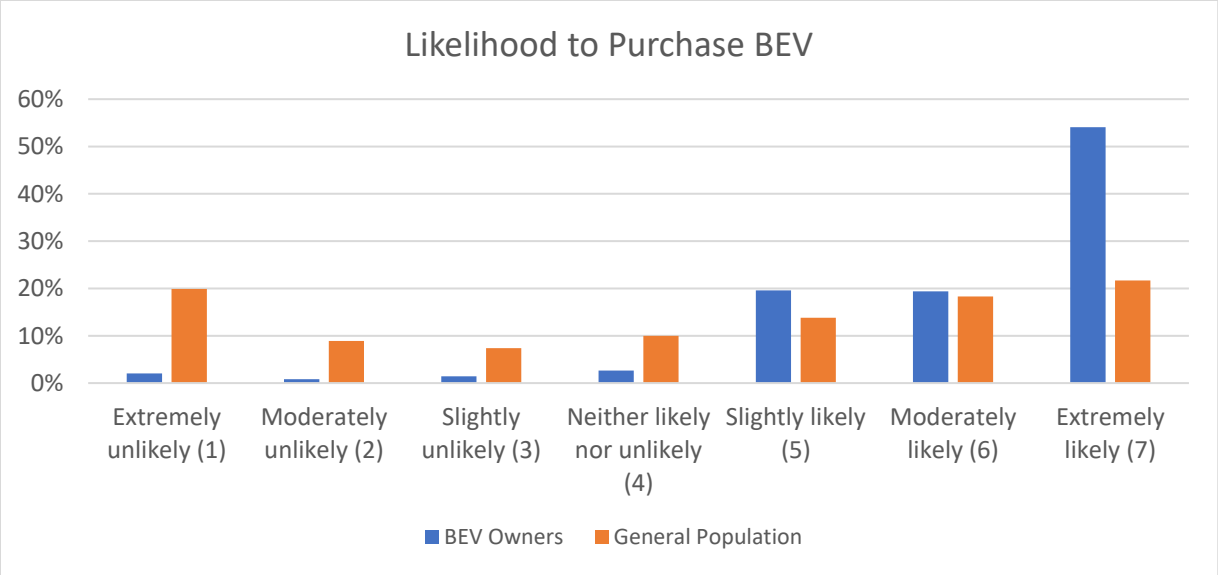

Figure 8. Likelihood of Purchasing BEV for Next Vehicle – BEV owner versus non-BEV owner

4.2. Battery Information and Source Matrix Variable Questions

Several Likert-scale-matrix questions were included in the survey to assess consumer preferences and concerns related to battery performance and information sources. Many of these are treated as continuous in regressions, despite the ordinal nature of Likert scale variables. It's common to do so in a survey context provided the scale has enough levels to mitigate the bias introduced by treating an ordinal scale as continuous [17].

4.2.1. Battery Rating / Guarantee Information and Source by Demographics

First looking at the distribution of ages, Table 4-4 presents the means and standard deviations for the coded age variable for each of the battery information questions broken down into each response category. To compare statistical significance, the regression in Eq. (1) was performed with the "one" value from the specific question being examined as the base. The interpretation of Eq. (1) will see α_{0_i} be the mean of the of the "one" group while the coefficients, $\boldsymbol{\alpha_{1_i}}$, for the categorical variable will be the difference between the mean of the "one" group and the mean for the labeled group being compared.

$$qY_i = \alpha_{0_i} + \boldsymbol{\alpha_{1_i}} * \boldsymbol{c.qX_i} \quad (1)$$

Where qY_i is the variable whose summary statistics are sought for each response group, for instance **Age** (q2). $\boldsymbol{c.qX_i}$ is the specific question of interest from the remaining **Battery Information Usefulness (Type)** (q60) and **Battery Information Usefulness (Source)** (q61) matrix questions that the responses in qY_i are being tabulated over, the "c." preceding the variable indicates that variable is either categorical (or an indicator variable if the category is binary).

This regression is equivalent to performing a difference in means test against the **Extremely Unuseful** group of the $\boldsymbol{c.qX_i}$ variable. This will be more evident in looking at the results in Table 4-4, Table 4-5, and Table 4-6.

For Table 4-4, the **Extremely Unuseful** value (α_{0_i} coefficient of the regression) represents the mean age group for those selecting that response, while the values in the **Moderately Unuseful**, **Slightly Unuseful**, **Neither Useful nor Unuseful**, **Slightly Useful**, **Moderately Useful**, and **Extremely Useful**, columns are the difference between the column entry and the **Extremely Unuseful** column value. If the value in the **Extremely Unuseful** column were added to the differences, the result would be the mean value for each age group. The values in parenthesis are robust standard errors. A one-unit change can be interpreted as moving up one age bin, which generally is a five-year grouping of ages. For example, for the expected remaining lifetime of the battery, a value of 9.044 means the average age group is 50 to 54 years old and a value of five corresponds to an average age of 30 to 34 years old. The results show that those who find battery information to be less useful or a particular source less useful skew older than the rest of the responses with a few exceptions for the **Moderately Unuseful** group for the **Federally rated (**q61_2) and **Industry rated (**q61_4) questions.

Table 4-4. Mean and standard error of coded age variable by response to battery information matrix questions[a,b]

Question	Extremely Unuseful	Moderately Unuseful	Slightly Unuseful	Neither Useful nor Unuseful	Slightly Useful	Moderately Useful	Extremely Useful
q60_1 Expected remaining lifetime of the battery	9.044 (0.314)	**-1.556*** (0.480)**	**-3.138*** (0.500)**	**-2.224*** (0.450)**	**-2.354*** (0.358)**	**-2.415*** (0.333)**	**-1.369*** (0.337)**
q60_2 Expected remaining driving range of the battery for a specific number of years	9.054 (0.292)	**-1.542*** (0.535)**	**-2.617*** (0.446)**	**-2.446*** (0.439)**	**-2.523*** (0.333)**	**-2.355*** (0.317)**	**-1.366*** (0.316)**
q60_3 Current remaining driving range of the battery	8.895 (0.314)	**-1.024* (0.562)**	**-2.713*** (0.486)**	**-2.378*** (0.407)**	**-2.351*** (0.371)**	**-1.882*** (0.340)**	**-1.415*** (0.334)**
q61_1 The battery is guaranteed to last for a specific number of years	9.086 (0.291)	**-2.172*** (0.523)**	**-3.143*** (0.435)**	**-2.101*** (0.457)**	**-2.827*** (0.323)**	**-2.301*** (0.314)**	**-1.387*** (0.315)**
q61_2 The battery is federally rated to last for a specific number of years	8.613 (0.318)	-0.420 (0.519)	**-2.063*** (0.519)**	**-1.578*** (0.440)**	**-2.218*** (0.351)**	**-1.482*** (0.346)**	**-1.080*** (0.341)**
q61_3 The battery is under manufacturer warranty for a specific number of years	9.021 (0.295)	**-1.771*** (0.448)**	**-2.952*** (0.619)**	**-2.140*** (0.452)**	**-2.879*** (0.331)**	**-2.266*** (0.318)**	**-1.314*** (0.318)**
q61_4 The battery is industry rated to last for a specific number of years	8.649 (0.318)	-0.184 (0.531)	**-2.172*** (0.540)**	**-1.156*** (0.425)**	**-2.066*** (0.380)**	**-1.493*** (0.341)**	**-1.246*** (0.342)**

[a] All coefficients are compared against the responses to the question in the **Extremely Unuseful** column in the same row

[b] The value in the **Extremely Unuseful** column is the mean age group, the values in the remainder of the columns are the differences between the mean of the group represented by the column and the mean found in the **Extremely Unuseful** column

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

Table 4-5 is generated by following the same analysis for the **Income** variable (q71) as qY_i. Based on the results it looks as though incomes in the **Moderately Unuseful** to **Neither Useful nor Unuseful** range are indistinguishable from the **Extremely Unuseful** responses except for the **Moderately Unuseful** group, which skews higher than the **Extremely Unuseful** group for **Expected remaining lifetime of battery** (q60_1), and all **Pre-owned information source** (q61) sub-questions except for the **Guarantee** (q61_1) question. Responses in the **Slightly Useful** or higher range are in the higher income brackets than those in the **Extremely Unuseful** response group. In Table 4-5, a one-unit increase in the mean of the income group corresponds to a $10 000 increase in mean annual household income of a respondent. A value of an eight indicates

that the average household income is between $70 000 and $79 999, while a value of twelve means the average household income is between $120 000 and $129 999.

Table 4-5. Mean and standard error of coded income variable by response to the battery information matrix questions[a, b]

Question	Extremely Unuseful	Moderately Unuseful	Slightly Unuseful	Neither Useful nor Unuseful	Slightly Useful	Moderately Useful	Extremely Useful
q60_1 Expected remaining lifetime of the battery	8.233 (0.622)	**3.069*** 1.170)**	0.298 (1.011)	1.158 (1.022)	**3.015*** (0.784)**	**4.181*** (0.695)**	**3.395*** (0.678)**
q60_2 Expected remaining driving range of the battery for a specific number of years	8.924 (0.648)	1.025 (1.195)	1.326 (1.148)	-0.356 (0.973)	**2.692*** (0.778)**	**4.010*** (0.739)**	**2.386*** (0.697)**
q60_3 Current remaining driving range of the battery	9.081 (0.669)	1.380 (1.292)	0.070 (1.189)	1.057 (0.912)	**1.898** (0.834)**	**3.147*** (0.759)**	**2.635*** (0.716)**
q61_1 The battery is guaranteed to last for a specific number of years	8.957 (0.626)	1.014 (1.241)	-0.186 (1.076)	0.864 (0.933)	**2.647*** (0.818)**	**3.850*** (0.710)**	**2.337*** (0.677)**
q61_2 The battery is federally rated to last for a specific number of years	8.500 (0.664)	**2.038* (1.078)**	1.600 (1.053)	0.648 (0.912)	**3.284*** (0.792)**	**3.617*** (0.743)**	**3.228*** (0.721)**
q61_3 The battery is under manufacturer warranty for a specific number of years	8.825 (0.587)	**2.786** (1.158)**	0.210 (1.323)	1.280 (0.966)	**2.431*** (0.764)**	**4.066*** (0.686)**	**2.426*** (0.639)**
q61_4 The battery is industry rated to last for a specific number of years	8.260 (0.647)	**3.112** (1.258)**	1.240 (1.102)	2.574 (0.905)	**2.629*** (0.819)**	**4.026*** (0.713)**	**3.327*** (0.707)**

[a] All coefficients are compared against the responses to the question in the **Extremely Unuseful column** in the same row

[b] The value in the **Extremely Unuseful** column is the mean income group, the values in the remainder of the columns are the differences between the mean of the group represented by the column and the mean found in the **Extremely Unuseful** column

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

Lastly, the procedure was done for the **Education** variable (q77) as qY_i, with the results shown in Table 4-6. As **Education** is an ordinal value, the mean carries no interpretable meaning in terms of the average level of education. However, the mean does serve as a useful statistical measure of the central tendency of the response distribution, which is the way the variable is used here.

Note that, although **Education** is being treated as continuous in the regression, the regression coefficients will be based solely on the means of the **Education** variable within the specified group, $i.qX_i$, because the values for each qX_i group will be identical (i.e., if regressing on $i.qX_i$, the constant term will have all independent values in the regression be a "one" response).

Aside from the **Federally rated** (q61_2), **Warranty** (q61_3), and **Industry rated** (q61_4) questions, those responding higher ("six" and "seven" groups) have higher educational attainment than those in the "one" group with those in the "two", "three", and "four" groups being indistinguishable from the "one" group. The mentioned exceptions all show a higher level of education than the "one" group, albeit in the "two" and "four" groups. The "five" group generally shows greater educational attainment on average, except for **Current range** (q60_3).

In Table 4-6 a one unit increase in the number indicates moving up one education level. For example, the fourth category is **Some college,** and the fifth category is **4-year college degree**.

Table 4-6. Mean and standard error of coded education variable by response to the battery information matrix questions[a, b]

Question	Extremely Unuseful	Moderately Unuseful	Slightly Unuseful	Neither Useful nor Unuseful	Slightly Useful	Moderately Useful	Extremely Useful
q60_1 Expected remaining lifetime of the battery	4.644 (0.182)	0.495 (0.325)	0.262 (0.404)	0.042 (0.285)	**0.586*** (0.221)**	**0.632*** (0.197)**	**0.678*** (0.194)**
q60_2 Expected remaining driving range of the battery for a specific number of years	4.717 (0.186)	0.257 (0.325)	0.595 (0.352)	-0.339 (0.300)	**0.562*** (0.214)**	**0.737*** (0.206)**	**0.509** (0.197)**
q60_3 Current remaining driving range of the battery	4.686 (0.183)	0.109 (0.355)	0.465 (0.355)	0.291 (0.266)	0.273 (0.235)	**0.739*** (0.201)**	**0.590*** (0.193)**
q61_1 The battery is guaranteed to last for a specific number of years	4.688 (0.179)	0.026 (0.334)	0.283 (0.341)	0.327 (0.276)	**0.392* (0.222)**	**0.791*** (0.195)**	**0.535*** (0.191)**
q61_2 The battery is federally rated to last for a specific number of years	4.462 (0.203)	**0.653** (0.295)**	0.488 (0.320)	0.435 (0.272)	**0.772*** (0.233)**	**0.968*** (0.219)**	**0.763*** (0.214)**
q61_3 The battery is under manufacturer warranty for a specific number of years	4.639 (0.179)	**0.805*** (0.308)**	0.257 (0.417)	0.018 (0.282)	**0.645*** (0.217)**	**0.774*** (0.197)**	**0.583*** (0.190)**
q61_4 The battery is industry rated to last for a specific number of years	4.506 (0.201)	0.354 (0.336)	0.084 (0.333)	**0.694** (0.270)**	**0.632*** (0.242)**	**0.980*** (0.214)**	**0.682*** (0.212)**

[a] All coefficients are compared against the responses to the question in the **Extremely Unuseful** column in the same row

[b] The value in the **Extremely Unuseful** column is the mean education group, the values in the remainder of the columns are the differences between the mean of the group represented by the column and the mean found in the **Extremely Unuseful** column

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

4.2.2. Between Question Comparisons

The battery performance related questions were analyzed using cross-tabulations as well as statistical testing to assess the ability to generate variables from the matrix questions for inclusion in the regression analysis.

The cross-tabulations provided interesting results, both in terms of commonalities and differences between BEV owners and non-BEV owners as well as perspectives on factors driving

new versus pre-owned decisions. On average, all groups of respondents found usefulness in battery info (life, range, etc.) with similar preferences across BEV owners and general population (typically 65 % to 80 % **Moderately Useful** or **Extremely Useful**). The exception was approximately 8 % of non-BEV owners that considered any battery information **Extremely Unuseful**. There were small or moderate differences in level of usefulness related to battery life and range. Potential purchasers found more use in expected life of the battery than range of the battery and had a moderate preference for stronger certainty of life and range. Current EV owners found more use in expected remaining driving range versus life and valued manufacturer warranty over a generic "guarantee."

