FINANCING DECARBONIZATION: A CHOICE-BASED CONJOINT ASSESSMENT OF LOAN PROGRAM PREFERENCES IN THREE SOUTHERN STATES

By

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A capstone submitted to Johns Hopkins University in conformity with the requirements for the Master of Science in Energy Policy and Climate

Baltimore, Maryland

December 2021

Executive Summary

Decarbonization in the United States will be battle fought on several fronts. Successfully decarbonizing the residential sector relies upon reducing overall electricity consumption—especially in regions served by carbon-intense grids. Energy efficiency (EE) measures are attractive since they provide additional benefits in the forms of energy savings and improved home value. Because of the financial benefits associated with EE investments, they could be popular in conservative parts of the country where legislated climate action is unlikely to find a foothold.

One of the identifiable obstacles to EE investment is the lack of readily available capital. Fortunately, there are numerous financing programs specifically designed to support residential efficiency improvements. These programs vary by loan type, payment terms, amortization period, interest rate, and other features.

The following research was designed to contribute to our understanding of consumer preferences for energy efficiency loans. This was done through a choice-based conjoint (CBC) experiment nested within a larger survey. The CBC questionnaire forced consumers who were interested in financing a large high-efficiency air-conditioning system upgrade to choose between randomly generated loan programs defined by key attributes. The resulting data shows which attributes are most important to consumers; likewise, it shows which distinct levels within each attribute are preferred. Ideally, the results of this research will prove useful in informing the design of residential EE financing programs in the Southeast.

Preface

Acknowledgements

This project would not have been possible with the help of Dr. Anna Broughel. There is no way to adequately thank her for the dozens of hours she put into mentoring me throughout this research process. From the concept work, experimental design, IRB submission and amendment, to the draft review she consistently gave thoughtful and prompt feedback. Her prior work with choice-based conjoint experimentation also proved crucial in implementing this methodology successfully.

I would also like to thank Dr. Zachary for the consistent help he provided throughout the course of this semester. He always made himself available for questions, providing thoughtful suggestions whenever I approached him with an issue.

Lastly, I would like to thank John Black for his consultation throughout the IRB submission and amendment processes.

Financial Support

The complete survey was designed on the Lighthouse Studio platform. The Academic Research License for this software was provided by Sawtooth Software through an academic grant.

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Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), the roughly 1°C of global mean temperature increase since the industrial revolution can be attributed to anthropogenic causes. Worse yet, the rising global mean temperature is projected to increase by 1.5°C–2°C over pre-industrial temperatures unless immediate action is taken (IPCC, 2018). With much of the world rapidly developing, the onus is on developed, energy-intensive nations to decarbonize.

Widespread renewable energy penetration in the utility-scale supply sector requires a combination of favorable wind or sun resource and the political goodwill to support this shift in energy generation. Policies such as a Renewable Energy Portfolio Standard (RPS), are designed to increase the share of energy produced by renewable energy sources(RES). Where conditions are not favorable for renewable energy investment, demand side electrification is likewise less effective in mitigating carbon emissions as electric power will continue to be supplied by carbon-intense forms of generation (EPA, 2021).

For regions where political will is lacking, energy efficiency (EE) investments may prove to be a more enticing alternative method of decarbonization. Fundamentally, efficiency measures reduce the amount of energy required to provide a given utility. A high-efficiency appliance consumes less energy while performing the same function as a standard-efficiency appliance. Reduced energy consumption means lower energy bills for consumers, making EE investments appealing regardless of the end user's views on climate change. Newer appliances will also increase home value. As such, EE

investments are a viable means of decarbonization in political jurisdictions where climate action is not prioritized.

The American Southeast has traditionally been a political bulwark of conservativism, and this conservativism extends to public opinion on climate change. Only 54% of Georgians, 52% of South Carolinians, and 56% of North Carolinians believe that global warming is caused mostly by human activities—3%, 5%, and 1% below the national average, respectively (Marlon, Howe, Mildenberger, Leiserowitz, & Wang, 2020). Policy-wise, these states are likewise less supportive of renewable portfolio standards (RPS) mandates than the national average even though NC has an RPS in place. The trend continues concerning individual responsibility, as these 3 states were all slightly below the national average in believing that citizens should do more to address global warming (Marlon, Howe, Mildenberger, Leiserowitz, & Wang, 2020).

Energy burden is defined as the fraction of income spent on home energy bills (Drehobl, Ross, & Ayala, 2020). Georgia and South Carolina are among the states with the highest low-income energy burden. Fortunately, the south Atlantic states of Georgia, South Carolina, and North Carolina are estimated as having high potential electricity savings for low-income homes, relative to the rest of the country (DOE, 2018). This data legitimizes EE's status as a pragmatic investment opportunity in the Southeast.

If there is a substantial and consistent upside to EE investments, why has the electricity savings potential not been realized? In fact, there exists a discrepancy between the actual and theoretical rates of efficiency adoption; however, the magnitude and causes of this "energy efficiency gap" are debated.

One frequently identified cause of the gap is that negative externalities are unpriced, leading to excessively cheap energy (Allcott & Greenstone, 2012; Gerarden, Newell, & Stavins, 2017). This market inefficiency could be addressed through a Pigouvian tax (Allcott & Greenstone, 2012). Other postulated explanations for the gap include imperfect information, split-incentives, and credit constraints (Gillingham & Palmer, 2014).

Split incentives are largely a non-issue for single family home where there is no rent-renter relationship. Imperfect information can exacerbate market failures as consumers are unaware of the real energy savings and life-cycle costs of high efficiency products. Research found that consumer willingness to pay (WTP) increased with more efficient dissemination of energy performance data in the form of labeling (Newell & Siikamaki, 2014).

The financing barrier, or liquidity/credit constraint, is the obstacle most relevant to our research. The lack of access to credit, common for low-income individuals, inhibits investments in energy efficiency (Gillingham & Palmer, 2014; Golove & Eto, 1996). A high-efficiency appliance is typically more expensive than its standard-efficiency counterpart, further disincentivizing purchase where credit constraint might be a limiting factor. Newell and Siikamaki observed that individual discount rates correspond to factors such as education, race, and credit score (2015). Low credit scores, less formal education, and African American racial identity were shown to correlate with higher individual discount rates. Across 4 models, the researchers noted a relationship between high individual discount rates and a lower willingness to make EE investments (Newell & Siikamaki, 2015).

There are numerous EE financing opportunities throughout the United States, so it is crucial to understand their strengths and weaknesses. Leventis et al. provides a typology, ordering the programs by characteristics (2016). Commercial and residential sectors are typically served separately as consumer needs differ considerably between them. Programs can be typologically listed as traditional or specialized, based on how they are designed to approach market obstacles. On-bill and Property Assessed Clean Energy (PACE) programs are classified as specialized, whereas lending and leasing programs are listed as being traditional (Leventis, Fadrhonc, Kramer, & Goldman, 2016).

Traditional loans can be further categorized by securitization measures, separating unsecured and secured programs. Secured loans offset the risk of default by placing a lien on equipment or real estate (DOE, 2010; Fuller, 2009). Contractor loans, home equity loans, and mortgages are secured. To offset the risk of default, unsecured programs often have high interest rates. The classification of *unsecured loan* includes financial institution loans and credit cards (Leventis, Fadrhonc, Kramer, & Goldman, 2016).

Relevant literature has provided assessments of the various EE programs, archiving program histories, consumer adoption rates, consumer default rates, loan terms, interest rates, and other attributes (Fuller, 2009; Hayes, Nadel, Granda, & Hottel, 2011; Kim, et al., 2012; Leventis, Fadrhonc, Kramer, & Goldman, 2016; Palmer, Walls, & Gerarden, 2012) . A discrete choice experiment (DCE) was carried out for a California Public Utilities Commission report. In this report, EE financing project attribute levels were combined to form product concepts. This study found that payment method was

the most important of the considered attributes, followed by monthly payment, project cost, interest rate, and monthly energy savings. (Opinion Dynamics, 2017).

