ANALYSIS OF THE FACTORS INFLUENCING THE INSTALLATION OF SOLAR HOT WATER HEATERS IN HOMES (ENERGY, TAX CREDIT, ECONOMETRIC, PROBIT).

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ANALYSIS OF THE FACTORS INFLUENCING
THE INSTALLATION OF
SOLAR HOT WATER HEATERS IN HOMES

by

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STATEMENT BY AUTHOR

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PREFACE

Data for this paper were collected under the auspices of the Western Project W-159, "Consequences of Energy Conservation Policies for Western Households."

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I would like to thank the many individuals who aided and abetted me in this sixty or so page distillation of the pile of computer output, books and who knows what which has astonished and amazed so many who have seen the state of my roving work space. As one of these individuals more or less put it "I don't know whether to be more or less impressed with what you do."

Special thanks to my advisor Dr. Bonnie Saliba, who was always encouraging despite a multitude of corrections hidden in the pages. My gratitude and thanks to my committee members -- Dr. Carpenter, without whom there would have been no data, computer, or computer package, and Dr. Megdal, without whom there would have been no methodology or understanding thereof -- without both of whom I would never have started this particular project. Additional thanks to Dr. Iams of the School of Family and Consumer Resources who helped me obtain the 1983 data.

To the unclassifiable members of the graduate room -- some of you have passed on, some of you should have, and the rest eventually will (and I'm glad to be out of that category, though I appear to be starting over) -- thanks for the fun of it.

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ABSTRACT

Policy-makers have mandated tax incentives at both the federal and state level in order to encourage the use of solar energy for household water heating. The influence of these credits, and current energy costs, on the probability of solar installation has not been analyzed at the household level. This analysis examines the influence of education, income, the level of the tax credit, energy costs, concern about the energy problem, pro-solar attitudes, and solar radiation availability. Results indicate that energy costs and the tax credit are important factors in the decision to install solar. Individuals with more than a high school education have a higher probability of installation. Net present value analyses indicate that tax credits may be higher than necessary in several western states to encourage solar installation in all-electric homes.

CHAPTER I

INTRODUCTION

The flurry of energy legislation which occurred in the seventies was primarily a response to the oil shortages in 1974 and 1977 and the price increases they caused. The primary objectives of the legislation were to increase the security and reliability of energy supplies and to reduce non-renewable energy consumption.

Conservation tax credits were created to encourage lower levels of non-renewable energy use either through conservation or through the use of renewable sources. At the residential level the most accessible renewable source generally supported by tax credit legislation was solar energy. In 1977 the residential energy credit was established as part of the National Energy Act. That credit now stands at 40% of the cost of solar water or space heating installations, and has been an important factor in encouraging solar adoption (Carpenter and Chester 1984). In addition, forty states offer some type of financial incentive, most commonly property tax exemptions. Nineteen states offer income tax credits. A few other states offer sales and/or franchise tax exemptions (Olsen 1981).

A good deal of controversy exists over both the usefulness and cost of solar tax credits. The Reagan administration takes the position that the market should determine the structure of energy use and availability. Former administrations, as well as a number of state governments, felt that diversification through renewable sources provided insulation against supply shocks, improved the balance of payments, and created a deterrent to monopolistic pricing. Increased reliance on solar energy could also decrease the negative externalities associated with energy production. Through reduction of demand for conventional energy sources, the pollution which accompanies it could be decreased. Those opposed to tax credits emphasize that if the systems were cost-effective, people would install solar without the credit, and, if systems are not cost-effective then solar should not be supported. Those in favor of solar credits cite external benefits, and government support for the petroleum and electric industries as justification for government involvement. Critics respond that there are external costs to solar equipment including pollution from materials production. Another concern is that tax incentives take money from one tax-paying group and return it to a more select group, causing horizontal or vertical transfers of income.

Examination of the motivations which influence individuals' energy use decisions and the characteristics of those individuals who install solar energy systems allows us to determine the importance of tax credits in encouraging installation. To date, most studies of solar installation have been theoretical rather than empirical, or are not primarily economic studies. In this study regression analysis is utilized to weigh the importance of economic factors on actual cases of installation. Dummy variables are used to represent non-economic issues which may affect individuals' perception of the viability of and need for a solar system.

This analysis seeks to discover how economic factors influence the purchase of solar devices. Analyses have reported breakeven points for installation of such devices based on current energy costs, tax incentives, and system costs. Other studies have examined the knowledge and motives of individuals who have actually installed solar systems. However no previous studies have incorporated both conceptual economic factors and actual individual installation decisions.

The objectives of this study are to determine whether economic factors are important in homeowners' decisions to install solar devices and to determine what other factors come into their decision process. The primary factors considered in this study are tax credits, energy prices, income, and education. Also considered are belief in the energy crisis, awareness of tax credits, and location -- which determines available solar radiation and thus relates to system size, cost, and efficiency.

The household level data used in this study came from two nearly identical studies issued in the western states in 1981 and 1983. Price and tax credit information came from government publications and the State Income Tax Codes.

It is necessary to use a special type of regression analysis when the dependent variable is dichotomous. In this the case the dependent variable takes on a value of one when the household has installed a solar device and a value of zero when it has not. This study requires a model which will predict installation based on the independent variables. The standard OLS model can be used to estimate the model but a number of its assumptions will be violated. In particular the error term will not be normally distributed. This means that one cannot apply the normal statistical tests to the estimated parameters. In addition, the predicted values of the dependent variable may have a probability greater than 1 or less than zero. Basically if the OLS model predicts a value of greater than 0.5 we assume it is predicting installation.

To overcome these problems the probit model is used. The probit model uses non-linear maximum likelihood estimation to fit the cumulative normal distribution function. This forces the estimates to lie between 0 and 1. The probit model predicts the likelihood of whether a case will fall into a particular category. The area under the curve (the density of this function) provides the likelihood estimate.

This study supports the hypothesis that consumers consider the economic factors of energy price and tax credits in determining whether to adopt solar. Level of education is also a significant factor in predicting installation. This may be because the educated tend to be more aware of and able to judge the benefits of new innovations. Income does not appear to be significantly related to solar installation. Neither does solar radiation availability or belief in the energy crisis.

This research report is organized as follows. Chapter 2 reviews existing economic and socio-demographic models: their data, methodologies, and conclusions. Chapter3 presents the theory behind the model constructed for this analysis. Chapter 4 presents the model and considers the data used in this study. Chapter 5 presents the empirical results, and Chapter 6 draws conclusions from these results and assesses their policy implications.

CHAPTER II

LITERATURE REVIEW

Two general types of research have been applied to solar energy use. The first consists of economic models which determine the circumstances under which consumers will benefit by retrofitting their homes with solar energy. Only one of these papers attempts to translate its analysis into actual demand for solar systems. The second type of analysis seeks to discover the socio-demographic factors which divide individuals into likely consumers and non-consumers of solar energy. Some of the factors considered include education, occupational status, position in family life-cycle, and psychological profile. This line of research also considers differences between the two groups in terms of their beliefs regarding the attributes of solar energy. This follows from a Richards and Shoemaker paper (1971) which relates the adoption of an innovation by an individual to their beliefs about its relative advantage, perceived risk, observability, trialability, and complexity.

Economic Models

There are a number of studies of the benefits and costs of installing a solar system. Manning and Rees

(1982) developed a synthetic demand model for Great Britain based on utility functions and budget constraints. A demand function was derived, which depended onalternative energy prices and states of the world, solar radiation availability, the interest rate, system capital and operating costs, and demand for hot water. Quantity of demand was represented by square meters of collector space demanded by a single household and the research concluded that demand was too low as to be practical, that is the amount demanded would not be of a viable system size. An article by Clark (1980) includes financing alternatives and inflation rates. His data showed payoffs of less than 10 years under some circumstances, including high levels of energy price escalation.