EV owners appear to have less range anxiety, but a significant portion at least "somewhat agree," showing that range anxiety remains a significant barrier to adoption. Similarly, range as a "major disadvantage" of owning a BEV is high for both EV owners (63 %) and potential vehicle purchasers (72 %) as well as "finding a place to charge" other than home (66 % and 72 %), and "often worry about running out of charge" (59 % and 75 %).

Resale concerns are similar when the respondent is asked about "new" vs "pre-owned" BEVs, with the depreciation of the battery of pre-owned BEV being slightly more concerning as shown in the results below for both BEV owners and potential vehicle purchasers (i.e., **genpop**), respectively:

Concern for New BEV (at least "somewhat agree")

- General resale (60 % and 64 %)
- Because of EV technology change (59 % and 59 %)
- Because depreciation of battery (56 % and 67 %)

Concern for Pre-Owned BEV (at least "somewhat agree")

- General resale (62 % and 65 %)
- Because of EV technology change (57 % and 57 %)
- Because depreciation of battery (60 % and 74 %)

Statistical testing was completed for the battery information usefulness matrix questions. Due to their similarities, the responses are expected to capture similar information about the respondent. Therefore, there is expected to be collinearity if all are included within a regression model.

The matrix questions (q60 and q61) are of particular interest. q60 contains three questions related to the desired information for making a decision to buy a pre-owned BEV, specifically:

- Q60_1 – remaining life of the battery
- Q60_2 – expected remaining driving range for the battery for a specific number of years
- Q60_3 – current remaining driving range

q61 covers questions of preferred information sources on battery life, including:

- Q61_1 – battery is guaranteed to last a specific number of years
- Q61_2 – battery is federally rated to last a specific number of years
- Q61_3 – battery is under manufacturer warranty to last a specific number of years

- Q61_4 – battery is industry rated to last a specific number of years

Respondents were asked to rate their responses on a 7-point scale from *Extremely Unuseful* (1) to *Extremely Useful* (7) with *Neither Useful nor Unuseful* being the midpoint (4). These questions were designed to elicit the same information in multiple rewordings to obtain better overall responses.

For the **Pre-owned information usefulness** matrix (q60), the mean values are nearly identical for "Current remaining driving range of the vehicle" (Mean: 5.81), "Expected remaining lifetime of the battery" (Mean: 5.77), and "Expected remaining driving range of the battery for a specific number of years" (Mean: 5.74). The only statistically significant difference is that people find "Current remaining driving range of the vehicle" to be more useful than "Expected remaining driving range of the battery for a specific number of years." All three types of information are seen as between Slightly Useful (5) and Moderately Useful (6) by the average survey participant.

Similar results are found for the **Pre-owned information source** matrix (q61): "The battery is under manufacturer warranty for a specific number of years" (Mean: 5.78), "The battery is guaranteed to last for a specific number of years" (Mean: 5.77), "The battery is industry rated to last for a specific number of years" (Mean: 5.69), and "The battery is federally rated to last for a specific number of years" (Mean: 5.64). Although small mean differences, manufacturer warranty and a battery guarantee are statistically significantly more preferred to an industry or federal rating. All four sources of information are seen as between Slightly Useful (5) and Moderately Useful (6) by the average survey participant.

Testing was done on both matrix questions to ensure that the responses achieved proper statistical properties for analysis and to determine the feasibility of using the average of the responses as an independent variable. Specifically, paired two-sample t-tests[4] and Chi-squared tests for independence were performed on each pairwise combination of questions within the same matrix. Table 4-7 presents these results.

[4] The histograms show deviations from normality. The sample sizes however are large enough that the Central Limit Theorem should make the distribution of the means sufficiently Normal in distribution.

Table 4-7. Pairwise comparison of variables within the q60 and q61 matrix question (n for BEV = 490, n for genpop = 1000)

Grouping	Variable 1	Variable 2	Mean (Var 1)	Std. Dev (Var 1)	Mean (Var 2)	Std. Dev (Var 2)	T-Test p-value	Chi Sq p-value
Full Sample	q60_1	q60_2	5.774	1.692	5.743	1.693	0.2236	<0.001
Full Sample	q60_1	q60_3	5.774	1.692	5.809	1.686	0.1835	<0.001
Full Sample	q60_2	q60_3	5.743	1.693	5.809	1.686	0.0136	<0.001
Full Sample	q61_1	q61_2	5.774	1.689	5.640	1.668	<0.0001	<0.001
Full Sample	q61_1	q61_3	5.774	1.689	5.777	1.704	0.9232	<0.001
Full Sample	q61_1	q61_4	5.774	1.689	5.687	1.636	0.0034	<0.001
Full Sample	q61_2	q61_3	5.640	1.668	5.777	1.704	<0.0001	<0.001
Full Sample	q61_2	q61_4	5.640	1.668	5.687	1.636	0.0894	<0.001
Full Sample	q61_3	q61_4	5.777	1.704	5.687	1.636	0.0029	<0.001
BEV	q60_1	q60_2	5.922	1.234	5.978	1.322	0.2224	<0.001
BEV	q60_1	q60_3	5.922	1.234	5.988	1.346	0.1384	<0.001
BEV	q60_2	q60_3	5.978	1.322	5.988	1.346	0.8389	<0.001
BEV	q61_1	q61_2	5.878	1.374	5.798	1.338	0.1141	<0.001
BEV	q61_1	q61_3	5.878	1.374	5.937	1.381	0.1704	<0.001
BEV	q61_1	q61_4	5.878	1.374	5.908	1.335	0.5203	<0.001
BEV	q61_2	q61_3	5.798	1.338	5.937	1.381	0.0097	<0.001
BEV	q61_2	q61_4	5.798	1.338	5.908	1.335	0.025	<0.001
BEV	q61_3	q61_4	5.937	1.381	5.908	1.335	0.5602	<0.001
genpop	q60_1	q60_2	5.701	1.872	5.628	1.837	0.0171	<0.001
genpop	q60_1	q60_3	5.701	1.872	5.722	1.824	0.5308	<0.001
genpop	q60_2	q60_3	5.628	1.837	5.722	1.824	0.003	<0.001
genpop	q61_1	q61_2	5.723	1.822	5.562	1.804	<0.0001	<0.001
genpop	q61_1	q61_3	5.723	1.822	5.698	1.837	0.4834	<0.001
genpop	q61_1	q61_4	5.723	1.822	5.579	1.756	0.0001	<0.001
genpop	q61_2	q61_3	5.562	1.804	5.698	1.837	0.0002	<0.001
genpop	q61_2	q61_4	5.562	1.804	5.579	1.756	0.6187	<0.001
genpop	q61_3	q61_4	5.698	1.837	5.579	1.756	0.0016	<0.001

Aside from the **Federally rated (**q61_2) question, the BEV group shows consistent agreement within the pairwise comparisons. The **genpop** group (non-BEV owners) however show mostly statistically different means from questions within the same matrix. These differences are small in magnitude (max difference is 0.161 on a seven-point scale) but statistically significant. The full sample results include both the **BEV** group and the **genpop** group, thus any differences in means for the groupings naturally impact it. The Chi-squared test for independence is significant for all pairings, indicating that all pairs are statistically dependent.

The fact that the BEV group shows no difference in the means for the **Pre-owned information usefulness** (q60) matrix may indicate that those who already own BEVs understand battery

lifetime and driving range are related, while the **genpop** differences may be driven by a lack of knowledge of this functional relationship. It's also possible that the BEV group is simply less concerned with the issue as they have experience with ownership. All averages are between slightly useful to moderately useful.

Results within the **Pre-owned information source** (q61) matrix reveal a few insights. Both the BEV and genpop groups put a higher degree of utility in a warranty for the battery life than a federal rating. With the BEV group also finding it more useful than an industry rating. The genpop group, however, views industry ratings and federal ratings as being equally useful. Furthermore, the genpop group views a guarantee as being more determinative in their decision making than federal or industry ratings. These results suggest that warranties and guarantees of performance are of more use to buyers on the used BEV market than ratings. All averages are between slightly useful to moderately useful.

Appendix A presents the histograms for the responses to **Pre-owned information usefulness** (q60) and **Pre-owned information source** (q61) matrix questions. The histograms show the same general distribution for q60 while for q61 the sub-questions **Federally rated** (q61_2) and **Industry** rated (q61_4) show a higher count within the "six" bin than the **Guarantee** (q61_1) and **Warranty** (q61_3). It's also worth noting that, for all questions in q60 and q61, there is a slightly higher number of responses falling in the **Extremely Unuseful** bin compared to the **Moderately Unuseful**, **Slightly Unuseful**, and **Neither Unuseful nor Useful** bins. This is potentially the result of respondents who have a preconceived negative bias related to BEVs though this cannot be confirmed from the survey results.

Given their high correlations, it was decided that the average of the **Pre-owned information usefulness** (q60) and **Pre-owned information source** (q61) questions would be treated as single variables, respectively, when performing regressions. This decision was made as 90.9 % of respondents had a maximum absolute value of difference of "one" between their average response for **Pre-owned information usefulness** (q60) and their individual responses for any question within the q60 matrix. For the **Pre-owned information source** (q61) matrix compared to the average, the difference to capture 91.1 % of the respondents was 1.5. Thus, within respondent ratings showed a fair amount of consistency.

Matrix questions **Range Anxiety** (q62), **Resale Anxiety (New)** (q63), and **Resale Anxiety (Pre-Owned)** (q64) were also developed to elicit the same general response through different questions wordings. For clarity, q62 covered questions related to range anxiety based on level of agreement on a seven-point scale ranging from *Strongly Disagree* as 1 to *Strongly Agree* as 7 with the following statements:

- Q62_1 – If I owned a BEV, I would worry about running out of charge
- Q62_2 – If I owned a BEV, I would worry about finding placed to charge it if I wanted to drive somewhere new
- Q62_3 – Range is a major disadvantage of owning a BEV
- Q62_4 – Control question asking the respondent to select "Strongly Disagree" to ensure they are paying attention while filling out the survey

q63 elicits responses about the resale price when purchasing a new BEV based on level of agreement with the following statements using the same seven-point scale as for q62:

- Q63_1 – If I bought a **new** BEV, I would worry that I would not get a good price when I resell it
- Q63_2 – BEVs are less valuable than gasoline cars on the resale market because the technology is always advancing
- Q63_3 – If I bought a **new** BEV, I would worry about fast depreciation because of battery technology (relative to gasoline vehicles)

q64 asks the same questions as q63 but with **new** replaced by **pre-owned**. This intentionally leaves q63_2 and q64_2 identical. A similar reasoning to that used in averaging the **Pre-owned information usefulness** (q60) and **Pre-owned information source** (q61) matrix responses is used to justify the averaging of matrix question **Range anxiety** (q62) through **Resale anxiety** (q63 and q64), all of which capture roughly 90 % (88.5 % for q62, 89.4 % for q63, 90.2 % for q64) for a maximum absolute difference of 1.667.

A similar analysis was done between the two defined groups (**BEV** and **genpop**) for all matrix questions (q60 through q64). In this case an unpaired t-test with unequal variances was used in conjunction with the Chi-squared test (Table 4-8).

Table 4-8. Pairwise comparison of matrix variables between groups

Variable	BEV - n	BEV - Mean	BEV - Std. Dev	genpop - n	genpop - Mean	genpop - Std. Dev	t-test p-value	Chi Sq p-value
q60_1	490	5.92	1.23	1000	5.70	1.87	0.0066	<0.001
q60_2	490	5.98	1.32	1000	5.63	1.84	<0.0001	<0.001
q60_3	490	5.99	1.35	1000	5.72	1.82	0.0016	<0.001
q61_1	490	5.88	1.37	1000	5.72	1.82	0.0682	<0.001
q61_2	490	5.80	1.34	1000	5.56	1.80	0.0046	<0.001
q61_3	490	5.94	1.38	1000	5.70	1.84	0.0052	<0.001
q61_4	490	5.91	1.33	1000	5.58	1.76	0.0001	0.001
q62_1	490	4.51	1.81	1000	5.19	1.70	<0.0001	<0.001
q62_2	490	4.85	1.76	1000	5.52	1.66	<0.0001	<0.001
q62_3	490	4.76	1.79	1000	5.24	1.67	<0.0001	<0.001
q62_4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
q63_1	238	4.48	1.71	514	4.78	1.67	0.0283	<0.001
q63_2	238	4.59	1.87	514	4.70	1.60	0.4255	<0.001
q63_3	238	4.46	1.90	514	4.90	1.68	0.0026	<0.001
q64_1	252	4.59	1.70	486	4.91	1.56	0.0149	0.001
q64_2	252	4.62	1.86	486	4.79	1.59	0.2266	0.004
q64_3	252	4.68	1.88	486	5.11	1.51	0.002	<0.001

All means show a statistical difference in means (to at least the 1 % significance level) level except for the q63_2 and q64_2, the question on BEVs being less valuable on the resale market due to the technology always advancing. The mean is higher for the BEV group for the q60 and q61 matrix questions, while being lower (excluding the above exception) for the q62 through q64 matrix questions indicating a higher degree of confidence in BEVs than the general population. The Chi-squared indicates that all pairs are statistically dependent, confirming that, with a 0.01 alpha, *group* does have a correlation with response.

Histograms for the questions in the **Range anxiety (q62)**, **New resale[5] (q63)** and **Pre-owned resale (q64)** matrices are found in Appendix A.

[5] "New" in this instance means the state of the vehicle at the time of the respondent's purchase.

5. Regression Results

Although the cross-tabulations and statistical testing provided better understanding of the factors that influence consumer perspectives on new and pre-owned BEV, regression analysis will provide a better understanding of the magnitude and statistical significance of these factors while controlling for the other factors. This section defines a series of regressions, specifically using robust standard errors to control for heteroskedasticity, provides the results and interprets those results to determine the most important factors in a BEV purchasing decision and consumer perspectives on battery performance and resale.

5.1. Model Specification

The independent variables utilized in the regression models are provided in Table 5-1. This set was determined through a combination of lasso regressions on all dependent variables of interest to reduce dimensionality and remove covarying independent variables as well as a check of Pearson's correlation. For instance, the responses to the question on the information type a respondent would find useful for buying a pre-owned BEV vehicle (q60) was omitted due to a high correlation (0.8625) with the question on the information source that would be found useful for purchasing a pre-owned vehicle (q61). This was similarly done for the number of vehicles owned for a household (q4) as it had a medium amount of correlation, 0.5114 and 0.4864 respectively, with both the number of drivers in a household (q73) and the number of people in a household (q72). Note that some of these variables required the aggregation of data within a survey question or the averaging of responses across survey questions.

