This is to certify that the

dissertation entitled

ENERGY TAX CREDITS AND HOUSING IMPROVEMENT

presented by

MICHAEL JAMES WALSH

has been accepted towards fulfillment
of the requirements for

PhD degree in Economics

Major professor

Date May 20, 1987

ENERGY TAX CREDITS AND HOUSING IMPROVEMENT

By

MICHAEL JAMES WALSH

A DISSERTATION

Submitted to:

Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Economics

1987

ABSTRACT

ENERGY TAX CREDITS AND HOUSING IMPROVEMENT

By

Michael James Walsh

This dissertation investigates whether federal and state tax credits allowed to households who make capital improvements to increase the energy efficiency of their dwellings lead to an increase in improvement activity.

Existing survey evidence regarding the awareness and usage of energy tax credits is reviewed. A two-period utility maximization model of household behavior is then developed and used to determine the theoretical influence of tax credits, energy prices and other relevant factors on the optimal magnitude of conservation capital improvement. Regressions using various qualitative measures of conservation improvement magnitudes as a dependent variable are estimated using household level data from the 1982 Residential Energy Consumption Survey. The results are used to test various hypotheses generated by the behavioral model.

Consistent with earlier research, the empirical tests performed here do not provide evidence to support the hypothesis that energy tax credits lead to more widespread or extensive energy conservation improvement activity.

To Kimberly, our families and William E. Murphy

ACKNOWLEDGEMENTS

Sincere thanks to Professors Ronald C. Fisher and John H. Goddeeris for their guidance and patience. I would also like to thank Professors Daniel B. Suits and Norman P. Obst for their assistance and advice. Comments from Ronald Balvers, Larry Marsh, Rob Wassmer and support from the University of Notre Dame College of Business Administration are also greatly appreciated.

Any errors in this study are the sole responsibility of the author.

TABLE OF CONTENTS

Page

List of Tables vi

List of Figures vii

Chapter 1: INTRODUCTION 1

Recent Residential Energy Trends 3

Tax Credit Programs and
Recent Conservation Activity 5

Energy Efficiency As A Public Good 14

Conclusion and Thesis Format 15

Chapter 2: MICROECONOMIC MODELS OF HOUSING IMPROVEMENT . 16

Introduction 16

Models of Home Heat Production 16

Optimum Marginal Investment Models 18

Constrained Utility Maximization Models . . 23

A Two-period Model of Conservation Improvement 30

The General Approach 36

Chapter 3: PREVIOUS EMPIRICAL FINDINGS AND ESTIMATION
OF THE CONSERVATION IMPROVEMENT MODEL 42

Survey Results 42

Simulation Evidence 44

Empirical Analysis of the Conservation
Improvement Model 45

Data Summary 46

Computation of Net-of-tax Price Terms . . . 50

Econometric Estimation 53

Results 55

Additional Evidence 73

Conclusions 78

Chapter 4: CONCLUSIONS AND POLICY IMPLICATIONS 79

Other Policy Implications 84

Concluding Comments 86

Appendix A: ANALYSIS OF COMPARATIVE STATIC DERIVATIVES OF THE OPTIMUM CONSERVATION IMPROVEMENT MODEL FROM CHAPTER 2 87

Appendix B: IDENTIFICATION OF STATE OF RESIDENCE FOR RECS HOUSEHOLDS 91

Appendix C: RESULTS OF FUEL CONSUMPTION AND TAX CREDIT IMPORTANCE REGRESSIONS 93

Appendix D: DESCRIPTIVE STATISTICS OF INDEPENDENT VARIABLES USED IN CHAPTER THREE REGRESSIONS 95

Bibliography 96

List of Tables

		Page
Table 1:	Real Energy Price and Consumption Growth Rates For Residential Consumers, 1970-1981	4
Table 2:	Per Household Energy Consumption, Fuel Expenditures and Expenditures As A Percent of GNP For Selected Years	4
Table 3:	Federal Government Residential Conservation Program Expenditures	7
Table 4:	Total Federal Tax Credit Claims By Conservation Device	8
Table 5:	Selected Data From State Energy Tax Credit Programs	9-12
Table 6:	Maximum Reductions in Net Price Implied by Federal and State Tax Credits and Deductions	12
Table 7:	Characteristics of Subsamples of RECS Households	48
Table 8:	Linear Probability Model Regression of Expression 27.	57
Table 9:	Logit Estimates of Expression 27. For "West" and Non-"west" Households	62
Table 10:	Multinomial Probit Estimates of the Conservation Investment Model	66
Table 11:	Improvement Actions Predicted by Multinomial Probit Results	68
Table 12:	Logit Regressions of "Major" Improvements	70
Table 13:	Percentage of All 1981 Federal Tax Returns Having An Energy Conservation Credit Claim by Income Category	74
Table 14:	Percentage of All Tax Returns Having An Energy Conservation Credit Claim For Selected States	76
Table B-1:	Steps Used In State Identification Process	92
Table C-1:	Fuel Demand Regressions	93
Table C-2:	Regression Results: Likelihood of Citing Tax Credits As One Reason For Making An Improvement	94

List of Figures

Page

Figure 1: Heat Flow As A Function of Insulation Thickness 22

Figure 2: Heat Flow Through Glass For Single, Double and Triple Pane Windows 22

Figure 3: "other goods"/temperature control indifference curves as fuel price increases 24

Figure 4: "other goods"/temperature control indifference curves for current and future consumption periods 31

Figure 5: "other goods"/temperature control indifference curves for future consumption period. 32

CHAPTER ONE

INTRODUCTION

The energy supply disruptions of the 1970's contributed to large fuel price increases throughout the world economy. Among the policies lawmakers enacted in response were personal income tax credits for taxpayers who improved the energy efficiency of their residences. The federal government and nine states allowed taxpayers to reduce their income tax liability (reduce taxable income in the case of deductions) by various percentages of expenditures for weatherization and other energy conservation equipment. Expenditures for insulation, storm windows, storm doors, caulking and weatherstripping were typically eligible for tax credits. Credits for solar, wind and other alternative generation devices have not been as frequently claimed and are not considered here.

Although proponents of these subsidies claimed they would stimulate energy conservation, the tax credits (around $3 billion worth at the federal level since 1978[1]) may have only rewarded taxpayers who would have weatherized their residences even in the absence of the credits. If this tax expenditure program did not "cause" much conservation activity, the higher tax rates or lower direct expenditures implied by the revenue loss of the program did not produce the desired result. The goal of this study is to determine whether tax credits have caused or merely rewarded energy conservation investment activity. This determination is the first step in calculating the return on public

---

[1] Internal Revenue Service, Statistics of Income: Individual Tax Returns 1978-1982.

investment in residential energy efficiency that the tax credit program may have generated.

The recently released 1982 Residential Energy Consumption Survey (RECS) is used to determine what economic, demographic and public policy factors are associated with increases in the stock of energy conservation capital in existing residences. The survey contains detailed descriptions of household income, fuel consumption and prices and family characteristics. It also details the size, age and thermal quality of the dwelling as well as recent improvements in the energy efficiency of the residence. Households who made improvements were also asked why they did so. Information assembled in other energy and housing surveys as well as IRS tax credit claim data are also used to examine the energy tax credit issue.

The model and data used here also allow estimation of the cross price elasticity between energy capital and fuel prices, and the effects of income and home ownership on conservation investment behavior. A large part of the long-run price elasticity of demand for energy is explained by adjustments in the stock of energy-using capital. The elasticity estimates might be useful for predicting future energy consumption levels and residential conservation capital adoption rates. Government and utility conservation program managers may find the results useful in development of other policies such as home energy audits or low interest loans designed to affect housing maintenance rates or energy usage patterns.

While a few authors have examined some of the factors associated with improvements in residential energy capital (Hirst et. al., 1981), (Hirst and Goeltz, 1985), no statistical analysis of this behavior has been done using a large post-1979 data base and none has examined the influence of federal and state tax credits on conservation investments. The timing of the 1982 RECS survey (December, 1980 through March, 1982) and the detail of its questions and demographic data makes it a unique data base for investigation of many questions important to energy and tax policymakers. While the popular urgency of energy conservation policy has declined with world oil prices, analysis of tax credits and the economic factors associated with conservation improvement may add to the body of knowledge needed for development of sensible energy pricing and conservation policies. Indeed, for many electric utilities, increased energy efficiency is the least cost way to serve their customers.

RECENT RESIDENTIAL ENERGY TRENDS

The catalyst for public action in the field of energy conservation was the impact of the 1973 OPEC oil embargo on domestic energy supplies and prices. Rapid growth in real prices of residential energy and scattered shortages of fuel oil and natural gas probably enhanced consumer awareness of the potential benefits of improving dwelling insulation. Table 1 shows changes in real prices (adjusted by the implicit GNP deflator) and consumption of residential energy between 1970 and 1981. Table 2 shows per household (end-use) energy consumption, total U.S. residential energy expenditures and expenditures as a percent of GNP for selected years.

TABLE 1

REAL ENERGY PRICE AND CONSUMPTION GROWTH RATES FOR RESIDENTIAL CONSUMERS, 1970-1981

	PERCENTAGE INCREASE IN REAL PRICES				QUANTITY GROWTH RATES			
YEARS	Elec.	N.Gas	Oil	All	Elec.	N.Gas	Oil	All
1970-73	-.5%	.8%	5.9%	4.0%	4.9%	-2.5%	-1.6%	-1.1%
1973-79	2.8	6.9	8.3	6.1	.7	-1.8	-6.7	-2.6
1979-81	5.4	9.9	19.0	11.4	-.4	-6.9	-17.2	-7.4

Source: U.S. Department of Energy, 1983 Energy Conservation Indicators

TABLE 2

PER HOUSEHOLD ENERGY CONSUMPTION, FUEL EXPENDITURES AND EXPENDITURES AS A PERCENT OF GNP FOR SELECTED YEARS

PER HOUSEHOLD FUEL CONSUMPTION		RESIDENTIAL FUEL BILL (unadjusted dollars)	FUEL BILL IN 1972 DOLLARS	FUEL BILL AS A % OF GNP
1965	136 Mbtu	n.a.	n.a.	n.a.
1970	152 Mbtu	$19.9 billion	21.6 billion	2.0%
1975	137 Mbtu	$36.8 bil.	29.2 bil:	2.37%
1980	114 Mbtu	$68.8 bil.	38.65 bil.	2.62%
1981	107 Mbtu	$77.8 bil.	39.91 bil.	2.61%

Source: U.S. Dept. of Energy, 1983 Energy Conservation Indicators.

During the late seventies and early eighties per household energy consumption fell below the levels that preceded the steady consumption increases of the sixties. Because residential consumption has remained a nearly constant share of all U.S. energy usage between 1960 and 1983 (around 20%) it is clear that energy consumption in other sectors also declined. Reductions in residential energy consumption are the result of adjustments in energy consuming behavior and improved energy efficiency of production and consumption activities. Behavioral changes include driving less and lowering thermostats. Also, capital improvements have led to increased energy efficiency of driving and indoor climate control as automobile design improvements and efficiency improvements in structures have occurred.

Because about 20% of all energy is used in the residential sector, even small proportionate reductions in residential consumption represent considerable savings. Three-fourths of the energy used in residences is used for space and water heating (15% of all energy consumption) while most of the remainder is used to operate appliances and air conditioners. Because heating is the largest end-use of residential energy it is sensible that improving heating efficiency is the central goal of tax credit and home energy audit programs. A 10% nationwide reduction in residential heating fuel consumption would reduce total residential consumption by at least 5% (assuming over 50% of home fuel is for heating) thereby lowering the annual fuel bill by at least $4 billion. Summing this potential benefit over many future years demonstrates that there has been and still can be large reductions in residential energy consumption and expenditures from improvements in energy efficiency.

TAX CREDIT PROGRAMS AND RECENT CONSERVATION ACTIVITY

From 1977 through 1985, the federal government allowed taxpayers a credit which reduces income tax liability by 15% of the amount they spend (up to $2000 of spending) on conservation improvements (such as insulation or storm windows) and a 40% credit for purchases of alternative generation devices (such as solar or wind units).[2] Credits

---

[2] Internal Revenue Service, 1978.

and deductions for expenditures on home energy efficiency improvements have also been allowed in 9 states. The after-tax price of eligible efficiency improvements is reduced 15% by the federal credit; in some states the combined credits imply net prices 34% less than retail prices. The magnitude of total revenue loss and the levels of participation in the federal tax credit program are shown in Table 3, and the number and value of claims in each category of conservation device are listed in Table 4. Also shown are the levels of budget authority of the U.S. Department of Energy for conservation expenditures for the relevant years. Note that tax expenditures for residential conservation make up the majority of all expenditures for energy conservation. Because a large share of direct expenditures are earmarked for conservation programs in transportation and other sectors, tax credits are the largest federal conservation program in the residential sector. A description of state level tax incentives is shown in Table 5.

