PREDICTING THE PROBABILITY OF CONVERSION TO NATURAL GAS IN THE FAIRBANKS NORTHSTAR BOROUGH

By

Jordan M. Hume, B.B.A.

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of

Master of Science
in
Resource and Applied Economics

University of Alaska Fairbanks
May 2017

APPROVED:

Dr. Christopher Wright, Committee Member

Dr. Joshua Greenberg, Committee Member

Dr. Joseph Little, Committee Chair, Department Chair
MS Resource and Applied Economics Program Director

Dr. Mark Herrmann, *Dean School of Management*

Dr. Michael Castellini, *Dean of Graduate School*

ABSTRACT

In 2013 a phone survey was conducted for Northern Economics Inc. by Ivan Moore Research Group, with the goal of determining the willingness of households in the Fairbanks North Star Borough to convert their residence to natural gas. This paper provides an analysis of prior household discrete choice experiments involving energy usage. Probit regression is used to determine the probability of conversion given different levels of household income, payback period, cost of conversion, and annual saving associated with conversion, in addition to these variables three statistically significant attitudinal variables are included. Marginal effects and elasticities are presented and interpreted. Findings are congruent with past research and indicate that to maximize the conversion rate of households, the cost of conversion needs to be minimized or, if possible, subsidized and the annual level of saving maximized. Initial results suggest conversion cost is weighed more heavily than annual savings.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACKNOWLEDGEMENTS

I would like to thank Camilla Kennedy and the staff at the Alaska Department of Environmental Conservation for research and funding support. I would also like to extend my gratitude to Northern Economics who generously provided the data used in this analysis. The work was supported by the Alaska Department of Environmental Conservation Grant # 10989. Any errors or omissions are the sole responsibility of the author.

1 INTRODUCTION

The Fairbanks North Star Borough (FNSB) located in the interior of Alaska has a recurring air quality problem. A large proportion of this problem is attributed to the use of woodstoves during winter months of extreme cold. Of the households surveyed 1.4% reported using wood as their primary heat source while, 20.4% had a wood heat as a secondary option (Northern Economics, 2013). Extreme cold creates an inversion layer, the combination of wood smoke and the inversion layer leads to high concentrations of PM 2.5 a fine particulate classified as an air pollutant. This area is frequently classified as a non-attainment area; meaning the air quality is so poor that it has adverse health effects on anyone exposed to the air. One way to reduce the high levels of PM2.5 is to provide residents an alternative, efficient heat source that does not give off PM2.5 as a byproduct of use. In the case of the FNSB this alternative fuel is natural gas. To gauge public opinion and determine the viability of offering natural gas to households in the FNSB a telephone phone survey was conducted by Ivan Moore Research Group for Northern Economics, a local Economic consulting firm, which was then provided to the Interior Gas Utility (IGU).

Data analyzed in this paper comes from a 2013 survey of 787 households spanning zip codes 99701, 99705, 99709, 99712 and 99714 in the FNSB. According to the 2010 census these five zip codes have a combined population of 86,644 residents living in 34,187 households and of those 34,187 households 21,398 are owner occupied. The primary purpose of the survey was to determine the probability of households converting their residential heat system to natural gas if it became available. The survey was conducted over the phone, consisted of 21 questions not including sub questions, and took approximately 16 minutes to complete. The interviewer also asked questions concerning primary and secondary heat systems, annual expenditures on home heating, the age of the primary heating system, participation in the Alaska Housing Finance Corporation Home Energy Rebate and Weatherization Program, interest in natural gas service for the residence, willingness to convert to natural gas conditioned on different conversion-cost/annual saving scenarios, opinion questions concerning the environment, interest in residential natural gas, structure characteristics, and socio-demographic information concerning the respondent and their respective household (Northern Economics, 2013).

The objective of this analysis is to determine the probability of a residence converting to natural gas using actual and imputed datasets. The extrapolation of actual responses allows for the creation of an imputed data set, this data set triples the amount of observed responses creating a larger sample population, this larger population provides relatively higher impacts on every aspect of the analysis.

The econometric method of probit regression is used to analyze both actual and imputed survey responses. In addition to this, factor variables, marginal effects, and elasticities concerning natural gas conversion with varying levels of conversion cost, annual saving, total household income and reasonable payback period are examined. Empirical results indicate there is an inverse relationship between conversion cost and the probability of conversion, and a positive relationship between annual saving, total household income, reasonable payback period and the probability of conversion for both probit regression models.

2 LITERATURE REVIEW

When a household is provided with the opportunity to use a new fuel source for home heating there are multiple variables that influence the decision of adopting a new appliance to provide heat. Human behavior is complex at both the individual and market setting (Bhattacharjee et al., 1993). Arguably the most important variable is the trade-off between the cost of installation and the savings associated with switching to a new appliance, e.g., natural gas fueled boiler. Different income groups will weigh this initial investment differently, the manner in which they weigh it is their individual discount rate. Another factor to consider is the amount of usage the appliance is projected to receive along with environmental impacts associated with use. Different age groups value characteristics differently, e.g., the environment, payback period, and energy price have different values to different demographics.

The primary focus of this paper is to conduct an analysis of residential household heat systems based on fuel type in the FNSB. When applying discrete choice models to residential energy demand, the discrete choice refers to the selection of energy-using equipment (Nesbakken, 2001). By providing a better choice for heat, social welfare increases. An increase in energy efficiency for an area should be a social objective because having a warm house is considered a basic need (Tovar, 2012).

Residential energy is a significant component of energy demand in the developed world. Residential space heating accounts for a large portion of energy demand (Michelsen and Madlener, 2012). The use of heating, cooling, lighting, refrigeration and other appliances accounts for a fifth of US energy demand (Fischer, 2005). In the United Kingdom residential energy usage contributes 30% to total consumption, 58% of which is used to generate heat (Tovar, 2012). If a household can reduce the amount they spend on household energy they can improve their quality of life and spend these savings on another activity, e.g., travel or recreation. Consumption decisions over time are "investment" decisions involving a tradeoff between current and future consumption (Bhattacharjee et al., 1993).

The cost-savings trade-off for a new appliance forces consumers to decide if it is in their best interest to purchase a new appliance. Every household in Alaska utilizes some form of heat. The two most important aspects of any household energy model use: 1.) the purchase price of the appliance and 2.) the operating cost which determines the units of final energy demand for the household (Hausman, 1979). Given the broad array of appliances that can be installed to provide heat to a household the market for these appliances offers substantial possibilities for trade-offs between purchase and operating costs (Kooreman, 1995). A byproduct of increased efficiency in a household appliance is an increase in the frequency of use the appliance experiences due to a lower marginal cost. Improvements in thermal characteristics are expected to increase the intensity with which the associated appliances are used, and will thereby attenuate some of the expected conservation from higher efficiencies (Dubin et al., 1986). If a household uses a considerable amount of energy to heat the residence it should be assumed that the household would switch given marginal savings. Households with a high demand for utilization are more likely to purchase energy-efficient durable goods and thus have a lower marginal cost of utilization (Davis, 2008).

Different heat sources result in different costs and benefits to the owner. For instance, heating oil and natural gas are capital intensive and produce CO_2 and SO_2 as a byproduct of combustion while a woodstove is time consuming and emits $PM_{2.5}$. Results indicate that none of the assessed technologies outperforms the others in every impact category, and trade-offs need to be made between impacts (Ekholm et al., 2014). This should drive consumers to focus on efficiency, an energy efficient appliance reduces the marginal operating cost of the service delivered (Dubin et al., 1986). This implies that consumers should readily adopt new, more efficient appliances as this will increase their overall welfare. Observations indicate that this is not the case. Increase in energy efficiency measures by British household has had slow growth (Tovar, 2012). Individuals appear to treat out-of-pocket expenses as more "painful" losses than the opportunity cost (potential but uncaptured gains) associated with an investment decision (Bhattacharjee et al., 1993). Gains and losses are weighted differently, with gains being outweighed by losses. This is magnified by the discount rates associated with income level.