The research undertaken within this paper builds on the existing literature and seeks to expand the general knowledge concerning consumer preferences for EE financing. This will be done primarily through the utilization of a choice-based conjoint experiment, a common method within marketing data analytics for measuring how a consumer values a product's individual attributes. The goal of this research is to determine which EE financing program attributes are most appealing to homeowners living in one of the following three Southeastern states: Georgia (GA), South Carolina (SC), or North Carolina (NC). It is hypothesized that interest rates will be the most important factor to this consumer base. It is also anticipated that Southeastern homeowners will value the loan term as the second most important attribute in a financing program, with longer loan terms to be preferred as they allow for lower monthly payments and more flexible payback timelines.

Given the expansive catalogue of EE programs throughout the United States, the research team was unable to thoroughly assess each program individually. As such, the case studies provided within the literature were used to provide comparisons to the respondents' data. Ideally, the results of this research will better inform the relevant parties—governing bodies, utilities, lenders—when they design loan programs for EE investments.

Experimental Methods

General Survey Design

This research undertaking was designed to better understand consumer preferences for energy efficiency financing programs. Intuitively, consumer preferences are expected to vary based on their individual needs. Anticipating this inherent variability within the sample population, further information about each respondent was required, adding context to the data set. For example, respondents planning to move within the short term may be less likely to make a substantial building efficiency investment. Similarly, low-income participants might require financing to make an energy efficient air-conditioning system upgrade.

The experiment consisted of simple survey questions and a Choice-Based Conjoint(CBC) scenario. The CBC scenario was placed just before the middle of the questionnaire, being preceded and followed by simple survey segments. Both portions were constructed in Sawtooth Software's Lighthouse Studio 9.12. The first leg of the simple survey consisted of 11 questions primarily concerned with the participant's living arrangement and air-conditioning system. The final 10 questions asked participants about their beliefs, politics, and demographics (see Appendix A).

The first screen shown to respondents requests that they input their Prolific ID (PID) (see Appendix B). Participants were asked to verify the demographic prescreening information in the subsequent 3 questions. If any of the answers contradicted their

Prolific profile's information, they would be prevented from continuing the survey and asked to return their submission.

After the prescreening questions, the participants were presented with questions about their air-conditioning system and preferences towards energy efficient appliances. Building on previous questions, the survey next presented participants with a product purchase scenario. Participants were told that they are looking to purchase a new, high-efficiency heat pump air-conditioning system that will cost $6,000 to buy and install. They are then told that there are 3 options for funding this project: pay all costs upfront, pay $2,000 upfront and finance the other $4,000, or finance the entire $6,000. These were the only choices, and respondents were asked which they preferred. If the respondent preferred not to finance—instead funding the entire project cost out-of-pocket—the survey would bypass the CBC experiment and ask them why they made this decision. Upon choosing either of the financing options instead, respondents would be presented with 15 choice tasks in a CBC experiment.

Regardless of how the respondent chose to pay for the brand-new high-efficiency air-conditioning system, they were asked if they would consider buying a similar unit in real life and if they would finance such a project.

The final 10 questions were designed to capture information about the respondent pertaining to their beliefs, demographic information, income, and credit score.

Choice-Based Conjoint Experiment Design

To most efficiently incentivize decarbonization, it is important to determine which distinct financing program attributes are most appealing to potential customers. For this purpose the research team chose to utilize Choice-Based Conjoint design, a stated choice experiment, to measure the utility of distinct financing program attributes.

Key to the CBC experiment's design is selecting the attributes which, when combined, define realistic financing program parameters. After reviewing the case study financing programs detailed in the literature, there were several attributes which were common all traditional loans (Fuller, 2009; Hayes, Nadel, Granda, & Hottel, 2011; Kim, et al., 2012; Leventis, Fadrhonc, Kramer, & Goldman, 2016; Palmer, Walls, & Gerarden, 2012). The 4 attributes chosen were **loan type**, **source of capital**, **payback period**, and **interest rate** (Table 1).

The attribute **loan type** describes how a loan is secured. For this experiment, this attribute was represented by three levels: home equity loans, loans secured through an equipment lien, and unsecured consumer loans. These levels were selected since they encompassed the majority of traditional loan programs (Leventis, Fadrhonc, Kramer, & Goldman, 2016).

The second attribute, **source of capital**, is a parameter that identifies the funding source for the loanable capital but not necessarily the funding source for the loan program's operation. Commonly, loan program administration costs will fund some combination of the following: marketing, processing, approving, or subsidizing the loan.

On the other hand, the actual capital utilized for lending may originate from another entity, and this entity may be tasked with some administrative duties as well.

Payback period, also called loan term or amortization period, is the maximum allotted period over which the loan must be paid. For this attribute's levels, 4 periods split by 2-year increments, ranging from 3 to 9 years were selected. This range was selected as it was representative of the loan terms recorded in the literature (Fuller, 2009; Hayes, Nadel, Granda, & Hottel, 2011; Kim, et al., 2012; Leventis, Fadrhonc, Kramer, & Goldman, 2016; Palmer, Walls, & Gerarden, 2012).

Similar logic was applied when selecting the levels for the final attribute, **interest rate**. Four levels—4%, 8%, 12%, 16%—were chosen to be representative of the wide range of loan program rates available. In reality, these rates are dependent upon consumer credit score, loan security type, and concurrent market rates; however, they specific range selected (4%–16%) represents a realistic range for most of the possible **loan type-source of capital** combinations. The maximum number of attributes was limited to 4 in order to reduce concept complexity and mitigate the chance of generating unrealistic choice task combinations.

Attributes	Attribute description	Attribute levels
Loan type	How the loan is secured.	Loan secured through home equity Loan secured through lien on fixtures Unsecured consumer loan
Source of capital	Source money to be loaned.	Ratepayer funded State or local government funded Fannie Mae or Freddie Mac Funded Private lender funded
Payback period	Maximum period of time allotted for the repayment of borrowed funds and resulting interest.	3 years 5 years 7 years 9 years
Interest rate	Rate of annual interest accrual.	4% 8% 12% 16%

Table 1. Choice-Based Conjoint Attributes and Attribute Levels

To ensure that the generated concepts were realistic, all possible combinations of loan type and source of capital were evaluated and related to existing or previously existing programs (Table 2). These case studies were aggregated in reports and whitepapers assessing EE financing programs; however, the cases that were used for comparison were primarily those compiled in *Enabling Investments in Energy Efficiency* by Merrian Fuller (2009). Only **loan type** and **source of capital** were considered for this matrix as **interest rate** and **payback period** varied within all cases. Thus, most of the representative **interest rate** and **payback period** levels could be realistically associated with any of the below cases depending on individual terms and applicant credit. The researchers found no case of lien-on-fixture secured loans funded by Fannie Mae or Freddie Mac. Similarly, no such case was found for a ratepayer funded loan

secured through home equity. These combinations were prohibited from being generated in task concepts to make the questionnaire more realistic.