Some variables also were treated as continuous for the purposes of the regression based on the number of possible responses while others have been collapsed for the purposes of analysis. The specific number of cars reported (q4) has been collapsed to a binary variable (single or multi-car household). The Battery Information Usefulness and Range Anxiety variables are now averages of their respective question matrix (q60 and q62) and are treated as continuous. The solar panel questions on whether solar panels are installed (q69) and whether they're leased or owned (q70) have been combined into a single variable. Race (q75) has been collapsed to a binary for white and non-white (anything with multiple responses has been labeled as non-white). The question on Hispanic, Latino, or Spanish (q76) has been collapsed to a binary of Hispanic or Non-Hispanic. The first three categories in the Education responses (q77) have been grouped into a combined **Some high school-High School-GED** group due to relatively small sample sizes. Sampling group is an indicator of whether the response came from a BEV owner or non-BEV owner (i.e., general population or "**genpop**"). The Assigned Matrix variable is an indicator for whether the respondent was provided with the Future Value Concern (New) matrix of questions (q63) or the Future Value Concern (Pre-Owned) matrix of questions (q64). Assigned Matrix does not appear in all regressions. Although the battery life / range (**Battery Information Usefulness (Type)**) (q60) matrix was of interest, it was highly correlated with the information source that would be found useful for purchasing a pre-owned vehicle (**Battery Information Usefulness (Source)** hereafter shortened to simply **Battery Information Usefulness**) (q61) matrix, thus only the rating / guarantee (q61) matrix average was included to represent the value of battery information in general.

Table 5-1. Independent variables for regression analysis

Variable	Survey Variable(s)	Description	Type	Base (if Categorical)
Age	q2	Age	Continuous	
Sex	q3	Sex (Male, Female)	Categorical	Male
Multicar	q4	Number of vehicles (Multicar or Not)	Categorical	Single Car
Charger	q42	Access to vehicle charging station at home (Yes, No, Unsure)	Categorical	Yes
Number of Long Trips	q43	Number of long trips (over 2.5 hours) taken in the last year for any reason.	Continuous	
Battery Information Usefulness	q61_1, q61_2, q61_3, q61_4	Information Source Preferences. Average of all responses used.	Continuous	
Range Anxiety	q62_1, q62_2, q62_3	Range Anxiety. Average of all responses used.	Continuous	
Risk Attitude	q65	Risk Attitude	Continuous	
Own/Rent	q68	Whether the residence is owned or rented	Categorical	Own
Solar	q69, q70	Solar Panel (Own, Lease, Other, or None)	Categorical	None
Income	q71	Income	Continuous	
Number of People in Household	q72	Number of people in household	Continuous	
White	q75	Race (white or non-white)	Categorical	White
Hispanic	q76	Hispanic or non-Hispanic	Categorical	Non-Hispanic
Education	q77	Maximum education attainment (Some high school-High School-GED, Some College, Associate's degree, 4-year college degree, Master's Degree, Doctoral/Advanced Degree, Other)	Categorical	Some high school-High School-GED
Climate Change Concern	q78	Climate change concern	Continuous	
Sampling Group	group	Group (BEV or general population)	Indicator	genpop
Assigned Matrix	N/A	Assigned question matrix (Pre-Owned or New)	Indicator	New

The dependent variables are provided in Table 5-2. The independent variables are used to estimate their impact on future value concerns, resale anxiety, battery information usefulness, and likelihood of purchasing a BEV. Additional regressions were run to determine differences in coefficients. These involved using the full survey results and using full interactions with the Assigned Matrix (new or pre-owned) indicator or the Sampling Group (BEV or genpop) indicator.

Table 5-2. Dependent variables for regression analysis

Variable	Survey Variable(s)	Description	Type
Future Value Concern (New)	q63_1, q63_2, q63_3	Average of the New Vehicle Matrix variable questions	Continuous
Future Value Concern (Pre-Owned)	q64_1, q64_2, q64_3	Average of the Future Value Concern (Pre-Owned) variable questions	Continuous
New/Pre-Owned Comparison	N/A	Combination of Future Value Concern (New) and Future Value Concern (Pre-Owned). Used to compare coefficients of the Future Value Concern (New) and Future Value Concern (Pre-Owned) coefficients.	Continuous
Resale Anxiety	q63_2, q64_2,	Combination of the two identical questions from the New and Pre-Owned matrix questions.	Continuous
Likelihood to Purchase BEV	q39	How likely it is that a respondent will purchase a BEV as their next vehicle	Continuous
Battery Information Usefulness	q61_1, q61_2, q61_3, q61_4	Information Source Usefulness. Average of all responses used.	Continuous

5.2. Future Value Concern (New and Pre-Owned)

Regressions that were performed were for the **Future Value Concern (New)** (751 responses) and **Future Value Concern (Pre-Owned)** (738 responses) variables.

$$Future\ Value\ Concern = \beta_0 + \beta_1 * Age + \beta_2 * c.Sex + \beta_3 * c.Multicar + \beta_4 * c.Charger + \beta_5 * Number\ of\ Long\ Trips + \beta_6 * Battery\ Information\ Usefulness + \beta_7 * Range\ Anxiety + \beta_8 * Risk\ Attitude + \beta_9 * c.Rent/Own + \beta_{10} * c.Solar\ Panels + \beta_{11} * Income + \beta_{12} * Household\ Occupants + \beta_{13} * c.White + \beta_{14} * c.Hispanic + \beta_{15} * c.White\#c.Hispanic + \beta_{16} * c.Education + \beta_{17} * Climate\ Change\ Concern + \beta_{18} * Sampling\ Group \quad (2)$$

These took the forms of Eq. (2) (a $\boldsymbol{c}$. prior to a variable denotes that variable as either categorical or an indicator, a # denotes an interaction between variables). The independent variables in the regression for the **Future Value Concern (Pre-Owned)** are identical to that of **Future Value Concern (New)**. Table 5-3 presents the results of the two regressions (a variable name followed by a dot and another value is read as $variable.category$ while a variable name followed by a list of other values indicates a *variable* as a heading followed by the *categories* for that variable). A p-value of 0.100 was used as the cutoff for significance.

Table 5-3. Regression results for the Future Value Concern regressions

Variable	New BEV Assignment Group Coefficient (Rob. Std. Err.)	Pre-Owned BEV Assignment Group Coefficient (Rob. Std. Err.)
Age	**-0.026* (0.016)**	-0.004 (0.018)
Female.Sex	0.015 (0.085)	-0.147 (0.092)
Multicar.Multicar	**-0.344*** (0.088)**	**-0.368*** (0.093)**
Charger		
No	0.002 (0.108)	0.062 (0.118)
Unsure	0.024 (0.199)	0.187 (0.211)
Number of long trips	**0.074* (0.038)**	0.050 (0.037)
Battery Information Usefulness	**-0.072** (0.032)**	-0.038 (0.029)
Range Anxiety	**0.624*** (0.032)**	**0.556*** (0.036)**
Risk Attitude	0.005 (0.017)	-0.022 (0.017)
Rent/Own		
Rent	-0.182 (0.124)	-0.166 (0.130)
Other	-0.181 (0.384)	0.490 (0.316)
Solar Panels		
Lease	0.314 (0.318)	0.132 (0.398)
Own	**0.221** (0.108)**	0.187 (0.115)
Other	0.057 (0.316)	0.149 (0.259)
Income	-0.012 (0.008)	-0.006 (0.009)
Household Occupants	0.059 (0.044)	**0.106** (0.044)**
Nonwhite.White	**-0.382** (0.152)**	0.032 (0.150)
Hispanic.Hispanic	-0.181 (0.146)	**-0.344** (0.157)**
White#Hispanic		
Nonwhite Hispanic	0.614 (0.383)	0.184 (0.335)
Education		
Some College	0.082 (0.157)	-0.138 (0.154)
Associate's Degree	**0.305** (0.152)**	-0.221 (0.168)
4-Year College Degree	0.177 (0.138)	0.095 (0.159)
Master's Degree	**0.420*** (0.159)**	**0.383** (0.185)**
Doctoral/Advanced Degree	0.165 (0.311)	0.117 (0.289)
Climate Change Concern	**-0.077* (0.041)**	-0.039 (0.043)
Sampling Group		
BEV	-0.085 (0.106)	0.007 (0.109)
_cons	**2.089*** (0.389)**	**2.285*** (0.388)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

Respondent perspectives on battery performance has an impact on their level of concern related to the future value of BEVs. Battery Information Usefulness is not statistically significant

for pre-owned BEVs. However, greater usefulness of battery information was correlated to decreased concerns about the future value of new BEVs. Additionally, greater climate change concerns are correlated to lower concerns about resale value for new BEVsBEVS, while not being statistically significant for pre-owned BEVs. One potential reason for these two findings is that purchasers of pre-owned vehicles have different priorities than new vehicle purchasers, with a focus on short-term needs instead of long-term concerns. Higher levels of range anxiety are correlated with increased concerns about future value of both a new and pre-owned BEV, showing a clear relationship with battery performance and future value concerns. Owning solar panels is correlated with more concern about future value for both a new and pre-owned BEV. The reason for this relationship is unclear.

Some demographic variables are statistically significant as well. Multi-car households are less concerned about the future value of both a new and pre-owned BEV. Larger households are more concerned about the future value of a pre-owned BEV. Non-white and Hispanic respondents show less concern about future value when purchasing a new BEV and pre-owned BEV, respectively. Education was statistically insignificant for pre-owned BEVs except those with a master's degrees relative to no college experience. For new BEVs, respondents with an associate's or master's degree have a greater concern about the future value of a new BEV relative to no college experience. However, respondents with a doctoral/advanced degree are not statistically different than those with no college experience.

A comparison of regression coefficients was performed, to determine if the coefficients in Table 5-3 were statistically different between the **new** and **pre-owned** groups. This involved regressing on full interactions (## in Eq. (3)) between the Assigned Matrix variable (**Future Value Concern (New)** as base) with the previously defined regression in Eq. (2). The comparison regression works by combining the **Future Value Concern (New)** and **Future Value Concern (Preowned)** into a single variable noting that the two responses are mutually exclusive based on the assigned block, i.e. a response in **Future Value Concern (New)** means that the response in **Future Value Concern (Preowned)** will be null and vice versa. Regressing on the interaction between the **Assigned Block** and the individual variables themselves (the $c.Assigned\ Block$ in Equation 3) the results will include the non-interacted term, which is equivalent to the **Future Value Concern (New)** regression coefficient, and the interacted term, which is the difference between the **Future Value Concern (New)** and the **Future Value Concern (Preowned)** coefficient. The comparison works because the interaction will, by the nature of the mutual exclusivity, restrict the non-interacted term in the regression to pulling from the responses associated with the block assignment (0 for **Future Value Concern (New)** and 1 for **Future Value Concern (Preowned)**. This can easily be validated by noting that the non-interacted terms are identical to the coefficients for the **New BEV Assignment Group** in Table 5-3 while the non-interacted term added to the value of the interacted term are equivalent to the values in the **Pre-Owned BEV Assignment Group** column. The p-value then determines the statistical significance of the difference between the coefficients.

$$New/Preowned\ Comparision = c.Assigned\ Block\#\#(\gamma_0 + \gamma_1 * Age + \gamma_2 * c.Sex + \gamma_3 * c.Multicar + \gamma_4 * c.Charger + \gamma_5 * Number\ of\ Long\ Trips + \gamma_6 * Battery\ Information\ Usefulness + \gamma_7 * Range\ Anxiety + \gamma_8 * Risk\ Attitude + \gamma_9 * c.Rent/Own + \gamma_{10} * c.Solar\ Panels + \gamma_{11} * Income + \gamma_{12} * Household\ Occupants + \gamma_{13} *$$

$$c.White + \gamma_{14} * c.Hispanic + \gamma_{15} * c.White\#c.Hispanic + \gamma_{16} * c.Education + \gamma_{17} * Climate\ Change\ Concern + \gamma_{18} * Sampling\ Group) \quad (3)$$

Table 5-4 presents the regression results. Most variables show no significant difference between new coefficients and the pre-owned assignment group (variables labeled Preowned in the table). Non-white respondents in the pre-owned BEV group are correlated with **Resale Anxiety** than the **New BEV** group and for associate's degree holders in the **Pre-owned BEV** group (0.414), who were less likely to worry about future value as are associate degree holders in the preowned group (-0.525). All other significant variables indicate that the **New BEV** group coefficient is significant.

Table 5-4. New/Pre-owned Future Value Concern Comparison regression results

Variable	Coefficient (Rob. Std. Err.)
Preowned.Assigned Matrix	0.195 (0.549)
Age	**-0.026* (0.016)**
Assigned Matrix#Age	
Preowned	0.022 (0.024)
Female.Sex	0.015 (0.085)
Assigned Matrix#Sex	
Female-Preowned	-0.162 (0.125)
Multicar.Multicar	**-0.344*** (0.088)**
Assigned Matrix#Multicar	
Multi-Preowned	-0.023 (0.129)
Charger	
No	0.002 (0.108)
Unsure	0.024 (0.199)
Assigned Matrix#Charger	
Preowned-No	0.060 (0.160)
Preowned-Unsure	0.162 (0.290)
Number of long trips	**0.074* (0.038)**
Assigned Matrix#Number of long trips	
Preowned	-0.023 (0.053)
Battery Information Usefulness	**-0.072** (0.032)**
Assigned Matrix#Battery Information Usefulness	
Preowned	0.035 (0.043)
Range Anxiety	**0.624*** (0.032)**
Assigned Matrix#Range Anxiety	
Preowned	-0.069 (0.048)
Risk Attitude	0.005 (0.017)
Assigned Matrix#Risk Attitude	
Preowned	-0.027 (0.024)

Rent/Own	
Rent	-0.182 (0.124)
Other	-0.181 (0.384)
Assigned Matrix#Rent/Own	
Preowned-Rent	0.015 (0.180)
Preowned-Other	0.671 (0.497)
Solar Panels	
Lease	0.314 (0.318)
Own	**0.221** (0.108)**
Other	0.057 (0.316)
Assigned Matrix#Solar Panels	
Preowned-Lease	-0.182 (0.509)
Preowned-Own	-0.034 (0.158)
Preowned-Other	0.092 (0.409)
Income	-0.012 (0.008)
Assigned Matrix#Income	
Preowned	0.006 (0.012)
Household Occupants	0.059 (0.044)
Assigned Matrix#Household Occupants	
Preowned	0.047 (0.062)
Nonwhite.White	**-0.382** (0.152)**
Assigned Matrix#White	
Nonwhite-Preowned	**0.414* (0.214)**
Hispanic.Hispanic	-0.181 (0.146)
Assigned Matrix#Hispanic	
Hispanic-Preowned	-0.163 (0.214)
White#Hispanic	
Nonwhite-Hispanic	0.614 (0.383)
Assigned Matrix#White#Hispanic	
Nonwhite-Hispanic-Preowned	-0.430 (0.509)
Education	
Some College	0.082 (0.157)
Associate's Degree	**0.305** (0.152)**
4-Year College Degree	0.177 (0.138)
Master's Degree	**0.420*** (0.159)**
Doctoral/Advanced Degree	0.165 (0.311)
Assigned Matrix#Education	
Preowned-Some College	-0.220 (0.221)
Preowned-Associate's Degree	**-0.525** (0.227)**
Preowned-4-Year College Degree	-0.083 (0.210)

Preowned-Master's Degree	-0.037 (0.244)
Preowned-Doctoral/Advanced Degree	-0.048 (0.425)
Climate Change Concern	**-0.077* (0.041)**
Assigned Matrix#Climate Change Concern	
Preowned	0.037 (0.060)
Sampling Group	
BEV	-0.085 (0.106)
Assigned Matrix#Sampling Group	
Preowned-BEV	0.092 (0.152)
Constant	**2.089*** (0.389)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

5.3. Resale Anxiety Regression

The specific survey question on range anxiety was the respondents' agreement with the following statement: *BEVs are less valuable than gasoline cars on the resale market because the technology is always advancing*.