In theory, a consumer discount rate should be equal to the cost of acquiring capital, e.g., the interest rate on a loan or credit card. This has been found to not be the case with the purchase of large durable items. Net present value is the present discounted value of the difference between total savings from, initial and operating costs of, pursuing a conservation measure for the life of the measure (Bhattacharjee et al., 1993). Prior studies indicate consumers assign appliances discount rates ranging from 20% (Hausman, 1979), 15% (Kooreman, 1995), and 10% (Corum and O'Neal, 1982). Discount rates vary inversely with income. Economic theory implies that the discount rate should decrease as income rises, even with perfect capital markets, since marginal tax rates rise with income while the services of consumer durables are untaxed (Hausman, 1979). This lack of correlation implies that consumers add additional factors into their decision making process. Results from earlier studies suggest the returns required on energy efficient investments are much higher than the expected capital market rate of return due to information barriers, particularly the operating cost of a durable good (Kooreman, 1995). This disconnect of rational behavior has been called “defective telescopic faculty”. In other words, a simple fact emerges that in making decisions which involve discounting over time, individuals behave in a manner which suggests a much higher discount rate than can be explained in terms of the opportunity cost of funds available in credit markets (Hausman, 1979). High discount rates can be attributed to the slow adoption of new energy efficient technologies.

Income, education, and sociodemographic factors have also been found to play an important role in whether or not a household will adopt new technology. Income is the most significant factor. Results suggest a negative relationship between the discount rate and the respondent’s level of income and a higher discount rate for women as compared to men (Kooreman, 1995). Households on the lower end of the income distribution self-impose the highest discount rate when it comes to purchasing a new appliance. Given the uncertainty of their income streams and their lack of savings, we would expect a high discount rate for this part of the population (Hausman, 1979). Households with less disposable income prefer appliances with lower upfront costs and which in turn lead to higher operating costs (Fischer, 2005). High-income households have been found to exhibit higher energy price elasticity and to be more sensitive to energy prices than low income households.

The level of education obtained by the head of a household influences the manner in which the household uses residential energy for heating purposes. Higher levels of education have been associated with energy efficient technology adoption and energy conservation (Mills and Schleich, 2012). This may be in part due to the positive relationship between education and income. The “warm glow” effect may also contribute to this link. University education increases the stated importance of energy savings for greenhouse gas reductions and decreases the stated importance for financial reasons (Mills and Schleich, 2012).

Household composition plays a major role in the adoption of energy efficient appliances. Adopters of gas-fueled and oil-fired condensing boilers with solar thermal support have a strong preference for energy savings, while adopters of a heat pump or wood pellet-fired boiler prefer being more independent from fossil fuels (Michelsen and Madlener, 2012). Middle-aged households should be the most likely to adopt capital-intensive energy efficiency measures (Mills and Schleich, 2012). It has also been found that households with young children are more likely to adopt energy-efficient technologies and energy conservation practices and place primary importance on energy savings for environmental reasons (Mills and Schleich, 2012). Younger households tend to prefer up-to-date technology, which is more energy efficient but they may be more likely to move which makes them less inclined to invest in energy improvements (Mills and Schleich, 2012). If a younger household planned to stay in a dwelling they would be able to capture a large amount of savings from the initial investment. Older household heads may be less likely to adopt energy efficient technologies because the expected rate of return is lower (Mills and Schleich, 2012). Lower adoption of energy efficient technologies by elder households may also interact with the cohort's fewer years of formal education, and lower levels of information on energy savings measures (Mills and Schleich, 2012). Households with a high share of elderly members place more importance on financial savings and have lower levels of technology adoption, energy conservation and knowledge about household energy use (Mills and Schleich, 2012).

The two best methods for increasing the conversion rate of residential heating systems to energy efficient, environmentally friendly appliances are; 1.) changing public policy and 2.) providing feedback to the public involving the health benefits associated with conversion. Different technological choices will have multiple environmental impacts, these impacts are often external to the decisions over technological alternatives, thus additional incentives need to be placed through policy in order to abate the negative externalities (Ekholm et al., 2014). To encourage more efficient appliance purchases, policy makers implement appliance standards, building codes and rebates or subsidies for buying energy-efficient equipment (Bernstein and Collins, 2014). If feedback to consumers is provided with easy to understand, frequent, interactive, and customized information, there is a chance consumers will use less energy, which means lower energy costs for consumer and fewer emissions in the future (Bernstein and Collins, 2014).

3 ANALYSIS

3.1 DATA DESCRIPTION

The survey data collected by Ivan Moore Research on behalf of Northern Economics Inc. includes multiple observations for each respondent which indicates if they are willing to convert to natural gas under different combinations of conversion costs and annual energy expenditure savings.

By transposing the data, each individual respondent could be treated as a unique set of observations, making it possible to control for individual heterogeneity in the analysis. Following the approach taken by Northern Economics, survey response data was reformatted so there are 24 observations for each respondent. In actuality, each respondent did not see all 24 potential combinations (Northern Economics, 2013). To account for this, separate models are estimated using actual and imputed responses. Imputed responses are extrapolated from actual responses, e.g., if a person said "no" to annual saving of $1,000 and conversion cost of $4,000, it is assumed that they would also say "no" to conversion costs of $8,000, $12,000 and $16,000 and annual saving of $500 holding the other variable constant. The imputed data set fills in the blank cost/saving scenarios which were not actually asked, given stated responses. There are a total of four separate conversion cost levels ($4,000, $8,000, $12,000, $16,000) and six annual savings levels ($500, $1,000, $1,500, $2,000, $2,500, and $3,000). In instances where the respondent indicated a "maybe" to a cost/savings combination they were removed from the analysis.

Noting there are 24 separate observations for each respondent in the predicted model the modelling approach relaxes the assumption of independence between each response. In actuality asked scenarios ranged from 4 to 10 for each respondent.

Three attitudinal variables are also incorporated into the models. Respondents were asked how converting to natural gas would affect their home value, if gas makes a home more attractive and if it would help air quality in their area. Responses to each question used the Likert Scale and had 5 possible answers: "Strong disagree" (1), "Mild disagree" (2), "Neutral" (3), "Mild agree" (4), and "Strong agree" (5). For the purpose of this paper each answer was coded from 1 to 5 respectively.

Total household income and reasonable payback period are represented as categorical variables (see Tables 1-4):

Table 1: Total Household Income Categories

Total Household Income	Category
$0 - $20,000	1
$20,000 - $40,000	2
$40,000 - $60,000	3
$60,000 - $80,000	4
$80,000 - $100,000	5
$100,000 - $150,000	6
$150,000 +	7

Table 2: Reasonable Payback Period Categories

Reasonable Payback Period	Category
3 years or less	1
4 to 5 years	2
6 years or more	3

Table 3: Descriptive Statistics for Actual Responses

Actual VARIABLES	(1) mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	0.464	0	0.499	0	1
Annual Saving	1,727	1,500	884.2	500	3,000
Conversion Cost	9,726	8,000	4,345	4,000	16,000
Total Household Income	4.6	5	1.6	1	7
Reasonable Payback Period	1.9	2	0.7	1	3
Increase Home Value	3.8	4	1.2	1	5
Gas Makes Home Attractive	4.2	4	1	1	5
Help Air Quality	4.3	5	0.9	1	5
N = 787					

Table 4: Descriptive Statistics for Imputed Responses

Imputed VARIABLES	(1) mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	0.464	0	0.499	0	1
Annual Saving	1,749	1,500	854.2	500	3,000
Conversion Cost	10,013	12,000	4,476	4,000	16,000
Total Household Income	4.5	5	1.6	1	7
Reasonable Payback Period	1.9	2	0.7	1	3
Increase Home Value	3.7	4	1.2	1	5
Gas Makes Home Attractive	4.1	4	1	1	5
Help Air Quality	4.2	5	1	1	5
N = 787					