Bezdek, Hirshberg, and Babcock (1979) calculated economic criteria for the installation of solar water heaters in the cities of Boston, Washington D.C., Los Angeles, and Grand Junction, Colorado. While they believe that economic criteria are not the only reasons consumers install -- mentioning environmental concerns, energy independence, and the desire to be "first on the block" -- economic feasibility is considered to be first in importance. Citing findings by market analysts that cash flow measures are most important to consumers, they used three criteria: payback of less than ten years, five years to recover down payment, and three years to positive cash flow. Their assumptions for analysis included a collector sized to replace 70% of the original energy used, a system life of 20 years, maintenance at 1.5% of installed cost per year, 80% financing over 30 years at 8.5%, a 10% discount and 5% inflation rate, electric and fuel oil prices escalating at 2% real and natural gas increasing at 5% real starting with 1977-78 prices. Bezdek et al. felt that systems meeting any two of the three criteria would be rated as acceptable by consumers. Electric homes in all four cities passed at least two of the criteria, and Los Angeles and Grand Junction passed even without the federal credit. State credits were not considered in this analysis.

Calculations by the California Energy Commission (1983) also indicated positive net benefits particularly for the all electric household. For natural gas users a reasonable payoff occurred only under conditions of high price escalation and high use and only with the state and federal credits. Under some conditions of use, electrical retrofits did not require the credits for economic viability. CEC assumptions are fairly similar to those used by Bezdek et al.. They use only a 15 year financing period, maintenance at 1.5% every third year plus replacing pumps and controls in the tenth year and the storage tank in the 15th year. The present value of the dollar stream of maintenance costs comes to $632 at a 4% discount rate, which is higher than the estimates for Bezdek et al.. Including the full cost of replacing the storage tank in year 15 is somewhat questionable since the tank would have an expected useful life ten years beyond the analysis period.

Socio-Demographic and Attribute Models

A number of studies have dealt with conservation practices at the household level. They have linked age, middle income level, and education to conservation practices. Cost is reported to be the most important factor in determining conservation behavior. Middle income households generally have the greatest conservation effort, possibly because the poor are already minimizing energy expenditures and the wealthy are minimally effected by increases in energy expenditures. Cunningham and Lopreato (1977), in a survey of Southwestern consumers, linked belief in the energy crisis to conservation behavior which in turn was linked to education. Belief in the energy crisis also increased with income over $20,000 per year, and decreased with age. They proposed a non-linear relationship between conservation and age and income, and a linear one between conservation and education (Figure 1). They did not, however, find the strong link between belief and behavior which has been found in other studies.

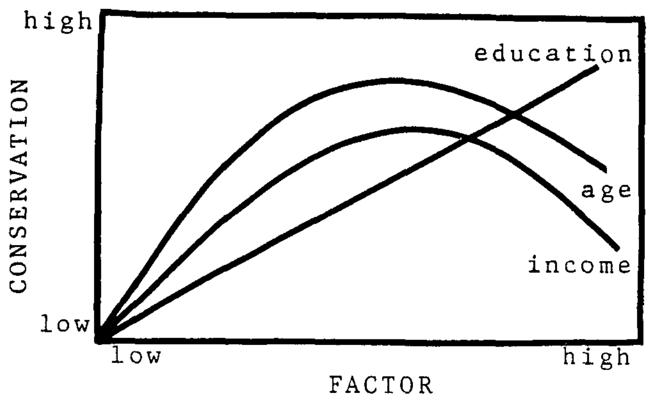

Fig. 1. Relation of Age, Education, and Income to Conservation

Source: Cunningham and Lopreato (1977), p. 27.

Heslop, Moran, and Cousineau (1981) explored the issue of "consciousness" in energy conservation behavior in Canadian households. They used socio-demographic characteristics such as family size and household characteristics along with attitudinal variables to measure environmental and price consciousness and social responsibility. Among the attitudinal variables, only price consciousness was found significant in predicting household energy use. Environmental and social attitudes were found more likely to inspire one-shot conservation activities such as the insulation of homes, rather than taking up more energy conserving lifestyles, in^luding lowering the thermostat or driving less.

Farhar-Pilgrim and Unseld (1982) produced a model of the decision-making process for solar energy adoption. The ability, technical ability (ease with use), and perception of its suitability for their home (structural retrofitability). They found that individuals who installed solar devices were more likely to have undertaken other conservation activities, such as weatherstripping and lowering their thermostat. Their study also seemed to indicate a preference among solar installers for self-reliance rather than utility company projects using solar energy.

Figure 2, below, shows two socio-demographic variables which are used or considered in this study as they were reported in Farhar-Pilgrim and Unseld. Their study did not find the age of installers to be significantly different than the typical distribution.

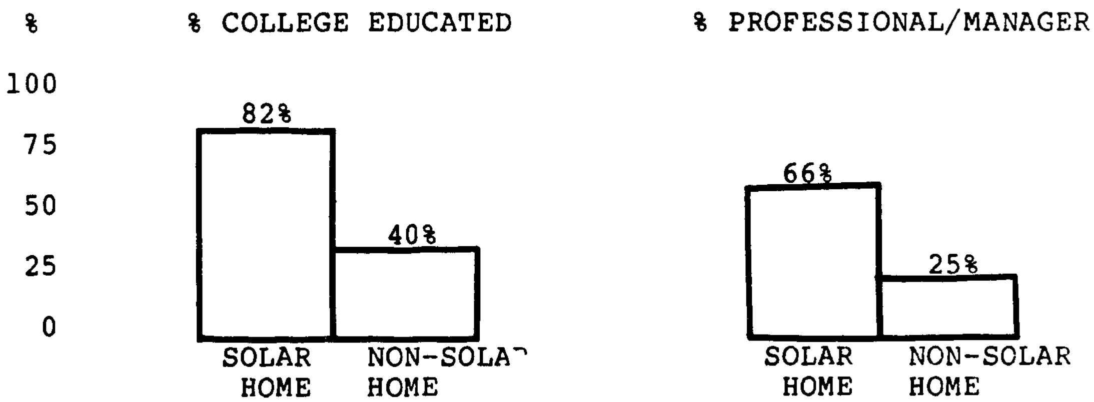

Figure 2. Per Cent of College Educated and Professionals Among Solar Homeowners and the General Population.

Source: Farhar-Pilgrim and Unseld, 1982.

model began with an awareness stage, then knowledge-evaluation, decision-intention, action, observation of effects, and continuance/discontinuance. The evaluation stage included the individual's perception of solar energy in general, and his opinion as to its personal use. Discontinuance is fairly unlikely once the system is installed unless the system is allowed to break down without repair. In the Farhar-Pilgrim and Unseld study the dependent variable was the stage of the decision process which an individual was in. Using cluster analysis they determined the characteristic differences of individuals at different stages of the process as determined by their knowledge of, or intention to adopt, solar systems. Their model included the individual's opinion on general social support for solar energy, his perception of the energy situation, awareness of and knowledge about solar energy, solar energy's perceived feasibility, concerns about risk, perceived relative advantage over other sources, business and policy knowledge and preferences. Awareness and knowledge referred to knowledge about marketers of solar equipment, its costs, knowledge about government programs to encourage solar use -- tax credits etc. -- and preferences to the individual's feeling about how the energy problem should be handled. Four barriers to personal use were hypothesized: local availability of purchase, financial

Another finding of the Farhar-Pilgrim and Unseld study is that many of the group designated as likely to install by the cluster analysis are willing to pay more per month for a solar system than they expect to receive in energy savings. This is based on an intent to finance the solar energy system through a home improvement loan. There are two explanations given for the willingness to pay more: (i) that solar is a good investment in terms of resale value and (ii) that non-economic benefits such as increasing self-reliance and fewer large power plants are rated as important or very important motivations by a majority of this market segment. Still the economic benefits were rated most highly by the households surveyed.