Thus, the regression in Eq. 4 can be viewed as examining the respondents' level of concern (i.e., anxiety) with resale of a BEV. Questions q63_2 and q64_2 (**BEVs are less valuable on the resale market because the technology is always advancing**) are identical between the assigned question matrix for the **New BEV** and **Pre-owned BEV** groups, respectively. Thus, a regression was run for the whole sample (Eq. (4)).

$$Resale\ Anxiety = \theta_0 + \theta_1 * Age + \theta_2 * c.Sex + \theta_3 * c.Multicar + \theta_4 * c.Charger + \theta_5 * Number\ of\ Long\ Trips + \theta_6 * Battery\ Information\ Usefulness + \theta_7 * Range\ Anxiety + \theta_8 * Risk\ Attitude + \theta_9 * c.Rent/Own + \theta_{10} * c.Solar\ Panels + \theta_{11} * Income + \theta_{12} * Household\ Occupants + \theta_{13} * c.White + \theta_{14} * c.Hispanic + \theta_{15} * c.White\#c.Hispanic + \theta_{16} * c.Education + \theta_{17} * Climate\ Change\ Concern + \theta_{18} * Sampling\ Group \quad (4)$$

Results of the regression are reported in Table 5-5. In terms of demographics, older respondents, women, non-whites, Hispanics, renters, and multi-car households were less likely to be agree with the statement **BEVs are less valuable on the resale market because the technology is always advancing** (q63_2 and q64_2). Non-White Hispanics and those possessing a master's degree or PhD or Advanced degree were more likely to agree. Those finding battery information sources more valuable have lower resale anxiety while those concerned with range anxiety have higher resale anxiety. Respondents that own solar panels have higher resale anxiety while those with greater concern about climate change have lower resale anxiety. As with the matrix regressions, a comparison of the coefficients was completed. Only the associate's degree holders for the pre-owned group assigned matrix showed any difference. The full regression can be found in Appendix B.

Table 5-5. Resale Anxiety regression results

Variable	Coef. (Rob. Std. Err.)
Age	**-0.039*** (0.015)**
Female.Sex	**-0.193** (0.083)**
Multicar.Multicar	**-0.249*** (0.083)**
Charger	
No	0.001 (0.105)
Unsure	0.133 (0.202)
Number of long trips	-0.016 (0.034)
Battery Information Usefulness	**-0.050* (0.028)**
Range Anxiety	**0.478*** (0.034)**
Risk Attitude	-0.014 (0.017)
Rent/Own	
Rent	**-0.279** (0.116)**
Other	0.216 (0.341)
Solar Panels	
Lease	0.125 (0.361)
Own	**0.482*** (0.107)**
Other	0.047 (0.296)
Income	-0.002 (0.008)
Household Occupants	0.050 (0.039)
Non-White.White	**-0.273** (0.133)**
Hispanic.Hispanic	**-0.334** (0.144)**
White#Hispanic	
Non-White Hispanic	**0.603* (0.318)**
Education	
Some College	-0.015 (0.144)
Associate's Degree	0.040 (0.145)
4-Year College Degree	0.166 (0.130)
Master's Degree	**0.351** (0.158)**
Doctoral/Advanced Degree	**0.693** (0.292)**
Climate Change Concern	**-0.112*** (0.039)**
Sampling Group	
BEV	-0.006 (0.102)
_cons	**3.246*** (0.347)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

5.4. Likelihood to Purchase a BEV Regressions

The regressions on the **Likelihood of BEV Purchase** (q39) are broken down by BEV/non-BEV group similar to the assignment group for the **Future Value Concern (New)** and **Future Value Concern (Pre-Owned)** regressions. The regression itself is defined in Eq. (5). Table 5-6 presents the results.

$$Liklelihood\ of\ BEV\ Purchase = \beta_0 + \beta_1 * Age + \beta_2 * i.Sex + \beta_3 * i.Multicar + \beta_4 * i.Charger + \beta_5 * Number\ of\ Long\ Trips + \beta_6 * Battery\ Information\ Usefulness + \beta_7 * Range\ Anxiety + \beta_8 * Risk\ Attitude + \beta_9 * Rent/Own + \beta_{10} * i.Solar\ Panels + \beta_{11} * Income + \beta_{12} * Household\ Occupants + \beta_{13} * i.White + \beta_{14} * i.Hispanic + \beta_{15} * i.White\#i.Hispanic + \beta_{16} * i.Education + \beta_{17} * Climate\ Change\ Concern \quad (5)$$

Numerous variables are statistically significant factors for the general population (**genpop**) group in their likelihood to purchase a BEV. Males are more likely to purchase a BEV and are more likely to identify as risk-taking individuals while age is negatively correlated with the likelihood decreasing as age increases. Multi-car households are less likely to purchase a BEV. Likelihood of a BEV purchase increases with both income and education level (exception of **Some College** and **Associate's Degree** responses) as well as concern about climate change. Not having access to an electrical outlet has a large negative impact on likelihood to purchase a BEV (nearly a full point drop). Also, owning solar panels increases the likelihood of BEV purchase by nearly a full point as well.

For the **BEV** group, few coefficients are statistically significant. A potential explanation is that BEV owners already have familiarity with the technology and are, thus, more likely to purchase another BEV regardless of other factors. The BEV group regressions do suggest that men are more likely to purchase another BEV than women, and that agreement with the usefulness of information sources predicts a higher likelihood of purchasing another BEV. Greater concern about climate change also predicts a higher likelihood of purchasing another BEV.

For both **BEV** and **genpop** groups, battery information and concerns related variables are statistically significant. Respondents that find battery information more useful are more likely to purchase a BEV with the same coefficient size for both groups. Also, higher range anxiety decreases the likelihood to purchase a BEV, although the coefficient for the **BEV** group is approximately 1/3 the size of the **genpop** group.

Table 5-6. Regression results for the Likelihood to Purchase BEV

Variable	genpop Coefficient (Rob. Std. Err.)	BEV Coefficient (Rob. Std. Err.)
Age	**-0.098*** (0.021)**	0.005 (0.027)
Female.Sex	**-0.507*** (0.112)**	**-0.334*** (0.120)**
Multicar.Multicar	**-0.293*** (0.113)**	-0.121 (0.125)
Charger		
No	**-1.064*** (0.137)**	-0.085 (0.282)
Unsure	0.109 (0.305)	-0.286 (0.543)
Number of long trips	-0.027 (0.041)	0.091 (0.064)
Battery Information Usefulness	**0.153*** (0.035)**	**0.162** (0.076)**
Range Anxiety	**-0.288*** (0.036)**	**-0.096*** (0.036)**
Risk Attitude	**0.075*** (0.018)**	-0.033 (0.022)
Rent/Own		
Rent	-0.042 (0.146)	-0.204 (0.294)
Other	0.446 (0.496)	N/A (N/A)
Solar Panels		
Lease	0.377 (0.493)	-0.458 (0.458)
Own	**0.956*** (0.147)**	-0.031 (0.118)
Other	**-0.891* (0.534)**	-0.800 (0.816)
Income	**0.025*** (0.008)**	0.008 (0.014)
Household Occupants	-0.009 (0.051)	0.052 (0.067)
Nonwhite.White	0.250 (0.169)	-0.007 (0.222)
Hispanic.Hispanic	0.160 (0.154)	0.113 (0.155)
White#Hispanic		
Nonwhite Hispanic	-0.198 (0.397)	-1.024 (0.631)
Education		
Some College	0.212 (0.193)	0.050 (0.262)
Associate's Degree	**0.394* (0.211)**	-0.066 (0.258)
4-Year College Degree	0.215 (0.169)	0.056 (0.269)
Master's Degree	**0.494** (0.197)**	0.182 (0.293)
Doctoral/Advanced Degree	**0.777*** (0.232)**	-0.314 (0.529)
Climate Change Concern	**0.385*** (0.052)**	**0.321*** (0.070)**
_cons	**4.161*** (0.401)**	**4.416*** (0.646)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

The regression for coefficient comparison is presented in Eq. (6). The general population (genpop) group is the base for the group variable.

$$Likelihood\ of\ BEV\ purchase = i.group\#\#(\beta_0 + \beta_1 * Age + \beta_2 * i.Sex + \beta_3 * i.Multicar + \beta_4 * i.Charger + \beta_5 * Number\ of\ Long\ Trips + \beta_6 *$$

$$Battery\ Information\ Usefulness + \beta_7 * Range\ Anxiety + \beta_8 * Risk\ Attitude + \beta_9 * Rent/Own + \beta_{10} * i.Solar\ Panels + \beta_{11} * Income + \beta_{12} * Household\ Occupants + \beta_{13} * i.White + \beta_{14} * i.Hispanic + \beta_{15} * i.White\#i.Hispanic + \beta_{16} * i.Education + \beta_{17} * Climate\ Change\ Concern) \quad (6)$$

The results are presented in Table 5-7. Many coefficients show statistically significant differences between the **genpop** and **BEV** owner groups. In general, the **BEV** group responses have fewer correlations to dependent variables than those of the **genpop** group. This could be the result of familiarity with the technology creating a greater comfort with purchasing another BEV or it could be that those in the **BEV** group were more likely to purchase to begin with and there's a selection bias when separating out the BEV purchasers. The former would indicate that those who aren't likely to purchase BEVs out of the **genpop** group could "come around" to purchasing a BEV if they were better informed, while the latter would mean that those who purchased BEVs were comfortable with it from the beginning and thus, didn't change their opinion after their initial purchase. It is worth noting that the previous scenarios are not mutually exclusive and there is likely a mixture within the **BEV** group, including possible explanations not offered here.

Table 5-7. Regression results for genpop-BEV coefficient comparison

Variable	Coefficient (Rob. Std. Err.)
Sampling Group (genpop base)	
BEV	0.255 (0.756)
Age	**-0.098*** (0.021)**
Sampling Group#Age	
BEV	**0.102*** (0.034)**
Female.Sex	**-0.507*** (0.113)**
Sampling Group#Sex	
BEV Female	0.173 (0.164)
Multicar.Multicar	**-0.293** (0.113)**
Sampling Group#Multicar	
BEV Multicar	0.172 (0.167)
Charger	
No	**-1.064*** (0.138)**
Unsure	0.109 (0.306)
Sampling Group#Charger	
BEV No	**0.979*** (0.312)**
BEV Unsure	-0.395 (0.619)
Number of long trips	-0.027 (0.041)
Sampling Group#Number of long trips	
BEV	0.117 (0.075)
Battery Information Usefulness	**0.153*** (0.035)**

Sampling Group#Battery Information Usefulness	
BEV	0.009 (0.083)
Range Anxiety	**-0.288*** (0.036)**
Sampling Group#Range Anxiety	
BEV	**0.192*** (0.051)**
Risk Attitude	**0.075*** (0.018)**
Sampling Group#Risk Attitude	
BEV	**-0.108*** (0.028)**
Rent/Own	
Rent	-0.042 (0.147)
Other	0.446 (0.498)
Sampling Group#Rent/Own	
BEV Rent	-0.162 (0.326)
BEV Other	N/A (N/A)
Solar Panels	
Lease	0.377 (0.495)
Own	**0.956*** (0.147)**
Other	**-0.891* (0.536)**
Sampling Group#Solar Panels	
BEV Lease	-0.835 (0.672)
BEV Own	**-0.987*** (0.188)**
BEV Other	0.091 (0.970)
Income	**0.025*** (0.008)**
Sampling Group#Income	
BEV	-0.017 (0.016)
Household Occupants	-0.009 (0.052)
Sampling Group#Household Occupants	
BEV	0.061 (0.084)
Nonwhite.White	0.250 (0.169)
Sampling Group#White	
BEV Nowhite	-0.257 (0.278)
Hispanic.Hispanic	0.160 (0.154)
Sampling Group#Hispanic	
BEV Hispanic	-0.046 (0.218)
White#Hispanic	
Nonwhite Hispanic	-0.198 (0.399)
Sampling Group#White#Hispanic	
BEV Nonwhite Hispanic	-0.827 (0.742)
Education	
Some College	0.212 (0.194)

Associate's Degree	**0.394* (0.212)**
4-Year College Degree	0.215 (0.169)
Master's Degree	**0.494** (0.198)**
Doctoral/Advanced Degree	**0.777*** (0.233)**
Sampling Group#Education	
BEV Some College	-0.162 (0.324)
BEV Associate's Degree	-0.460 (0.332)
BEV 4-Year College Degree	-0.158 (0.316)
BEV Master's Degree	-0.313 (0.351)
BEV Doctoral/Advanced Degree	**-1.091* (0.574)**
Climate Change Concern	**0.385*** (0.052)**
Sampling Group#Climate Change Concern	
BEV	-0.064 (0.086)
_cons	**4.161*** (0.403)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

5.5. Battery Information Usefulness Regressions

The final regression focuses on the **Battery Information Usefulness (Source)** (q61_avg) variable. The **Battery Information Usefulness (Type)** (q60_avg) variable also touches on the topic, however it is highly correlated with q61_avg and, thus, it is not regressed separately. The regression took the form of Eq. (7). Table 5-8 provides the regression results.

$$Battery\ Information\ Usefulness = \beta_0 + \beta_1 * Age + \beta_2 * i.Sex + \beta_3 * i.Multicar + \beta_4 * i.Charger + \beta_5 * Number\ of\ Long\ Trips + \beta_6 * Range\ Anxiety + \beta_7 * Risk\ Attitude + \beta_8 * Rent/Own + \beta_9 * i.Solar\ Panels + \beta_{10} * Income + \beta_{11} * Household\ Occupants + \beta_{12} * i.White + \beta_{13} * i.Hispanic + \beta_{14} * i.White\#i.Hispanic + \beta_{15} * i.Education + \beta_{16} * Climate\ Change\ Concern + \beta_{17} * Sampling\ Group \quad (7)$$

Those who are more likely to find battery information useful tend to be younger, have access to a charger at their residence, and take fewer long trips. They also tend to have less range anxiety and are more likely to self-identify as risk seeking. Owning solar panels decreases the self-reported value in battery information. Having a higher income, a higher concern for climate change, or a doctoral or advanced degree increase the likelihood that a respondent would find battery information useful. Lastly, already owning a BEV also increases the perceived usefulness of battery information.