TABLE 3

FEDERAL GOVERNMENT RESIDENTIAL CONSERVATION PROGRAM EXPENDITURES

	TOTAL NUMBER ENERGY TAX CREDITS CLAIMED FOR CONSERVATION EQUIP. (billions of dollars in claimed expenditures in parentheses)	REVENUE LOSS FROM CONSERVATION CREDITS (billions)	US DOE BUDGET FOR CONSERVATION (billions)
1978	5.9 million ($4.1)	$.559	$.527
1979	4.8 million ($3.3)	$.436	$.659
1980	4.6 million ($3.2)	$.418	$.660
1981	3.7 million ($2.9)	$.364	$.815
1982	3.1 million (n.a.)	$.338	$.736

Sources: 1978-1982 Statistics of Income; Individual Income Tax Returns; Department of the Treasury, Internal Revenue Service. Washington D.C.

U.S. Government Budget, Fiscal Years 1979-1983. Washington D.C., U.S. Government Printing Office.

TABLE 4

TOTAL FEDERAL TAX CREDIT CLAIMS BY CONSERVATION DEVICE

Number of claims in millions, expenditures claimed in billions of dollars.

	INSULATION	STORM WINDOWS and DOORS	CAULKING, WEATHERSTRIPPING and OTHER
1978			
claims:	3.92 million	3.36	n.a.
amount:	$1.76 billion	$1.8	
1979			
claims:	2.9	2.54	2.26
amount:	$1.3	$1.4	$.567
1980			
claims:	2.7	2.46	2.1
amount:	$1.15	$1.44	$.526
1981			
claims:	2.2	2.04	1.58
amount:	$1.15	$1.46	$.372
1982			
claims:	3.06	n.a.	n.a.
amount:	not avail.		

Source: 1978-1982 Statistics of Income; Individual Income Tax Returns.

TABLE 5

SELECTED DATA FROM STATE ENERGY TAX CREDIT PROGRAMS

ARIZONA: a 25% credit against tax liability is allowed on expenditures for insulation, reflective glass or film, thermal windows and doors, ventilation devices and swimming pool covers.

YEAR	# CLAIMING CONSERVATION CREDITS	TOTAL ALLOWED CREDITS	AVERAGE CREDIT	% OF TAXPAYERS CLAIMING CREDIT
1979	20,318	$1.38 mil.	$67	n.a.
1980	35,527	$2.39 mil.	$67	n.a.
1981	35,223	$2.55 mil.	$72	n.a.
1982	36,985	$3.05 mil.	$82	3.5%
1983	31,332	$2.49 mil.	$79	3.0%
TOTALS	159,385	$11.8 mil.		

NOTE: more Arizonians claimed a credit for conservation purchases than for solar purchases, although the total credit allowed was considerably larger for the latter.

ARKANSAS: conservation expenditures are deductible from income. Income tax rates range from 1% to 7% at $25,000. Eligible items include insulation, storm doors and windows, caulking and weatherstripping, automatic thermostats, vent fans, automatic furnace igniters, flue modifications on furnace openings.

YEAR	# TAKING DEDUCTION	AVERAGE DEDUCTION	REVENUE LOSS
1980	22,034	$673	$593,000
1983	15,312	$797	$488,367

NOTE: An average of less than 2% of Arkansas taxpayers took this deduction.

CALIFORNIA: a 40% credit is allowed on conservation purchases although the credit is reduced by the amount of available federal credit; hence the state credit is actually 25% of costs. Maximum total credit is $1500 per home. The following items are eligible for the credit through 1/1/86 or 1/1/87 depending on dwelling type: insulation, weatherstripping, swimming pool and hot tub covers, water heater insulation, floor insulation in electrically heated residences, heat pumps, shower flow restrictors, vent fans. The following items are eligible for the state credit if recommended by

(Table 5 continued)

a state energy auditor: automatic furnace igniters, modifications to heating or cooling system openings, floor insulation, shading devices and movable insulation (shutters and drapes), storm windows and doors and load management devices.

CALIFORNIA

Tax Year	INSULATION	STORM WINDOWS & DOORS	WEATHERSTR. & CAULKING	POOL COVERS
1981				
# OF CREDITS	131,090	10,601	3,102	22,661
AVERAGE EXPENSE	$715	$1,083	$90	$738
AVERAGE CREDIT	$194	$303	$24	$163

TOTAL ENERGY CREDITS ON PERSONAL INCOME TAX FORMS 1981: $52.8 million

1982 # OF CREDITS	135,286	15,574	2,683	15,835
AVERAGE EXPENSE	$1,004	$1,173	$265	$313
AVERAGE CREDIT	$264	$310	$68	$113

TOTAL CREDITS 1982: $61.1 million

1983 # OF CREDITS	99,147	15,960	6,892	10,412
AVERAGE EXPENSE	$889	$1776	$238	$467
AVERAGE CREDIT	$224	$436	$63	$159

TOTAL CREDITS 1983: $49.4 million

In each of these three years there were around 7000 claims for water heater insulation (ave. credit of $15), around 6400 for automatic ignition devices and vent dampers (ave. credit of $110) and around 9000 claims for load management devices and computer control devices (ave. credit of $220).

COLORADO: a credit of 20% of expenditures (maximum credit of $400) is allowed against tax liability. Eligible items include structural and water heater insulation, storm and thermal windows and doors, caulking and weatherstripping, automatic thermostats and furnace igniters, furnace replacement burners, modifications of flue openings and energy use meters.

(Table 5 continued)

YEAR	NUMBER OF RETURNS (% OF TOTAL)	AVERAGE EXPENDITURE/CREDIT	REVENUE LOSS
1981	69,429 (5.2%)	$703/$141	$9.76 MIL.
1982	64,588 (4.9%)	$629/$126	$8.12 MIL.
1983	45,736 (3.4%)	$674/$135	$6.16 MIL.
TOTALS	179,753		$24.04 MIL.

IDAHO: conservation expenditures are deductible from income. Tax rates range from 0% to 7%. Insulation, weatherstripping thermal and storm doors and windows are eligible.

	# DEDUCTING	TOTAL DEDUCTIONS	AVERAGE DEDUCTION
1983	11,258	$9.25 mil.	$821

INDIANA: conservation expenditures can be deducted from income. Indiana taxes income at a 3% rate. Eligible items include structural and water heater insulation, storm and thermal windows and doors and caulking and weatherstripping. Tax credit claims data were not provided by the state.

MONTANA: a 5% credit is allowed (up to $150) on expenditures for energy conservation. Eligible items are: insulation in existing buildings (allowed for new buildings to the extent that it exceeds established construction standards), pipe, duct and water heater insulation, insulating siding, storm windows and doors, triple glazed windows, caulking and weatherstripping, shower flow limiters, waste heat recovery systems, automatic thermostats and lighting controls.

YEAR	# CLAIMING CREDIT (% OF TAXPAYERS)	AVERAGE CREDIT	TOTAL CREDITS
1981	14,035 (3.4%)	$37.91	$532,058
1982	12,881 (3.14%)	$76.63	$987,048
1983	11,561 (2.84%)	$42.33	$489,375

NORTH CAROLINA: a 25% credit was allowed on conservation expenditures between 1/1/77 and 12/31/78. No data are available.

OREGON: a credit of 25% of conservation expenditures (up to $125 credit) is allowed against tax liability. Eligible items include structural, duct and water heater insulation,

(Table 5 continued)

weatherstripping and caulking, storm and thermal windows and doors, replacement burners for furnaces and boilers, automatic thermostats and ignition devices, humidifiers, dehumidifiers and ventilators.

	# OF CREDITS	AVERAGE CREDIT	REVENUE LOSS
1980	48,579 (4.2% of returns)	$88	$4.26 million

TABLE 6

MAXIMUM REDUCTIONS IN NET PRICE IMPLIED BY FEDERAL AND STATE TAX CREDITS AND DEDUCTIONS

STATE	Maximum Net Price Reduction
Arizona	36%
Arkansas	21%
California	36%
Colorado	31%
Idaho	21%
Indiana	21%
Montana	28%
North Carolina	36%
Oregon	35%

Sources: U.S. Internal Revenue Service, 1977-1983. Respective State Departments of Revenue.

Between 1978 and 1982 over 22.1 million conservation tax credits were claimed on federal tax returns. The fact that the sum of credit claims for specific items exceeds the total number of claims implies that many taxpayers claimed credits for installation of more than one type of conservation equipment. The maximum possible reduction from retail prices of conservation capital caused by federal and state tax policies is shown in Table 6. The calculations include the effects of the increased federal (state) tax liability that results when state (federal) tax credits reduce state (federal) income tax liability.

An Energy Department summary of survey data[3] indicates that between 1978 and 1982 over 75% of households living in single-family dwellings made some kind of improvement in the energy efficiency of their residence. The specific improvements made in many of the 58 million single-family units were:

* 75% installed weatherstripping or caulking
* 42% installed ceiling, wall or floor insulation
* 39% installed storm windows or doors.

Some of these households installed more than one type of device. More households made some conservation improvement in 1980 than in any other year from 1978 through 1982. (Detailed conservation improvement activity data are not available for years prior to 1978). In 1980, 19% of households installed caulking, 13% weatherstripping, 6% ceiling insulation, 3.5% wall insulation, 5.8% storm doors and 4.3% storm windows. The insulation and storm doors and windows numbers indicate a major conservation improvement was made by over 20% (around 11 million) of families living in single-family dwellings. The 1982 RECS asked households why they installed conservation materials; among those who purchased expensive items (insulation or storm windows) 13-15% cite tax credits as one reason for making the improvement.[4] Responses to similar survey questions from other studies are discussed in chapter three.

---

[3]U.S. Department of Energy, Energy Conservation Indicators, 1983.

[4]U.S. Department of Energy, 1982 Residential Energy Consumption Survey: Housing Characteristics.

ENERGY EFFICIENCY AS A PUBLIC GOOD

If the social value of "saved" energy exceeds the market price of energy, markets fail to reflect the full cost of energy and society underinvests in conservation. Policies that reduce energy consumption reduce the amount of negative externalities that result from energy consumption. A policy which leads to more efficient use of energy lowers energy demand profiles and thereby yields public benefits.

The most commonly cited public benefits associated with reduced energy consumption are the national security improvement from reduced dependence on foreign energy sources and reduced environmental damage from hydrocarbon extraction and combustion. Some consider public assistance to subsidize conservation investments of low income families to have a public good characteristic as this redistributes purchasing power from all taxpayers to low income families. It is not clear why reducing the energy cost burden of low-income people is attempted instead of reducing their tax burden or reducing the price of some other good or service they consume in relatively high proportions. Because tax credits are valuable only to taxpayers who have a sufficiently positive tax liability, they do not provide a subsidy to very low income families. Grants, loans and other assistance programs have more potential for helping specific target groups, such as low income households, than do passive tax credits.

Public expenditures for reducing energy consumption generate a net gain to society if the total social value of the resulting energy savings exceeds the net utility loss (utility reduction of all taxpayers minus the utility gain to credit recipients) taxpayers bear by funding a conservation program. An appropriate calculation of the public benefit of a conservation program requires the difficult tasks of determining how much energy savings the program causes as well as assigning a public valuation to each unit of saved energy. A cost-benefit approach for analysis of the effectiveness of the federal energy tax credit program is presented in the concluding chapter.

CONCLUSION AND THESIS FORMAT

No previous study has used a large data base to measure the influence of tax credits on residential energy capital adoption rates. These tax expenditures have totaled in the billions of dollars yet there is little evidence of their effectiveness. The current study fills this analytical gap by testing for the presence of a statistical association between variations in the size of available tax credits and more extensive or more widespread adoption of weatherization capital.

In the next chapter, microeconomic models of home energy consumption and weatherization improvement are reviewed. A two-period utility maximization model is then used to determine the theoretical influence of tax credits and other factors on the optimum magnitude of energy conservation improvement. Existing survey evidence of taxpayer awareness of tax credits and previous findings regarding the factors that influence residential weatherization actions are reviewed in chapter three. The Residential Energy Consumption Survey data set and the econometric specifications and results from testing the behavioral model from chapter two are then presented. Conclusions and policy implications are discussed in Chapter 4.