Voluntary simplicity of lifestyle, which was considered by Farhar-Pilgrim and Unseld, has also been linked to energy conservation. Leonard-Barton (1981) utilized a questionnaire to identify such practices as bicycling, recycling of resources and goods, self-sufficiency in goods and services, and closeness to nature. Recycling of goods could refer to used clothing, self-sufficiency in goods to making clothing or furniture, and self-sufficiency in services applies to being your own handyman. The final index related fairly strongly to such low expense conservation practices as caulking and turning pilot's lights off for the summer. When applied to installation of solar energy devices the voluntary simplicity index did not show a significant difference between adopters and non-adopters. However when solar pool heater owners were eliminated from the sample the results were more encouraging. Pool heater owners scored an average of 5.5 on the 19 point index while other solar owners scored a 9.2. These figures, however, did not showasignificant difference at greater than the 10% t-test level. Using the analysis to predict intent to install solar showed the index to be the second greatest predictor in a stepwise discriminant analysis. Number of other owners known was highest and attitude towards solar equipment and payback period were third and fourth among the variables found significant.

The work of Labay and Kinnear (1981) applied a new technique, multinomial scale analysis -- a type of discriminant analysis -- to compare the value of the socio-demographic characteristics to the value of beliefs regarding the attributes of solar systems in predicting adoption or non-adoption. They divided their dependent variable into three groups of Maine homeowners: adopters, knowledgeable non-adopters, and a control group representing the general population. The demographic factors considered were age, education, income, family life-cycle stage, and occupational status. As expected, greater education, income and occupational status, and lower age and family life-cycle were supported by Chi-squared tests. The attributes of solar technology considered were relative advantage, perceived risk (economic and social), complexity, compatibility with values, trialability and observablity. The first attribute refers to economic advantage over other sources. Complexity refers to the expected difficulty in operation and maintenance of a solar system; trialability to the opportunity to make a limited less costly investment to see how well solar works. Observability relates to how visible the result of innovating is to others (peer awareness). The expected values of the attributes were relative advantage (+), perceived risk (-), complexity (-), compatibility (+), trialability (+), and observability (+). The Chi-square tests supported all their hypotheses except observability, which was negative, and trialability which was not significant. The latter was not surprising in that solar systems are too large an investment to make trial practical. The observability finding was explained as the result of knowledge leading to perception of the innovation as less of a novelty, hence they believed solar was less observable to others once they had installed.

In comparing the predictability of the attributes group versus the socio-demographic group of variables, Labay and Kinnear found the former to predict a higher number of cases. The former predicting 62%, the latter 56%. These rates can be compare to random assignments of 37% and 39% respectively. However the attributes-perception model raises questions about the direction of causality. Do solar adopters perceive greater advantage and less risk because of experience or did they adopt because of these beliefs? In consideration of this point it would be well to ask whether adopters do have a relative advantage. If proportionately more high cost energy sources are found in adopter homes they may well have a real advantage. An all electric home would save a great deal of money in Maine with a solar water heater, while a heating oil home would be a marginal improvement. Natural gas would just pay off over the entire lifetime. A second question considered was whether there are any characteristic differences between early and late adopters. In the time period of this study, there were none.

A paper by Houston (1983) relates willingness to invest in hypothetical energy-saving devices via the discount rate to income, housing type, recent experience with energy conservation measures, intention to invest shortly, household heating demand (square footage), number of members in household, and age of home. Personal discount rates were measured by expected savings/year from a $100 energy saving device. Intention, home size, and the home age dummy (1=pre-1974) were all negative. Family size was positive. All other variables were insignificant. The housing age variable was not expected to be negative, the explanation offered was that those in older homes did not expect the savings to be as high as claimed. This sort of inference was found to be a general problem with the survey -- many respondents wrote in that savings would not be as high when all costs were considered. The correlation coefficient for the discount rate regression (Tobit analysis) was less than .06, this may have been partially due to the affect of inferences made on the questionnaire. The discount rates did not appear to decrease much with income, the highest rate was in the $5000 to $10000 group at 25.4%, the lowest at over $25,000 at 19.9%. At under $5000 the rate was 21.6%. The low explanatory power of the regression as well as the short range of income groups does not give us much confidence in these results. A second analysis used the probit model to determine differences between individuals that responded with an "I don't know" or "uncertain" response rather than an estimate to the expected savings question. The income variable became significant in this analysis -- there was a definite trend of decreasing "uncertain" responses with increasing income. The correlation coefficient was slightly higher for this analysis but still not very good, less than .14.

Summary

The probit model used in this research has not been previously applied to the installation of solar energy devices. The probit model was originally designed for biological use specifically to predict pesticide effectiveness under varying conditions (Finney 1964). The greatest use of probit for consumer models has been in the field of public goods to determine the liklihood of an individual voting for a particular candidate or issue (Aldrich and Cnudde 1975). Some form of discriminant analysis is perhaps the most widely used model for consumer goods, but for the dichotomous case probitis a logical choice and its results are simpler to interpret.

In the main, the papers reviewed here have focused on socio-demographic variables in determing consumer decisions. When economic factors have been included, they have focused on consumer perceptions of relative advantage and risk without accounting for whether these perceptions are justified. Economic factors have also been neglected in terms of relative cost -- both in terms of available tax credits and the system size/cost relationship determined by location. The broad cross-section of data used in this study is an advantage in looking at these issues, though the number of solar installers which may be analysed is small in comparison to studies which were aimed specifically at solar installers. The consideration of economic factors in this study allows important policy issues involving consumers' responsiveness to both tax credit size and price of alternative energy sources to be discussed.

III. A THEORETICAL MODEL OF SOLAR ADOPTION

The process by which a consumer decides to make a solar purchase may be considered within a broad conceptual framework. The first requirement is awareness of the system's application to their home. Once this has been established the consumer must evaluate its benefits and costs -- including how much it will save, how much it will cost to install, and available government incentives. In many cases government incentive programs will have brought solar energy to the initial attention of the individual. With this information the individual can decide whether they wish to install, the next stage being actual installation. The evaluation stage may bring the consumer to a stand-still if he feels that he does not have enough information with which to decide and views the value of getting more information as currently not worth the effort.

```
  TAX CREDIT  -----↘                           DON'T KNOW
      |               EVALUATION                  ↑
  AWARENESS              Cost                     |
 & KNOWLEDGE   ---->   Savings ---->DECISION CRITERIA
OF SOLAR ENERGY          Risk             DEVELOPED
                                    yes       ↓
      ACTION <-----  INTENTION  <------   DECISION
```

Figure 3. Solar Decision Model

The evaluation stage is a complex one: the ability to evaluate is based on experience and knowledge of investments, for which education may be a substitute and a complement. Also specific knowledge on the technology in question might come from the personal experience of acquaintances who have installed. These factors have an impact on how certain an individual may be of the expected benefits, and can determine whether he will actually install. However, there are many other factors which are not related strictly to monetary benefits and costs, but which may influence the decision.

Consumer theory presents a model of consumer spending based on utility maximization. An individual or household purchases a bundle of goods and services which will provide the greatest benefits given a limited income. The value or utility of an item to an individual may be greater than its price. Many individuals are unable or unwilling to expend money to purchase an item which, though it may save them money in the long run, will require a large commitment of capital now. So purchase of a capital good such as a solar water heater must compete against other items whose benefits may be economically greater or perceived as greater to a particular individual.