Loan Type	Source of Capital	Existing Case (best fit)
Loan secured through home equity	Ratepayer funded	
Loan secured through home equity	State or local government funded	AFC First Financial Keystone HELP
Loan secured through home equity	Private lender funded	Efficiency Vermont Loan
Loan secured through home equity	Fannie Mae or Freddie Mac funded	Energy Efficiency Mortgage (EEM)
Loan secured through lien on fixtures	Ratepayer funded	Sacramento Municipal Utility District Residential Loan Program
Loan secured through lien on fixtures	State or local government funded	Nebraska Energy Office Dollar and Energy Saving Loan Program
Loan secured through lien on fixtures	Private lender funded	NYSERDA HPwES Loan Program
Loan secured through lien on fixtures	Fannie Mae or Freddie Mac funded	
Unsecured consumer loan	Ratepayer funded	Manitoba Hydro Power Smart Residential Loan
Unsecured consumer loan	State or local government funded	AFC First Financial Keystone HELP
Unsecured consumer loan	Private lender funded	Cambridge Energy Alliance
Unsecured consumer loan	Fannie Mae or Freddie Mac funded	Viewtech Financial Services Fannie Mae Loan Program

Table 2. Existing Case Comparisons by Attribute Level Combination

Potential borrowers would be interested in knowing the monthly payment amount of each loan. Minimum monthly payment due is a function of both interest rate and payback period. To further simulate a life-like consumer-product interaction, a calculated conditionally displayed monthly payment amount was provided in each financing program concept.

Both pathways—66.6%(2/3rds) financed and 100% financed—were designed to be identical other than the text at the top of the screen and the conditional display value

monthly payment. Each CBC questionnaire consisted of 15 choice tasks. Since the study involved complex choice concepts in EE loan programs, each of the 15 choice tasks contain only 2 loan program concepts. There is an additional “none” option in case the respondent would prefer not to finance project costs with either program. Additionally, since this published study was designed to be accessed on a personal computer or a mobile device, it was decided that 2 generated product concepts would be optimal as anything more could make navigating the CBC exercise tedious on small screens.

Both CBC designs were generated through complete enumeration. Per Sawtooth Software, complete enumeration is a heuristic design algorithm that randomizes the placement of attribute level combinations within each choice task concept. Typically, designs displaying fewer concepts than attribute levels are better suited for balanced overlap generation instead; however, when testing the design within Lighthouse Studio, complete enumeration yielded more favorable results (Sawtooth Software, 2017).

Estimating Consumer Preference

In CBC analysis, the utility score provides several key pieces of information about the relative desirability of levels within each attribute. Within a given attribute, the score allows for comparisons between different levels; however, any level's utility score is arbitrary, making outright utility score comparisons between levels of different attributes meaningless. Likewise, the zero point is arbitrary in this data, meaning that even if the utility score of a level is shown to be zero or negative, it does not mean that this specific level is inherently undesirable. Instead, it simply means that it is less desirable than the other levels within its attribute that have higher utility scores (Orme, 2019).

The range in utility scores within an attribute allows for the measurement of attribute importance. This measurement is calculated as a percentage which has a meaningful zero-point reference. An attribute with a greater importance has more impact on the total utility of the relevant "product". The attribute importance percentages can be compared to one another meaningfully (Orme, 2019).

Analyzing Choice-Based Conjoint Data: Hierarchical Bayesian

This research project used a Hierarchical Bayes (HB) model to estimate individual-level part-worth utilities. Sawtooth Software notes the efficacy of this model in approximating part-worths, even when the respondent has only provided a few answers of choice-based data (2021). This form of modeling is built on the concept of *conditional probability*. In short, Bayesian analysis allows for iterative updating of probabilities using pre-validated probability estimates, a conditional probability estimate, and a post-validated probability estimate (Sawtooth Software, 2021). The novelty of the HB solution is that it estimates probabilities at two distinct levels. The upper level operates off the assumption that the part-worths of individuals exist along a multivariate normal distribution. The lower level operates off the assumption that, knowing an individual's part-worths, their chance of choosing certain alternatives can be estimated using a multinomial logit model. It is a calculation-intense operation that can, fortunately, be assessed within minutes in Lighthouse Studio.

Analyzing Choice-Based Conjoint Data: Latent Class

The HB model provides a mean of attribute part worth utilities via HB estimation, and it works well in capturing a sample population's heterogeneity if that heterogeneity is continuously distributed. For sharply segmented consumer preferences exist within a

group heterogeneity is better explored through latent class analysis (Sawtooth Software, 2021). This model allows researchers to compare segmentations by distinct preference within the studies population. Researchers must then assess the various segmentation scenarios to determine which best models the respondent group. From the dataset, 4 latent class scenarios (2-group, 3-group, 4-group, and 5-group) were compared to determine how the population should be segmented. There are a few indicators that can be used to determine segmentation superiority. Each scenario's parameters--percent certainty, Consistent Akaike Information Criterion (CAIC), chi square--should be assessed when determining the optimal number of segments to represent discrete heterogeneity within a population. For more information on these parameters and how they relate to latent class segmentation, refer to Sawtooth Software's *The Latent Class Technical Paper* (2021)

Sample

To accurately gauge the preferences of southern homeowners located within the selected three states, a representative sample of respondents were paid to participate. Desiring a 95% confidence interval with a 5% margin of error, it was determined that 318 participants would be required to represent the roughly 17,000,000 homeowners in Georgia, South Carolina, and North Carolina (US Census Bureau, 2019).

The experiment's CBC scenario allowed for 3 distinct pathways: 2 similar CBC paths and an alternative option that bypasses any CBC task screens. The "rule of thumb" estimate for minimum CBC sample size is given by the below inequality:

$$n \geq \frac{500 * c}{q * a}$$

where *q* is the number of questions shown to each respondent. Variable *a* is the number of alternatives per question (excluding the “none” alternative). *c* is the maximum number of levels of any attribute (Orme, 2019).

Per the given inequality, a minimum sample size of 67 respondents would be required for a CBC experiment. However, the standard error was projected to be considerable in Lighthouse Studio’s test design feature as it was above 0.05 for most attribute levels—Sawtooth suggests standard errors below 0.05 for main attributes (Sawtooth Software, n.d.). Therefore, a larger sample was deemed ideal. The survey was eventually paused when CBC data from 205 respondents was collected. As expected, lower standard error was projected for this larger population in the software’s test design feature.

When designing the experiment, it was discovered that Prolific estimated only 989 eligible participants that met the 4 prescreening requirements. These participants had to be living in the either Georgia, South Carolina, or North Carolina; and living in a home that they own. The experiment was designed with 15 choice task screens. There exists an inversely proportional relationship between product concepts per task and total number of task screens shown to participants in the given formula. In this experiment, wherein loan program concept preferences were tested, the task complexity was deemed to be high. As such, only 2 product concepts were shown per screen along with the “none” alternative. Consequently, a synthesis of high task count and low concept count was chosen to minimize the necessary population sample, choice task difficulty, and respondent fatigue.

Publishing

The survey was published on crowdsourcing site Prolific which provided automated prescreening based on the desired demographic requirements.

The survey was estimated to take roughly 12 minutes to complete. Each participant would be paid $2.00 for a complete submission, equating to a payout rate of $10.00 per hour. Participants were presented with the informed consent language in the study description. This was done so that participants would be aware of key details pertaining to the research prior to being linked to the online survey, mindful of the publisher's guidelines (Prolific, 2018). After inputting their PID, they were again presented with the informed consent form which notified them that proceeding with the questionnaire would be tantamount to consent.

Results

Survey Analysis

The most rudimentary analysis consists of breaking down the simple survey data. The survey was withdrawn from publication with 321 completes, 5 incompletes, and 16 disqualifies. Of the completed submission, 38% lived in Georgia, 41% lived in North Carolina, and 21% lived in South Carolina. The overwhelming majority of respondents lived in detached homes (94%). Almost half of respondents (49%) had been living in their current home for 5 years or less. A majority (83%) of respondents said that they had air-conditioning systems with heat pumps--a sensible solution in the more temperature climes of GA, NC, and SC. Of these various air-conditioning systems, 65%

had been installed for fewer than 10 years and 36% had been installed for fewer than 5 years. A notable 7% of participants answered that their current air-conditioning system was not adequate at cooling their living space.