CHAPTER TWO

MICROECONOMIC MODELS OF HOUSING IMPROVEMENT

INTRODUCTION

In this chapter several existing models of housing improvement behavior are reviewed and a simple model used to describe the theoretical relationship between optimum energy conservation improvement magnitudes and tax policy and other economic variables is developed. Results of the tests of this model are presented in the next chapter as are related empirical findings of other researchers.

The decision to upgrade the thermal efficiency of a housing unit can be modelled by treating the household investment action as a method of changing the cost and production functions for home heat levels (i.e."minimizing cost"), as an investment in accord with the optimum path of housing maintenance (i.e. optimum dynamic investment), or as an explicit attempt to change the utility tradeoff involved in accepting uncomfortable rooms in exchange for higher "after heating" income. All three can be considered in static or dynamic terms and all offer testable inferences about the factors which affect household purchases of energy conservation equipment.

MODELS OF HOME HEAT PRODUCTION

The simplest approach to analysis of conservation investment behavior is a single period cost minimization model of home temperature production. Collins and Gray (1983) use the temperature production function shown as expression 1. (also used by Sinden, 1978 and Peterson, 1974) as a constraint in a cost minimization to derive optimum input combination conditions. Along an indoor temperature isotherm (T_{in} is a constant) and when T_{in} exceeds E, external temperature (i.e. during the heating season):

1. $$T_{in} = RF/ftsq + E$$

where: T_{in} = indoor temperature
- E = external temperature
- R = 1/K
  = unit thermal resistance to heat flow
- ftsq = floor area of heated rooms
- K = conductivity factor of structural materials, i.e. a measure of the number of Btus that one square foot of material will conduct per hour for a given temperature differential, $[T_{in} - E]$.
- F = Btus (British thermal units) of heat produced by the heating unit.

(The correct measure of resistance, R, measures heat flow per inch thickness of material; the denominator of R is multiplied by the number of inches of a wall or insulator). Using the technology expressed as 1. as a constraint in a cost minimization yields the Lagrangian, expression 2:

2. $$L = P_f F + P_R R + M(T_{in} - g(F, R, E))$$

where: P_f = unit fuel price
- P_R = unit insulation price
- M = the Lagrange multiplier
- g( ) = temperature production function (expression 1).

Rearrangement of the first-order conditions yields the following expressions for optimum quantities of thermal insulation, R' and fuel consumption, F':

3. $$R' = \{(P_f sqft[T_{in} - E])/P_R\}^{(1/2)}$$

4. $$F' = \{(P_R sqft[T_{in} - E])/P_f\}^{(1/2)}$$

Condition 3 indicates that optimum R rises not only with higher fuel prices and lower capital prices, but also is higher the colder the cl

A

it

ou

Mu

th

app

wit

Amo

var

ove

con

the

meas

Seve

resu

OPTI

part

pain

aspec

the b

utili

Provi

climate, i.e. the larger is T_{in} - E, and the larger the dwelling size. A tax credit allowed against purchases of insulation equipment lowers its net relative price by a factor of t, the proportion of capital outlays refunded by the tax authority (15% at the federal level). Multiplying P_R by (1 - t) raises the right-hand side of expression 3. thus making a greater amount of insulation optimal.

Even if it is believed that cost minimization is a realistic approach to household behavior, there are numerous technical problems with the above approach that make it difficult to use with precision. Among these are the problems of defining output (temperature) because it varies throughout a structure, the difficulty of actually measuring the overall value of R, the failure to address the "putty-clay" nature of conservation investments that may have occurred in earlier periods and the problems that different heating system efficiencies present in measuring final heat production (as opposed to fuel consumption)[1]. Nevertheless, these models are useful for obtaining comparative static results.

OPTIMUM MARGINAL INVESTMENT MODELS

Other researchers model improvements in home energy capital as a part of a general home maintenance schedule. Just as a fresh coat of paint or a repaired sidewalk increases the investment and consumption aspects of a home, weatherization is considered as a method of altering the bundle of home characteristics in order to increase household utility. These theories examine investment in energy saving capital as providing future cost and benefit streams and prescribe actions on the

[1]See Scott and Capper for additional critique of these models.

basis of maximizing either return on investment or long run utility. The more sophisticated approaches use control theory to derive an optimum future schedule of investments. A simple marginal utility approach would indicate that an investment to increase energy efficiency is desirable to a consumer if the marginal benefits of an investment exceed the marginal costs, i.e. if condition 5. holds:

5. $MB_i > MC_i$ where (private) $MB_i = DU(\sum_{t=1}^{T} DF_{it} * P_{ft} e^{-rt} + DSV_i e^{-rT})$

where: DU = change in utility as a function of changes in future income

MC_i = marginal cost of improvement i

T = final date of occupancy for current household

DF_{ti} = reduction in fuel use resulting from item i at time t

= $F_{ti} - F_{to}$ where F_{to} is fuel consumption in period t in the absence of item i

P_{ft} = fuel price in time t

DSV_i = change in sales price of the residence resulting from the presence of the improvement

t = time period subscript, r is the consumer's discount rate

This is similar to approaches used by Isakson (1983), Johnson and Kaserme (1984) and Hirst and Goeltz (1984). This analysis assumes that any improvement increases the non-depreciating stock of energy capital for an indefinite period. Again, this approach ignores the increases in comfort and the social benefits which adoption of conservation equipment may imply. Presumably one could add a term to acc

ber

pub

the

on

ta

ur

es

al

es

oh

pt

nc

ap

re

o

nt

re

account for "public" benefits from energy savings to the marginal benefit expression to make it a more complete measure of private and public benefits (See Johnson and Kaserme). Expression 5. indicates that the level of desirable investment rises (other factors held constant):

i) the lower the after-tax price of improvements

ii) the greater is DF; the more fuel saved by a particular capital improvement

iii) the higher is P_{ft}; i.e. higher future fuel prices

iv) the higher is DSV_i; i.e. the higher the proportion of the value of reduced "operating" expenses that are capitalized into the sales price of the residence

v) the lower the discount rate applied to future reductions in fuel outlays

vi) the larger the increase in utility as future income rises

Conclusions i) and iii) are essentially the same as the results of the static cost-minimization model. Ceteris paribus, a larger number of future periods of fuel savings makes more conservation improvement desirable. If, however, consumers believe that some portion of the value of weatherization is capitalized into the sales price of the residence (there is some evidence in support of capitalization, see Johnson and Kaserme) then the influence of expected home tenure on optimum improvement depends on the discount rate applied to that increase in resale value and the proportion of value believed to be capitalized into the home price. The tenure and capitalization factors are particularly relevant for analyzing the behavior of renters (those who directly pay their fuel bills and improvement costs). Because renters tend to stay in a particular dwelling for a shorter time than owner-occupants, an improvement made at the expense of the renter is attractive only if it pays for itself very quickly. Also, the future increase in rent or enhanced marketability of a rental unit that may result from better energy efficiency will not benefit current renters at all.

Another implication of 5. is that higher future fuel prices make it optimal to undertake more weatherization. Larger fuel price increases make larger weatherization improvements attractive for two reasons: an unimproved structure will be farther from the optimum mix of fuel and capital the larger the price increase, and an adaptive approach to predicting fuel price increases leads to expectations of even higher future prices and potential savings. This point may explain why many households waited until 1979 or later to install energy efficiency improvements. Between 1973 and 1979 real residential fuel prices rose 2.8% for electricity, 6.9% for natural gas and 8.25% for fuel oil. These were greatly exceeded by the increases of the three year period of 1979-1981 when prices rose 5.4% for electricity, 9.9% for natural gas and 19% for fuel oil (U.S. Department Of Energy, 1983). Conservation measures which did not appear to be economically attractive before 1979 suddenly became economic when larger fuel price increases occurred and suggested the possibility of even higher fuel price growth rates in the future.

The result which causes monetary benefits from efficiency improvements is, of course, a reduction in fuel consumption. The magnitude of reduction depends on the level of pre-improvement fuel consumption. A higher marginal product (fuel use reduction) of conservation devices increases the return on investment thus making these purchases more desirable. The proportionate reduction in fuel use from adding, for example, three inches of attic insulation, is larger the more poorly insulated is the structure before its addition. This reflects diminishing marginal productivity of structural weatherization as demonstrated in the following figures taken from engineering-cost analyses.

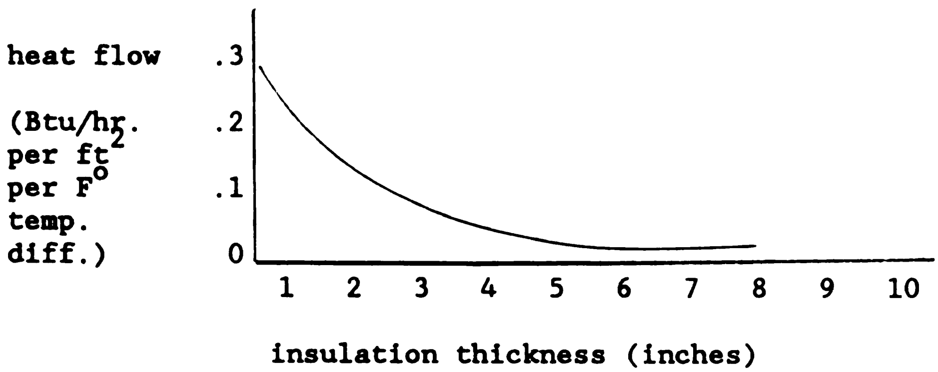


Figure 1

HEAT FLOW AS A FUNCTION OF INSULATION THICKNESS

Source: U.S. Department of Agriculture, 1975

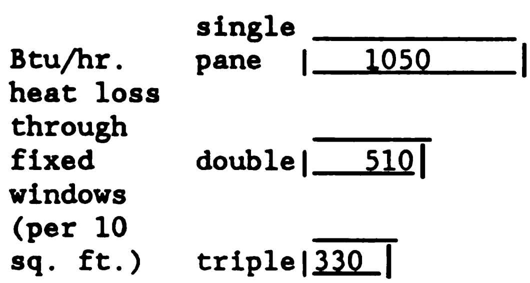


Figure 2

HEAT FLOW THROUGH GLASS FOR SINGLE, DOUBLE AND TRIPLE PANE WINDOWS

Source: Small Homes Council, Univ. of Illinois, 1979

A lower initial level of insulation implies a higher available marginal product for a given increase in the insulation level of a structure. This raises the value of the marginal benefit expression thus making weatherization investments more attractive. In summary, the hypothesis just developed is that changes in the amount of energy saving capital will be negatively correlated with initial levels of this capital stock.

CONSTRAINED UTILITY MAXIMIZATION MODELS

Consider a simple model of utility maximizing behavior in the consumption of home temperatures. Note that it is the demand for comfortable home temperatures that yields the derived demand for fuel and capital inputs. Just as the cost minimization model for temperature production dictates substituting capital for fuel when fuel prices rise, utility maximization prescribes substituting away from consumption of home heat towards other goods as the relative price of heat rises. Also, as depicted in Figure 3, the income effect of a fuel price increase shifts the heat vs. other goods budget constraint inward, thus forcing lower consumption of other goods as well (assuming "other goods" are normal goods). This increase in "temperature" price results as the price of fuel inputs rises. A household optimizing in both consumption and production will "consume" less heat and, as suggested by cost minimization models, be less fuel intensive in producing heat.

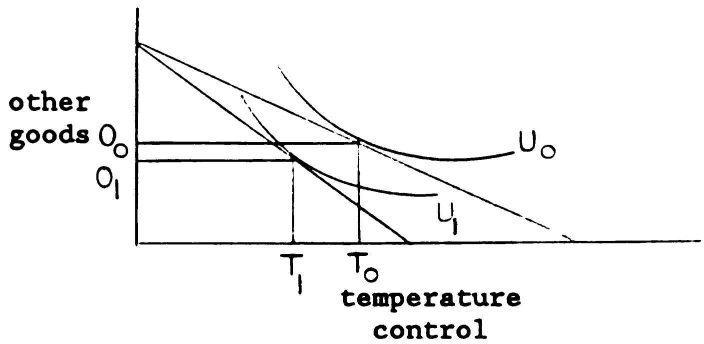


Figure 3

"OTHER GOODS"/TEMPERATURE CONTROL INDIFFERENCE
CURVES AS FUEL PRICE INCREASES

Models that include both preferences and production are now examined. These are used later in the formulation of appropriate behavioral models for evaluating the influence of prices, income, policy and other factors on conservation capital adoption rates. Some of these models are found in the optimal housing maintenance literature and are adapted for the current purposes, while others were specifically developed for analysis of energy conservation investments.