The homeowner may also obtain utility from the purchase of a solar water heater above and beyond the savings in energy costs. Many solar purchasers perceive solar as more independent or more natural. This reflects the voluntary simplicity of lifestyle hypothesis. There are also studies which support the theory that early installers perceived themselves as innovators and community leaders -- the person who wants to be first on the block. In light of these considerations there is some expectation that those who installed before the 1981 survey were less dependent on economic criteria in making their decision than those who installed in 1981 and 1982. For this later group the solar market would have passed the earliest stage in which installers are primarily members of the innovator psychological group, and be in the respectable or deliberate set of early to middle adopters. This study does not have the information available with which to classify individuals as innovators or the deliberate type, but the ability of the model to predict installers based on economic considerations should allow some insights into whether economic considerations were more important to the later installing group. This study can consider the economic aspects and, to some extent, the consumers ability to evaluate them through the dummy variable on education. If there is a difference in predictive power between the models estimated for the late and early group, it would indicate that the solar market has reached the second stage of development.

The survey on which this analysis is based provides information on whether a consumer has installed a solar device and what power sources their home has available as an alternative. This allows assignment of an alternative energy price. The survey also reports the respondent's education, and an estimate of their income. The availability of tax credits in each state was also determined. These and the above variables formed the basis for the regressions run in this analysis.

How do these variables relate to the the consumer's decision? A consumer considers how much money he will save in energy costs compared to how much the installed system will cost. Energy savings are based on how much less the installer will spend on energy for water heating. This is primarily dependent on the current energy source; an all electric home spent at least twice as much as the natural gas home for the same amount of water heating in 1980 in Arizona. However, in Washington in 1980 an electric home owner would have spent almost the same as the Arizona natural gas homeowner.

The standard formula for computing net present value or payback on an investment is the discounted cash flow. Suppose an individual installed a system at the end of 1980 for $3000 and originally had water heating bills of $316 (electric), and saved 68% (based on California Energy

Commission efficiency calculations)[1] of that, $215, saved $1200 off the purchase price from the federal tax credit and with Arizona tax credits another $1050. This leaves an installed cost of $750 in Arizona. If you consider an expected 2% real increase in electric prices and use a 4% discount rate payback[2] would occur in less than 4 years. Without the state credit this payback would have taken 9 years. These calculations do not include maintenance. Over a 20 year period the net present value[3] of the system is $2852 with the credit and $1802 without. The present value of maintenance costs over 20 years is approximately $500 in 1980 dollars by the CEC calculations -- $200 of this is the present value cost of replacing the storage tank in the 15th year.

Installation of a solar water heater appears to be a good investment for the all electric home in Arizona. The Electric Home Payback Period Graph (Figure 4), shows how different starting energy prices change the net present value of a system for different tax credit levels. This graph assumes a $3000 dollar installed solar hot water

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1. 72% energy saved less 4% to run the solar systems pump.

2. Payback period = t where System Cost= First Year Savings * $\Sigma((1+r)/(1+d))^t$.

3. NPV(Net Present Value) = System Cost - [First Year Savings * $\Sigma((1 + r)/(1 + d))^t$.

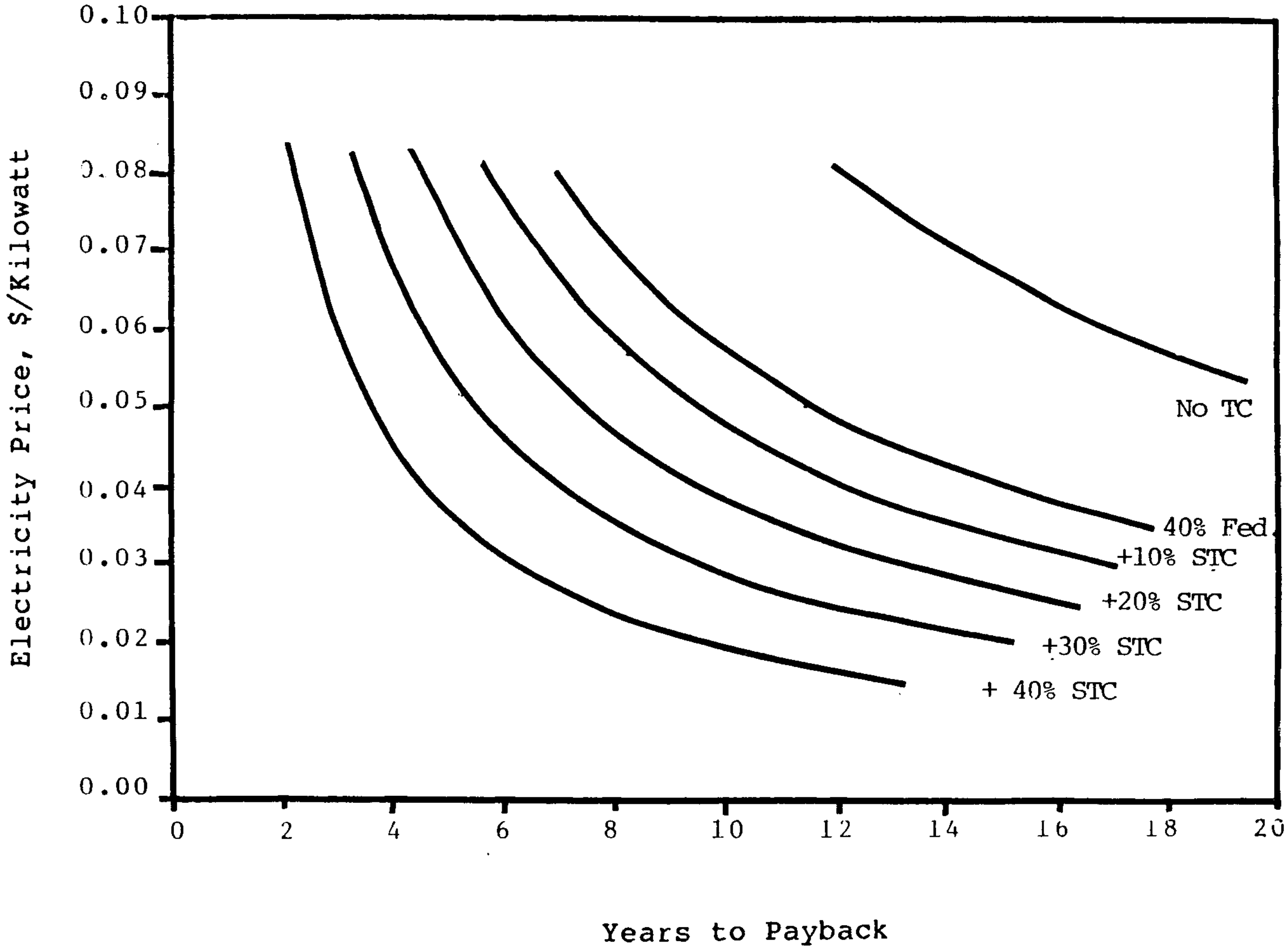

Fig. 4. Electric Home Payback Period Graph

system, and the same discount and escalation rates mentioned above, 4% and 2% real. The non-discounted present value may be a better representation of what many installers consider as their criteria for investment. Not because they don't discount but because they discount after calculating savings, not as part of calculating the savings. The $3000 installed price is probably a little low for the states further north in the study group. Solar collector size must increase as solar radiation decreases in order to achieve the same amount of energy savings -- which increases the system cost in a non-linear fashion. Retrofitting solar in natural gas homes does not appear to be as good an investment as retrofitting electric homes (Tables 1 and 2). This would not be true if natural gas prices had increased as many individuals expected following deregulation.