3.2 PROBIT REGRESSION MODELS

The binary design of probit regression produces results for the dependent variable a one or zero. In the context of this paper a value of y = 0 represents "will not convert" and y = 1 represents "will convert".

$$\Pr\ (0,1) = \begin{cases} y = 0 \\ y = 1 \end{cases} \tag{1}$$

The model used to predict the probability of conversion to natural gas given a respondent's response to the survey is:

$$Y_i = \alpha_i + \beta_i Savings_{it} + \beta_i Cost_{it} + \beta_i Income_{it} + \beta_i Payback_{it} + \beta_i IncHomeVal_{it} + \beta_i GasAttract_{it} + \beta_i HelpAirQual_{it} + e_i + u_I \tag{2}$$

The dependent variable Y_i indicates the probability of a household converting to natural gas from another type of primary heating fuel. Alpha (α_i) is the constant found in the regression model, $Savings_{it}$ is the level of savings and, $Cost_{it}$ is the actual cost of conversion. The variable $Income_{it}$ represents the household income category to which the household belongs and the variable $Payback_{it}$ represents the period of time the respondent is willing the wait to recoup the initial conversion costs. The payback period is the point at which the sum of annual savings is equal to the cost of conversion. $IncHomeVal_{it}$, $GasAttract_{it}$ and $HelpAirqual_{it}$ represent the three attitudinal response questions gauging the respondent's opinion concerning how converting to natural gas will affect home value, the attractiveness of a gas home and if it will help air quality. The variables "e_i" and "u_i" represent errors inherent in the models. The "e_i" error term occurs due to the heterogeneity of respondents. Not all people are the same so they will have different thresholds for costs and savings. The "u_i" error term reflects that the models will not be able to take everything into account and the relationship between independent and dependent variables are not perfectly explained by the model.

The significance level each variable is denoted by an *. A single * means the coefficient is found to be significant at the 10% significance level, ** means the coefficient is found to be significant at the 5% significance level, and *** means the coefficient is found to be significant at the 1% significance level. Any coefficient without an * behind is as not significantly different from zero. The positive (negative) sign of a coefficient is interpreted as a positive (negative) effect on the probability of conversion.

4 RESULTS

Table 5 shows the impact independent variables have on the dependent variable (probability of conversion) for actual and imputed datasets.

Table 5: Probit Regression Model

VARIABLES	(1) Actual	(1) Imputed
Conversion Cost	-0.000116***	-0.000189***
	(5.24e-06)	(3.47e-06)
Annual Saving	0.000291***	0.000698***
	(2.50e-05)	(1.71e-05)
Total Household Income	0.03***	0.07***
	(0.01)	(0.008)
Reasonable Payback Period	0.54***	0.68***
	(0.03)	(0.02)
Increase Home Value	0.09***	0.11***
	(0.02)	(0.01)
Gas Makes Home Attractive	0.04*	0.06***
	(0.02)	(0.01)
Help Air Quality	0.07***	0.15***
	(0.02)	(0.01)
Constant	-1.6***	-2.47***
	(0.13)	(0.09)
Observations	4,968	14,456

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Both models show an inverse relationship between conversion cost and the probability of conversion. Annual saving, total household income, and reasonable payback period show a positive relationship to the probability of conversion. These findings coincide with prior research concerning consumer consumption of appliances. The negative sign on the constant is interpreted as consumer's behaving in a "sticky" manner and not wanting to convert. This could be attributed to the hassle associated installing a new primary source of heat, among other outside factors. Independent variables are found to be significant at the one percent significance level. The imputed model exhibits relatively higher values concerning the impact of each variable on conversion.

4.1 FACTOR VARIABLES

Factor variables allow reference to a set of indicator variables based on categorical variables. The use of factor variables allows for the creation of expanded probit regression models (see Table 6).

Table 6: Expanded Probit Regression Model

VARIABLES	(1) Actual	(2) Predicted
Conversion Cost		
$4000	-	-
$8000	-0.76***	-0.97***
	(0.05)	(0.03)
$12000	-1.14***	-1.66***
	(0.05)	(0.03)
$16000	-1.36***	-2.23***
	(0.06)	(0.04)
Annual Saving		
$500	-	-
$1000	0.49***	0.61***
	(0.06)	(0.04)
$1500	0.47***	0.9***
	(0.06)	(0.04)
$2000	0.91***	1.3***
	(0.07)	(0.04)
$2500	0.75***	1.5***
	(0.07)	(0.04)
$3000	0.73***	1.79***
	(0.07)	(0.05)
Total Household Income		
$0 - $20,000	-	-
$20,000 - $40,000	0.21*	0.54***
	(0.12)	(0.08)
$40,000 - $60,000	0.22*	0.48***
	(0.11)	(0.07)
$60,000 - $80,000	0.26**	0.52***
	(0.11)	(0.07)
$80,000 - $100,000	0.23**	0.53***
	(0.11)	(0.07)
$100,000 - $150,000	0.3***	0.58***
	(0.11)	(0.07)
$150,000 +	0.4***	0.86***
	(0.11)	(0.07)

Reasonable Payback Period		
3 years or less	-	-
4 – 5 years	0.62***	0.77***
	(0.05)	(0.03)
6 years or more	1.17***	1.45***
	(0.06)	(0.04)
Constant	-0.68***	-1.16***
	(0.12)	(0.08)
Observations	4,968	14,456

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The expanded probit regression model uses factor variables to explain the impact of each level of each independent variable using the lowest level as the base. The imputed probit continues to exhibit relatively higher importance expressing a higher probability of conversion. Conversion cost, annual saving and reasonable payback period are still significant at the 1% significance level. Actual response data indicates that as total household income increases, income becomes more significant. An increase in annual saving from $1,500 to $2,000 causes a substantial increase in the probability of conversion for actual respondents. The constant is similar to the initial model and reinforces the idea people are not comfortable with change.

4.2 MARGINAL EFFECTS

Marginal effects show how movement between levels changes the probability of conversion. A negative sign means the shift will decrease the probability of conversion holding all else equal. A positive sign indicates the shift leads to an increase in the probability of conversion holding all else equal. To determine how a shift in a variable will affect the model, move up or down each matrix using the horizontal axis as the starting point and the new value on the vertical axis. For example, an increase in conversion cost from $4,000 to $16,000 leads to a decrease in the probability of conversion equal to 46.1%.

By combining marginal effects from conversion cost with annual saving, total household income and reasonable payback period the corresponding graphs provide a clear representation of how a change in one or both variables will impact the conversion rate. The vertical axis provides a range of 0 to 1, translated to represent predicted conversion. A "1" represents 100% conversion and "0.5" represents a 50% conversion rate. The margin of error for each combination is represented by the range on each point moving vertically up and down from the point on the horizontal line. Predictive margins for each graph are categorized at the 5% significance level. The horizontal axis indicated the level of annual saving, total household income or reasonable payback period. Each possible conversion cost is depicted by a line graph. A circle represents conversion cost of $4,000, a square represents conversion cost of $8,000, a triangle represents conversion cost of $12,000 and a diamond represents conversion cost of $16,000. Each increase in conversion cost leads to a decrease across all graphs, this decrease shifts each line down reflecting the decrease of respondent interest given increased costs to convert. An increase in annual saving, total household income and reasonable payback period leads to an increase in all graphs, this is depicted by the positive slope of each line.