Table 5-8. Regression results for Battery Information Usefulness

Variable	Coef. (Rob. Std. Err.)
Age	-0.024 (0.017)
Female.Sex	0.092 (0.079)
Multicar.Multicar	**0.140* (0.079)**
Charger	
No	**-0.269** (0.114)**
Unsure	**-0.693*** (0.241)**
Number of long trips	**-0.066** (0.033)**
Range Anxiety	**0.198*** (0.029)**
Risk Attitude	**0.052*** (0.016)**
Rent/Own	
Rent	**0.233** (0.117)**
Other	0.328 (0.385)
Solar Panels	
Lease	-0.017 (0.263)
Own	**-0.188** (0.086)**
Other	0.029 (0.446)
Income	**0.018** (0.008)**
Household Occupants	0.001 (0.042)
Non-White.White	-0.064 (0.135)
Hispanic.Hispanic	-0.112 (0.138)
White#Hispanic	
Non-White Hispanic	0.321 (0.251)
Education	
Some College	0.040 (0.160)
Associate's Degree	0.162 (0.166)
4-Year College Degree	**0.258* (0.146)**
Master's Degree	**0.294* (0.157)**
Doctoral/Advanced Degree	**0.438** (0.200)**
Climate Change Concern	**0.177*** (0.038)**
Sampling Group	
BEV	**0.181** (0.081)**
_cons	**3.713*** (0.292)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level

6. Associate's Degree Group

One surprising result from the regressions are the statistical significance of the **Associate's Degree** group. For the Resale Anxiety and Likelihood to Purchase regressions, the coefficient goes against the trend of lower education levels having no significance before significance is reached for higher education levels. It also has a large difference in value when compared against other education levels. An analysis is done to understand the reasons for this result.

The first step involves looking at the demographics of the **Associate Degree** group. Table 6-1 presents the summary statistics for the **Age**, **Sex**, **White**, **Hispanic**, and **Income** variables across the education groups.

Table 6-1. Demographic information for the Education variable

Variable	Some high School-High school-GED	Some College	Associate's degree (2-year degree)	4-year college degree	Masters degree	Doctoral degree/ advanced degree
Age[a]	7.143 (3.260)	7.200 (2.928)	7.279 (2.748)	7.406 (2.868)	7.199 (2.468)	7.492 (2.867)
Sex	42.4 % Male	41.4 % Male	42.5 % Male	54.1 % Male	60.5 % Male	57.14 % Male
White	83.9 % White	85.8 % White	90.7 % White	85.1 % White	92.0 % White	96.8 % White
Hispanic	11.1 % Hispanic	5.02 % Hispanic	7.52 % Hispanic	15.1 % Hispanic	12.2 % Hispanic	9.52 % Hispanic
Income[a]	6.482 (4.867)	8.611 (4.715)	9.739 (4.351)	12.384 (6.361)	15.780 (6.403)	19.349 (8.102)

[a] These variables are treated as continuous, thus the reported values are mean and (standard deviation). These variables are reported in their coded form

Based on the values in Table 6-1, the **Associate's Degree** group does not appear to be distinctly different from the other education groups. It is skewed more female than the **4-year college degree** and higher groups but is in line with the **Some high school-high school-GED** and **Some college** groups, and is predominantly white and non-Hispanic, which is true for all groups. **Income** follows the expected trend of increasing with higher education levels as well. The age variable is in line with the rest of the sample; however, it is possible that there may be a distributional difference. Figure 9 presents a bar plot of age distribution by education level. To prevent labels from making the plot area unreadable, the **Some high school-high school-GED** label has been replaced with **HSE or less** meaning a high school equivalent education or lower.

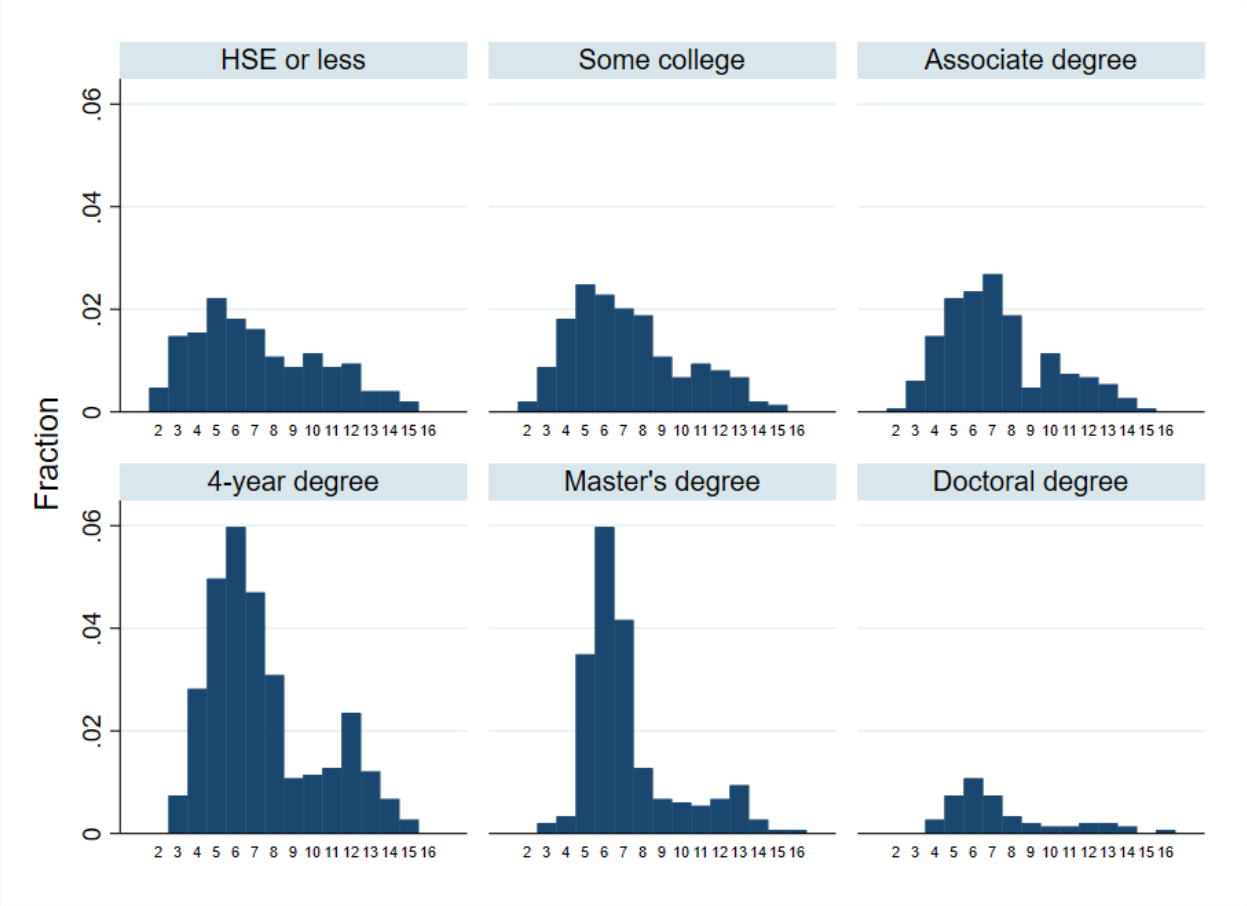

Figure 9. Histograms of Coded Age by Education

The figure shows that the distribution for the **Associate's Degree** group is very similar to those of the **Some College** and **Some high school-high school-GED** groups. Based on the distribution there is no reason to believe that an issue related to how the **Associate's Degree** group was sampled would be the cause. Similarly for the **Income** variable (Figure 10) there is no obvious issue related to the distribution that would suggest a sampling error. Furthermore, the sample size for the **Associate's Degree** group contains enough values (~110) to achieve significance, even when divided into **genpop/BEV** or **New/Pre-owned** blocks. Worth noting is that the sparse population of the **Doctoral degree/advanced degree** group is due to the relatively low percentage of the population with a Ph.D. or advanced degree. There is a spike in income towards the higher end of the **4-year college degree** and higher education levels, likely due to differentiation in the average income associated with different degree types.

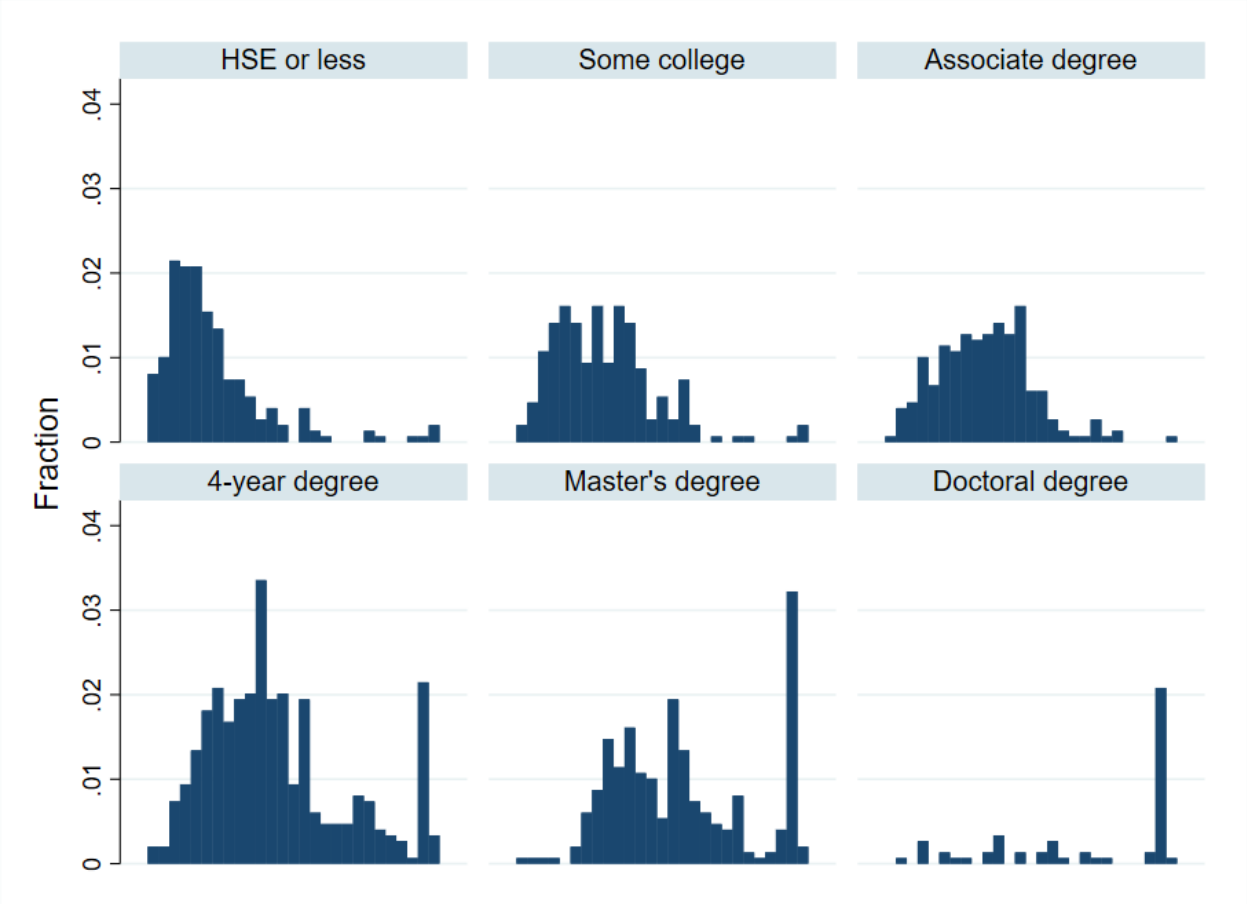

Figure 10. Histograms of Coded Income by Education. Due to the large number of Income categories, and that the distribution shape is what is pertinent, x-axis (income group) values have been suppressed.

Having explored the basic demographics further examination was done looking at household characteristic variables, specifically the **Multicar**, **Rent/Own**, **Charger Access**, **Solar Panels**, and **Number of Long Trips** variables (see Table 6-2).

Table 6-2. Household characteristic variables for the Education variable

Variable	Some high School-High school-GED	Some College	Associate's degree (2-year degree)	4-year college degree	Masters degree	Doctoral degree/ advanced degree
Multicar	48.2 % Multicar	56.9 % Multicar	38.9 % Multicar	56.3 % Multicar	62.7 % Multicar	61.9 % Multicar
Charger Access	49.1 % Have Access	65.7 % Have Access	61.1 % Have Access	74.3 % Have Access	82.9 % Have Access	84.1 % Have Access
Rent/Own	45.5 % Rent	24.7 % Rent	25.7 % Rent	14.4 % Rent	5.92 % Rent	9.52 % Rent
Solar Panels	86.2 % No Solar Panels	85.4 % No Solar Panels	66.4 % No Solar Panels	64.1 % No Solar Panels	48.8 % No Solar Panels	55.6 % No Solar Panels
Number of Long Trips[a]	2.585 (1.323)	2.787 (1.192)	2.969 (1.160)	3.082 (1.305)	3.394 (1.352)	3.175 (1.519)

[a] These variables are treated as continuous, thus the reported values are mean and (standard deviation). These variables are reported in their coded form.

Most of the variables suggest that the population sample for the **Associate's Degree** group is in line with expectations except for the **Multicar** responses. There is a significantly smaller amount of multi-car homes in the **Associate's Degree** group, suggesting either associate's degree holders are less likely to live in multi-car households, or there is an under sampling of multi-car households in this group. Figure 11 plots the distributions for the **Number of Long Trips** variable. As with the other histograms, nothing in the plots suggests a difference in sampling that could bias results.

Based on the included variables, there is little that suggests the singular behavior of the **Associate's Degree** group is sampling driven, however the possibility of some unknown correlation still exists. Assuming there is no sampling issue there may be a geographic pattern in the group that isn't picked up in the non-spatial analysis. This would need to be explored in future research. Other hypotheses, none of which are testable with the current survey results, include, but are not limited to, the following:

- Differences in the nature of an associate's degree from other degrees (i.e. different most common fields of study)
- Uncaptured financial differences such as the income level of the respondent's family at the time of enrollment
- First time college attenders
- Cheaper cost of attendance