The household problem of how much to increase the stock of imbedded energy-related capital in a current residence is not fundamentally different from the problem of sustaining the right pace of overall housing maintenance and improvement. Any allocation of resources for upkeep or betterment of a dwelling is presumably done to provide future benefits in the form of higher housing quality ("utility" return on investment; more comfort etc.) lower "operating" costs (smaller fuel bills) and/or a higher resale price (pecuniary return on investment). The following analysis pursues this line of thinking in development of marginal conditions for optimum housing maintenance schedules.

In seeking to maximize the utility provided by their dwelling, households typically allocate improvement and maintenance expenditures over a wide variety of home improvements. Households can be assumed to maximize some combination of visual attractiveness, location, convenience and comfort from a dwelling subject to a housing cost constraint that includes "fixed" costs such as mortgage payments, operating costs and improvement expenses. Reducing the operating cost (fuel cost) portion in the cost constraint causes an outward shift of the heat/other goods isocost lines. Investments in weatherization may thus allow the household to attain a higher indifference surface in the future. As fuel prices rise, expenditures for energy efficiency have a greater marginal effect on shifting out (or avoiding an inward shift) operating cost isocost functions, thus making such expenditures more attractive compared to other improvement options. This change shifts the "best" maintenance path toward investments in energy efficiency.

Dildine and Massey (1974) and Sweeney (1974) formalize the above approach. They examine the problem faced by landlords in deciding the best strategy for maintaining rental units in order to maximize their net lifetime rent. When analyzing homeowner optimization related to housing consumption and investment, the problem becomes one of long run utility maximization of owner-occupied housing.

The landlord's problem in the Dildine and Massey paper is to maximize after-cost rents, a discounted stream of per unit rents times the number of housing quality units minus operating and improvement costs (expenditures on the latter affect quality and gross rental value). This optimization is subject to a differential equation that describes the time path of housing quality as a function of improvement inputs and quality depreciation rates.

Similarly, Sweeney's approach considers optimum maintenance paths for a utility maximizing owner-occupant. The owner is assumed to maximize expression 6., economic surplus:

$$6. \quad U = \int_0^T [W(Q) - C(M,Q,t)]e^{-rt}dt + SV[Q(T), T]e^{-rt} - SV(Q_0,0)$$

where W(Q) is the owner-occupant's willingness to forego other goods and services in order to consume housing services having quality Q. This "willingness to pay" is assumed to measure willingness net of current costs such as property taxes and heating bills. The other arguments in the objective function are:

C(M,Q,t) = costs of maintenance as a function of:
M, rate of maintenance,
Q, housing quality
t, time period
and r = discount rate
SV = sales value of dwelling
T = final period
Q_0 = initial quality of the dwelling.

The household is assumed to choose an optimum path of M and Q and would not purchase the dwelling unless $U \geq 0$. If $U < 0$, another residence would be purchased or rented. The first order condition from the Hamiltonian optimization gives a maximization of surplus to the owner-occupant (willingness to pay minus costs plus revenue from the sale of the unit minus initial cost). The maintenance path M* is optimal if the marginal cost of all M*(t) (the "quantity" of maintenance purchased in period t) equals its marginal contribution to the value of the housing unit. This rule is the dynamic analog to the optimum conservation investment rules derived earlier in the chapter.

Investments in energy efficiency fit in this optimization process by increasing Q, the quality of a dwelling (by making it more comfortable) or by reducing C, the cost of "maintaining" the dwelling. In either case the goal is presumably to increase economic surplus. These dwelling improvements and operating cost reductions are compared with the costs of making the improvements to yield the optimum improvement path. As was found in other models, the optimum quantity of improvement rises with reductions in the price of improvements or reductions in the discount rate, and increases as the marginal effect on quality or operating costs rises or as the number of time periods over which benefits are enjoyed increases.

One novel but sensible result from this model is that energy efficiency investments which drastically reduce the visual attractiveness or increase the inconvenience of living in the home (reductions in Q) may be undesirable as these disadvantages might overwhelm the value the owner places on the resulting reduction in fuel bills. Alternatively, these problems may reduce the resale value of the residence.

A recent paper by Karp (1984) uses a utility maximizing approach for explicit analysis of consumer demand for insulation and fuel. The first stage of the two stage model determines the desired level of non-negative insulation upgrade. The second, done first, minimizes daily disutility of heating, a weighted sum of discomfort from "too cool" rooms and the cost of heat. The second stage minimizes expression 7., daily disutility, with respect to X, fuel consumption.

$$7. \quad u(X(t)) = \int_0^d (w/2)(T^* - T(t))dt + \int_0^{24} cX(t)dt$$

where: w = weighting parameter giving the dollar equivalent of the disutility of the deviation of actual temperature from ideal temperature
d = number of hours per day occupants are concerned about dwelling temperature
T^* = ideal indoor temperature
$T(t)$ = actual indoor temperature setting
c = cost of a unit of energy
$X(t)$ = rate of consumption of energy at time t

subject to a temperature dynamics function approximated by:

$$8. \quad \dot{T} = [A/RhVCp](E - T(t)) + [X(t)/hVCp]$$

where: A = surface area of external walls
R = unit thermal resistance
V = volume of rooms being heated
h and Cp are known physical parameters.
E = external temperature

Minimization over the interval (0, d) yields a solution for daily fuel usage which dictates using additional units of fuel if the costs of doing so do not exceed the benefits it provides. The conditions generated by the Hamiltonian minimization yields equation 9. which describes consumer weighting of temperature discomfort:

$$9. \quad w = ac/f(T^* - T(t))$$

where $a = A/RhVCp$, $f = 1/hVCp$ and $T(t)$ is the actual temperature setting.

The total disutility associated with a full season of heating is found by summing the daily levels of discomfort disutility (discomfort weight "w" multiplied by discomfort magnitude $(T^* - T(t))$) and the daily cost of maintaining actual temperature $T(t)$. The total disutility value U^* is then used in the first stage of the problem, computation of R', the optimum increase in R. The first stage problem is to minimize over R expression 10. (assuming an infinite time horizon):

$$10. \quad \sum_{s=0} BU^*(a(R)) + k(R' - R_0)$$

where: B = the consumer's discount rate
U* = the disutility of a heating season of discomfort and heating costs associated with some chosen level of T(t)
k = the cost of increasing insulation from existing level R_0 to new level R'.

Karp contends that R is not a continuous variable, thus preventing derivation of a first-order condition from 10. to which the implicit function rule might be applied. Because of this assumption, the optimum change in R derivable only by numerical methods. This assumption seems to be incorrect because changes in R are indeed continuous. Weatherization can be done in any amount; one could, for example, caulk one or several windows or completely insulate the walls or ceiling of a structure. The former actions can cause small, continuously variable changes in the overall thermal efficiency of a building.

The only qualitative conclusion reported in the Karp paper is that the optimum increase in R is non-decreasing in B, the consumer's discount rate. Other important contents in the paper include the recognition of the importance of differences in home occupancy rates and temperature discomfort weightings across households. Energy consumption and conservation studies should control for these factors when data are available to represent the differing home usage and utility function parameters displayed by different households.

A TWO-PERIOD MODEL OF CONSERVATION IMPROVEMENT

In this section, a two-period utility maximization model of consumer behavior is used to describe the expected effects of economic and policy variables on conservation capital improvement activity. The approach used here is a simplification that summarizes the intertemporal nature of conservation investments. The model assumes consumers compare the current period sacrifice implied by improvement outlays with the benefits that occur in the future period to determine the optimum capital improvement. The optimum improvement in energy conservation capital is found to be a complex function of preference parameters, income, initial thermal quality of the consumer's dwelling, external temperatures, fuel prices and, of particular interest here, after-tax-credit prices of conservation improvements. The influence of the utility function parameters on the optimum quantity of improvement can be used to predict the direction of influence expected home tenure has on optimum improvement quantities. The model provides a framework for choosing variables appropriate for testing hypotheses regarding the influence of tax credits and other variables on residential conservation improvement activity.

While focusing on two periods, it is best to interpret the current model as a long-run equilibrium model that prescribes the optimum long-run quantity of thermal integrity a household should have but ignores the path between the current quantity and the optimum quantity. The possibility for continuous amounts of conservation improvement was not allowed by Karp, but is critical here as it permits the formulation of a first-order condition for optimum conservation capital improvement.

The behavioral model assumes that consumer utility increases as more "spendable income" (or "other goods"), income net of expenditures on conservation improvements is available in the current period, and as home temperature control and income net of expenditures on temperature control are greater in the future period. Expenditures for home energy conservation affect utility by reducing current period "other goods" consumption and by allowing increased "other goods" and temperature control consumption in the future period. A marginal energy conservation improvement is worthwhile if the utility of increased future "other goods" and temperature control consumption outweighs the utility loss implied by reductions in current period "other goods" consumption.

In terms of the current and future period temperature/other goods indifference diagrams shown as Figures 4 and 5, the optimum expenditure for conservation is such that the current period utility loss implied by a shift from Uc_0 to Uc_2 (Uc_2 is below Uc_1 because temperature control consumption has already been chosen) just equals the (discounted) utility gain implied by a shift from Uf_0 to Uf_1.

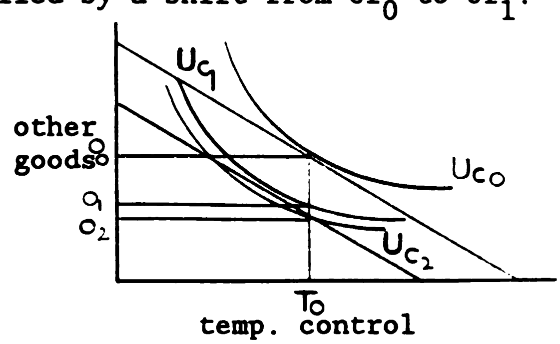
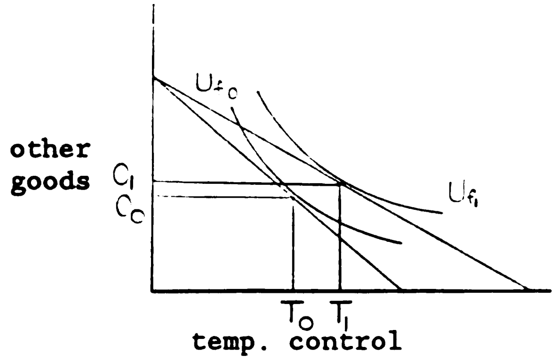


Figure 4

CURRENT PERIOD "OTHER GOODS"/TEMPERATURE CONTROL INDIFFERENCE CURVES



future period

Figure 5

FUTURE PERIOD "OTHER GOODS"/TEMPERATURE CONTROL INDIFFERENCE CURVES

The utility function 11. adds together the Cobb-Douglas functions used to represent utility in current and future periods. Consumers choose R′ and T to maximize:

11. $$U = Y_0^{a} + DY_1^{b}T^{(1-b)}$$

where:

Y_0 = current period income after conservation capital expenditures ("other goods")

$= Z_0 - R'P_R$

where: Z_0 = current period gross income

R' = "quantity" of thermal integrity improvement purchased at the end of the current period

P_R = $MC_R(1-t\rho)$, the perceived net price of conservation equipment, i.e., the marginal cost of unit increases in R multiplied by one minus the perceived proportion of expenditures allowed to be credited against income by the tax authorities.

ρ represents the extent to which consumers accurately perceive the price reduction implied by a tax credit. Here it is assumed $0 \leq \rho \leq 1$. $\rho = 1$ if consumers accurately perceive the credit. ρ approaches zero if consumers have less than perfect knowledge, implying a tax credit has a smaller perceived price reducing effect.

D = a discount factor
  = $1/(1+r)$ where r is the consumer's discount rate

Y_1 = future period income after expenditures on temperature control

  = $Z_1 - P^f F(T, R_1, E)$

where: Z_1 = future period gross income

P^f = future period fuel price

F = future period fuel consumption which is a positive function of T, the chosen temperature control level in the future period and a negative function of R_1, the thermal quality of the dwelling in the future period. In the heating season F is inversely related to E, external temperatures, while it is positively related to E in the cooling season.