As expected, summer energy bills were the highest by comparison, correlating with the region's high cooling degree days (Figure 1). This was followed by winter. Winter heat pump operation is inefficient—even in the Southeast—yet this number is offset by the moderate number of heating degree days and the alternative or supplemental usage of fossil fuel combustion to heat the living space. The "shoulder" months in spring and fall tend to be more temperate, with ambient averages close to that of the building setpoint, meaning that the air-conditioning/heat pump unit is required to perform less work. This is reflected in the data.

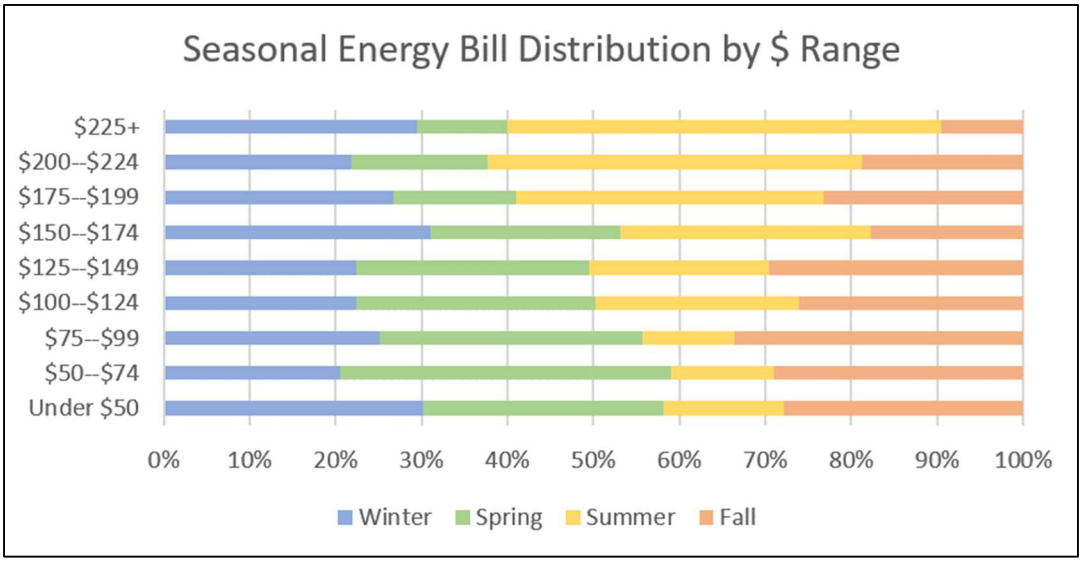

Figure 1. Seasonal Energy Bill Distribution by Dollar Range

The next portion of the survey explored consumer preferences for EE when purchasing an air-conditioning unit. A majority (59%) of participants considered EE important when making such a purchase. Similarly, respondents were asked how long they would be willing to wait for an EE investment to break-even. Only 10% of the surveyed population stated that they were willing to wait longer than 5 years. In the CBC scenario, 36% of participants chose not to finance the high-efficiency unit, instead choosing to pay upfront. Slightly over 20% of respondents preferred financing all $6,000 of project costs whereas 42% were more interested in financing 66.6%(2/3rds) of the project. For those who opted not to finance, they were asked why. In the open text prompt, respondents provided their reasoning. Some common explanations were already having an emergency fund for larger purchases such as this, choosing not to finance any purchase on principle, and wanting to avoid accruing interest. Some verbatim quotes typical of the sample are shown below:

"I try to remain as debt free as possible."

"I don't want to pay interest and I don't want to have to pay another bill."

"I don't like paying interest."

"I have the money available and would prefer to pay for it upfront, thereby not incurring any debt with interest."

"I have an emergency fund that is fully stocked so I can pay for it up front. I DO NOT finance anything, I don't even have a credit card and my home and cars are paid for."

"If you dont have the money to pay for it now you shouldnt pay for it. Safe way of thinking to avoid debt."

Concluding this scenario, respondents were asked if they would consider purchasing a high efficiency unit in real life and whether this purchase would be financed. Common responses besides *yes* and *no* included wanting to purchase a unit since their system is old, not wanting to purchase a unit since their system is new, and being willing to finance under favorable terms. Some of these answers are shown below:

"Yes, we will be facing this scenario very shortly. Our AC unit is older and we know we will need to replace it soon. We would always like to choose the most efficient option, and we would be willing to pay a little more for it. We would prefer to save the full amount before replacing but may need to finance some if it breaks before we have the money saved."

"My system is too new to replace but if it did break down somehow, I prefer to have a more efficient model and to finance it at good rates and terms"

"Only if there's a special promo on financing. Like a '6 or 12 months same as cash' promo."

"Considering I just did this a couple years ago, yes. I would. If I hadn't already done it."

"I am not currently interested in a new system because my Lennox heat pump works well. I would not want to finance any part of a new system unless I absolutely had to, which I don't anticipate."

A notable 86% of respondents believe that global warming is occurring and 76% believe that it is mostly caused by human activities. The majority of participants said that they either worried a moderate amount (41%) or a great deal (30%) about global warming. Policy-wise, energy efficiency investments were shown to be popular with the surveyed population: 84% either strongly or somewhat support funding more EE programs. The largest share of respondents identified as liberal Democrats with another 16% identifying as moderate/ conservative Democrats accounting for almost half of the surveyed sample. Only 29 respondents(~9%) were under the age of 26, and the mean participant age was 41.08 years. Over two-thirds (68%) of those surveyed identified as female. White participants accounted for 86% of the sample. Only 10% made under $30,000 per year whereas, 69% made over $60,000. A slight majority (51%) claimed to have a credit score of 726 or above.

Using respondent electricity bill and income data in conjunction, the distribution of the sample population's energy burden can be mapped. Energy burden is based on all energy expenses—typically excluding water and transportation energy expenses (Brown, Soni, Lapsa, Southworth, & Cox, 2020). The survey only collected electricity bill expenditure estimates, thus the electricity bill energy burden tabulated here leaves off fuel consumption costs (Figure 2). Therefore, this analysis provides a low-end estimate of the total energy burden for households in regions that do not heavily rely on gas heating. Gas-fired cooking can likewise add to this discrepancy. The relationship is such that, in a given population, the electricity bill energy burden will always be less than or

equal to the total energy burden. Electricity bill burden would be equal to total energy burden when the home and its appliances are strictly powered by electricity.

The median total energy burden for households in the United States is 3.1% (Drehobl, Ross, & Ayala, 2020). In the surveyed population, 23% percent had electricity bill energy burdens above that median. Colton defines energy bills that are greater than 6% of gross income are unaffordable (2011). At least 8% of the surveyed respondents were paying unaffordable energy bills. Brown et al. mentions that a 12% threshold is used to determine the energy impoverishment in Georgia (2020). By this measure, only about 2% of respondents could be confidently considered energy impoverished.