Discount rates and the difficulty of obtaining the necessary capital are expected to be higher for lower income individuals. While loans for energy saving equipment are becoming easier to obtain, this was not true in the early, untried years of solar equipment. Therefore despite the fact that the net cost of solar was very low in a state like Arizona, the initial upfront cost was large and would not be returned until tax refunds occurred. Theoretically the discount rate is generally thought to vary inversely with

Table 1. Payback Periods and Net Present Values for All-Electric Homes

State	Simple	2% Real/4% Discount	Net Present Value
Arizona	3.5	3.6	2852
Colorado	5.4	5.6	1893
Idaho	15.7	18.6	100
Nevada	10.5	11.6	1074
Oregon	9.7	10.7	758
Utah	7.7	8.2	1781
Washington	27.7	+20	-714
Wyoming	16.6	19.7	20

Table 2. Payback Periods and Net Present Values for Natural Gas Homes

State	Simple	3% Real/4% Discount	Net Present Value
Arizona	11.8	12.4	416
Colorado	16.7	18.1	84
Idaho	20	20+	-162
Nevada	28.4	20+	-643
Oregon	11.9	12.5	569
Utah	36.0	20+	-667
Washington	21.6	20+	-275
Wyoming	41.0	20+	-996

Note: Simple Payback = System Cost/1st Year Savings.

Discounted Paybacks have yearly savings discounted by $((1 + r)/(1+d))^t$. This sum less the cost = NPV.

income and is generally found to be higher than credit market and opportunity costs would seem to indicate. A number of studies dealing with energy savings investments support this. Hausman (1979) did not however deal with the purchase of a good which would save energy directly but with those which would use comparatively less energy, such as choice between different models of cars or air conditioners. A later study by Houston (1983), described in more detail in the last chapter, developed an implicit discount rate for an untried hypothetical energy-saving durable. The mean observed discount rate he calculated was 22.5%, but these results did not show a relationship to income. Hausman's results ranged from 89% at $6000/year and 5.1% at $50,000/year. The four per cent chosen here is certainly low given Houston's results but does reflect market values net of inflation. It also reflects an at least somewhat known quantity -- that is how well the solar system is expected to work, unlike Hausman's hypothetical device.

As we move north the collector space necessary for equal energy savings will increase hence the system cost will increase. There is also a good deal of variation in incentives available in the various states. Arizona has the second highest credit in the West, after California which had a 55% credit at the time of the first survey (California was excluded from the 1983 survey). The different credits available may have lead to somewhat inflated system costs in some states. Where system costs after taxes are lower a small supplier market may be able to capture more of the consumer surplus. The following findings (DOE 1980, 1981) seem to support this hypothesis. The average cost in Washington with no state credit is $200 less than that in Oregon with a 25% credit, despite greater collector space in Washington. The average cost in Wyoming (no credit) and Colorado (30%) is nearly identical, despite Wyoming collector space being almost a third larger. In 1981 actual collector sizes in these two states were nearly the same but cost in Colorado was about 19% greater than in Wyoming.

These calculations form a rough basis for determining under what conditions a solar water heater is a good investment for a homeowner. They will be compared to the findings of the econometric model. We are interested in determining whether those that have installed are operating under economic considerations rather than determining whether all who might obtain net economic benefits actually do install.

CHAPTER IV

METHODOLOGY AND SAMPLE

Model

Two econometric models have been chosen to estimate the parameters influencing installation of solar water heaters. These are the linear probability model and the probit model.

Linear Probability Model

Use of the linear regression model for a dichotomous dependent variable creates the linear probability model. The form of the linear probability model is:

$$Y_i = b_o + \Sigma b_k X_{ik} + e_i \qquad (1)$$

where Y_i = 1 if first option is chosen(install solar)
0 if second option is chosen (not install)

X_{ik} = the value of the independent variable k for the ith individual

e_i = independently distributed random variable with 0 mean

The expected value of Y_i is

$$E(Y_i) = b_o + \Sigma b_k X_{ik} \qquad (2)$$

and since Y_i can only equal one or zero, the probability distribution of Y, can be described as P_i = Prob(Y_i = 1) and 1 - P_i = Prob(y_i = 0); therefore we find --

$$E(Y_i) = 1(P_i) + 0(1 - P_i) = P_i \quad (3)$$

or

$$P_i = b_o + \Sigma b_k x_{ik}. \quad (4)$$

So the probability that Y_i = 1 is a linear function of the x's. Since the linear model may produce values of greater than one or less than zero we must interpret P_i as follows:

$$P_i = \begin{cases} b_o + \Sigma b_k X_{ik} & \text{when } 0 < b_o + \Sigma b_k X_{ik} < 1 \\ 1 & \text{when } b_o + \Sigma b_k X_{ik} \geq 1 \\ 0 & \text{when } b_o + \Sigma b_k X_{ik} \leq 0 \end{cases} \quad (5)$$

The primary problem with the linear regression model is the assumption that e_i, the error term, is an independently distributed random variable. In fact the error term is not normally distributed and it is heteroscedastic -- the variance is not independent of P_i. Therefore we can not assume the normal statistical tests are valid. The second problem is that the model may predict impossible probabilites, that is less than zero or greater than one. To correct both of these problems maximum likelihood estimation (MLE) is used.

Probit Model

Maximum likelihood estimation allows us to estimate non-linear models, in this case the probit model. The probit is designed so the the purchase of a solar water heater (SOL_i)

$$\begin{aligned} &= 1 \text{ if } \quad x_i' \beta_i + \varepsilon_i > 0 \\ &= 0 \text{ if } \quad x_i' \beta_i + \varepsilon_i \leq 0 \end{aligned} \qquad (6)$$

where $\varepsilon_i \sim N(0,1)$.

X' is the row vector of independent variables and represents a column vector of the coefficients.

Since ε_i is assumed to be normal with a mean of zero and a standard deviation of one the problem of heteroscedasticity disappears by assumption. It is necessary to use a function which will compute the probability that Y_i equals one given the value of $x_i' \beta_i$ -- $Pr(Y_i = 1) = F(x'_i \beta_i)$, where $0 \leq F(x'_i \beta_i) \leq 1$. The probit model utilizes the cumulative normal probability function to compute these probabilities according to the following:

$$P_i = F(x'_i \beta_i) = 1/(2\pi)^{.5} \int_{-\infty}^{x_i' \beta_i} \exp[-.5\, \varepsilon^2]\, d\varepsilon. \quad (7)$$

Where ε is evaluated at $x_i' \beta_i$. P_i is therefore a non-linear function of the independent variables, x'. The maximum likelihood estimators are normal asymptotically; so, for sufficiently large samples standard hypothesis testing may be done.

A number of assumptions underlie the dichotomous dependent variable for solar installation. First, all solar water heat systems cost the same amount of money before the tax credits are taken. Second, all systems save the same amount of energy. In reality the amount of energy saved depends on the solar radiation available, the collector size, andhousehold hot water use which in turn depends on factors such as family size and lifestyle.

Data and Sample

The data used in this study came primarily from two nearly identical household energy surveys of the western states issued in 1981 with a sample size of 8,639 and reissued in 1983 to subsets of both previous respondents and an entirely new group. State participants included in this study were Arizona, Colorado, Idaho, Nevada, Oregon, Utah, Washington, and Wyoming. Researchers in California participated only in the 1981 survey and this state is examined only among that subset. Since this analysis is based on cross-sectional information, combined or time series examination is limited. Data on solar installation does not include the exact year of installation. Therefore precise assignment of certain variables is impossible. This limitation particularly affects two explanatory variables -- alternative energy price levels and the level of any available tax credits. The following sections of this chapter will discuss each of the major explanatory variables in turn, looking first at the values found, their source, and then at any problems which may exist with the data. Variables included are the levels of the state tax credit, income, education, price of alternate energy supplies, and solar radiation availability. Also considered are the belief and attitudinal variables regarding the seriousness of the energy situation, and the use of solar energy to meet future energy needs.

Education

A number of specifications of education as a dummy variable are examined based on the highest education level of the family heads. These specifications include beyond high school (includes trade school), some college, and a college degree. Education is expected to have a positive influence on installation, primarily due to increased ability to judge its benefits.