T = future period temperature control[2].

  = $(T^* - |T^* - Ta|)/T^*$

where: T* is an "ideal" indoor temperature, the one chosen if heating or cooling were free. Ta is the actual indoor temperature (approximated by the thermostat setting) and $| \ |$ is the absolute value operator.

In the heating season T*>Ta so $T = Ta/T^*$.

$R_1 = R_0 + R'$ = thermal quality in the future period

  = initial thermal quality of the dwelling (R_0) plus R' thermal improvement occurring in the current period

  "a" and "b" are utility parameters assumed to be less than one.

The temperature control level in the "current" period is not included in the utility function because it assumed to have been chosen prior to the conservation improvement decision and is thus irrelevant to the choice of optimum thermal improvement. The first-order condition for optimum R', thermal improvement, can be derived if the relationship

---

[2]This temperature control variable is similar to that described in Karp, (1984).

between fuel consumption and thermal quality is added to the model. A simple technical expression for (heating) fuel consumption along isotherm Ta is 12.[3].

12. $F = (Ta - E)Ah/R_1$

Thus heating fuel consumption rises with Ta, actual indoor temperature and A, area being heated (assumed exogenous here) and falls as external temperature (E) or thermal quality (R_1) are higher. h is an exogenous physical parameter. The second derivative of F with respect to R is positive, implying diminishing marginal fuel use reductions as R is increased. When TT* is substituted for Ta, the partial derivative of F with respect to R_1 is:

13. $\partial F/\partial R_1 = -(TT^* - E)Ah/(R_1)^2$

Expressions 14. and 15. are the first-order conditions for the choice variables R' and T. These are derived by computing the unconstrained maximum of U with respect to R' and T (budget constraints are implied in the objective function). Because the maxima are computed by taking partial derivatives with respect to the choice variables, the influence of an increase in R on the optimum level of temperature control ($\partial T/\partial R'$), is ignored when the optimum increase in R is derived.

14. $$\partial U/\partial R' = aY_0^{a-1}(-P_R) + \\ + bDY_1^{b-1}T^{1-b}(-P_f)\{-(TT^*-E)Ah/(R_0+R')^2 | T_0\} = 0$$

---

[3]The isotherm expression is derived from the temperature dynamics approximation described in Kreith and Black.

$$15. \quad \partial U/\partial T = (1-b)DY_1{}^{b}T^{-b} + bDY_1{}^{b-1}T^{1-b}(-P_f)[T^*Ah/(R_0+R')] = 0$$

Expression 14. includes the utility reduction implied by a current period expenditure on R′ and the utility increase implied by increased future period "other goods" consumption that result from the fuel savings as R is increased. The latter is the magnitude of fuel savings multiplied by P_f, the price of fuel. ($-P_f$ is also the derivative of net income with respect to fuel consumption). The second term of 14. expresses the utility of fuel savings resulting from an increase in R if T were held constant at T_0 (the assumed level of current period temperature control).

It is useful to rearrange 15. and express optimum future period temperature control as a function of R_1. Expression 16. shows this relationship:

$$16. \quad \text{optimum } T = [(1-b)/T^*]\{Z_1(R_0 + R')/P_fAh + E\}$$

Optimum future period temperature control is a positive function of the utility parameter for temperature control (1-b), gross income (Z_1), the degree of thermal integrity (R_1) and external temperatures, and is negatively related to the utility parameter of net income (b), fuel prices (P_f) and home size (A).

Expression 16. indicates that the optimum value of T is an implicit function of R′. Also, the optimum value of R′ depends on the chosen future level of T. Thus it is not possible to solve for a single expression to describe the optimum value for R′. In order to determine the direction of influence of energy tax credits, energy prices and other exogenous variables on the optimum amount conservation improvement, it is necessary to take advantage of the fact that 14. and 15. are a pair of simultaneous equations that are both implicit functions. An approach described by Chiang (1974) is used to determine the signs of comparative static derivatives of optimum R' with respect to the exogenous variables of interest.

THE GENERAL APPROACH

Equations 14. and 15. are the specific expressions for $\partial U/\partial R'$ and $\partial U/\partial T$. It is convenient to use their general forms in the derivation of the formulae for comparative-static derivatives of the optimum R'. Renaming 14. and 15. as F^1 and F^2 we have:

$$17. \quad F^1: \ \partial U/\partial R' = (\partial U/\partial Y_0)(\partial Y_0/\partial R') + (\partial U/\partial Y_1)(\partial Y_1/\partial F)(\partial F/\partial R' | T_0) = 0$$

$$18. \quad F^2: \ \partial U/\partial T = \partial U/\partial T + (\partial U/\partial Y_1)(\partial Y_1/\partial T) = 0$$

In order to explain the general approach, the partial derivative of optimum R' with respect to P_R, the net-of-tax-credit price is now presented. The procedure requires that the other variables be held constant.

If one takes the total differential of 17. and 18., sets all differentials except dP_R equal to zero and rearranges terms, we have:

$$19. \quad (\partial F^1/\partial R')dR' + (\partial F^1/\partial T)dT = -(\partial F^1/\partial P_R)dP_R$$

$$20. \quad (\partial F^2/\partial R')dR' + (\partial F^2/\partial T)dT = -(\partial F^2/\partial P_R)dPR$$

Dividing each side by dP_R yields:

$$21. \quad (\partial F^1/\partial R')(dR'/dP_R) + (\partial F^1/\partial T)(dT/dP_R) = -(\partial F^1/\partial P_R)$$

22. $(\partial F^2/\partial R')(dR'/dP_R) + (\partial F^2/\partial T)(dT/dP_R) = -(\partial F^2/\partial P_R)$.

These equations can be expressed in the general matrix form Ax=b which is:

23.

$$\begin{bmatrix} \partial F^1/\partial R' & \partial F^1/\partial T \\ \partial F^2/\partial R' & \partial F^2/\partial T \end{bmatrix} \begin{bmatrix} dR'/dP_R \\ dT/dP_R \end{bmatrix} = \begin{bmatrix} -(\partial F^1/\partial P_R) \\ -(\partial F^2/\partial P_R) \end{bmatrix}.$$

Assuming the determinant of the "A" matrix is positive as required by the second order conditions for a maximum, Cramer's rule indicates that the sign of dR'/dP_R is the same as the sign of $(-F^1{}_{PR})(F^2{}_T) + (F^2{}_{PR})(F^1{}_T)$. (Because the other exogenous variables are held constant, the derivatives dR'/dX_i can be interpreted as partial derivatives. Thus those derivatives are hereafter labelled $\partial R'/\partial X_i$.) Because $F^2{}_{PR}$ is equal to zero and $F^2{}_T$ is negative (it is the second derivative of U with respect to T) it is only necessary to determine the sign of $F^1{}_{PR}$ to sign $\partial R'/\partial P_R$. From 17., $F^1{}_{PR}$ is found to be:

$$F^1{}_{PR} = (a-1)a(Z_0-R'P_R)^{a-2}(-R')(-P_R) \quad + \quad (-1)a(Z_0-R'P_R)^{a-1}$$

Because a<1, $F^1{}_{PR}$ is clearly negative. Thus the model indicates that $\partial R'/\partial P_R$ is negative, implying that households that have larger perceived income tax credits for conservation improvements are predicted to make larger increases in R, other factors held constant. A larger tax credit implies a smaller P_R and the latter increases the optimum R'. Conversely, a value of ρ close to zero (unperceived tax credit) implies a smaller reduction in net improvement prices thus implying smaller optimum increases in R.

Cramer's rule is also used to determine the signs of the derivatives of optimum thermal improvement with respect to the other exogenous variables of interest. As shown in Appendix A, the derivative of optimum R' with respect to Z_0 is unambiguously positive. Thus households having higher current period income are predicted to make larger increases in R.

The derivative of optimum R' with respect to "D", the discount factor is also positive. Households that apply a higher discount rate against increases in future temperature control and "spendable income" have a lower value for "D" and thus are found to have a lower optimum increase in R. The optimum increase in R declines as "a", the utility parameter on current period "spendable" income rises. This conclusion indicates that a larger weighting for current period net income in the household's "lifetime" utility function implies a smaller optimum increase in R. Thus households that have "shorter" future period should make smaller increases in R. The practical implication of this result is that older households and renters (who have shorter expected tenures in their dwellings) will receive shorter streams of benefits from increases in R and thus should make smaller improvements.

The derivative of the optimum increase in R with respect to "b", the utility parameter of future period "other goods" consumption, is indeterminate. Recall that 1-b is the utility parameter of future period temperature control. If the utility parameters on future period "other goods" and temperature control were independent, a larger weighting on future period "other goods" in the lifetime utility function would probably imply a larger optimum increase in R to reflect the relative importance of having large amounts of after-fuel income in future periods. The same reasoning would apply if the weight on future period temperature control was independent of that on "other goods". In the current model, however, a larger weight on future temperature control (which would imply a larger increase in R so that more temperature control could be consumed in the future) implies a smaller weight on future after-fuel income. The smaller weight on "other goods" dictates a smaller increase in R while the larger weight on temperature control suggests the opposite. The comparative static derivative of optimum R′ with respect to "b" is quite complicated because "b" appears as an exponent in several parts of the relevant expressions of the derivative.

The sign of the comparative static derivative of optimum R′ with respect to P_f, future fuel prices, cannot be unambiguously determined. As shown in the appendix, the appropriate determinant has both positive and negative components. This can be explained by considering the offsetting "substitution" and "scale" effects that an increase in fuel prices implies for the production of home temperature control. As shown by other models, least-cost temperature control production requires the use of more thermal integrity (insulation) as fuel prices rise. Thus the substitution effect of a fuel price increase dictates a higher optimum value for R. Recall, however that expression 16. indicated optimum temperature control consumption falls as fuel prices increase. A simple single-period model of utility maximization that yields a choice of the optimum insulation level indicates that the optimum value of R is positively related to the chosen level of temperature control.

Thus the "scale" effect of a fuel price increase dictates consuming less temperature control, and a lower level of temperature control leads to a lower optimum value of R. Clearly the substitution and scale effects work in opposite directions.

The influence of E, external temperatures, on optimum R′ is also indeterminate. While least cost production of T suggests an increase in R as E falls (a colder climate), optimum T declines as E falls. Again, the "scale" effect (a lower E implies a lower T, a lower T implies a lower optimum R) works against the "efficient production" conclusion that R should rise a E falls. For the same reasons, the effect of "A", area size of the dwelling, on optimum R′ is also indeterminate. Again, in both cases the determinants that yield the comparative static derivatives are too complicated to indicate the conditions under which either of the opposing effects would dominate.

The derivative of R′ with respect to R_0, the initial thermal integrity of the dwelling is also indeterminate. The single-period static optimization approach to the choice of R cannot help explain this result because that approach does not assume there was a pre-existing level of R. Intuition suggests that the expected sign of $\partial R'/\partial R_0$ is negative as a higher (lower) initial level of R implies a smaller (larger) fuel use reduction from marginal increases in R. A lower level of initial thermal integrity does, however, imply a lower level of "real" income (net-of-fuel purchasing power) which intuitively suggests that households having a lower R_0 are less able to afford outlays for thermal improvement. Thus households with poorly insulated dwellings may be less able to afford thermal improvements because their current fuel bills absorb such a high proportion of their gross incomes.

Absent such an explanation, it is unclear why the "diminishing returns" effect that suggests adding less insulation to an already well-insulated home does not dominate whatever other possible effects there might be.

An empirical test of the model is presented in the next chapter. Households from the 1982 Residential Energy Consumption Survey are assigned a net-of-tax-credit price of conservation improvements based on their state of residence and predicted income tax rates and filing status. Variables to represent income, current fuel prices, dwelling size and outdoor temperatures are available in the RECS data set. It is necessary to use proxies to represent the influence of expected future fuel prices, expected housing tenure and initial thermal integrity variables.

CHAPTER THREE

REVIEW OF EMPIRICAL RESEARCH AND ESTIMATION OF THE CONSERVATION IMPROVEMENT MODEL

A review of existing empirical studies and results from estimation of several forms of the conservation investment model developed in the previous chapter are now presented. Additionally, Internal Revenue Service data on energy tax credit claims are reviewed.

SURVEY RESULTS

The general finding of survey evidence regarding awareness and use of energy tax credits is that most people are aware of the credits, but very few change their behavior because a credit is available.