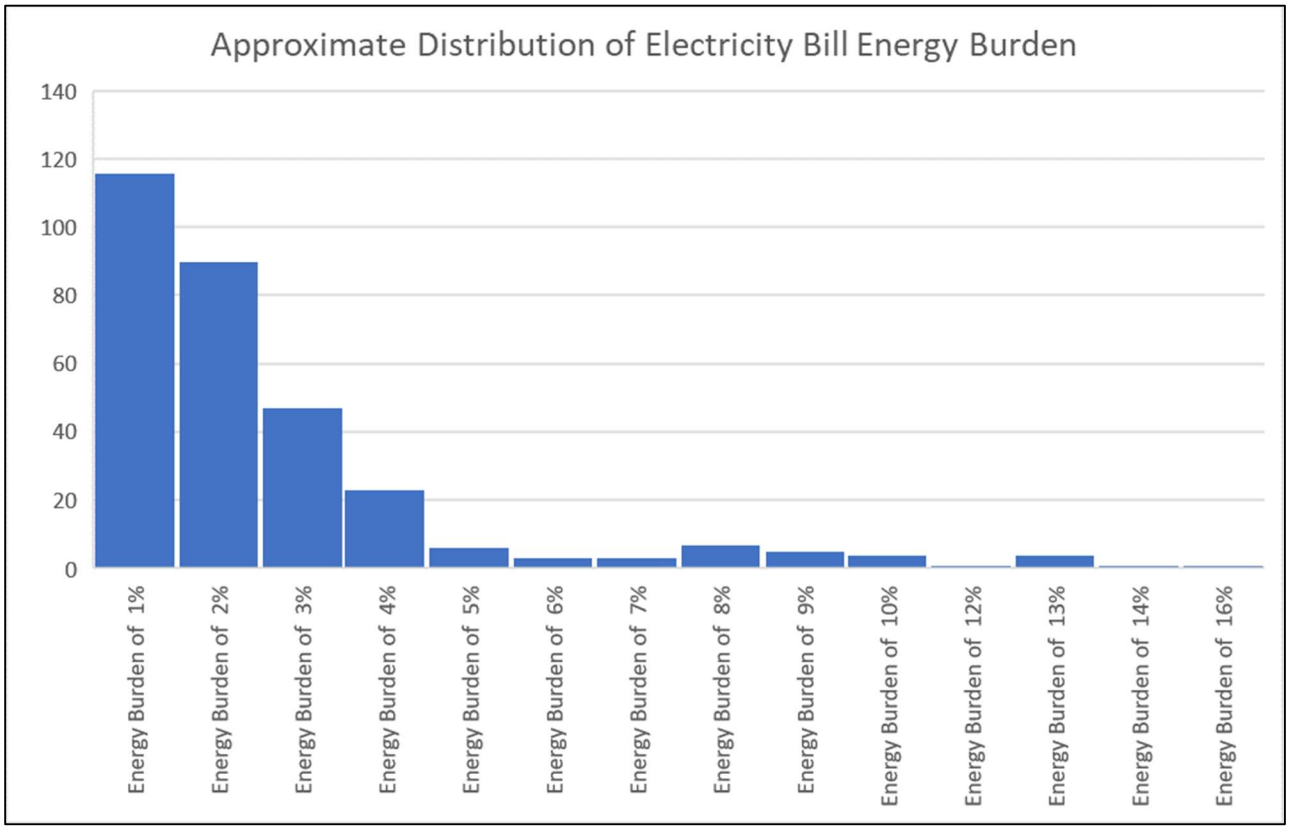

Figure 2. Approximate Distribution of Electricity Bill Energy Burden

Choice-Based Conjoint Analysis

Hierarchical Bayesian

Survey responses were transposed from an imported CSV file to Lighthouse Studio in which analysis could be conducted by the software. A Hierarchical Bayesian model was applied to the CBC data set to estimate individual-part-worth utilities (Table 3).

Attributes and attribute levels	Mean Utility	Standard Deviation	Lower 95% CI	Upper 95% CI
Loan Type				
Loan secured through home equity	8.31	20.47	5.51	11.12
Loan secured through lien on fixtures	-16.33	21.29	-19.25	-13.42
Unsecured consumer loan	8.02	19.7	5.32	10.72
Source of Capital				
Ratepayer funded	-9.77	16.62	-12.05	-7.5
State or local government funded	5.36	17.73	2.93	7.78
Fannie Mae or Freddie Mac funded	0.62	19.32	-2.02	3.26
Private lender funded	3.8	14.43	1.82	5.77
Payback Period				
3 years	-0.49	65.11	-9.41	8.42
5 years	20.93	17.32	18.56	23.3
7 years	3.08	31.29	-1.21	7.36
9 years	-23.51	47.76	-30.05	-16.97
Interest Rate				
4%	107.94	52.01	100.82	115.06
8%	34.66	15.46	32.54	36.78
12%	-35.6	17.11	-37.95	-33.26
16%	-107	43.21	-112.91	-101.09
None	-18.58	129.4	-36.29	-0.87

Table 3. HB Mean Utilities Report

From this data, respondent preferences become apparent. Concerning the **type of loan**, the survey population showed comparative aversion to loans that are secured through fixture filings. Home equity and unsecured consumer loans were both assigned similar average utilities—both preferable compared to securitization through fixture liens.

Source of capital was the attribute considered least important in choosing an EE financing program, according to the HB model; however, the calculated importance was roughly equivalent to that of **loan type** (Figure 3). Participants showed similar favorability towards private lender funds and state/local government funds. Ratepayer funding was assigned the lowest utility score within this attribute.

For the second most important attribute, **payback period**, the surveyed population showed preference towards 5-year loan terms with 9 years being the least preferred level. With this available data, the hypothesis that longer loan terms would be deemed preferable must be rejected. However, the researchers did anticipate that **payback period** would be the second most important attribute since it, along with interest rate, directly affects the loan's minimum monthly payment.

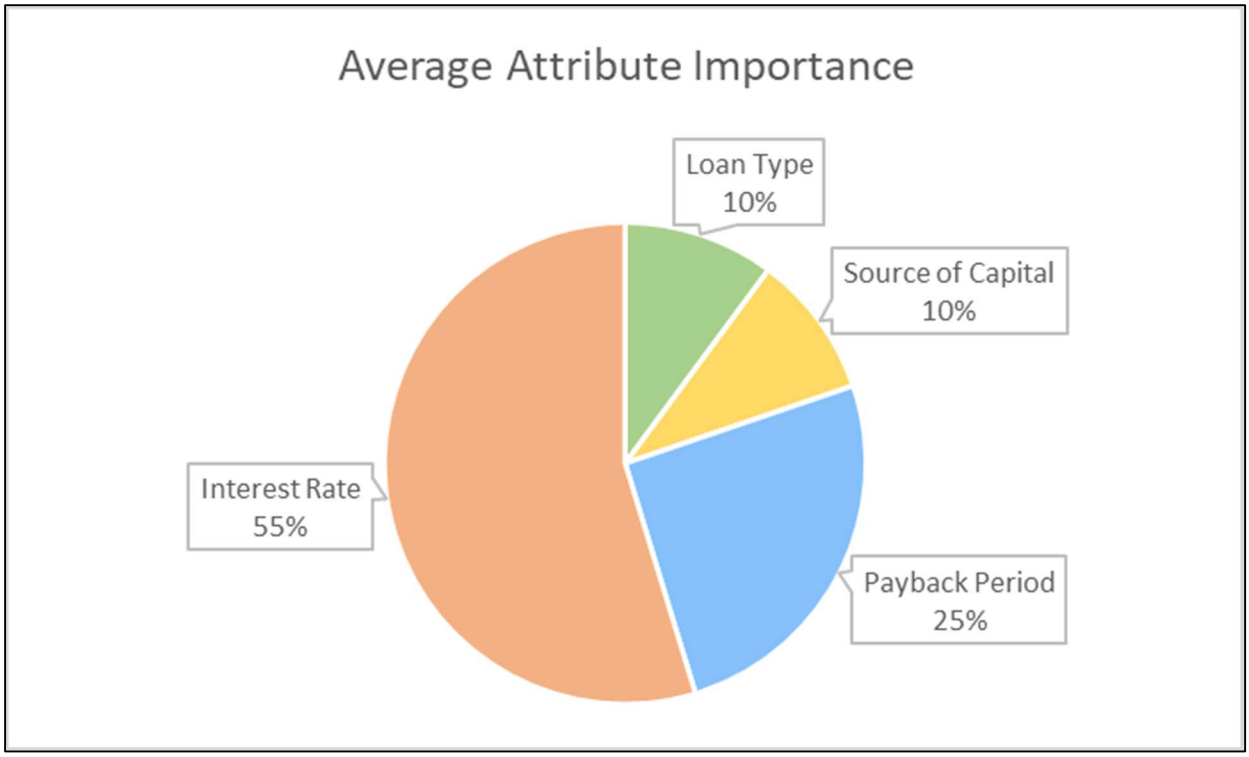

Figure 3. Average Attribute Importance

The most important attribute considered when selecting a financing program is the loan's **interest rate.** Average utility decreased with higher rates. The high comparative mean utility for levels representing low rates means that this preference was a common pattern throughout the surveyed population. This data derived from the HB model supports the research hypothesis that **interest rate** would be the most important attribute and that participants would intuitively prefer lower rates.