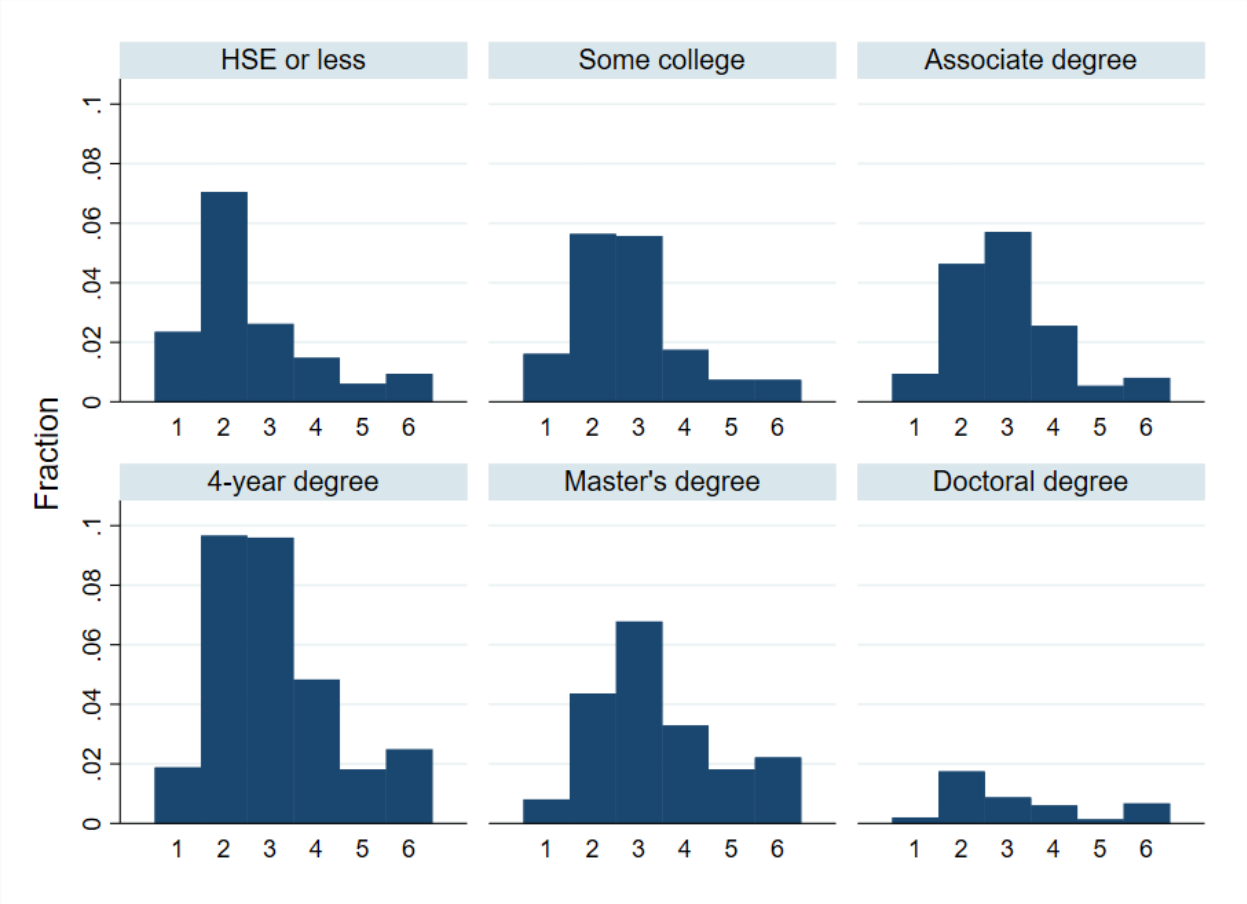

Figure 11. Histograms of Coded Number of Long Trips by Education. The x-axis is the number of long trips group (1 – Never, 2 – one to three, 3 – four to six, 4 – seven to nine, 5 – nine to eleven, 6 – 12 or more)

7. Conclusion

U.S. BEV and PHEV sales have been expanding significantly from nearly zero in 2010 to over 1.4 million in 2023, most of which accounted for by BEVs. Sales are projected to continue to increase, in part due to federal and state policies targeting greenhouse gas reductions in the transportation sector. Considering the increasing public demand, domestic production, and regulatory push for more BEVs, it is increasingly important to understand the public's understanding of these vehicles, what guides their perceptions, and what information sources and tools they use to make their decisions on new vehicle purchases. Additionally, as the market for BEVs matures, an increasing number of vehicles will end up on the market as pre-owned vehicles and purchasers on the pre-owned market may have differing concerns on the nature of BEVs. In particular, perspectives on BEV battery performance over time is of interest to assess what type of information is desired and in what form that information should be provided to consumers to assist in making better decisions.

This study provides a better understanding of the attitudes of potential vehicle purchasers in the U.S. regarding BEVs in general and specific interest in battery performance concerns and information preferences. The survey instrument collected consumer perspectives from 1490 respondents from across the U.S., 490 current BEV owners and 1000 potential vehicle purchasers, through questions on respondent's demographics, personal preferences, and vehicle ownership. The survey also collected information on BEV battery performance concerns and information needs for a BEV purchase decision. Of the 1490 respondents, 752 were asked specific questions related to new BEV vehicles while 738 were asked specific questions related to pre-owned BEV purchases.

Several demographics are important factors driving who is more likely to consider purchasing a BEV for their next vehicle. Younger, more educated, higher income, non-Hispanic, males are more likely to consider purchasing a BEV for their next vehicle purchase. Household factors are also important, with current BEV owners, multi-vehicle households, access to charging at home, and homes with owned solar panels are more likely to consider a BEV for their next purchase. Less risk aversion and more concern about climate change leads respondents to more likely consider buying a BEV.

The battery performance related questions were analyzed using cross-tabulations. On average, all respondents found usefulness in battery info (life, range, etc.) with similar preferences across BEV owners and potential vehicle purchasers. There were small or moderate differences in level of usefulness related to battery life and range. Non-BEV owners found more value in expected life of the battery than range of the battery and had a moderate preference for stronger certainty of life and range. Although small in magnitude, manufacturer warranty and a battery guarantee are statistically significantly more preferred to an industry or federal rating.

EV owners expressed less range anxiety, but they at least "somewhat agree" that range is a concern, showing that range anxiety remains a significant barrier to adoption. Similarly, range as a "major disadvantage" of owning a BEV as well as "finding a place to charge" other than home and "often worry about running out of charge" is high for both EV owners and potential vehicle purchasers. Resale concerns are similar for when the respondent is asked about "new"

vs “pre-owned” BEVs, with the depreciation of the battery of pre-owned BEVs being slightly more concerning.

Although cross-tabulations can provide some anecdotal interpretations, more robust statistical analysis was used to determine the magnitude impact of factors on consumer perspectives of BEVs. Regression models were used to analyze the factors that impact concerns of future value of BEVs (both new and per-owned), resale anxiety, likelihood to purchase a BEV for their next vehicle, and battery information usefulness.

The future value concern for new and pre-owned BEVs were modeled separately and then compared to determine what factors are statistically different between the two models. For both new and pre-owned BEVs, a higher concern for the future value of a BEV is correlated with single car households, larger households, households with solar panels, respondents with higher range anxiety, and a Master’s degree. For new BEVs, a higher concern for the future value of a BEV is also correlated with respondents with Associate’s and 4-year college degrees and lower concern of climate change as well as those that find battery information less useful.

The resale anxiety model found that older respondents, women, non-whites, Hispanics, and multicar households have lower resale anxiety. Non-white Hispanics and those possessing a Master’s or Advanced degree were more likely to have resale anxiety. Those finding battery information sources more valuable have lower resale anxiety while those concerned with range anxiety have higher resale anxiety as well. Respondents who own solar panels have higher resale anxiety while those with greater concern about climate change have lower resale anxiety. As with the future value concern regressions, a comparison of the coefficients was completed. Only the associate degree holders for the pre-owned group assigned matrix showed any difference.

A respondent’s likelihood to purchase a BEV for their next vehicle was modeled for current BEV owners, non-BEV owners, and then compared to identify differences. For both BEV owners and non-BEV owners, battery information and concerns related variables are statistically significant. Respondents that find battery information more useful are more likely to purchase a BEV with the same coefficient size for both groups. Also, higher range anxiety decreases the likelihood to purchase a BEV, although the coefficient for the BEV owner group is approximately 1/3 the size of the non-BEV owner group. Numerous variables are statistically significant factors for non-BEV owners. Males, those with risk-taking attitudes, and younger, higher income, and higher education level respondents are more likely to show a preference to purchase a BEV. Multicar households and respondents with less concern about climate change are less likely to purchase a BEV. Not having access to an electrical outlet has a large negative impact while owning solar panels has a positive impact on likelihood to purchase a BEV. For the BEV group, few coefficients are statistically significant. The BEV group regressions do suggest that men and those more concerned about climate change are more likely to purchase another BEV. Also, agreement with the usefulness of information sources predicts a higher likelihood of purchasing another BEV.

Many coefficients show statistically significant differences between the non-BEV owner and BEV owner groups. The lack of statistical significance for many of the variables for the BEV group could be the result of familiarity with the technology creating a greater comfort with

purchasing a BEV again or it could be that there is selection bias as BEV owners were more inclined to purchase a BEV in the first place. The former would indicate that those who aren't likely to purchase BEVs out of the non-BEV owner group could be influenced by better information, while the latter would imply that those who purchased BEVs were comfortable with it from the beginning and thus, didn't change their opinion after their initial purchase. It is worth noting that the previous scenarios are not mutually exclusive and there is likely a mixture within the BEV group, including possible explanations not offered here.

Also, a regression model evaluated the factors that impact a respondent's perspective regarding the usefulness of battery information. Those who are more likely to find battery information useful tend to be younger, have a higher income, doctoral or advanced degree, higher concern about climate change, access to a charger at their residence, and take fewer long trips. They also tend to have less range anxiety and are more likely to self-identify as risk-seeking. Owning solar panels decreases the self-reported utility in battery information. Lastly, already owning a BEV has the same impact.

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Appendix A. Histograms for matrix questions

For all histograms:

1 – Extremely Unuseful

2 – Moderately Unuseful

3 – Slightly Unuseful

4 – Neither Unuseful nor Useful

5 – Slightly Useful

6 – Moderately Useful

7 – Extremely Useful

A.1. Information type matrix

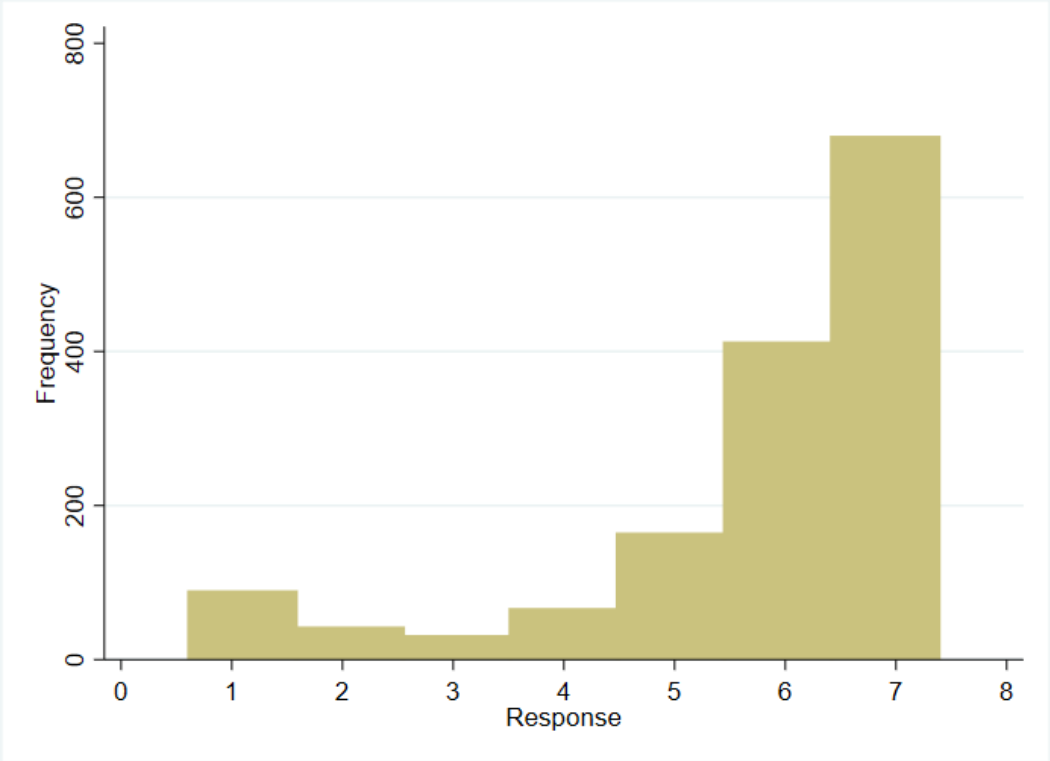

Figure 12. Histogram for q60_1 responses

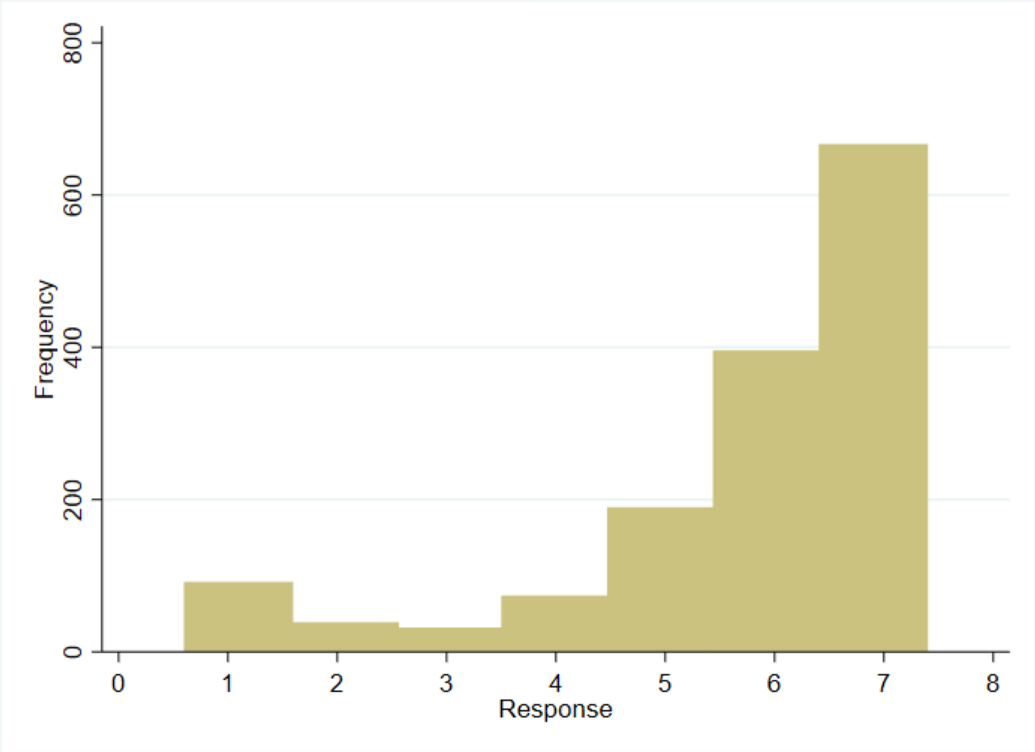

Figure 13. Histogram for q60_2 responses

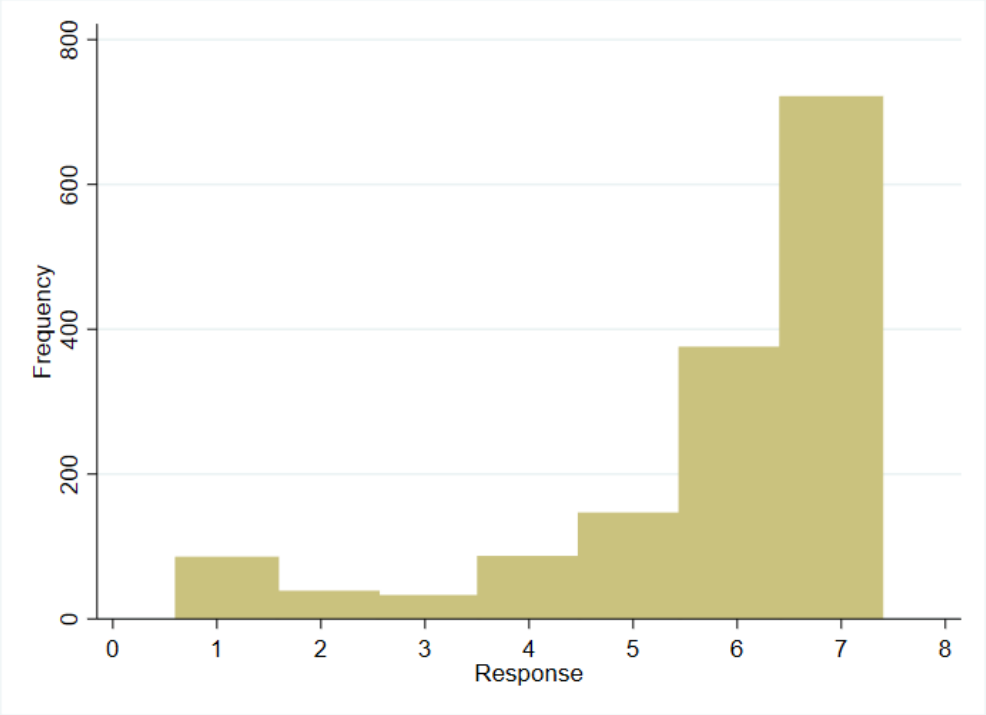

Figure 14. Histogram for q60_3 responses

A.2. Information source matrix

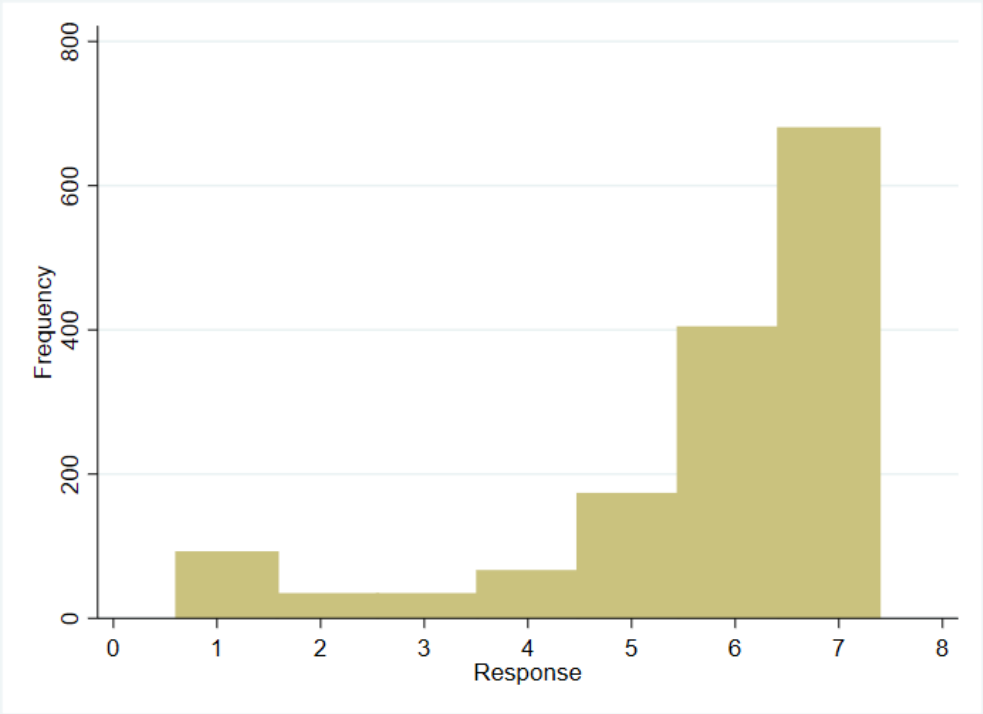

Figure 15. Histogram for q61_1 responses

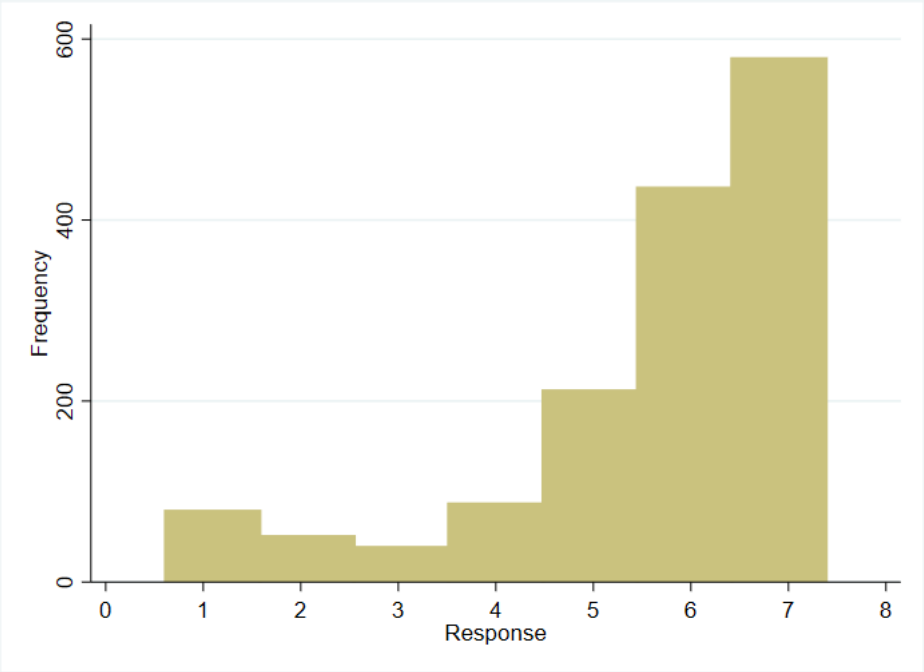

Figure 16. Histogram for q61_2 responses

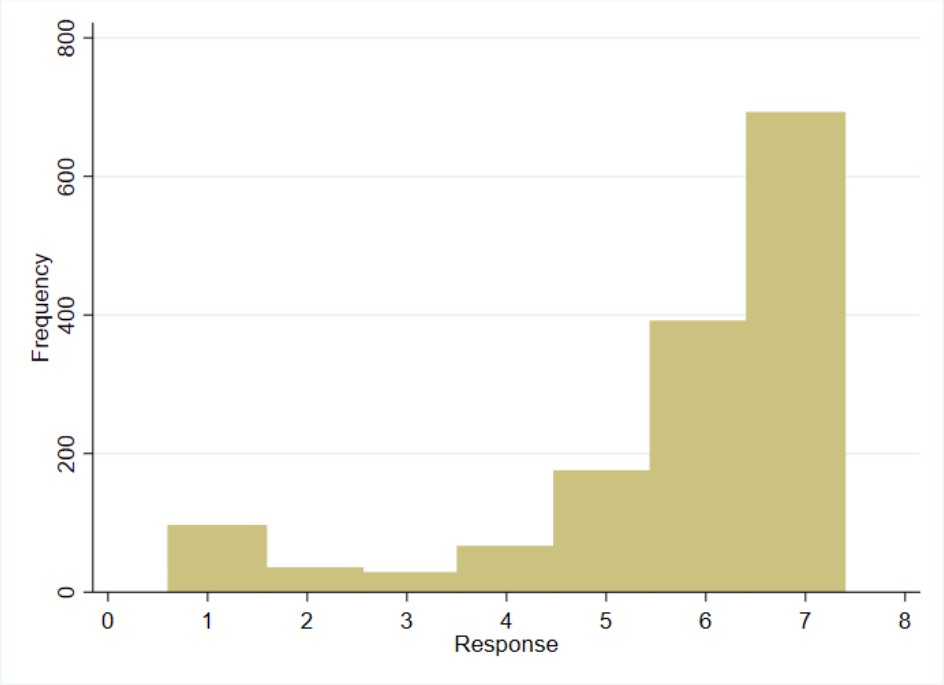

Figure 17. Histogram for q61_3 responses

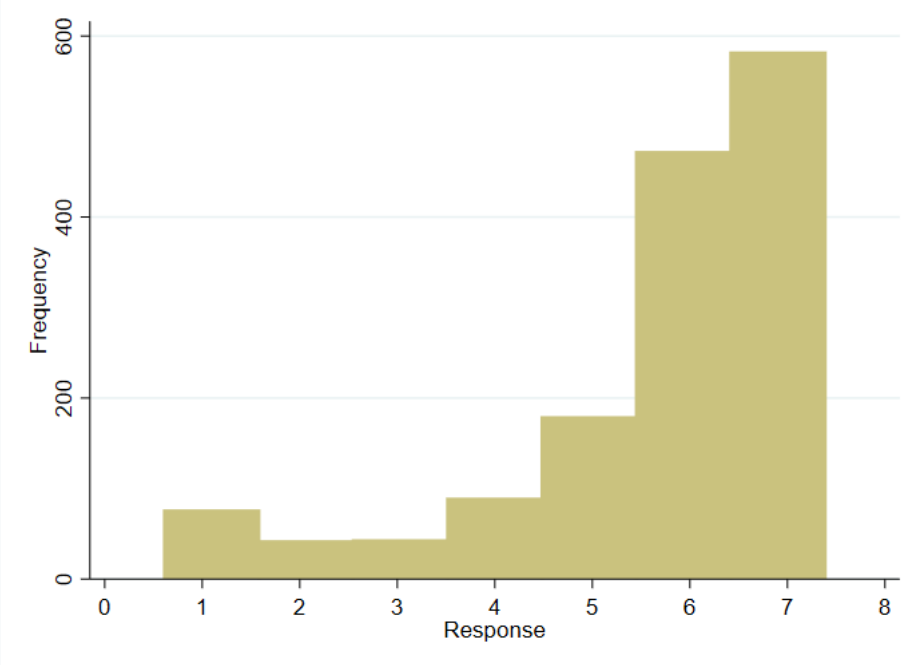

Figure 18. Histogram for q61_4 responses

A.3. Range anxiety matrix

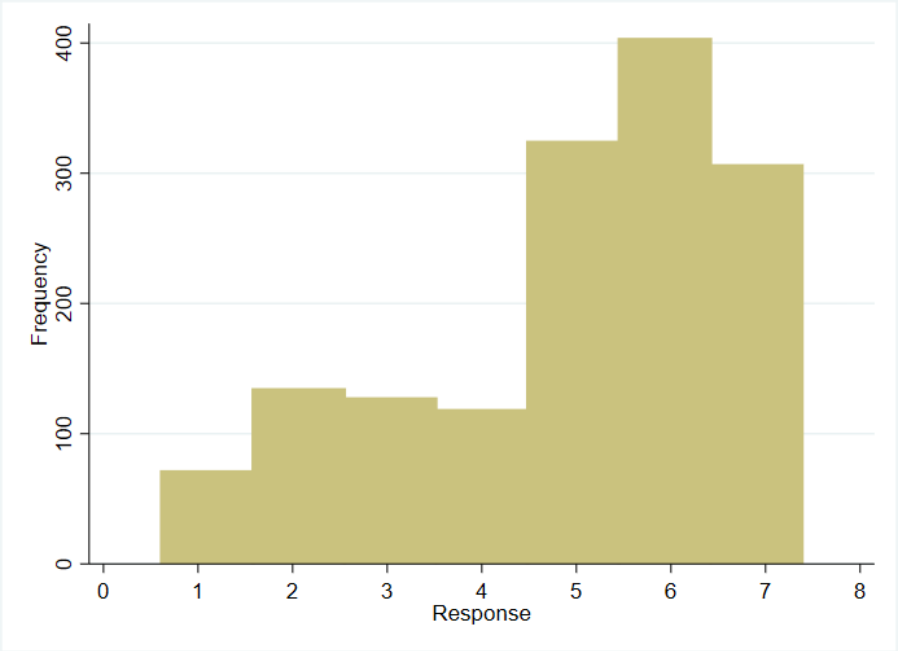

Figure 19. Histogram for q62_1 responses

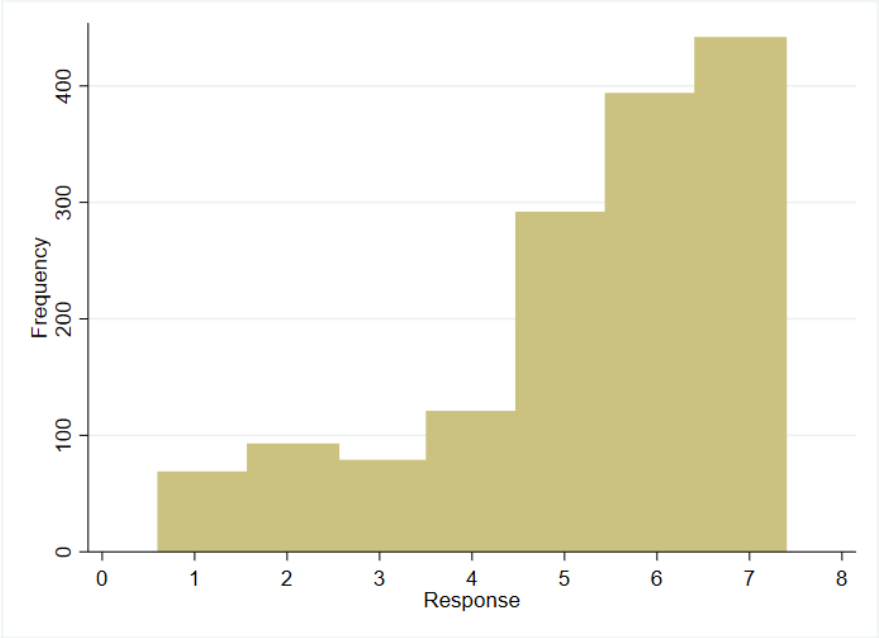

Figure 20. Histogram for q62_2 responses

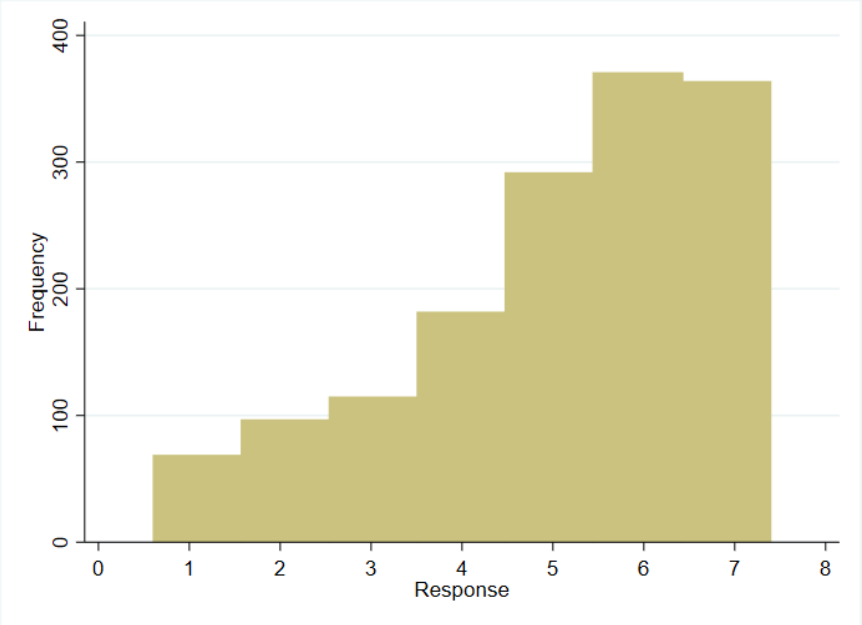

Figure 21. Histogram for q62_3 responses

A.4. New resale matrix

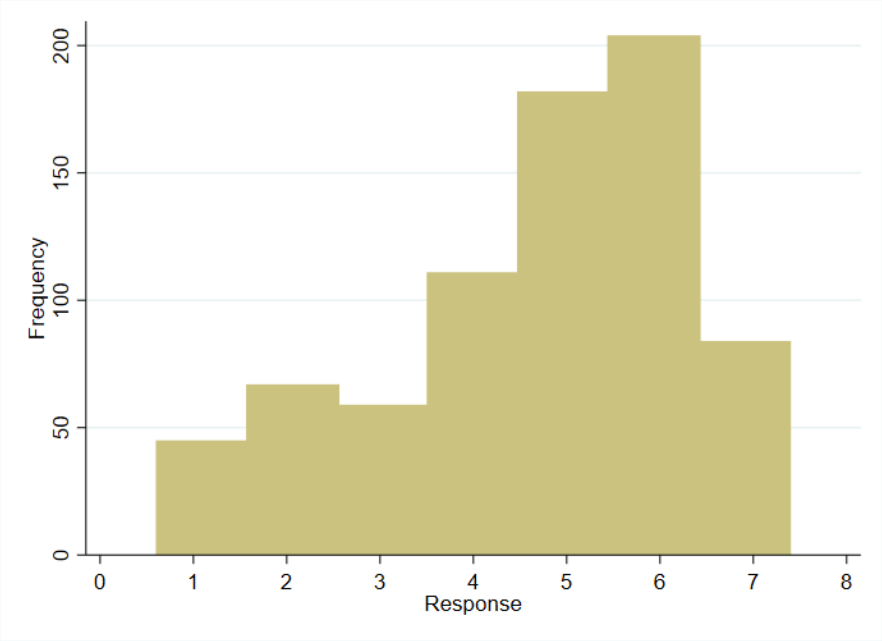

Figure 22. Histogram for q63_1 responses

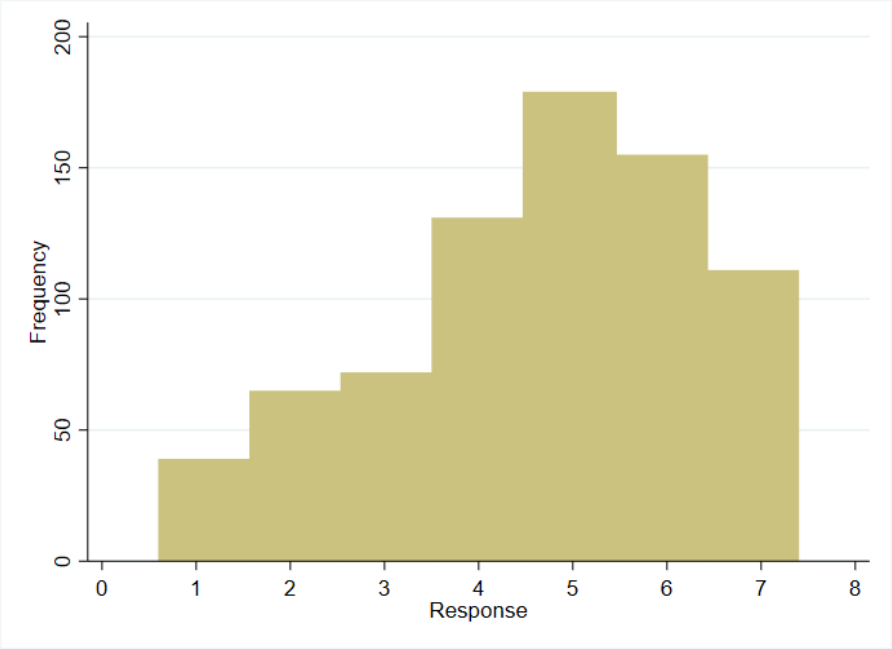

Figure 23. Histogram for q63_2 responses

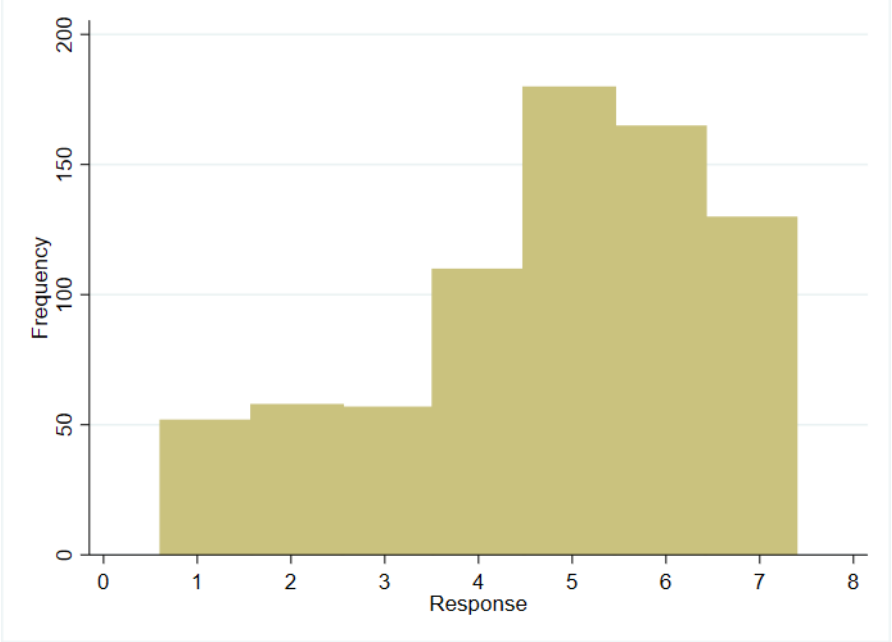

Figure 24. Histogram for q63_3 responses

A.5. Pre-owned resale matrix

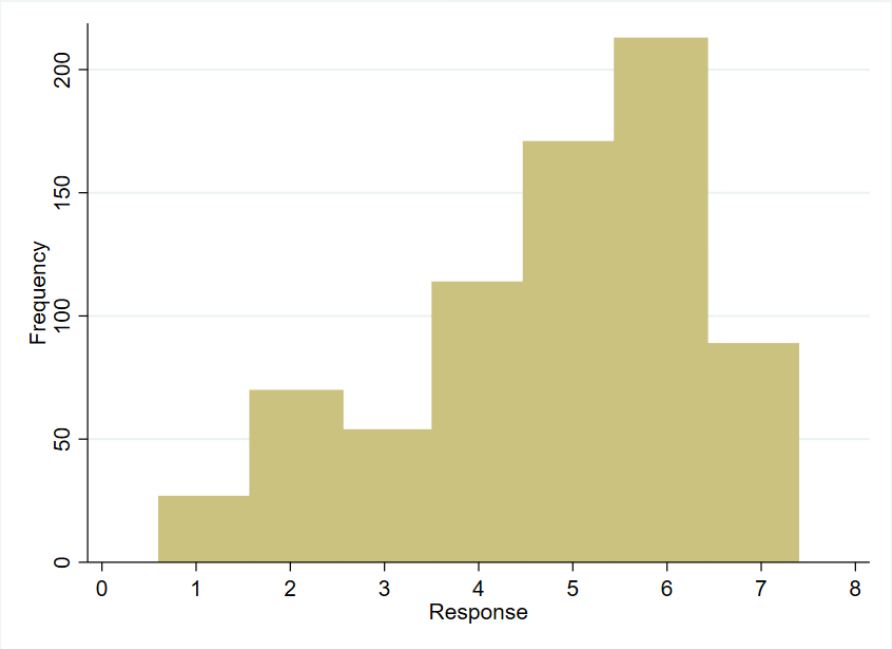

Figure 25. Histogram for q64_1 responses

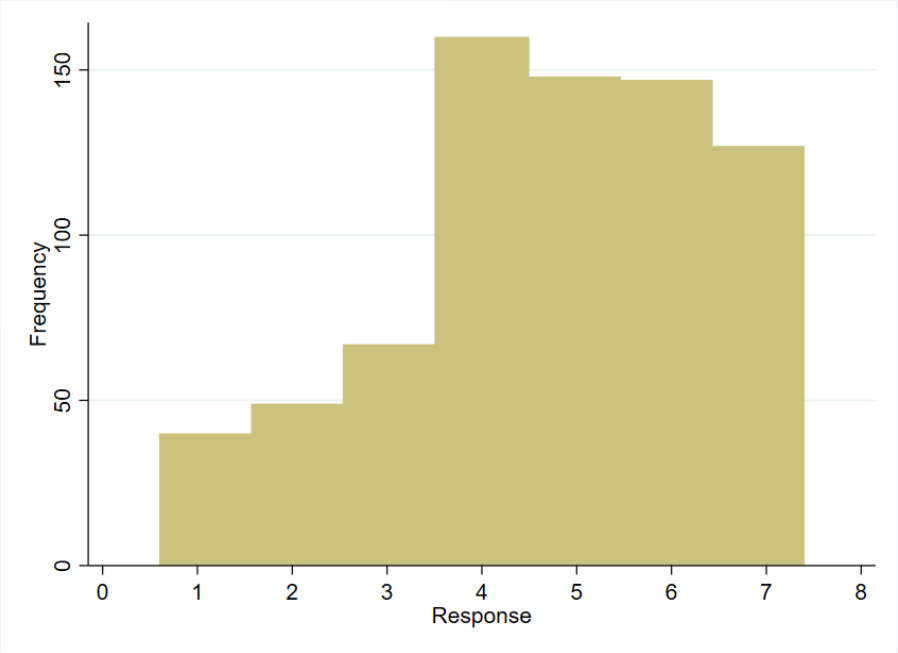

Figure 26. Histogram for q64_2 responses

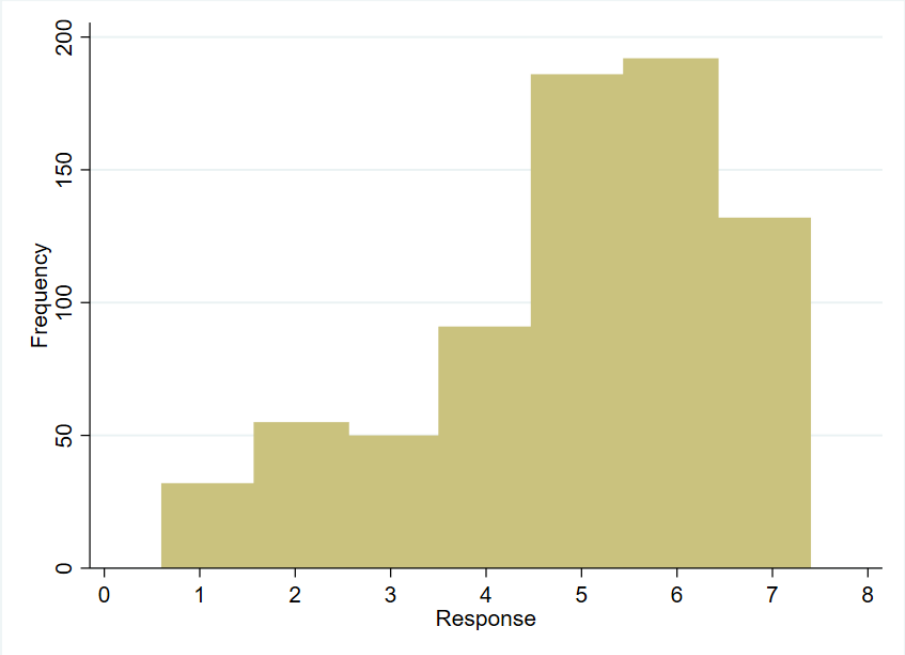

Figure 27. Histogram for q64_3 responses

Appendix B. Coefficient Comparison for Resale Anxiety Regression

Table B-1. New/Pre-owned Resale Anxiety Comparison regression results

Variable	Coefficient (Rob. Std. Err.)
Preowned.Assigned Matrix	-0.290 (0.701)
Age	**-0.042** (0.020)**
Assigned Matrix#Age	
Preowned	0.016 (0.030)
Female.Sex	-0.127 (0.116)
Assigned Matrix#Sex	
Female-Preowned	-0.128 (0.166)
Multicar.Multicar	**-0.207* (0.117)**
Assigned Matrix#Multicar	
Multi-Preowned	-0.131 (0.169)