Pitts and Wittenbach (1981) surveyed 146 households from the upper midwest who had conservation improvements installed by local contractors. Among those eligible for a (federal) credit, 18% did not claim one. Those who did claim the credit had, on average, higher incomes, more education, more valuable homes and a better understanding of the nature of the tax credit. Only 37% correctly understood how a credit works; many confused it with deductions or other adjustments to income.

When asked to rank the reasons why they made improvements, 95% of those surveyed ranked "energy costs" as most important and none ranked availability of a tax credit as most important. Also, none of the respondents said they would not have made the improvements if the tax credit was not available. Indeed, 39% learned of the credit after making their purchase. Those who knew of the credit before purchase did not spend more than those who learned of it after making an improvement. The fact that relatively few households accurately understood the tax credit or knew of the credit before making an improvement supports the hypothesis that ρ, the factor used in the model to represent the accuracy of perception of tax credits, is less than one.

Carpenter and Chester (1984) examined 8369 voluntarily returned questionnaires (64% of those sent out) from residents of ten western states. Of the 4892 homeowners, 87% were aware of the federal tax credits and 1440 (29%) made conservation improvements and claimed a credit. Among those who claimed a credit, 1% said they "definitely would not" have made the improvement they did if the credit was not available, while 5.3% said they "probably would not" have made the improvement in the absence of the credits. The remainder said they probably or definitely would have made their improvements even without the credit being available. Incidentally, 27% of those who purchased solar energy equipment said they probably or definitely would not have purchased that equipment if the large solar credits were not available.

Petersen (1985) used a data base similar to that reported by Carpenter and Chester and further disaggregated the categories of respondents. He found that the proportion of taxpayers who claimed the tax credit rose with amounts spent on conservation improvements. This is not surprising because the total value of a credit rises (up to a $300 maximum credit) with the amount spent. Also, the proportion of those saying they would have spent less if the credit was not available rose from 15% of those spending $70-$200 to 37% of those spending more than $2000. Consistent with IRS data, Petersen reports that the proportion of households who claimed a credit rises steadily with income, thus confirming the distributional result found by other authors. Unfortunately none of these studies differentiated between awareness or effectiveness of federal versus state energy tax credits.

A recent Energy Information Administration report provides new evidence of the apparent ineffectiveness of tax credits. Among households who made conservation improvements, the proportion of those who did NOT claim a tax credit rose from 68% among those with incomes above $30,000 to 92% among those with incomes below $10,000. The great majority indicated they would have made the same improvement if the credit was not available. The tax credit apparently was a windfall for those respondents. When asked why they did not claim the credit, lack of awareness and failure to file the long form were cited by around half the lower income households and by 11% of those with incomes above $30,000. Around one-fourth of the households who made improvements said the credit was not claimed because it was too much trouble to get the forms or the amount of the credit was too small. The latter reasons were more commonly cited by higher income respondents. Further analysis confirmed that the credit was more likely to be claimed the higher the income and the larger the conservation expenditure. For example, the great majority of those who installed insulation or storm doors or windows and had incomes above $30,000 did claim the credit.

SIMULATION EVIDENCE

Cameron (1985) used a nested logit model of conservation activity for analysis of discrete choices where there are many conservation improvement alternatives. Her results from a simulation based on 1977-78 data indicate that a government subsidy equal to 15% of improvement costs would cause 3% of all households to undertake some

conserva
that all
to the s
same (es
would ha
equipme
percent
storm v
insula
used b
inclu
insul
impro
assum
the l
found
assum
below

EMPIR

RECS
total
report
variab
two. R
conserv

conservation improvement. Implicit in the analysis is the assumption that all households were perfectly informed of the tax credit (contrary to the somewhat uninformed status described above) and all faced the same (estimated) pre-tax equipment prices. This means a tax credit would have the same direct effect as a reduction in conservation equipment prices. The simulation results also showed that for each percentage point decrease in net improvement costs, installation of storm windows and wall insulation would increase by .5% to .6% and wall insulation installations would rise by .9%. The discrete choice model used by Cameron allowed for nine different conservation actions including "no improvement" and eight different combinations of attic insulation, wall insulation or storm windows. Other frequently made improvements were not considered. Certainly the "perfect information" assumptions implicit in the simulations must be considered suspect given the lack of information regarding tax credits that was consistently found in the survey studies. The questionable validity of such assumptions may help explain some of the empirical results presented below.

EMPIRICAL ANALYSIS OF THE CONSERVATION INVESTMENT MODEL

An analysis of residential energy conservation activity using the RECS data set is now presented. First, descriptive statistics of the total sample and households that made conservation improvements are reported. Next, actual and proxy data are matched with the relevant variables used in the conservation investment model presented in chapter two. Results from econometric estimation of several forms of the conservation improvement model are then presented.

DATA SUMMARY

The data set used in the current study is the 1982 Residential Energy Consumption Survey (RECS) compiled for the Energy Information Administration of the U.S. Department of Energy by Response Analysis Corporation. It includes in-home survey responses collected in late 1982 from over 4600 continental U.S. households. In addition to detailed demographic and housing characteristics data, participants reported what energy conservation actions they had taken in the previous two years. Detailed fuel price and consumption data were provided by the respondents' energy suppliers. Dwelling measurements made by the surveyor and local temperature data were added for each household.

Regional variations in the proportion of households that made any conservation improvement reveal a trend that helps explain results presented later in the chapter. In the nationwide sample, 32.8% of households in single-family units and mobile homes made some conservation improvement in the eighteen months prior to the survey. Among different regions the following proportions of households made improvements:

Northeast:	35.4%
North Central:	45.7%
South:	28.5%
West:	21.5%.

For all specific conservation devices except water heater insulation and automatic thermostats, adoption rates in the West were below the national average. Because the majority of states that allow energy tax credits are in the western region, conservation improvement activity appears to be negatively correlated with state energy tax credits.

For the current analysis, only households who made improvements which are eligible for the federal tax credit are categorized as "improvement" households. Renters who do not directly pay utility bills and households who received government assistance for heating or home improvement are removed from the total RECS sample. Also removed were households living in structures built since 1978 (conservation improvements in these dwellings are not eligible for federal or state tax credits) and households who do not use natural gas, electricity, fuel oil or LP gas as their main heating fuel (fuel price data are only available for these fuels). The refined subsample that remains after the above exclusions are made is labeled the "whole" sample. Various characteristics of the "whole" sample and households in that sample who made conservation improvements are shown in Table 7. Because the refined "whole" sample excludes households who were much less likely to make an improvement, the figures shown in Table 7 overstate the overall extent of conservation improvement reported above for the four geographic regions.

Of the selected households, 43.6% made some kind of conservation improvement during the time period in question. Improvement households tend to have higher incomes, larger homes, consume more heating and cooling fuel, live in colder climates (experience more heating degree-days) and are more likely to own their residences.

TABLE 7

CHARACTERISTICS OF SUBSAMPLES OF RECS HOUSEHOLDS

	"WHOLE" SAMPLE	IMPROVEMENT HOUSEHOLDS
Number of observations	2911	1275
% making any improvement	43.6%	100%
% making a "major" improvement	27.7%	63.4%
% making a minor improvement	15.9%	36.6%
mean heating and cooling fuel consumption (millions of Btus)	95.1	105.9
mean heating degree-days (base 65 degrees F)	4839	5397
mean heated home area (square feet)	1631	1871
mean household income	$24397	$27625
% renters	21.2%	7.1%
% stating availability of the tax credit as one reason they made the improvement		9.6% (N=108)

Improvement actions were broken down into "major" and "minor" improvements. Items categorized as "major" are, in declining order of their frequency, storm doors, roof or ceiling insulation, storm windows, wall insulation, floor insulation and automatic or clock thermostats. These items are long-lived and typically cost more than $100. "Minor" improvements are shorter-lived and/or typically cost less than $100. These are (in order of frequency) caulking, weatherstripping, plastic window-covering sheets, hot water heater insulation blankets, hot water pipe insulation and duct insulation. Many of the households that made "major" improvements also made minor improvements.

Clearly not all the items listed increase the R-value of a structure. Some increase the efficiency of a heating system or increase the efficiency of its usage. The cost-benefit approach for analysis of the desirability of the the latter items is, however, completely analogous to the analysis of optimum structural improvements.

When shown a list of ten reasons for making the improvements and asked "which of these were most important in your decision to add or install (item X)" and allowed to circle as many reasons as they wanted, only 9.6% cited "to take the cost as a credit on income tax return" as a reason. In declining order, "saving money", "comfort", "replacement" and "making other improvements" were cited as reasons more often than were tax credits. Thus 9.6% may be the extreme upper bound for the proportion of improvement activity actually "caused" by tax credits in the two year time period being considered.

An (ad hoc) Logit regression of a zero/one dependent variable, one indicating that the household cited tax credits as one reason for making an improvement, was run to examine the factors associated with listing tax credits as a reason. Among households who made an improvement, the likelihood of citing tax credits as important rose with the magnitude of the improvement and income and fell with age. The available tax credit term had a positive coefficient in this regression, and is significant at the 95% level (see appendix C). This indicates that the larger the improvement or available tax credit, and therefore the larger the value of the credit, the more likely the household is to cite the credit as important. If one assumes that anyone who claimed a credit would cite it as o

claimin

results

energy

Rather

as one

the va

cited)

COMPUT

After

credit

federa

feedba

any ho

tax li

the ne

states

24.

it as one important factor, these results may indicate the act of claiming a credit is more likely as its magnitude grows. The above results do not, however, provide support for the hypothesis that larger energy tax credits lead to more extensive conservation improvement. Rather, this result only suggests that the act of citing the credit as one reason for making an improvement is positively associated with the value of the credit. Thus the credit may have been claimed (and cited) because it was larger in magnitude.

COMPUTATION OF NET-OF-TAX PRICE TERMS

After identifying residents of states which allow conservation tax credits or deductions (see appendix B for details of this procedure), federal and state tax credit values and state/federal tax deduction feedback effects were assigned to each household. It is assumed that any household with gross income above $4000 and thus a positive federal tax liability, is eligible for the 15% federal credit. Equation 24. is the net price of $1 of conservation expenditures for resident i in states which did not allow tax credits or deductions.

24. $$\text{net-of-tax-price}_i = 1 - FC_i + (FD)(FC_i)(SMTR_i)[1-ITEM*FMTR_i]$$

where: FC_i = applicable federal tax credit (0 or .15)

FD = 1 in states that allow federal taxes to be deducted from state taxable income or calculate state taxes as a percent of federal taxes, 0 otherwise.

$SMTR_i$ = state marginal tax rate for household i.

ITEM = 1 for households that are designated as itemizers of federal tax returns

$FMTR_i$ = federal marginal tax rate for household i.

The last term reflects the increase in state taxes (when FD=1) that occurs when a federal tax credit is claimed and the reduction in federal tax liability that occurs as itemizers claim the larger deduction for state taxes that occurs if FD equals 1.

Internal Revenue Service data on federal tax itemizing rates are used as a guide for designating households as itemizers of federal income tax returns. Residents of states other than Arkansas, Idaho and Indiana are assumed to itemize deductions on their federal return if their 1981 gross income exceeds $18,500 or they own their residence and income exceeds $5000.[1] Homeowners are assumed to be itemizers as they often have sufficient mortgage interest and local and state taxes to justify itemizing. Substantially fewer residents of Arkansas, Idaho and Indiana itemize their federal returns compared to residents of other states which allow energy credits or deductions. Households who live in those three states are categorized as itemizers if their income exceeds $25,000 or they own their residences and income exceeds $5000. These assumptions are admittedly rough approximations but they are consistent with itemizing rates published by the IRS for 1982.[2]

Sixteen states allow deduction of federal taxes on state forms and three calculate state taxes as a percent of federal taxes. Delaware is one of the former and Vermont the latter, but no RECS participants live in these states. The typical effect of state deductibility of federal taxes is to raise the value of expression 24. from .85 to .86. Inability to identify residents of six states which have a value of "FD" equal to one (AL, KY, LA, OK, SC, RI) implies the net-of-tax price

---

[1]Internal Revenue Service, 1982.

[2]Ibid.

assigned to residents of these states (.85) is lower than its actual value of .856-.87. Thus an error of about 1.2% is present for these households (about 9% of the total sample households).