4.2.1 CONVERSION COST

Table 7: Actual Conversion Cost Marginal Effects

Actual Response Cost	(1) $4000	(2) $8000	(3) $12000	(4) $16000
$4000	-	0.25***	0.39***	0.46***
		(0.01)	(0.01)	(0.01)
$8000	-0.25***	-	0.13***	0.2***
	(0.01)		(0.01)	(0.01)
$12000	-0.39***	-0.13***	-	0.07***
	(0.01)	(0.01)		(0.01)
$16000	-0.46***	-0.2***	-0.07***	-
	(0.01)	(0.01)	(0.01)	
Observations	4,968	4,968	4,968	4,968

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Imputed Conversion Cost Marginal Effects

Imputed Cost	(1) $4000	(2) $8000	(3) $12000	(4) $16000
$4000	-	0.25***	0.46***	0.6***
		(0.008)	(0.008)	(0.008)
$8000	-0.25***	-	0.2***	0.35***
	(0.008)		(0.009)	(0.009)
$12000	-0.46***	-0.2***	-	0.14***
	(0.008)	(0.009)		(0.009)
$16000	-0.6***	-0.352***	-0.147***	-
	(0.008)	(0.009)	(0.009)	
Observations	14,456	14,456	14,456	14,456

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 ANNUAL SAVING

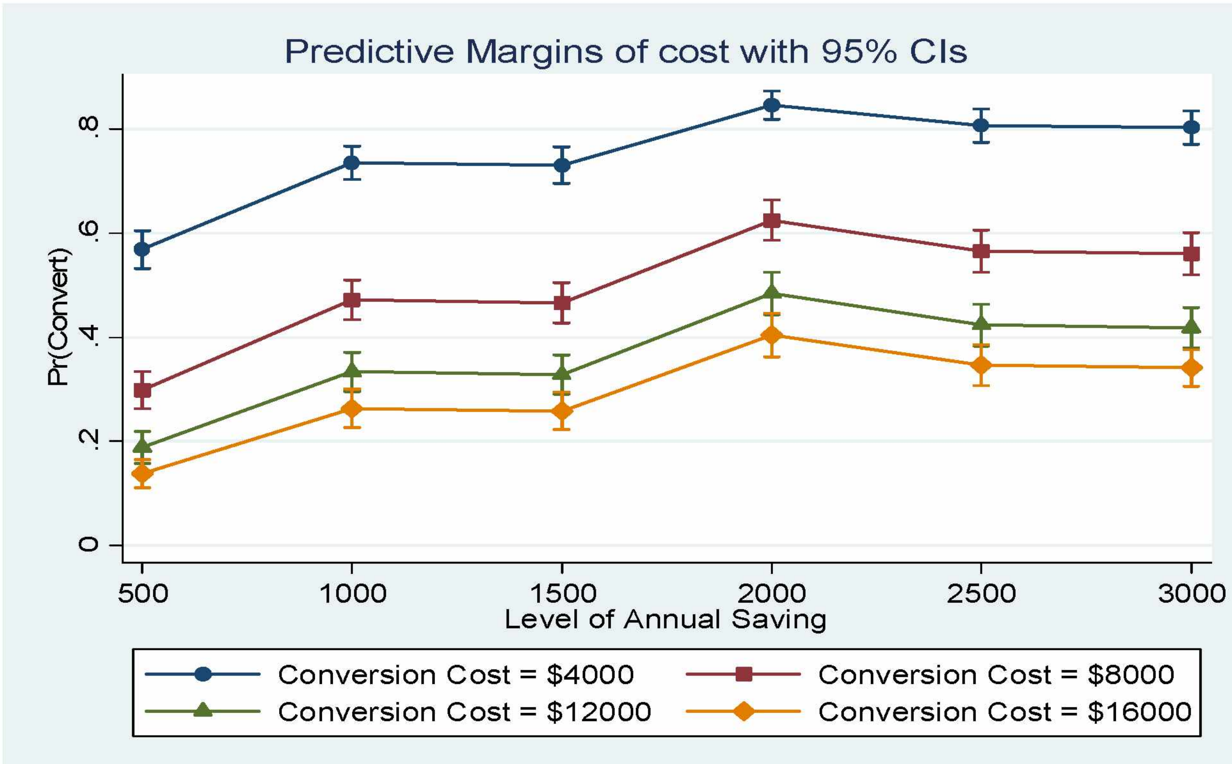

Figure 1: Actual Probability of Conversion Given Conversion Cost and Annual Saving

Table 9: Marginal Effects of Actual Annual Saving

Actual Response Saving	(1) $500	(2) $1000	(3) $1500	(4) $2000	(5) $2500	(6) $3000
$500	-	-0.15***	-0.15***	-0.3***	-0.24***	-0.24***
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$1000	0.15***	-	0.01	-0.14***	-0.08***	-0.08***
	(0.02)		(0.02)	(0.02)	(0.02)	(0.02)
$1500	0.15***	-0.01	-	-0.14***	-0.09***	-0.08***
	(0.02)	(0.02)		(0.02)	(0.02)	(0.02)
$2000	0.3***	0.14***	0.14***	-	0.05**	0.06***
	(0.02)	(0.02)	(0.02)		(0.02)	(0.02)
$2500	0.24***	0.08***	0.09***	-0.05**	-	0.01
	(0.02)	(0.02)	(0.02)	(0.02)		(0.02)
$3000	0.24***	0.08***	0.08***	-0.06***	-0.01	-
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	
Observations	4,968	4,968	4,968	4,968	4,968	4,968

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

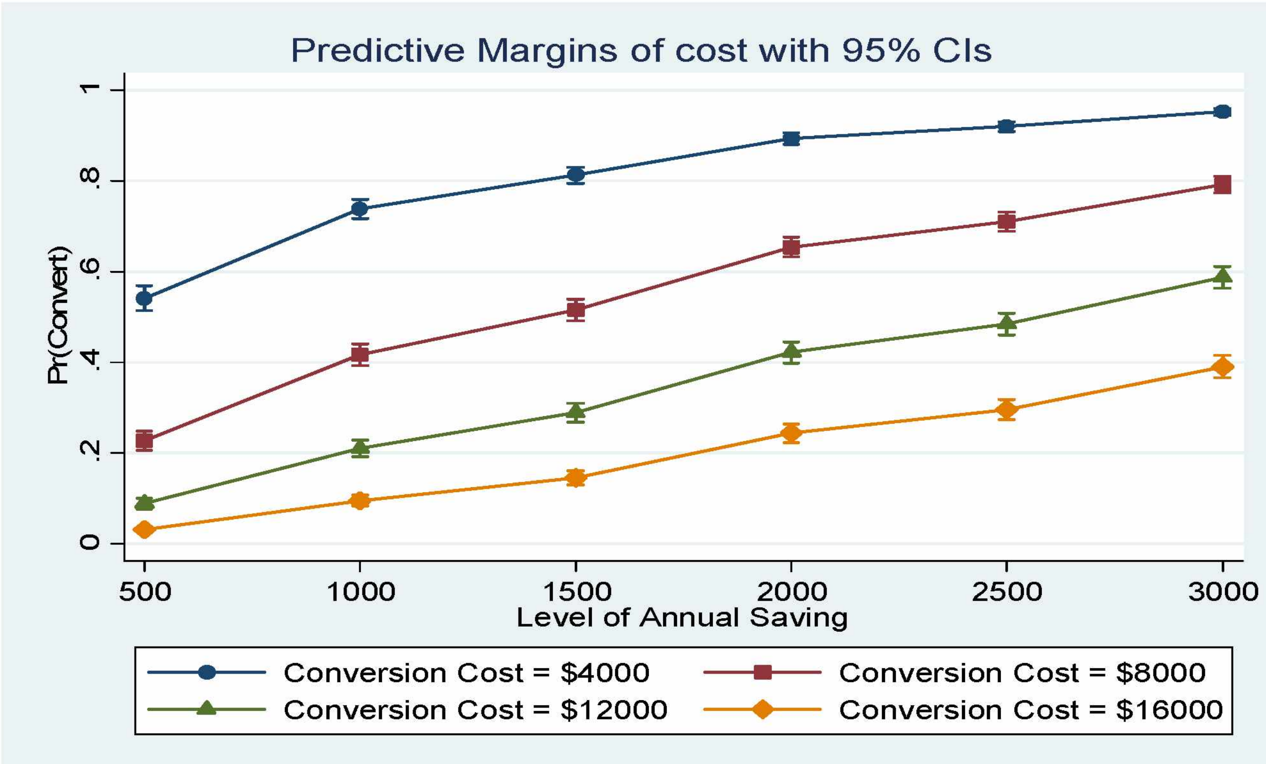

Figure 2: Imputed Probability of Conversion Given Conversion Cost and Annual Saving