Income

The survey questionnaire asked respondents to place themselves in income categories. Categories were divided into 9 groups by increments of 5000 dollars up to 40,000 dollars, the next category being 40 to 50,000 and the final category being 50,000 and above. Since the effect of income is not expected to be linear the natural log of the income was used. Additional specifications examined are allowing middle income individuals to have the greatest response, and using a dummy variable for a minimum income necessary.

State Tax Incentives

The highest state tax credit was 35% in Arizona, followed by 30% in Colorado from 1980 on, 25% in Oregon, 10% in Utah from 1980 on, a 100% income tax deduction in Idaho taken over four years -- approximately equal to a 7% credit, and no credits in Nevada, Washington, or Wyoming. The tax credit was 55% in California and inclusion of this state in the early survey runs does create problems with the level of the state tax credit, possible reasons for which will be discussed in the results chapter. Prior to 1980 Utah had no credit and Colorado had a 100% income tax deduction taken in the year of installation and equal to an 8.0% credit for incomes over $10,000 per year. Since neither survey required precise information on year of installation, itis unknown whether an installer considered the higher or lower of these benefits in determining purchase of a solar system.

To account for the tax credit at the time of installation both the pre-1980 and 1980 incentives are tried for the 1981 survey group. A number of other specifications are also tried in order to account for the number of years the credit had been available.

One additional factor which is not accounted for is the various additional benefits which exist in some states. These include a property tax exemption equal to the value of the system in Oregon and an exemption from a use tax and increases in property tax in Arizona. Arizona also has accelerated amortization while California and Oregon have special loans available.

Alternate Energy Prices

The model also included the lowest price energy readily available to the individual homeowner. This meant that a homeowner with only electricity was assigned that price, those with propane or heating oil those respective prices and similarily for homes with natural gas (which had the lowest price). Because it was impossible to determine the exact level of alternate energy prices existing when the decision to install was made, the prices were assigned by state averages in dollars per MBTU over the relevant years and adjusted by expected efficiencies. The efficiencies used were those for systems installed since 1972

(FEA 1974). Deparment of Energy (1983) information presenting the weighted average of each alternate energy price was used to calculate the averages after adjusting for inflation using the consumer price index for the West. (BOI 1984). These average values are fairly accurate with the exception of electrical energy, for which the price varies considerably, especially within the hydroelectric power states -- Oregon, Washington and Idaho -- where individual cities may have independent hydroelectric systems.

Solar Radiation Availability

Solar radiation availability is an important factor in the size of the solar system -- less availability implies a greater surface area is needed to collect an equal amount of solar radiation necessitating a higher cost system. Solar radiation availability is measured as kilowatt hours/square meter falling on a south-facing 45 degree surface. 45 degrees is approximately the average optimum surface for capture in the relevant latitudes. High solar radiation availability decreases the percentage of time the back-up system is needed, increasing the benefits of the system. The solar radiation availability ranged from a low of 3.75 in northwestern Washington to a high in Arizona of 6.25.

Variables of Belief

Level of belief in the energy problem ranging from "not a serious problem" to a "very serious problem" was specified as a dummy variable with higher levels of concern rating a one. Attitude towards using more solar energy ranged from "strongly oppose" to "strongly favor" was also specified as a dummy variable. Different cut-off points were examined. Both of these are expected to have a positive influence on installation.

Additional characteristics which we would have liked to consider were the interrelated voluntary simplicity of lifestyle and "post-materialist values" which a number of studies found to be related to solar installation. Voluntary simplicity includes bike riding to work, canning vegetables, recycling, and self-sufficiency. Post-materialist values include protecting nature, civic involvement, grass-roots politics, and a less impersonal society. Lack of data availability precluded controlling for such factors.

Table 3 presents a list of the variables regressed, their assigned symbols, their expected signs and the data source.

Table 3. Variable Definitions and Data Sources

Symbol	Definition	Expected Sign	Source
Dependent:			
SOL	Dummy variable representing installation of a domestic solar hot water heater		Energy Directions Survey
INT	Dummy variable representing intent intent to install solar hot water		
Independent:			
CO	Dummy variable = 1 for some college education and above	+	Energy Directions Survey
LN	Natural log of household income in dollars	+	Energy Directions Survey
LTC	Level of the state tax credit	+	State Tax Guide
EC	Average cost of least cost available energy source in $/MBTU adjusted for expected efficiency	+	DOE (1984)
VSP	Dummy variable = 1 for meeting U. S. energy needs is a serious problem	+	Energy Directions Survey
PR	Dummy variable = 1 for favoring more use of solar energy	+	Energy Directions Survey
SRA	Solar radiation availability	+	Solar Energy Handbook (1981)

Sample

It was necessary to reduce the sample size substantially in order to do the Probit analysis, due to the small proportion of solar water heater installers in the population. Initial reductions were made in order to limit the sample to that part of the population which would benefit, namely homeowners. The primary analysis was of those who had actually installed and those who said they did not intend to install within the next to years. The excluded group, those who intend to install within the next two years, have formed the basis for analysis in many other studies due to the small proportion of actual installers. Differences between those intending to install and actual installers is also examined in this study.

The data set was also limited to those who answered the questions concerning the relevant variables, and finally a sample of this set was taken in order to allow the probit algorithm to predict something other than zeros. By dropping those cases among the non-installers who did not answer questions on place of residence, current fuel supply, education and income an assumption was made that non-answerers were randomly distributed on these questions. While there is some question as to whether the randomness assumption is correct, particularly for income, respondents are generally assumed to be undeterred from answering this question since it was categorical rather than direct. The final sample for the 1983 sample contained 33 installers and 63 non-installers. The 1981 survey sample contained 58 installers and 167 non-installers after dropping California. In both cases non-installers represented 3% of the homeowner population of each state.

Summary

The major advantage of this model over others developed is that it allows us to calculate actual marginal changes in the likelihood of installation for the change in alternative energy price and the level of the tax credit. The model does not, however, reflect all factors involved in consumer installation decisions. Two factors which influence installers are not directly accounted for in the central model: the rate of energy price escalation, and the interaction of energy savings and tax savings on total net benefits. In response to this consideration models which calculate different economic criteria combining these two influences are regressed and compared. These include net present value and payback period. Using these models different rates of escalation for energy prices can be considered directly.

CHAPTER V

RESULTS

The econometric model described in the lastchapter appears in its regression form below.

$$SOL_i = {}_o + {}_1CO_i + {}_2LN + {}_3LTC + {}_4EC + {}_5 + {}_6VSP + {}_6PR + {}_7SRA + {}_i \qquad (8)$$

The symbol definitions are described in Table 3, Chapter 4. This regression model is also analyzed using intent to install (INT) as the dependent variable.

The conceptual model developed in Chapter III is generally supported by the empirical results. A number of different models were estimated using the 1981 and 1983 survey groups. Table 4 presents the estimated coefficients and t-statistics for the 1983 survey group including both the linear probability and probit models. Table 5 presents the 1981 results.

Tests of Model Performance

Three tests are used to measure model performance. The first is how well the model predicts individuals to fall into their respective category of installer or non-installer. For the linear probability model a household is predicted to be a one if $x_i'\beta_i$ is greater than or equal to 0.5. For the probit model $x_i'\beta_i$ must be greater than or equal to 0. The second involves the likelihood ratio. This test takes the natural log of the ratio of the likelihood function (described below) of the restricted model to the likelihood of the unrestricted model multiplied by -2. This statistic has a Chi-squared distribution with the number of restrictions as the degrees of freedom. The tables present this calculation against the restricted slopes model. F-tests are presented for the OLS model. The restricted slopes model is the model where all the variable coefficients equal zero. In this circumstance the probability of installation would equal the percentage of installers in the population. In all cases the models are significant at greater than the 0.01% level. The final test creates a statistic comparable to the R^2, which is calculated as 1 - ln[likelihood ratio].