For residents of states which allow conservation tax credits or deductions the net-of-tax price term is expressed as 25.:

$$\text{25.}\quad \text{net-of-tax price}_i = 1 - FC_i - SC_i - (SMTRi)(DED) + (FMTR_i)(ITEM)(SC_i) + (SMTR_i)(DED) + (FC_i)(MTRS_i)(FD) - MTRF_i{*}FC_i{*}MTRS_i{*}ITEM_i - (SC_i + SMTR_i{*}DED){*}FMTR_i{*}ITEM$$

where: SC_i = state tax credit allowed for household i

$SMTR_i$ = state marginal tax rate for household i

$FMTR_i$ = federal marginal tax rate for household i

DED = 1 in states that allow conservation expenditures to be deducted from taxable income

ITEM = 1 for households that are designated as itemizers of federal tax returns

Expression 25. reflects the reduction in state taxes caused by a tax credit or deduction which increases federal tax liability for those who itemize (deduct state taxes on federal returns). Also, primary and secondary "feedback" effects for both state and federal tax deductions are included because, for example, a state tax credit or deduction raises federal tax liability, while this federal tax increase reduces state tax liability in states that allow deduction of federal taxes.

The net-of-tax price term ranges from a low of .64 for residents of Arizona and California in the 14% federal marginal tax bracket, to 1.0 for households who have gross incomes too low for a positive federal tax liability. The most common after-tax-price is .85, that assigned to households in states which do not allow tax credits or deductions, do not allow federal taxes to be deducted from state taxable income and do not calculate state taxes as a percent of federal taxes.

ECONOMETRIC ESTIMATION

The hypotheses from the model of optimum energy conservation improvement are tested across 2911 of the households described above. Because data that describe details of the thermal integrity of housing units are absent for most observations, age of the dwelling is used as a proxy for Ro, the initial thermal integrity variable. Regressions of fuel consumption and fuel consumption per square foot on prices, income, outdoor temperatures and dwelling age consistently show that fuel consumption increases with the age of the structure (see Appendix C). Energy inefficiency is caused by several factors common in older buildings such as lower conventional levels of insulation when built, depreciated insulation and weather seals and the presence of leaks and cracks due to structural settling.

There are no consumer or producer price indices available to allow comparison of retail prices of conservation equipment in different geographic regions. The best available evidence supports the contention that pre-tax prices of conservation equipment are nearly equal across households. Thus the gross price portion of P_R in the optimum improvement model is set equal to one for all consumers. Representatives from several insulation producers have indicated that their wholesale prices are essentially uniform across regions. Also, the fact that there are numerous producers and distributors in virtually all well populated regions indicates that transportation costs should not cause significant price differentials and that weatherization equipment industries are fairly competitive.

Age of the head of each household and renter/owner dummy variables are used to proxy expected housing tenure (expected benefits period). As discussed above, renters are expected to remain in their current residence for a relatively short time. Mendelsohn (1977) concludes that among homeowners, middle-aged owners have the longest expected tenures because mortality strikes the elderly while younger owners move.[3]

Future fuel prices are assumed to be a multiple of current prices and the price growth rate of the previous four years. Fuel price growth rates assigned to each household are regional price growth rates, or, when state of residence is identified, state level price growth rates. The fraction of total fuel consumption used for heating and cooling is based on earlier energy-use studies (Hirst et. al., 1981) and is adjusted depending on the extent to which households use their air conditioners. Heating and cooling degree-days are used to describe local climates. Both measures are used to represent E, external temperatures.

"A", the dwelling size variable used in the model, is proxied by the square foot heated area of the residence. A variable to indicate that a household lives in a single-family dwelling is also included to reflect the different possibilities for improvement faced by owners of

---

[3] see Mendehlsohn, 1977.

these dwellings compared to owners of units in multiple-family structures.

The dependent variable in the behavioral model is the optimum increase in R, the thermal integrity of the dwelling. It is very difficult to estimate how much additional "R" one gets when various improvement actions are taken. For this reason, a simpler approach for testing the model is used. The simplest observable value of the dependent variable, R', is whether households made any improvement. In this case a dependent variable to represent improvement activity is:

$$26. \quad Y_i = \begin{cases} 1 & \text{if } R' > 0 \\ 0 & \text{if } R' = 0. \end{cases}$$

This approach yields a "qualitative" dependent variable that is a function of continuous and qualitative independent variables. The Linear Probability model is used to examine the linear relationship and degree of explanatory power of the "improvement"/"no improvement" specification of the conservation improvement model. Because the Linear Probability model has some well known difficulties, Logit estimates of the "improvement"/"no improvement" regression are also presented.

RESULTS

Table 8 shows results from Linear Probability regression estimation of expression 27. for three different samples. The dependent variable in 27. has a value of one for households that made any improvement and a value of zero for households that did not make a conservation improvement.

27. Y_i = ao + a1(after-tax-price) + a2(income) + a3(future fuel price) + a4(yearmade) + a5(renter) + a6(age) + a7(HDD) + a8(CDD) + a9(sq ft of home) + a10(house)

where: Y_i equals 1 for households who make a conservation improvement or 0 for those who do not

after-tax-price= $(1-t_i)$ where t_i is the total available tax credit for household i. This is the after-tax-price of spending $1 on conservation equipment.

income = 1981 gross household income (in 1981 dollars)

future fuel price = (current price)x(price growth rate of past four years)

yearmade = an index of home newness;

0=pre-1940, (the "basis" level of dwelling age)
1=1940-50
2=1950-55
3=1955-60
4=1960-65
5=1965-70
6=1970-75
7=1976
8=1977

renter = 1 if household rents their current residence

age = age of household head

HDD = heating degree days

CDD = cooling degree days

sq. ft. of home = heated area of the residence

house = 1 for households that live in single-family dwellings

Descriptive statistics of data used in these and later regressions are shown in Appendix D.

Table 8

LINEAR PROBABILITY MODEL REGRESSION OF EXPRESSION 27.

dependent variable = 1 if an improvement was made
= 0 otherwise

SAMPLE:	(1) "WHOLE"	(2) "WEST" HOUSEHOLDS ONLY	(3) NON-"WEST" HOUSEHOLDS
independent variable:			
net-of-tax price	.70 (.14)**	.13 (.20)	.64 (.74)
income	.0000012 (.0000005)**	.0000010 (.00000009)	.0000016 (.0000006)**
future fuel price	.0023 (.0013)*	.01 (.003)**	.0003 (.001)
year dwelling constructed	-.01 (.004)**	-.009 (.007)	-.009 (.005)*
renter	-.28 (.02)**	-.23 (.04)**	-.29 (.03)**
age of hh head	-.004 (.0005)**	-.0006 (.001)	-.005 (.0006)**
heating degree days	.00004 (.000006)**	.00005 (.000009)**	.00002 (.000009)**
cooling degree days	-.000033 (.000016)**	-.00002 (.00003)	-.00008 (.00002)**
sq. ft. of home	.00004 (.00001)**	.00004 (.00002)**	.00003 (.00001)**
"house" dummy	.17 (.02)**	.08 (.046)*	.21 (.03)**
N	2911	787	2124
adjusted R^2	.19	.17	.19
F-statistic	68	18	50

* : statistically significant at the 95% level of confidence
** : statistically significant at the 99% level of confidence

W

strong

of the

applie

one-ta

T

indepe

signs

fuel

singl

likel

clima

rente

likel

dwell

older

are m

the

less

"your

head.

house

statis

coeffi

availa

larger

With the exception of the net-of-tax price variable, theory strongly suggests negative or positive signs on the coefficients on each of the independent variables. Thus a two-tailed test of significance is applied to the coefficient on the net-of-tax price variable and a one-tailed test is applied to the others.

The results in column (1) of Table 8 indicate that all the independent variables except the net-of-tax-price term have the expected signs. Households who have higher incomes, higher "expected" future fuel prices, older dwellings, larger dwellings, younger household heads, single-family units and who own their homes are, ceteris paribus, more likely to make a conservation improvement. Those who live in warmer climates, rent their dwellings and live in multi-family units (some renters live in single-family structures, some owners do not) are less likely to make an improvement. The negative coefficient on the "year of dwelling construction" variable indicates that households who live in older dwellings (those expected to have a lower initial thermal quality) are more likely to make an improvement. The negative coefficient on the "age of household head" variable indicates that older households are less likely to make an improvement. Households were also categorized as "young", "middle-aged" and "older" depending on the age of the household head. When this form of the "age" variable was used, "young" households were still the most likely to make an improvement.

The coefficient on the net-of-tax-price variable is <u>positive</u> and statistically significant in the "whole" sample regression. A negative coefficient would be evidence in support of the hypothesis that larger available tax credits stimulate conservation improvement activity. (A larger credit makes the after-tax-price term smaller). However, the res

eli

are

dur

reg

'wh

the

the

'we

cre

impr

spur

Thus

to m

rele

The

unme

othe

'wes

Prob

resu

sepa

net-

subs.

net-c

some

results from the "whole" sample regression indicate that households eligible for larger tax credits (primarily due to state of residence) are actually less likely to make a conservation improvement. When a dummy variable indicating the household lives in the Mountain or Pacific region ("west")• was substituted for the net-of-tax price term in the "whole" sample ("west" and non-"west") regression, the coefficients on the other variables were essentially unchanged and the coefficient on the "west" dummy was negative and significant at the .01 level. The "west" dummy performed just as well, with the same sign, as the tax credit variable. This suggests that the lower rates of conservation improvement among "west" households is a regional phenomenon that is spuriously correlated with relatively large conservation tax credits. Thus the aggregate trend that western region households were less likely to make a conservation improvement appears to hold even when the other relevant factors that are measured or proxied here are held constant. The lower rates of improvement among western households may reflect unmeasured differences in dwelling construction, expected home tenure or other important factors.

To investigate the hypothesis that the estimated relationship for "west" households is different from the non-"west" households, Linear Probability regressions were also run on these two subsamples. The results are shown in the second and third columns of table 8. This separation yields results similar to the full sample regression, but the net-of-tax price term is not statistically significant in either of the subsample regressions. This result supports the contention that the net-of-tax price term in the "whole" sample is strongly correlated with some unmeasured characteristic common among western households. The expl

of t

hyp

reg

sub

mod

resu

subs

usin

esti

mode

regr

28.

wher

regr

wher

In e
sign
rejec
regre

explanatory power (R^2) of each of subsample regression remains near that of the full sample.

An F-test[4] allows rejection (at the .01 level of confidence) of the hypothesis that the coefficients of the linear probability model regression of expression 27. are equal for the "west" and non-"west" subsamples. Because the estimates of the conservation improvement model are statistically different for the two regional subsamples, the results from additional regression analyses are reported for these subsamples only.

To avoid the econometric problems inherent in an OLS regression using a binary dependent variable, the Logit technique was used to estimate the regressions discussed above. In the context of a Logit model, if the optimum increase in R for household i is labeled Y_i*, a regression model of the relationship of interest is:

28. $Y_i* = \beta' X_i + u_i$

where the only observable value of Y_i* is Y_i from 26.) (0 or 1) and X_i

---

[4]The statistic to test the hypothesis that coefficients from regressions on two subsamples of data are different from each other is:

$$\frac{[(RSS_1+RSS_2) - RSS_1]/k}{(RSS_1+RSS_2)/(N + M - 2k)} \text{ is distributed } F_{k,\ N+M-2k}$$

where: $RSS_{1,2}$ are the residual sum of squares from each subsample regression, k is the number of regressors and N and M are the sample sizes of the two subsamples.

In each case that used this test statistic, the resulting F value was significantly significant at the 99% level of confidence, thus allowing rejection of the hypothesis that the coefficients in each subsample regression are equal.

is a vector of variables that influence Y_i. Thus the probability that Y_i equals one equals the probability that $\beta' X_i + u_i$ is greater than zero, or:

$$29.\quad \begin{aligned} Prob(Y_i = 1) &= Prob(u_i > -\beta' X_i) \\ &= 1 - F(-\beta' X_i) \end{aligned}$$

where F is the cumulative distribution function for u (Maddalla, 1986). The β vector is estimated by maximizing a likelihood function based on a binomial process for each Y_i depending on the value of X for each household. The likelihood function is

$$30.\quad L = \prod_{Y_i = 0} F(-\beta' X_i) \prod_{Y_i = 1} [1 - F(-\beta' X_i)]$$

where F in the Logit model is the logistic distribution, i.e.:

$$F(-\beta' X_i) = 1/[1 + e^{(\beta' X_i)}].$$

Table 9 shows results from Logit estimation of the "improvement"/ "no improvement" regression described by expression 27. for the two regional subsamples. Columns 1 and 3 show Logit coefficients estimated by an SPSS routine. Columns 2 and 4 show the partial derivatives of p, the probability of making an improvement, with respect to changes in each of the dependent variables.