Table 10: Marginal Effects of Imputed Annual Saving

Predicted Saving	(1) $500	(2) $1000	(3) $1500	(4) $2000	(5) $2500	(6) $3000
$500	-	-0.14***	-0.21***	-0.33***	-0.37***	-0.45***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$1000	0.14***	-	-0.07***	-0.18***	-0.23***	-0.31***
	(0.01)		(0.01)	(0.01)	(0.01)	(0.01)
$1500	0.21***	0.07***	-	-0.11***	-0.16***	-0.23***
	(0.01)	(0.01)		(0.01)	(0.01)	(0.01)
$2000	0.33***	0.18***	0.11***	-	-0.04***	-0.12***
	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)
$2500	0.37***	0.23***	0.16***	0.04***	-	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)		(0.01)
$3000	0.45***	0.31***	0.23***	0.12***	0.07***	-
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Observations	14,456	14,456	14,456	14,456	14,456	14,456

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.2.3 TOTAL HOUSEHOLD INCOME

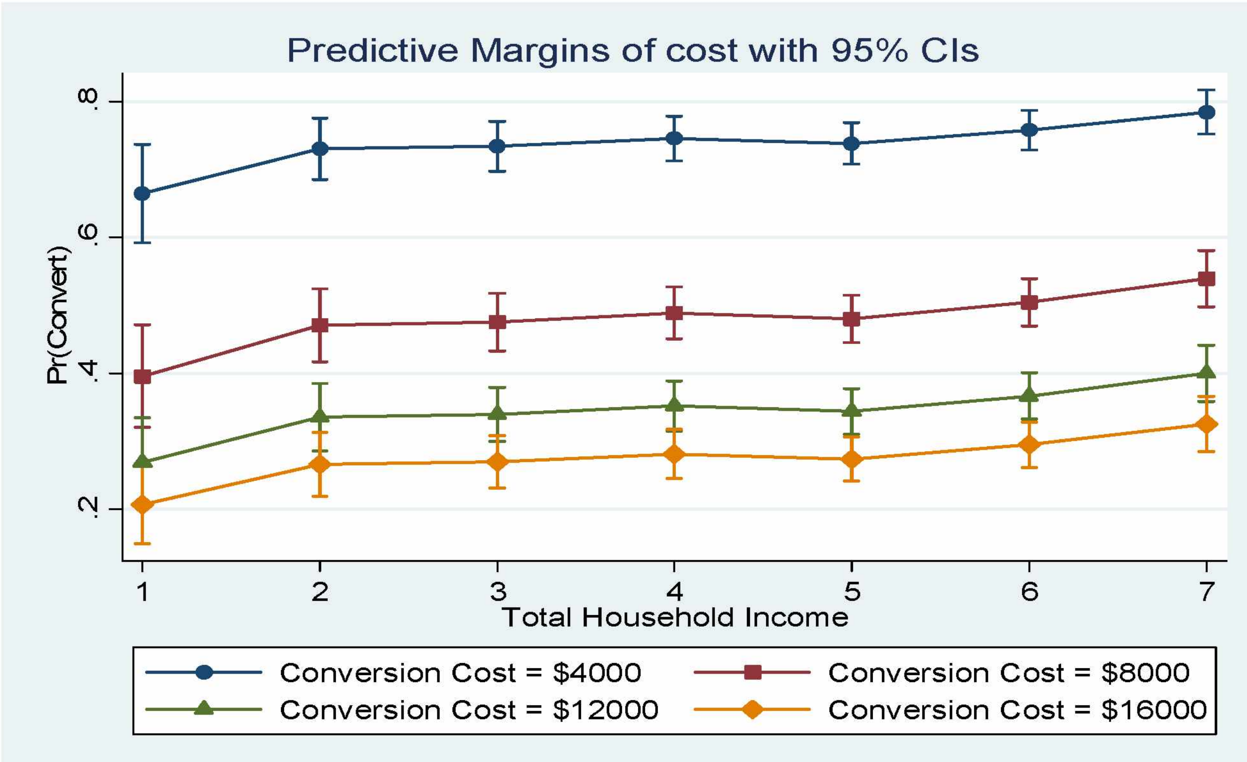

Figure 3: Actual Probability of Conversion Given Conversion Cost and Level of Household Income

Table 11: Marginal Effects of Actual Total Household Income (thousands of dollars)

Actual Response	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total Household Income	$0 - $20	$20 - $40	$40 - $60	$60 - $80	$80 - $100	$100 - $150	$150 +
$0 - $20,000	-	-0.07*	-0.07*	-0.08**	-0.07**	-0.1***	-0.13***
		(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
$20,000 - $40,000	0.07*	-	-0.004	-0.01	-0.008	-0.03	-0.06**
	(0.04)		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$40,000 - $60,000	0.07*	0.004	-	-0.01	-0.004	-0.02	-0.06**
	(0.03)	(0.02)		(0.02)	(0.02)	(0.02)	(0.02)
$60,000 - $80,000	0.08**	0.01	0.01	-	0.008	-0.01	-0.04**
	(0.03)	(0.02)	(0.02)		(0.02)	(0.02)	(0.02)
$80,000 - $100,000	0.07**	0.008	0.004	-0.008	-	-0.02	-0.05**
	(0.03)	(0.02)	(0.02)	(0.02)		(0.01)	(0.02)
$100,000 - $150,000	0.1***	0.03	0.02	0.01	0.02	-	-0.03
	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)		(0.02)
$150,000 +	0.13***	0.06**	0.06**	0.04**	0.05**	0.03	-
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	
Observations	4,968	4,968	4,968	4,968	4,968	4,968	4,968