Charger	
No	0.056 (0.145)
Unsure	-0.055 (0.304)
Assigned Matrix#Charger	
Preowned-No	-0.086 (0.211)
Preowned-Unsure	0.331 (0.403)
Number of long trips	-0.035 (0.049)
Assigned Matrix#Number of long trips	
Preowned	0.049 (0.069)
Battery Information Usefulness	**-0.106*** (0.037)**
Assigned Matrix#Battery Information Usefulness	
Preowned	**0.106* (0.055)**
Range Anxiety	**0.497*** (0.046)**
Assigned Matrix#Range Anxiety	
Preowned	-0.036 (0.068)
Risk Attitude	-0.006 (0.023)
Assigned Matrix#Risk Attitude	
Preowned	-0.020 (0.033)
Rent/Own	
Rent	-0.209 (0.165)
Other	-0.108 (0.555)
Assigned Matrix#Rent/Own	
Preowned-Rent	-0.136 (0.235)
Preowned-Other	0.641 (0.689)
Solar Panels	
Lease	-0.113 (0.502)
Own	**0.433*** (0.156)**

Other	-0.183 (0.421)
Assigned Matrix#Solar Panels	
Preowned-Lease	0.633 (0.730)
Preowned-Own	0.087 (0.216)
Preowned-Other	0.572 (0.560)
Income	0.005 (0.011)
Assigned Matrix#Income	
Preowned	-0.012 (0.016)
Household Occupants	0.028 (0.057)
Assigned Matrix#Household Occupants	
Preowned	0.051 (0.080)
Nonwhite.White	**-0.404** (0.189)**
Assigned Matrix#White	
Nonwhite-Preowned	0.347 (0.264)
Hispanic.Hispanic	-0.126 (0.193)
Assigned Matrix#Hispanic	
Hispanic-Preowned	-0.411 (0.291)
White#Hispanic	
Nonwhite-Hispanic	**0.697* (0.399)**
Assigned Matrix#White#Hispanic	
Nonwhite-Hispanic-Preowned	-0.252 (0.634)
Education	
Some College	0.140 (0.200)
Associate's Degree	**0.373* (0.197)**
4-Year College Degree	0.265 (0.171)
Master's Degree	**0.398* (0.209)**
Doctoral/Advanced Degree	**0.904** (0.431)**
Assigned Matrix#Education	
Preowned-Some College	-0.326 (0.291)
Preowned-Associate's Degree	**-0.693** (0.296)**
Preowned-4-Year College Degree	-0.238 (0.263)
Preowned-Master's Degree	-0.086 (0.318)
Preowned-Doctoral/Advanced Degree	-0.481 (0.587)
Climate Change Concern	**-0.148*** (0.056)**
Assigned Matrix#Climate Change Concern	
Preowned	0.065 (0.078)
Sampling Group	
BEV	0.045 (0.145)
Assigned Matrix#Sampling Group	
Preowned-BEV	-0.105 (0.204)
Constant	**3.369*** (0.487)**

* Significant at a 0.10 level, ** Significant at a 0.05 level, *** Significant at a 0.01 level