Latent Class

A latent class analysis was run on the data so that attribute utilities could be examined when adjusted for population population segments with different preferences. Although relevant metrics CAIC and percent certainty both become better with higher group

segmentation, it was decided that the more-segmented groups failed to engender substantial, distinct consumer preference characteristics, instead begetting seemingly redundant segments. Instead, a more simple segmentation (2-group) was selected to represent the *loan loving* and *loan averse* segments within the respondent population. The *loan averse* segment showed a strong preference for the “none” option within the choice tasks. Compared to the total population mean utilities, this *loan averse* group also favored private lender funded programs and shorter loan terms. The *loan loving* segment exhibited a strong aversion to the “none” option. They also showed slight comparative favorability to longer loan terms relative to the combined group (Figure 4).

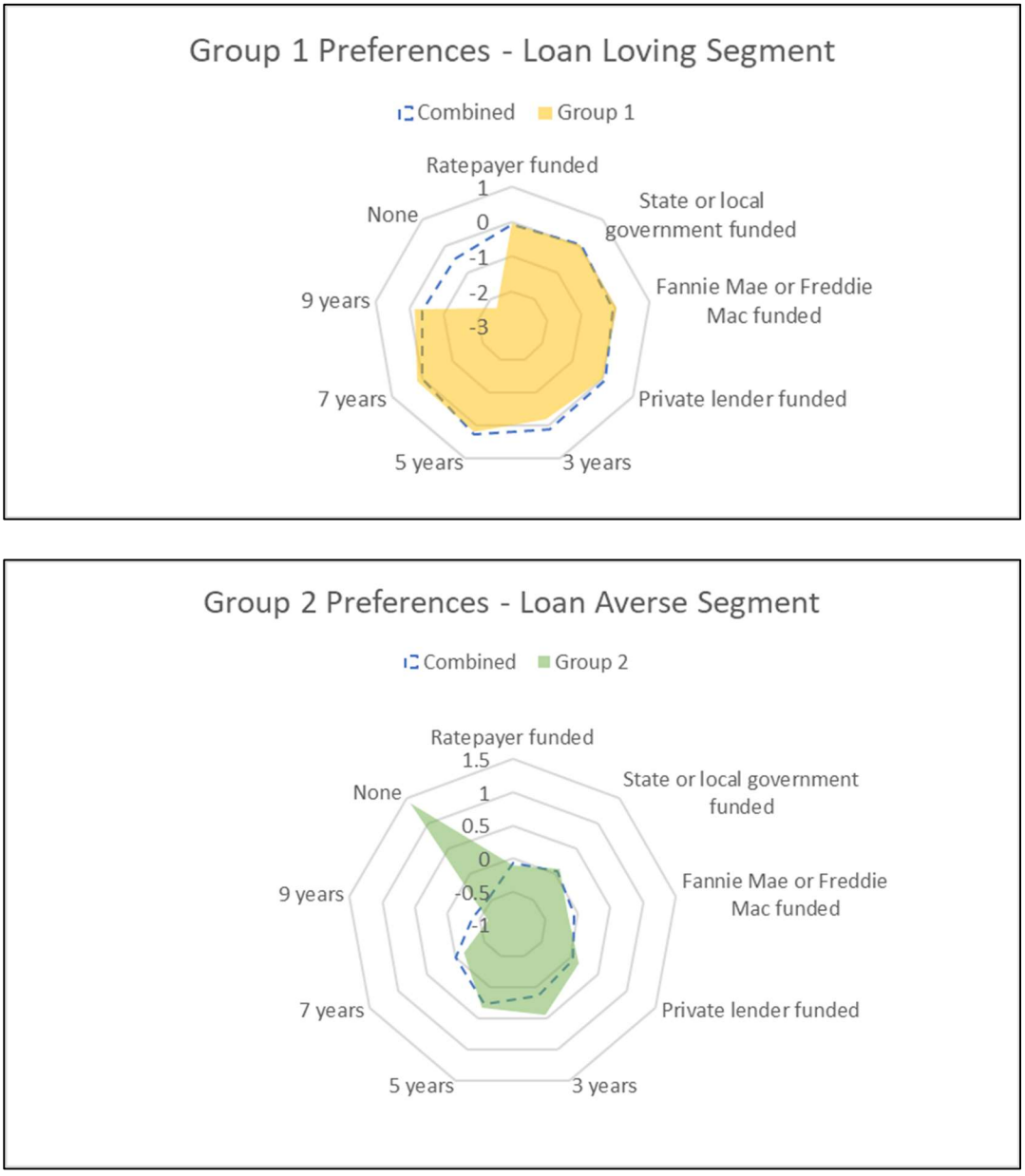

Figure 4. Attribute Preferences by Loan Loving and Loan Averse Customer Segments

Lighthouse Studio allows for data filtration by variables established in the simple survey. This allowed for exploration into correlation between respondent socio-demographic data and their distribution into either *loan loving* or *loan averse* segments. Political

views, beliefs concerning climate change, attitude towards energy efficiency—none of these factors appears to correlate strongly with placement in either segment. However, inclusion in these segments does appear to correlate with income level (Figure 5).

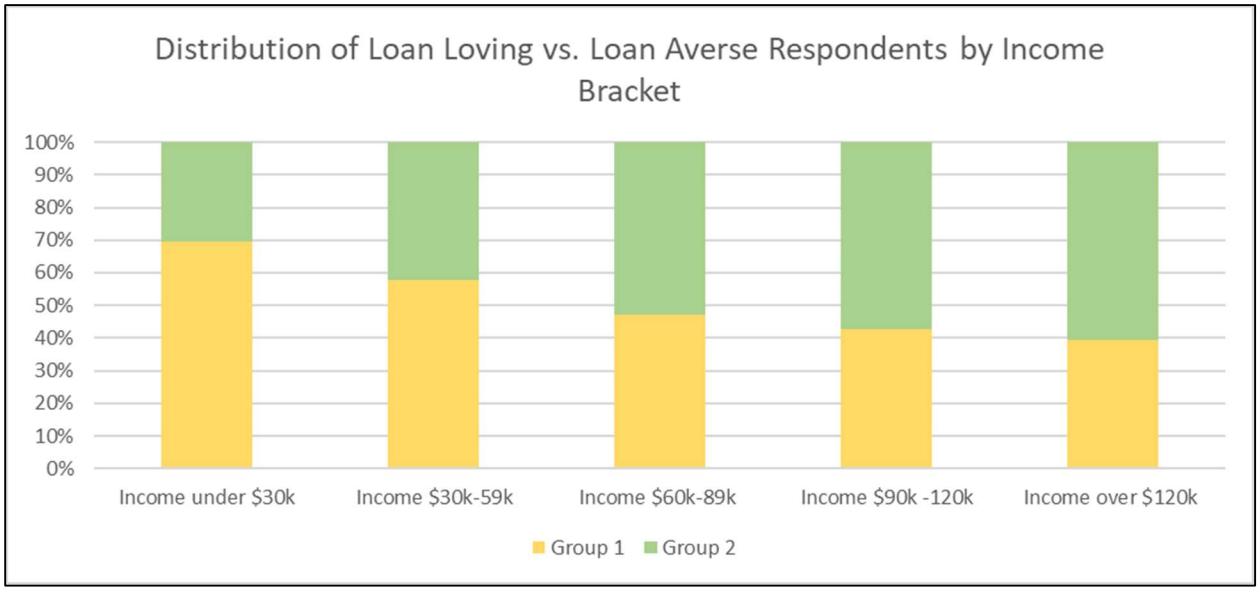

Figure 5. Distribution of Loan Loving vs Loan Averse Respondents by Income Bracket

Experimental Bias

Sample populations on Prolific are not necessarily representative of the larger population being studied.