The likelihood function is the method by which the probit model is estimated. Probit estimates values of β so that high values $x_i'\beta_i$ will be found for installers and low values will be found for non-installers. It does so by maximizing the likelihood function:

$$L = \prod_{i=1}^{T} F(x_i'\beta_i)^n \, [1 - F(x_i'\beta_i)^{T-n} \qquad (8)$$

where $F(x_i'\beta_i)$ equals the probability of installation, P_i, n equals the number of installers, and T equals the total number of cases. The likelihood function, L, increases as our predictions become closer to one, if the case is an installer, or zero if it is not. The likelihood ratio, is the ratio of the entire model's likelihood function to that of the restricted slopes likelihood function. The likelihood ratio also allows testing of whether the addition of a particular variable significantly improves a model.

Table 5. Estimated Coefficients, T-Statistics, and Summary Statistics - OLS and Probit 1981 Models

Variable	OLS (t-stat)	MLE (t-stat)	MLE (t-stat)	MLE (t-stat)
Intercept	-0.7033 (-1.921)	-4.4237 (-2.890)	-0.1781 (-2.732)	-2.1921 (-7.718)
CO	0.0857 (1.439)	0.3349 (1.377)	0.1156 (2.061)	0.4643 (2.041)
LN	0.0547 (1.457)	0.2300 (1.494)		
LTC	0.4346 (2.257)	1.5421 (2.134)	0.4416 (2.289)	1.5360 (2.136)
EC	0.0036 (6.021)	0.1102 (5.045)	0.0036 (6.036)	0.1096 (5.046)
n	225	225	225	225
SOL=1	58	58	58	58
Cases Correct	180	179	182	181
F or L-L Ratio	16.25	50.69	20.85	48.38
Fraction Explained	.214	.197	.210	.188

Table 4. Estimated Coefficients, T-Statisitics, and Summary Statistics
OLS and Probit 1983 Models

Variable	OLS	Probit	OLS	Probit	OLS	Probit
Intercept	-1.0322 (1.240)	-6.2232 (-1.815)	-0.6111 (-0.9871)	-5.1500 (-1.786)	-0.2382 (-2.431)	-3.0666 (-4.851)
CO	0.2602 (2.432)	1.4201 (2.456)	0.2773 (2.651)	1.4528 (2.607)	0.3024 (3.156)	1.5649 (2.914)
LN	0.0440 (0.689)	0.2360 (0.825)	0.0385 (0.610)	0.2103 (0.751)		
LTC	1.0684 (3.610)	4.3511 (3.492)	1.0386 (3.511)	3.8818 (3.313)	1.0478 (3.559)	1.2721 (3.380)
EC	0.0211 (3.281)	0.0740 (3.059)	0.0193 (3.020)	0.0638 (2.799)	0.0197 (3.121)	0.0649 (2.852)
VSP	-0.1771 (-1.887)	-0.7328 (-1.875)				
PS	0.1040 (0.7980	0.4339 (0.734)				
SRA	0.0595 (0.662)	0.0875 (0.662)				
Cases Correct(96)	77	77	73	73	73	73
F-Test or L-L	6.97	41.61	11.01	38.81	14.66	38.23
Pseudo-R^2	.306	.348	.297	.314	.301	.309

Results

Economic variables relating to system cost and savings were always significant. The dummy variable for education above the high school level was always significant when regressed without the income variable, and was always significant in analysis of data from the second survey. Multicollinearity seemed to be a problem when including both the education and income variable within the 1981 survey group. In some instances income actually diminished the predictive power of the model. Three variables which were expected to influence solar installation but did not were solar radiation availability, pro-solar attitudes, and level of concern about the energy problem. The effect of SRA on system benefits can be looked at in two ways. As solar radiation availability increases a smaller system can produce the same energy savings. So either one spends more for the system in the northern states or one is satisfied with a lesser amount of energy savings. Solar radiation availability did not appear to influence the probability of installation.

A pro-solar attitude is more common than not, especially in the West, and this may reduce any chance of its showing a significant influence on installation. The fact that level of concern about the energy problem is significant at the 10% level but negative raises the hypothesis that this lack of concern is a result of installation. Perhaps families who have installed are managing to reduce their energy costs so that rising energy costs are no longer regarded by them as a problem. This hypothesis is supported by the findings on intent to install, which show a highly significant coefficient on the variable representing a belief that energy is a very serious problem.

Adding the income variable does not significantly improve the model. In the 1981 (Table 5) survey group the model actually makes worse predictions when it is included. The most logical explanation for this is that the income variable has a large potential for understatement. Many respondents are unlikely to have mentioned their entire income -- they may have only considered wages. A second problem is that retirees may have put themselves in the lowest category, no income, though they may be living off of savings or pensions from high past income. One other possible factor is that many purchasers are young professionals who expect their income to rise and are willing to make payments on a solar water heater. The 1983 survey group (Table 4), where we see that income is even less significant, may also have found it easier to obtain loans for a solar installation than earlier installers, hence the importance of income would drop.

Predictions are definitely best for the 1983 survey group. One explanation for this is that a greater proportion of individuals installing from 1981 on were more motivated by economic reasons than environmental issues and are individuals of the second wave who are more cautious than earlier, innovator-type installers.

Table 6 presents the pooled regression. The pooled regression included both the 1981 and 1983 sample. This model is used to see whether relative importance of the variables changed between 1981 and 1983. The additional cases included may also improve the significance of certain variables. In the pooled group inclusion of the income variable in the model is significant at the 10% level. The income-included pooled model was not significantly worse than allowing all variables to differ between the two time periods. The model without the income variable included was better if the coefficients were allowed to vary between the two time periods but only at the 10% level. The variable which apparently makes the difference is the level of the state tax credit which does change considerably between the the 1981 and 1983 models.

Table 6. Estimated Coefficients, T-Statistics, and Summary Statistics - Pooled 1981 and 1983 OLS and Probit Models

Variable	OLS (t-stat)	MLE (t-stat)	OLS (t-stat)	MLE (t-stat)
Intercept	-0.6850	-4.3822	-0.1794	-2.2577
	(-2.205)	(-3.446)	(-3.359)	(-9.368)
CO	0.1293	0.5223	0.1605	0.6516
	(2.490)	(2.462)	(3.308)	(3.273)
LN	0.0527	0.2192		
	(1.652)	(1.715)		
LTC	0.6597	2.3253	0.6654	2.3199
	(4.125)	(3.934)	(4.150)	(3.946)
EC	0.0282	0.0859	0.0288	0.0872
	(6.648)	(5.706)	(6.786)	(5.810)
n	321	321	321	321
SOL=1	91	91	91	91
Cases Correct	254	253	256	255
F or L-L Ratio	33.43	82.92	25.89	79.89
Fraction Explained	.237	.217	.233	.209

Table 7 presents the estimated elasticities from the 1983 model on the basis that this model is the best in terms of predictions and perhaps the best estimator in terms of the influence of economic factors. Listed in the fifth column are elasticities at the mean. These are computed using the marginal effects in column four which are derived from the coefficients presented in Table 3 and the mean values for the right hand side variables. The last column presents elasticities with CO equal to one. Since this is a dummy variable, presenting these results at the mean is unrealistic. Basically this model assumes that the educated are more aware of solar energy and more able to judge its benefits to their home, therefore are more able to be in the group of potential installers. The model expects that benefits would have to be more obvious or larger before the less educated would be willing to risk installation. The elasticities can not be interpreted as the standard elasticities for an item of continuous demand. These elasticities represent the percent change in probability of purchase for a 1 percent increase in the level of the independent variable. The values presented are at an income equivalent to $30,638 per year, a tax credit of 16%, and an energy cost of $9.67 per efficiency adjusted MBTU's. These are the mean values of the estimated sample population. The latter is equivalent to a three cents per kilowatt hour or sixty-eight cents a therm of natural gas. At these values installation would not be predicted, that is the mean individual with a college education would not be expected to install -- though with the 35% Arizona credit he would. A 24% credit would be the break even point for predicting installation at these energy costs as required by the estimated model. Given the 1980 electricity cost in Arizona it would take only a 9% tax credit to predict installation at the average residential electric price which was 6.3 cents per kilowatt hour.