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

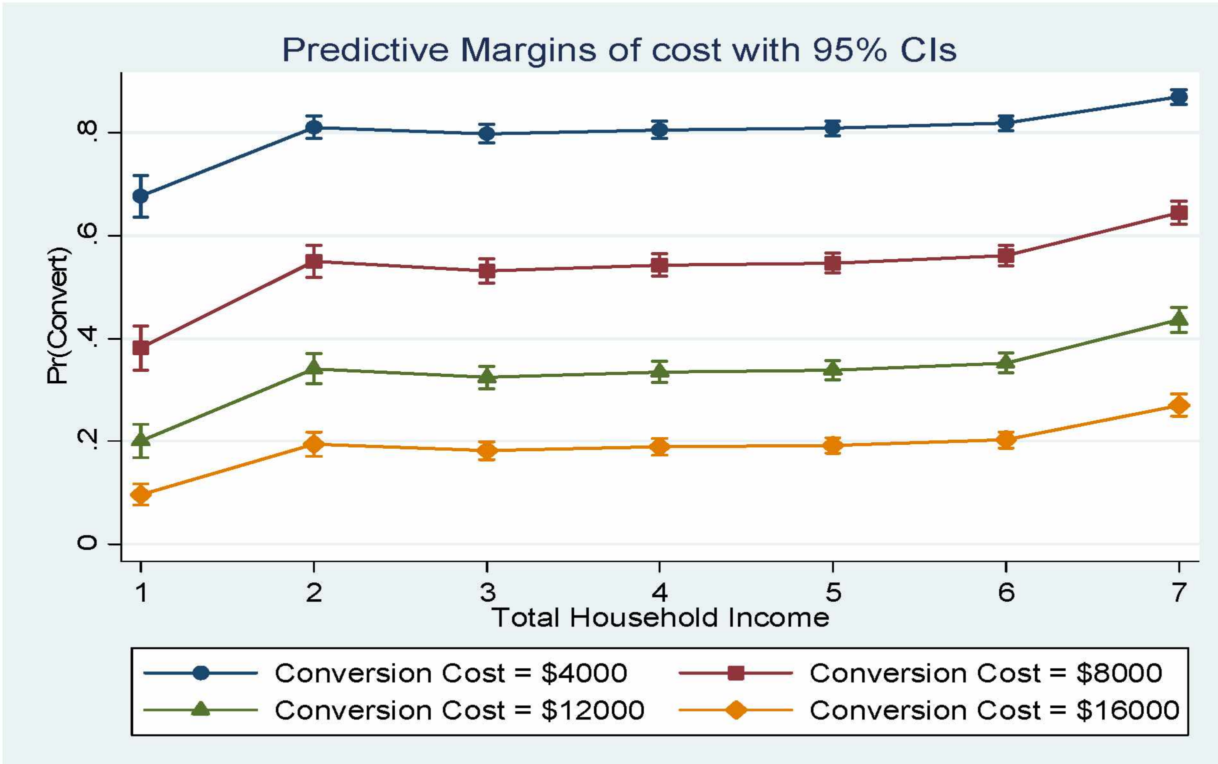

Figure 4: Imputed Probability of Conversion Given Conversion Cost and Level of Household Income

Table 12: Marginal Effects of Imputed Total Household Income (thousands of dollars)

Predicted Total Household Income	(1) $0 - $20	(2) $20 - $40	(3) $40 - $60	(4) $60 - $80	(5) $80 - $100	(6) $100 - $150	(7) $150 +
$0 - $20,000	-	-0.13***	-0.11***	-0.12***	-0.13***	-0.14***	-0.21***
		(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$20,000 - $40,000	0.13***	-	0.01	0.005	0.002	-0.009	-0.08***
	(0.02)		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$40,000 - $60,000	0.11***	-0.01	-	-0.009	-0.012	-0.02**	-0.09***
	(0.01)	(0.01)		(0.01)	(0.01)	(0.01)	(0.01)
$60,000 - $80,000	0.12***	-0.005	0.009	-	-0.003	-0.01	-0.08***
	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)	(0.01)
$80,000 - $100,000	0.13***	-0.002	0.01	0.003	-	-0.01	-0.08***
	(0.01)	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)
$100,000 - $150,000	0.14***	0.009	0.02**	0.01	0.01	-	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)		(0.01)
$150,000 +	0.21***	0.08***	0.09***	0.08***	0.08***	0.07***	-
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Observations	14,456	14,456	14,456	14,456	14,456	14,456	14,456

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.4 REASONABLE PAYBACK PERIOD

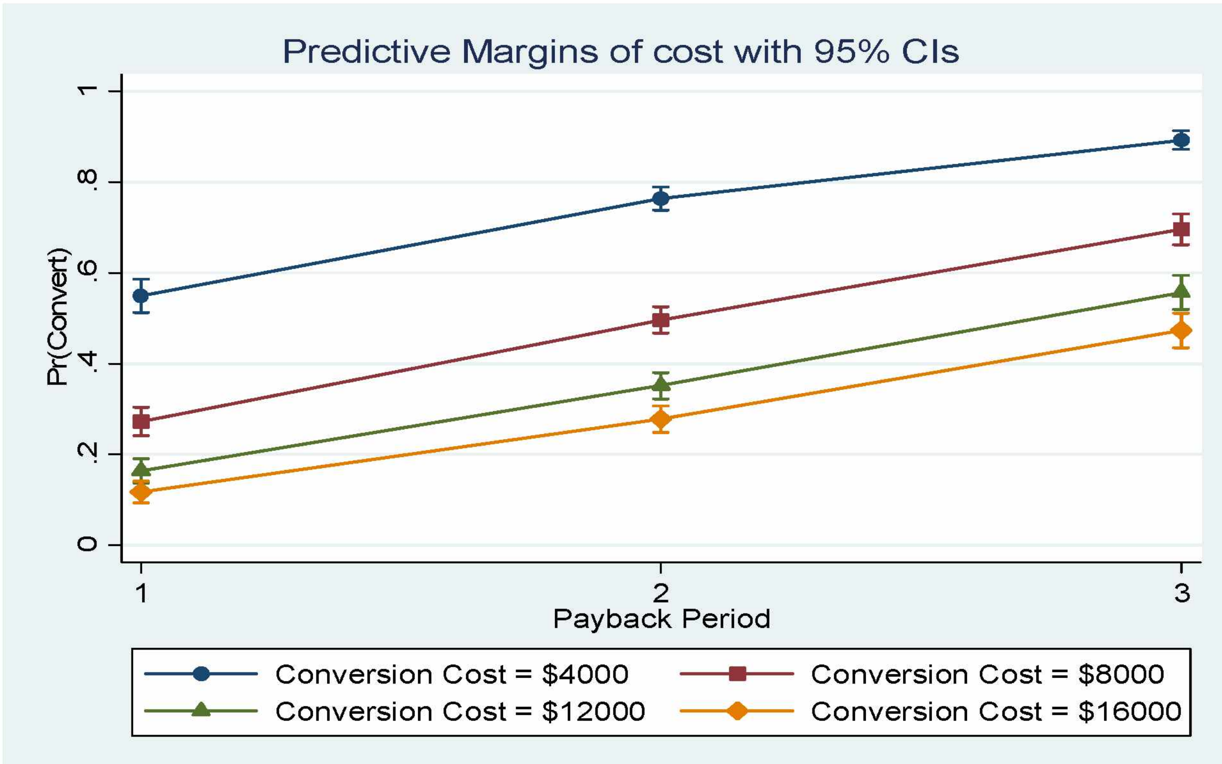

Figure 5: Actual Probability of Conversion Given Conversion Cost and Reasonable Payback Period

Table 13: Marginal Effects of Actual Reasonable Payback Period (in years)

Actual Response Reasonable Payback Period	(1) > = 3	(2) 4 - 5	(3) 6 = <
3 years or less	-	-0.2*** (0.015)	-0.39*** (0.0185)
4 – 5 years	0.2*** (0.015)	-	-0.18*** (0.015)
6 years or more	0.39*** (0.018)	0.18*** (0.015)	-
Observations	4,968	4,968	4,968