The survey contained a concept check that explained how liens are used to secure loans. Since “lien” was mentioned in one of the attribute levels, respondents may have viewed this particular level negatively. HB and logit analysis showed it to have the lowest utility score within its attribute.

Discussion

Alignment with Hypotheses

The results from the HB model largely align with the hypotheses. **Interest rate** was anticipated as being the most important attribute when choosing a financing program. The average utilities calculated for **payback period** were surprising as the 5- and 7-year amortization periods were seen as preferable to the longer 9-year period. Even the 3-year loan was shown to be comparatively preferable to the 9-year loan. Longer loan periods will accrue more overall interest, yet they often provide the borrower with the flexibility to either pay it off early or make regular minimum payments over the long timeframe.

Case Study Comparisons: Which Loan Would be the Best Fit?

Home equity and consumer loans were seen as comparatively preferable attributes along with private and state/local funding. Based on this information, the AFC First Corporation Keystone Home Energy Loan Program and Efficiency Vermont Home Performance loan programs would be most favorable to this respondent group, using the case studies listed in Table 2.

Case Study 1: AFC First Corporate Keystone Home Energy Loan Program

Started in 2006, the Keystone Home Energy Loan Program (HELP) offered both secured and unsecured options. The unsecured loan charged a marginally higher interest rate. The other option was a mortgage-secured loan. (Fuller, 2009) The CBC experiment results indicate that both combinations of loan attribute levels would be popular with borrowers; however, the HELP home equity-secured loan was primarily

designed for financing large projects with a maximum loan amount of $35,000 and a loan term of 10 years at 6.4%–8.9%. For a $6,000 air-conditioning system project, the unsecured loan would likely be more attractive with slightly higher (~9%) but comparable interest rates and flexible payback periods of 3, 5, and 10 years (Fuller, 2009).

The program described above halted in 2014 due to a lack of funding. It was revitalized in 2016 through the support of secondary loan market funding, partnering public and private capital. The new program offered $20,000 for unsecured loans with loan repayment terms of 5, 7, and 10 years and fixed interest rates typically between 5% and 8% (Renew Financial, 2016; Leventis, Fadrhonc, Kramer, & Goldman, 2016). This program initially operated off funds from the State Treasury of Pennsylvania; however, the revitalized program adopted a turnkey financing protocol in an attempt to attract private investors' interest (Leventis, Fadrhonc, Kramer, & Goldman, 2016; Renew Financial, 2016).

Case Study 1: Policy Implications

Whether publicly or privately funded, the program's attribute profile aligns with the consumer preferences revealed by the CBC experiment. It should be noted that a treasury-funded loan program in the Southeast might face comparable funding issues if it were to rely solely on public backing. As such, similar programs should be designed to attract private capital early, and eventually transition to lending primarily through private sector partners. A similar loan could be appealing to both *loan loving* and *loan averse* segments as it would offer flexible payback periods

Case Study 2: Efficiency Vermont Home Performance Loan

Per Fuller, the Efficiency Vermont's Home Performance with ENERGY STAR Loan Program started in 2006 (Fuller, 2009). Efficiency Vermont's loan program is operated by the not-for-profit Vermont Energy Investment Corporation (VEIC), but funding is provided through private lenders (ILSR, 2021). The Vermont State Employee Credit Union(VSECU) was historically the most active financing partner. The lending institution is tasked with processing the loan application. Efficiency Vermont then subsidizes the interest rate if the homeowner's proposed efficiency measures are approved (Fuller, 2009). Fuller notes that around $250 is spent per loan in administrative fees. Another $670 is paid in subsidy to lower the borrower's interest rate. The lender is charged with underwriting and servicing the loan (2009). Although loanable capital is provided by private lenders, the operation of Efficiency Vermont is paid for through an energy efficiency charge (EEC) included on consumer electric bills (ILSR, 2021).

Securitization of the loan is flexible, largely depending on the lender. All three of the attribute levels for **loan type** are available securitization measures within this program, with the larger loans requiring asset backing. Home equity can be used for these larger loans—likely the favorable option based on the CBC data.

Even if the respondent chose to finance the entire 100% of project costs presented in the scenario, the maximum loan amount of $20,000 would suffice (Efficiency Vermont, 2021). Efficiency Vermont also offers various loan terms of up to 15 years. For clients with an annual household income beneath 60,000, the program's subsidized interest rates range from 0% to 3%. The interest rates least subsidized, for annual household incomes of over 90,000, can range from 5% to 7% (Efficiency Vermont, 2021).

Case Study 2: Policy Implications

The Efficiency Vermont Home Performance loan program's key features all correspond to attribute levels found to have high utility shares with Southeastern homeowners. Furthermore, if implemented like Efficiency Vermont, with subsidized interest rates for low-income households, the program could mitigate the energy burden experienced by the poor in Georgia, South Carolina, and North Carolina. Based on the latent class analysis controlling for income, there was a higher incidence of *loan loving* behavior amongst lower income respondents. Couple this with the subsidized interest rates--a program based on the Efficiency Vermont model could be successful in promoting EE within a low-income consumer base.

The largest obstacle would be getting the state to create and fund an operating body like Efficiency Vermont. Considering how unpopular ratepayer funding was for loan capital, there would be expected pushback if the regulated utilities in GA, SC, or NC began charging an EEC to cover program costs.

Conclusion

Room for Improvement in Future Research

The CBC experimental design elements were primarily built on existing energy efficiency loan program research. Unfortunately, the most thorough works archiving these programs are from 2009-2012 when interest rates were considerably higher than those of today. Based on this and the desire for the **interest rate** attribute to be representative of excellent credit home equity loans as well as poor credit private loans, the chosen attribute levels are 4%, 8%, 12%, and 16%. Future experiments based on this research might find it useful to condense this range to be representative of contemporary low interest rates offered.

The CBC experiment tested within this research project was designed to optimize the efficiency of measuring attribute main effects. Future work on this topic should explore two-way effects between attributes with greater accuracy. This can be done by increasing attribute level overlap within choice tasks, which is achieved through several methods[1].

Another improvement would be to increase the sample size. If future experiments are published on Prolific, the scope should be expanded to include neighboring Southeastern states, increasing the eligible participant pool.

[1] The number of product concepts can be increased so that attribute levels might repeat within each choice task, with overlap within an attribute guaranteed when the number of product concepts is greater than number of levels within said attribute. The design could instead be generated using the *random* or *balanced overlap* methods instead of the *complete enumeration* used to generate the design in this research project.

Contribution

The goal of this research was to measure consumer preferences for EE loan program attributes within a scenario designed to realistically model how homeowners would react when presented with various financing programs at once. The application of CBC analysis in this manner represents a novel approach that differs from prior implementation by attempting to maximize the realism of the consumer-concept interaction (Opinion Dynamics, 2017). Ideally, the results from this experiment might inform business and policy approaches to EE finance, increasing the rate of consumer adoption as well as tailoring the program features to accommodate vulnerable population groups.

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Appendices

Appendix A: Primary Survey Questions

Q0. Please enter your Prolific ID:

[open text response]

Q1. What US state do you currently live in?

- Georgia
- North Carolina
- South Carolina
- Other

Q2. What type of property do you live in?

- Apartment/Flat (purpose built block)
- Apartment/Flat (converted within other property type such as house)
- Terraced house or townhouse
- Semi-detached house (shares one wall with another home)
- Detached house
- Other
- Not applicable

Q3. Do you own the property that you live in?