Table 8 presents the current state tax credit for each state, the minimum price (1980$) of electricity and natural gas necessary to predict installation in that state as designated by the estimated model, and the actual 1980 price. As you can see only in Arizona is the natural gas price high enough to predict solar installation. In the states of Arizona, Colorado, and Oregon electric homeowners are all predicted to install -- Utah comes very close with its 10% credit. Oregon makes it, despite its fairly low priced hydro-electricity, due to its 25% tax credit. We must remember that these are based on the average 1980 price for the state, not necessarily the actual price for each homeowner. The second to last column presents the net present value necessary to predict installation as calculated from the necessary energy price and the actual state credit. The last column presents the actual net present value based on actual energy costs and the tax credits. These values imply that individuals are more strongly influenced by the tax credits than the actual dollar benefits would indicate. Only with extraordinarily high cost savings would non-credit states have any installers predicted. And if one looks at actual savings, Utah electric homeowners have greater justification for installation than Oregon homeowners although the model predicts the opposite. However in terms of utility maximization households may be justified in weighing current system savings more highly than long-term energy cost savings.

The best model in terms of predictive power is based on the net present value for households calculated from the present value of the savings over 20 years less the average cost of installation by state times the percentage of cost paid after tax credits in that state. In this manner the simultaneous influence of system and energy costs over time is considered. This model, with the college and income variables included, predicted 77 out of 96 cases correctly for the 1983 sample.

It is difficult to compare the econometric results with the economic net present value model. The econometric model portrays a non-continuous variable relating to installation and non-installation while the net present value is a continuous dollar amount. We can examine the net present value associated with the cut-off energy costs under each state tax credit. The net present values developed in the second to last column of Table 8 are the cut-offs, the lowest net present values at which a 50% likelihood of installation is found for the tax credit available. The last column presents the net present value for the actual price found in that state. These are based on electric prices -- only in Arizona is installation predicted for natural gas homes. Actual average present value for the natural gas home in Arizona is $525. The elasticity of the net present value to the level of the tax credit is 1.002 by the economic model, the elasticity of NPV to the alternative energy cost is about 1.02. Therefore the increase in consumer benefits for a 1% increase in the tax credit is about 1% and slightly higher for a 1% increase in energy prices. This cannot really be compared to the elasticities of Table 7 which are for the change in probability of installation, not for a change in benefits.

Turning to analysis of survey respondents who reported an intent to install a solar systems, the variables which are significant for installation are generally also significant for intent to install. Education, the level of the tax credit, and energy cost are significant. The model makes better predictions without the inclusion of income. Two variables which were not significant for installers were significant for those intending to install. These are the variables indicating belief that more solar energy should be used in this country and the belief that energy is a very serious problem for the United States. Believing energy to be a very serious problem is a complete reversal from the findings for actual installers. This indicates that predicting installation among those who have yet to install is in fact related to the strength of their belief in the energy problem, despite its contradictory results for those who have already installed. It is possible that once the homeowner installs solar they feel that energy is not a very serious problem. A chi-square test, however, shows a significant difference, at the 1% level, between the intent to install group and the non-intent, non-install general population on this question. A significant difference is not found between installers and intenders or the general population. The 1983 installer group may be too small to statistically detect a difference between installers and other survey respondents for this question. Solar radiation availability, while not a significant addition to the models explanatory power, certainly improved predictive power for the intent to install group.

CHAPTER VI

CONCLUSIONS

This analysis finds that tax credits and energy costs significantly effect the probability of solar installation, as reported in the regression results. Education is also found to be significant while income is not. Variation in initial cost of installation due to system size appears to be insignificant. Level of concern about the energy problem apparently is a factor in intention to install. The relative influence of benefit and cost factors on the likelihood of installation appears to be linked to the effect these factors have on the net present value of the system.

While it appears that most homeowners are responsive to and consider the cost of their current source of energy in determining whether to retrofit solar, some individuals install solar despite an apparently negative discounted system net benefit. Unless policy makers believe that natural gas prices will rise more rapidly than current projections; government should not be subsidizing solar retrofit for natural gas homes. Unless conservation of natural gas yields a social benefit beyond its current that is, there is an external cost associated with its use, there is no economic rationale to support the replacement of natural gas with solar energy at this time. However if policymakers desire to encourage natural gas homeowners to install solar units a higher subsidy will be necessary, due to the long payback periods and negative present values reported in this study.

If the government desires to encourage solar energy through the use of tax credits, the optimum size of the credit is such that the governments penetration goals are achieved at the least possible cost. In Arizona approximately 60% of homes are supplied with natural gas. The remainder primarily use electricity or other sources ranging between natural gas and electricity in price. Propane homes are close to natural gas in cost, heating oil homes close to electricity. The 3.5 year payback period for electric homes may be more generous necessary to encourage them to install. Even with no credit an electric home in Arizona could be expected to pay off in less than ten years, which is better than a natural gas homeowner could expect with the credit. Colorado electric homeowners would pay off in just over ten years without that state's credit as well. Oregon's lower electric prices requires its 25% credit to pay off in under 11 years.

If (for reasons other than cost-effectiveness) the government wishes to encourage solar it must offer higher credits or incentives to natural gas homeowners. However if the government wishes to decrease growth of electricity demand it could do so most efficiently by offering a smaller credit to electric homeowners and focusing on these homes in a publicity campaign to point out solar cost effectiveness, by requiring solar water on new all-electric homes, and perhaps by requiring retrofitting before resale. Retrofit and requiring solar installation in new homes has been mandated in some California communities. Santa Barbara County is the only one to limit the new home requirement only to electric homes (Hausker and Bardach, 1983).

The inability of the model to predict with greater accuracy is not necessarily the result of a poor model, but is primarily a result of incomplete knowledge. For instance many households which would benefit from installation of a solar system in terms of net present value are better off using their money elsewhere from a utility maximization perspective. They may also be unaware of the benefits of solar installation or be located where they have no access to solar installers. These are possible reasons for those instances where the model predicted installation for households which have not installed.

People who are not predicted to install but have installed may also reflect imperfect knowledge from the survey data. Installers with marginal economic benefits may have other non-economic motives for installation, such as those discussed in the literature review. Also some homes may have higher energy costs or energy usage increasing benefits. Individual households may have had lower installation costs than average. A do-it-yourselfer could have saved a $1000 off of the system cost. This savings may not mean much in Arizona where the individual may only pay $250 of that $1000 after the tax credits but in Nevada they would save $600. A do-it-yourselfer approach can greatly increase economic benefits.

Three types of information would have benefited this analysis -- more accurate assessments of each household's current energy costs and usage, actual year of installation, and life-cycle income. In addition, information with which to compare the findings of those studies which used the voluntary simplicity of lifestyle index would have been interesting. The latter should probably be used as dummy variable to indicate that those who follow such practices are more prone to installation despite marginal economic benefits, while those for whom benefits are obviously high would be predicted to install whether they adhered to voluntary simplicity or not.

The contradictory findings of the variable on belief in the seriousness of the energy problem would be interesting to examine in a before and after context. Questions just before a person installed and a couple of years later would be very interesting.

In conclusion we find that economic benefits and costs are highly important in the decision to install a household solar energy system. Other factors may have additional influence. Economic factors are becoming more important over time, at least in terms of predicting installation, either because individuals are more knowledgeable about benefits or because recent installers are less idealistic and innovative concerning solar energy use, and more interested in the basic economic costs and benefits associated with solar installation.

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