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

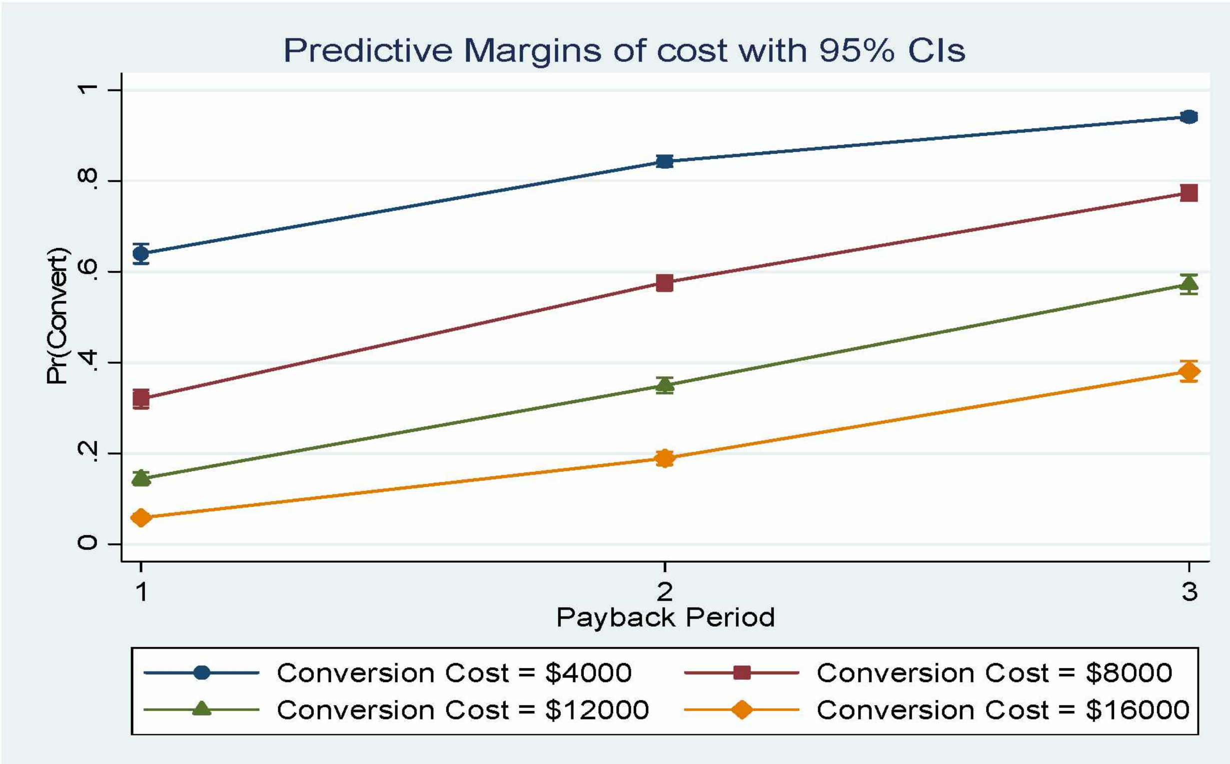

Figure 6: Imputed Probability of Conversion Given Conversion Cost and Reasonable Payback Period

Table 14: Marginal Effects of Imputed Reasonable Payback Period (in years)

Predicted Reasonable Payback Period	(1) >=3	(2) 4 - 5	(3) 6=<
3 years or less	-	-0.19***	-0.37***
		(0.007)	(0.009)
4 – 5 years	0.19***	-	-0.17***
	(0.007)		(0.008)
6 years or more	0.37***	0.17***	-
	(0.009)	(0.008)	
Observations	14,456	14,456	14,456

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 ELASTICITY

Elasticity provides a method to determine how a change in an independent variable impacts the dependent variable. If there is an elasticity of 1, a 1% change in the independent variable causes a 1% change the independent variable, an elasticity of 0.5 means a 1% increase in the independent variable leads to 0.5% increase in the dependent variable. For the purpose of this paper elasticities for conversion cost and annual savings with respect to the probability of conversion are calculated for both actual and imputed datasets.

$$\varepsilon lasticity = \frac{\%\ Change\ in\ Probability\ of\ Conversion}{\%\ Change\ in\ Independent\ Variable} \quad (3)$$

4.3.1 ACTUAL

Findings show a negative elasticity of -0.67 for conversion cost and a positive elasticity of 0.21 for saving at the mean value. A 1% increase in cost is associated with a 0.67% decrease in conversion, meanwhile a 1% increase in saving is associated with a 0.21% increase in conversion. Average elasticity across the sample implies a 1% increase in cost is associated with a decrease of 0.74% in conversion and a 1% increase in saving is associated with a 0.21% increase in conversion.

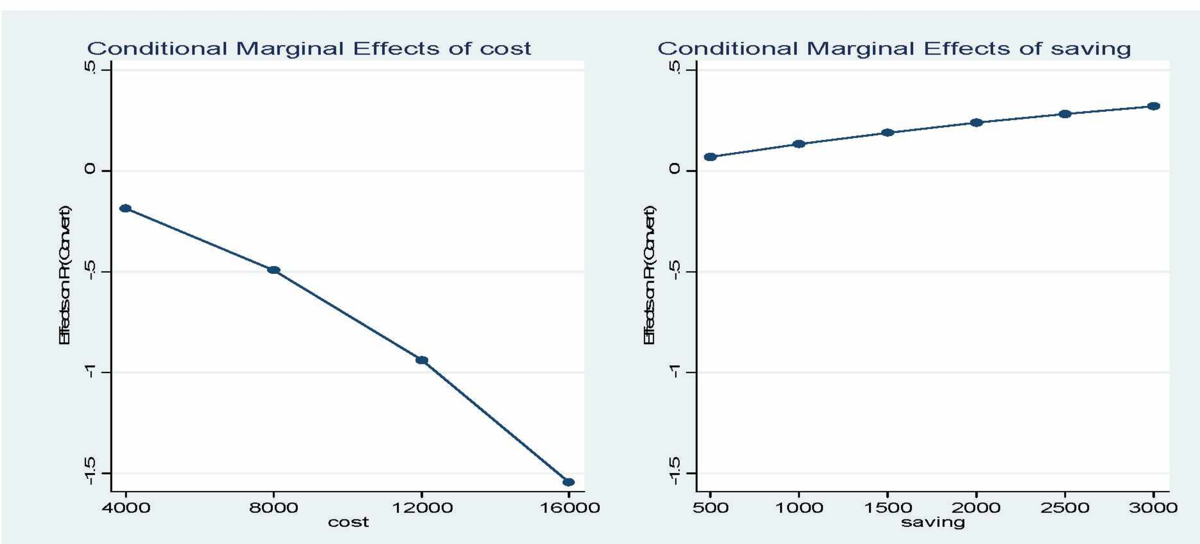

Figure 7: Elasticity of Actual Probability to Convert Given Cost and Saving Profiles

4.3.2 IMPUTED

The imputed model projects an elasticity of -1.41 for conversion cost and a positive elasticity of 0.91 for saving at the mean value. A 1% increase in cost is associated with a 1.41% decrease in conversion, while a 1% increase in saving is associated with a 0.91% increase in conversion. The average elasticity across the sample suggest a 1% increase in cost is associated with a 1.86% decrease in conversion and a 1% increase in saving is associated with a 0.83% increase in conversion.

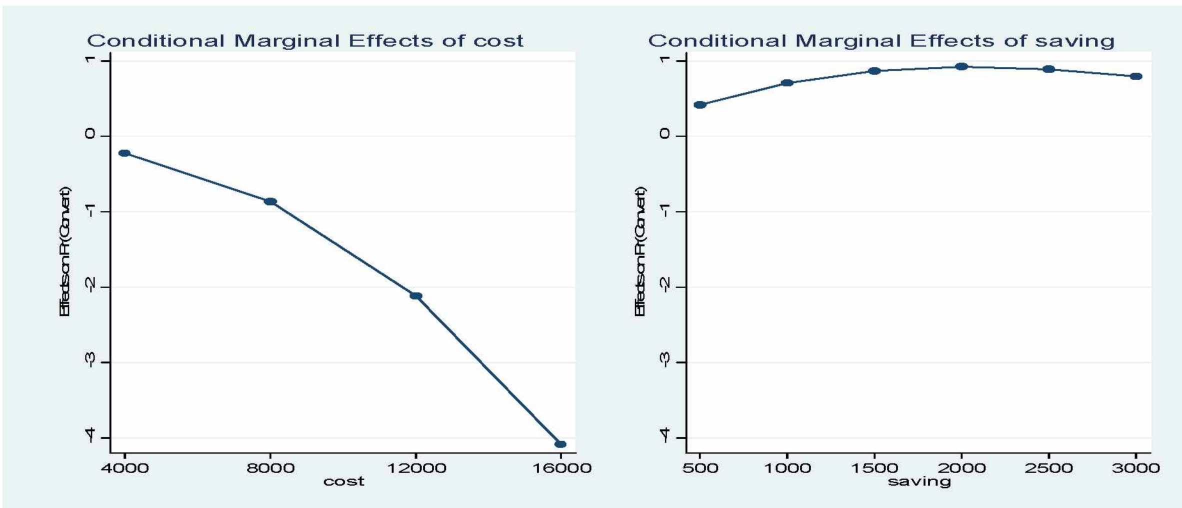

Figure 8: Elasticity of Imputed Probability to Convert Given Cost and Saving Profiles

4.4 ANALYSIS OF EXTREME SCENARIOS

Of households surveyed, 126 were asked if they would convert given the worst possible scenario, a conversion cost of $16,000 accompanied by an annual saving of $500.