- I own the property I live in
- I live in privately rented accommodation
- I live in social housing or affordable-rented accommodation

- Prefer not to say
- Not applicable

Q4. How many years have you been living in your current home?

[open text response]

Q5. As a percentage, estimate the probability that you will change primary residences in the next 5 years? For example: 0% means that there is no chance that you will move in the next 5 years

- Definitely would not (0%)
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Definitely would (100%)

Q6. What type of air-conditioning system is used in your home?

- Air-conditioning system without a heat pump (only provides cooling)
- Air-conditioning system with a heat pump (can provide heating and cooling)
- Don't use an air-conditioning system

Q7. How old is your central air-conditioning equipment?

- o Less than 2 years old
- o 2 to 4 years old
- o 5 to 9 years old
- o 10 to 14 years old
- o 15 to 19 years old
- o 20 or more years old
- o Don't know

Q8. Is your home's current air-conditioning system adequate at providing cooling for your living space?

- o Yes
- o No

Q9. To the best of your memory, please estimate your average monthly electricity bill ($/month) for each of the four seasons.

	Under $50	$50-$74	$75-$99	$100-$124	$125-$149	$150-$174	$175-$199	$200-$224	$225+	Don't know	
Winter	O	O	O	O	O	O	O	O	O	O	($/Month)
Spring	O	O	O	O	O	O	O	O	O	O	($/Month)
Summer	O	O	O	O	O	O	O	O	O	O	($/Month)
Fall	O	O	O	O	O	O	O	O	O	O	($/Month)

Q10. In selecting an air-conditioning system for your home, was energy efficiency:

- o Not important

- Somewhat important
- Important
- Don’t know

Q11. Consider a situation where you would be purchasing a new air-conditioning system for your home. A high efficiency model would be more expensive than a standard efficiency model. But over time, total energy savings from the high efficiency model would exceed the extra expense paid for it. What is the maximum period of time that you would be willing to wait for this payback on your energy efficiency investment?

- Willing to wait less than 1 year
- Willing to wait up to 1 year
- Willing to wait up to 2 years
- Willing to wait up to 3 years
- Willing to wait up to 4 years
- Willing to wait up to 5 years
- Willing to wait up to 6 years
- Willing to wait up to 7 years
- Willing to wait longer than 7 years
- Don’t know

Q12. The following portion of the survey involves the financial concept of a lien. To better help you understand it in the context of this survey, you will be provided a definition and tested for comprehension.

A lien is a legal claim that is placed on property assets to secure the payment of a debt. A lien can be placed on real estate, on installed fixtures, or on other assets not attached to the property.

True or False: A creditor might use a lien to secure payment of debts from a borrower?

- True
- False

Q13. Consider the following scenario as if you were actually living it.

You are looking to replace your home's current air-conditioning system with a more efficient unit. You specifically want a heat pump unit which can be used for both heating and cooling your home. It is fully electric, and it is one of the most energy efficient devices on the market. You decide to get a quote from a contractor for the equipment and installation.

The contractor states that the unit which would best compliment your living space will cost $6,000. This price includes the equipment and the professional installation. After providing the quote you requested, the contractor tells you that several financing programs are available for energy efficiency projects like this planned air-conditioning system upgrade. The first decision that you need to make is to decide how much of the $6,000 cost you would like to finance. The contractor mentions that customers typically choose one of these three options:

	Option 1	Option 2	Option 3
	Fully self-funded, no financing	2/3 of costs financed	Fully Financed, no upfront payment
Upfront cost	$6,000	$2,000	$0
Amount financed	$0	$4,000	$6,000

Based on the information that the contractor has provided, how would you prefer to pay for this $6,000 project? Please consider this choice as if you were actually making this decision in your real life. For example: if you choose to finance 0% of the project costs, would you have $6,000 readily available for this purchase?

- 0% financed; $6,000 paid upfront
- 66.6% (2/3rds) financed; $2,000 paid upfront
- 100% financed; $0 paid upfront

Q14. 66.6% financed CBC experiment.

You have selected to pay $2,000 and finance the other $4,000 of project costs. The contractor is now going to present you with 2 loan programs at a time. Each loan program will be defined by four attributes: loan type, source of capital, payback period, and interest rate. You will also be shown what the expected monthly payment would be for each loan program. This calculated payment is based on the amount you chose to finance, the loan's interest rate, and the loan's payback period. Of course, the loan could be paid off before the payback period is over. Let the contractor know which program you prefer on each screen. There will be 15 screens shown consecutively. If you prefer neither, you can choose Option 3.

The respondent was then presented with 15 different choice tasks with a header reading:

When purchasing a high efficiency air-conditioning system for $6,000, you decide to finance 66.6% ($4,000) of the project costs. If these were the only financing programs available, which would you choose?

Q15. 100% financed CBC experiment.

You have selected to pay $0 and finance the entire $6,000 project. The contractor is now going to present you with 2 loan programs at a time. Each loan program will be defined by four attributes: loan type, source of capital, payback period, and interest rate. You will also be shown what the expected monthly payment would be for each loan program. This calculated payment is based on the amount you chose to finance, the loan's interest rate, and the loan's payback period. Of course, the loan could be paid off before the payback period is over. Let the contractor know which program you prefer on each screen. There will be 15 screens shown consecutively. If you prefer neither, you can choose Option 3.

The respondent was then presented with 15 different choice tasks with a header reading:

When purchasing a high efficiency air-conditioning system for $6,000, you decide to finance 100% ($6,000) of the project costs. If these were the only financing programs available, which would you choose?

Q16. 0% financed open-text response. Please explain why you chose this answer.

[open text response]

Q_Scenario_Conclusion. If you were faced with the previous scenario in real life, would you actually be interested in replacing your existing air-conditioning system with a more efficient model? If so, would you consider financing any portion of the project costs?

[open text response]

Q17. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. Do you think that global warming is happening?

- Yes
- No
- Don't know

Q18. Assuming global warming is happening, do you think it is… ?

- Caused mostly by human activities
- Caused mostly by natural changes in the environment
- None of the above because global warming isn't happening

Q19. How worried are you about global warming?

- Not at all
- Only a little
- A moderate amount
- A great deal
- Don’t know

Q20. How much do you support or oppose the policy of funding more energy efficiency programs?

- Strongly support
- Somewhat support
- Neither support nor oppose
- Somewhat oppose
- Strongly oppose

Q21. Of the provided categories, which would best describe your political beliefs?

- Liberal Democrat
- Moderate/ Conservative Democrat
- Independent/ Other
- Liberal/ Moderate Republican
- Conservative Republican
- Not willing to disclose

Q22. What is your age, in years?

[open text response]

Q23. What is your sex?

- Male
- Female
- Not willing to disclose

Q24. Please select one of the descriptions below corresponding to the ethnic group with which you identify.

- Hispanic or Latino
- White
- Black or African American
- Native Hawaiian or Pacific Islander
- Asian
- Native American or Alaska Native
- Two or more races
- Not willing to disclose

Q25. What is your estimated total household income in the past 12 months from all sources of income? Report amount before deductions for taxes, bonds, and dues. For income from self-employment, report NET income after business expenses.

- Income under $30k
- Income $30k-59k
- Income $60k-90k

- Income over $90k
- Income over $120k

Q26. What is your FICO score (as of the last time you checked)?

- Very low credit score (under 550)
- Low credit score (551-625)
- Medium credit score (626-699)
- Good credit score (700-725)
- Excellent credit score (726 and above)
- Do not know credit score

Appendix B: Prolific ID

Since the survey was published on Prolific, the individual Prolific identification number (PID) had to be captured to properly align responses with completed submission. This PID had to be input on the initial screen of the survey per the crowdsourcing host site's rule (Prolific, 2021).