Table 15: Survey Respondents asked the Worst Scenario

Worst Case VARIABLES	(1) mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	0.2	0	0.4	0	1
Total Household Income	4.7	5	1.7	1	7
Reasonable Payback Period	2.3	2	0.6	1	3
Increase Home Value	3.9	4	1.2	1	5
Gas Makes Home Attractive	4.2	4.5	0.9	1	5
Help Air Quality	4.4	5	0.8	1	5
N = 126					

Of those 126 respondents 35 (27.8%) said yes to worst option. This subset of respondents may have altruistic reasons for being willing to convert their heat to natural gas. These households may recognize the positive long term benefits associated with conversion. They may experience a “warm glow” effect caused by doing something that they believe benefits society. Both of these has been found to contribute to a respondent’s willingness to convert in prior studies.

Table 16: Survey Respondents Willing to Convert Given the Worst Scenario

“Yay-Saying” VARIABLES	(1) Mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	1	1	0	1	1
Total Household Income	4.7	5	1.9	2	7
Reasonable Payback Period	2.2	2	0.7	1	3
Increase Home Value	4.1	5	1.2	1	5
Gas Makes Home Attractive	4.4	5	0.8	2	5
Help Air Quality	4.4	5	0.8	2	5
N = 35					

Of households surveyed, 136 were asked if they would convert given the best possible scenario, a conversion cost of $4,000 accompanied by an annual saving of $3000.

Table 17: Survey Respondents asked the Best Scenario

Best Scenario VARIABLES	(1) Mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	0.6	1	0.4	0	1
Total Household Income	4.2	4	1.7	1	7
Reasonable Payback Period	1.6	1	0.7	1	3
Increase Home Value	3.3	4	1.4	1	5
Gas Makes Home Attractive	3.9	4	1.1	1	5
Help Air Quality	3.8	4	1.2	1	5
N = 136					

Of those 136 respondents 45 (33%) stated they would not be willing to convert. This suggests these people were exhibiting protest behavior, in other words they do not want to switch to natural gas. These respondents may be happy investing time instead of money in their heat source and burn wood, the intrusion of others in their house could contribute to their reluctance. They may not plan to stay in the residence for a period of time long enough for them to re-coup the cost or, they may be happy with the way things are and not feel motivated to change.

Table 18: Survey Respondents Unwilling to Convert Given the Best Scenario

"Protesters" VARIABLES	(1) Mean	(2) median	(3) sd	(4) min	(5) max
Probability of Conversion	0	0	0	0	0
Total Household Income	3.5	3	1.8	1	7
Reasonable Payback Period	1.4	1	0.6	1	3
Increase Home Value	2.6	3	1.4	1	5
Gas Makes Home Attractive	3.5	4	1.3	1	5
Help Air Quality	3.5	4	1.3	1	5
N = 45					

5 CONCLUSION

The results of this analysis corroborate past studies and show that there is an inverse relationship between conversion cost and the stated willingness of a household converting to natural gas, and there is a positive relationship between annual saving, total household income, and reasonable payback period. High income households who realize large annual savings with a longer payback period are the most likely to convert holding conversion cost constant.

To maximize the probability of residents converting to natural gas in the Fairbanks North Star Borough, annual saving need to be maximized while the cost of conversion needs to be minimized. It is interesting to note that the probit regression models using actual respondent answers appears to experience less dramatic impacts from changes in variable levels, it only explains 9.1% of the movement in the data. The probit regression using the predicted data set amplifies the impact of everything and explains 32% of the movement in the data.

Elasticities indicate consumers are more sensitive to the cost of conversion than to the annual savings associated with conversion. This reinforces past research indicating consumers will weigh initial cost more heavily than potential future savings. For the actual data set the elasticities at the means indicated a 1% increase in conversion cost has roughly the same effect as a 3% increase in annual savings.

Respondents exhibiting potential “yay-saying” and “protest” behavior provide a small subset of the sample. Some respondents have stated a desire to convert their residence to natural gas given the worst possible scenario which requires a large initial cost to convert and low annual savings. For the purpose of this study they are identified as “yay-saying”, which means respondents tell the surveyor what they think they want to hear so the survey will continue. Another motivating factor could be altruism, they want the best for their community and natural gas provides clean energy.

The subset other subset exhibited “protest” behavior, these respondents indicated they are not going to convert even if they are given the best possible scenario with minimized conversion costs and maximized saving. This implies they, dislike change, don’t want to deal with hassle of converting, and / or are against relying on a utility company to provide heat (these people may be happy burning wood in a wood stove, the largest cost for this type of behavior is the time consumed in collecting, transporting and seasoning firewood).

Further analysis was conducted and the incorporation of the three attitudinal variable was found to be significant at the 1% level. Among the questions asked these three stand out as being important to respondents. Given the recurring problem with air quality in the Fairbanks Northstar Borough, residents appear to consider natural gas a new alternative fuel source that will have a positive impact on the poor air quality. In addition to this, households recognize the value an investment in natural gas can provide to their home value which most respondents believe will benefit them in the long run. The attractiveness of natural gas was also indicated to be important to the respondent's willingness to convert to natural gas if it became available. These three attitudinal variables provide insight into factors that motivate people to indicate they are interested in converting to natural gas. Helping with air quality benefits everyone in the surrounding area improving social welfare meanwhile an increase in home value and the attractiveness of natural gas shows respondents are also motivated to act in their own self-interest.

6 WORK CITED

Bernstein, M., & Collins, M. (2014). Saving Energy Through Better Information: A New Energy Paradigm? *Contemporary Economic Policy, 32*(1), 219-229.

Bhattacharjee, V., Cicchetti, C. J., & Rankin, W. F. (1993). Energy utilities, conservation, and economic efficiency. *Contemporary Economic Policy, 11*(1).

Corum, K. R., & O'Neal, D. L. (1982). Investment in energy-efficient houses: An estimate of discount rates implicit in new home construction practices. *Energy, 7*(4), 389-400.

Davis, L. W. (2008). Durable goods and residential demand for energy and water: evidence from a field trial. *The RAND Journal of Economics, 39*(2), 530-546.

Dubin, J. A., Miedema, A. K., & Chandran, R. V. (1986). Price Effects of Energy-Efficient Technologies: A Study of Residential Demand for Heating and Cooling. *The RAND Journal of Economics, 17*(3), 310.

Ekholm, T., Karvosenoja, N., Tissari, J., Sokka, L., Kupiainen, K., Sippula, O., . . . Savolainen, I. (2014). A multi-criteria analysis of climate, health and acidification impacts due to greenhouse gases and air pollution—The case of household-level heating technologies. *Energy Policy, 74*, 499-509.

Fischer, C. (2005). On the importance of the supply side in demand-side management. *Energy Economics, 27*(1), 165-180.

Hausman, J. A. (1979). Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables. *The Bell Journal of Economics, 10*(1), 33.

Kooreman, P. (1995). Individual discounting, energy conservation, and household demand for lighting. *Resource and Energy Economics, 18*(1), 103-114.

Michelsen, C. C., and Madlener, R. (2012). Homeowners' preferences for adopting innovative residential heating systems: A discrete choice analysis for Germany. *Energy Economics, 34*(5), 1271-1283.

Mills, B., & Schleich, J. (2012). Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries. *Energy Policy, 49*, 616-628.

Nesbakken, R. (2001). Energy Consumption for Space Heating: A Discrete-Continuous Approach. *Scandinavian Journal of Economics, 103*(1), 165-184.

Northern Economics, Inc. (2013) Natural Gas in the Fairbanks North Star Borough: Results from a Residential Household Survey. Prepared for Interior Gas Utility. November 2013.

Tovar, M. A. (2012). The structure of energy efficiency investment in the UK households and its average monetary and environmental savings. *Energy Policy, 50*, 723-735.