TABLE 9

LOGIT ESTIMATES OF EXPRESSION 27.
FOR "WEST" AND NON-"WEST" HOUSEHOLDS

DEPENDENT VARIABLE = 1 for households that made an improvement
= 0 for households that did not make improvements

SAMPLE:	"WEST" HOUSEHOLDS ONLY		NON-"WEST" HOUSEHOLDS	
	1	2	3	4
	Logit coefficient	$\partial P/\partial X_i$#	Logit coefficient	$\partial P/\partial X_i$#
net-of-tax-price	.56 (.56)	.209	1.55 (2.08)	.76
income	.0000021 (.0000026)	.0000008	.0000037 (.0000015)**	.0000018
future fuel price	.032 (.010)**	.011	-.0018 (.0037)	-.00088
year dwelling constructed	-.025 (.013)**	-.0075	-.025 (.012)**	-.012
renter	-.79 (.15)**	-.30	-.78 (.08)**	-.387
age of household head	-.002 (.002)	-.00092	-.013 (.001)**	-.006
heating degree days	.00014 (.00003)	.000053	.00005 (.00002)**	.000025
cooling degree days	-.0001 (.0001)	-.000038	-.00023 (.00006)**	-.00011
sq.ft. of home	.0001 (.00006)*	.000038	.00005 (.00003)*	.000025
"house" dummy	.36 (.16)**	.135	.62 (.09)**	.307
intercept	2.96 (.53)**		3.77 (1.78)**	
N	787		2124	

Standard errors in parentheses

* : statistically significant at the 95% level of confidence
** : statistically significant at the 99% level of confidence
\# : evaluated at mean values of the independent variables

The increase in the likelihood of an improvement being made as a result of an increase in an independent variable, $\partial P/\partial X_i$ calculated at the sample means of the X_i's, is $.38b_i$ for the "west" subsample (where bi is the Logit coefficient of interest) and $.494b_i$ for the non-"west" subsample.[5]

The Logit results are not greatly different from those of the Linear Probability regressions. The results for the "west" subsample indicate that residents of higher tax credit states are not more likely to make a conservation improvement than residents of states that have low or no conservation tax credits. Also, non-"west" households who are eligible for a larger tax credit do not appear to be more likely to make a conservation improvement, ceteris paribus. Because variation in tax credits among non-"west" households is primarily due to differences in federal tax filing status that was assigned to each household, and because that assignment process is only a rough approximation, less confidence is placed on the latter conclusion.

As in the Linear Probability results, the age of household head (used to proxy expected tenure in the dwelling) is not statistically significant in the "west" Logit. If this result is not due to the smaller sample size being used, it suggests that the age of household head variable is not a good proxy for the underlying variable (expected home tenure) or that the underlying variable does not influence improvement activity in the west as it does elsewhere.

---

[5]SPSS uses the following specification for estimation of Logit coefficients: $\ln (p/1-p)/2 + 5 = X'\beta$. Thus the partial derivative of p with respect to X_i is: $2\beta_i \exp[2X'\beta-10]/(1 + \exp[2X'\beta-10])^2$ where β_i's are SPSS Logit coefficients. (SPSS, 1986).

Whe

home ene

coeffici

of conf

partici

improve

their s

filter

proper

signi

effec

credi

were

impro

"mino

inte

dist

impr

acti

(the

"maj

repr

Proba

1981,

estim

When a dummy variable to indicate the household participated in a home energy audit was added to each of the above Logit regressions, its coefficient was positive and statistically significant at the 99% level of confidence. It is possible, however, that households who participated in an audit may have already been further inclined to make improvements and the audit supported that inclination or helped guide their spending. If the latter is true, the "audit" dummy acts as a filter that identifies those households that already had a higher propensity to make conservation improvements. Nevertheless, the significant positive coefficient does suggest that audits may effectively promote conservation improvement activity.

To test the hypothesis that households eligible for a larger tax credit made "larger" improvements, two additional sets of regressions were estimated. Both utilize the "major"/"minor" categorization of improvements discussed above. It should be recognized that several "minor" improvements may actually yield a larger improvement in thermal integrity than a major improvement. Thus the "major"/"minor" distinction may not always accurately reflect a greater magnitude of improvement.

The first approach using the "major"/"minor" ranking of improvement actions uses a scaled dependent variable to represent "no improvement" (the dependent variable is set equal to 1), "minor improvement" (=2) and "major improvement" (=3). Ordinary Least Squares estimation of this representation of the model has the same inherent problems as the Linear Probability model when a zero/one dependent variable is used (Amemiya, 1981, McKelvey and Zavoina, 1975). The appropriate technique for estimation when using an ordered qualitative dependent variable that can have more than two values is a multinomial logit or probit. The latter is used here as computer software to estimate the model was available.

The ordered multinomial approach assumes there is an underlying index Z_i which, in the current case, describes the desired amount of conservation improvement for household i. The only observed values of the dependent variable are 1, 2 and 3. Thus the regression model:

31. $Z_i = \alpha + \beta X_i + \varepsilon_i$

is estimated using Y_i, a proxy for Z_i, where:

32. $$Y_i = \begin{cases} 3 \text{ if } Z_i \geq \mu_1 \\ 2 \text{ if } \mu_2 \leq Z_i \leq \mu_1 \\ 1 \text{ if } Z_i \leq \mu_2 \end{cases}$$

where μ_1 and μ_2 represent cut-off values for desired amounts of conservation improvement (Pindyck and Rubinfeld, 1981).

A maximum likelihood routine for Probit estimation of the β coefficient vector yielded the results shown in Table 10 for the two regional subsamples. The estimation technique normalizes the dependent variable so that the variance of ε equals one and has a mean of zero. The second (lower) cut-off value (μ_2) is set equal to zero and μ_1 is estimated.

Table 10

MULTINOMIAL PROBIT ESTIMATES OF THE CONSERVATION INVESTMENT MODEL

Dependent variable = 1 if no improvement was made
= 2 if a "minor" improvement was made
= 3 if a "major" improvement was made

maximum likelihood estimates of the coefficients are shown, standard errors are in parentheses

Sample:	"WEST" HOUSEHOLDS ONLY	NON-WEST HOUSEHOLDS
independent variable:		
net-of-tax-price	1.11 (.64)	2.4 (2.3)
income (in thousands)	.004 (.003)	.004 (.001)**
future fuel price	.03 (.01)**	-.003 (.004)
year dwelling constructed	-.03 (.025)	-.04 (.01)**
renter	-.88 (.16)**	-.95 (.09)**
age of household head	-.002 (.003)	-.01 (.001)**
heating degree days	.0001 (.00003)**	.00006 (.0003)
cooling degree days	-.0001 (.0001)	-.0002 (.00006)**
sq. ft. of home	.00009 (.00007)	.00007 (.00003)**
"house" dummy	.50 (.18)**	.62 (.10)**
N	787	2124
-2 times log likelihood ratio	162	431
μ_1	.33	.55
μ_2	0	0

**: statistically significant at the 99% level of confidence

As shown in Table 11, the multinomial probit results predict that in both regions, a household having the mean values for independent variables would not make a conservation improvement. However, when the effect of the error term is also included, the "west" regression predicts that the probability that an "average" household would make a minor improvement is .35 and the probability of a major improvement is .17. The actual values among "west" households indicate that 68% made no improvement, 9.1% made minor improvements and 22.9% made major improvements. The probabilities of minor and major improvements for an "average" family outside the west region are slightly higher. (Actual values: 52.1% made no improvement, 18.5% made minor improvements and 29.5% made major improvements). In the second scenario, the household is assumed to own a single-family dwelling and has a $42,500 annual income (one standard deviation above the mean). The regression results for both regions predict such a household would make a minor improvement, and that the probability that a major improvement would be made is .45 (west) or .38 (non-west). There is a similar likelihood that such a household would make no improvement. Finally, a household that rents a dwelling in a multi-family structure and has a $15,000 income is predicted to make no improvement and is very unlikely to make minor or major conservation improvements.

Table 11

IMPROVEMENT ACTIONS PREDICTED BY MULTINOMIAL PROBIT RESULTS

	WESTERN HOUSEHOLDS	NON-WESTERN HOUSEHOLDS
	$\mu_1 = .326$ $\mu_2 = 0$	$\mu_1 = .559$ $\mu_2 = 0$
independent variable values:	improvement actions:	1 = no improvement 2 = minor improvement 3 = major improvement
mean X's	dependent variable = -.615 predicted action = 1	dependent variable = -.0706 predicted action = 1
	prob(action = 2) = prob($-.615 + \varepsilon_i$) > 0 = prob (normal Z > .615) = .35	prob(action = 2) = prob($-.0706 + \varepsilon_i$) > 0 = .47
	prob(action = 3) = prob($-.615 + \varepsilon_i$) > .326 = .17	prob(action = 3) = prob($-.0706 + \varepsilon_i$) > .559 = .26
household owns dwelling, single-family structure, income = $42,500, all other X's at means	dependent variable = .196 predicted action = 2	dependent variable = .26 predicted action = 2
	prob(action = 1) = prob ($.196 + \varepsilon_i$) < 0 = .42	prob(action = 1) = prob($.26 + \varepsilon_i$) < 0 = .40
	prob(action = 3) = prob($.196 + \varepsilon_i$) > .326 = .45	prob(action = 3) = prob($.26 + \varepsilon_i$) > .559 = .38
household rents dwelling, multi-family structure, income = $15,000, other X's at means	dependent variable = -1.68 predicted action = 1	dependent variable = -1.42 predicted action = 1
	prob(action = 2) = prob($-1.68 + \varepsilon_i$) > 0 = .046	prob(action = 2) = prob($-1.42 + \varepsilon_i$) > 0 = .08
	prob(action = 3) = prob($-1.68 + \varepsilon_i$) > .326 = .022	prob(action = 3) = prob($-1.42 + \varepsilon_i$) > .559 = .024

The final regression analysis to investigate whether households eligible for larger tax credits made larger conservation improvements uses a binomial Logit to estimate the influence of the independent variables on the likelihood of making a "major" improvement. In this case the dependent variable equals one if a "major" improvement was made and equals zero otherwise. Results from estimation of this Logit for the two regional subsamples are shown in Table 12. Logit coefficients from SPSS estimation are shown in columns 1 and 3, partial derivatives of the dependent variable with respect to independent variables are shown in columns 2 and 4.

TABLE 12

LOGIT REGRESSIONS OF "MAJOR" IMPROVEMENTS

Dependent variable = 1 for households making "major" improvements
= 0 otherwise

SAMPLE:	"WEST" HOUSEHOLDS ONLY		NON-"WEST" HOUSEHOLDS	
	1	2	3	4
	Logit coefficient	$\partial P/\partial X_i$#	Logit coefficient	$\partial P/\partial X_i$#
net-of-tax price	1.5 (.62)**	.435	3.33 (2.4)	1.29
income	.0000044 (.0000024)*	.0000013	.0000042 (.0000015)**	.0000016
future fuel price	.016 (.010)	.0046	-.002 (.004)	-.00094
year dwelling constructed	-.04 (.024)*	-.012	-.043 (.013)**	-.016
renter	-.70 (.17)**	-.20	-.85 (.10)**	-.33
age of household head	-.0015 (.0032)	-.00043	-.012 (.001)**	-.0048
heating degree days	.00007 (.00003)**	.00002	(.00004) (.00002)**	.000015
cooling degree days	-.00005 (.00011)	-.000014	.000003 (.00006)	-.0000012
sq. ft. of home	.00004 (.00006)	.000011	.00006 (.00003)**	.000023
"house" dummy	.64 (.23)**	.186	.33 (.10)**	.131
intercept	2.33 (.58)**		1.9 (1.9)	
N	787		2124	

Standard errors in parentheses

* : statistically significant at the 95% level of confidence
** : statistically significant at the 99% level of confidence
\# : evaluated at mean values of the independent variables

th
in
th
fo

an
st
ha
th
st

es
sp
si
ne
ex
s

n
B
o
o
t
t
h

At the mean values of the independent variables, the increase in the likelihood of a "major" improvement being made as a result of an increase in an independent variable can be calculated to be $.289b_i$ for the "west" sample (where b_i is the SPSS Logit coefficient) and $.391b_i$ for the non-"west" subsample. (See footnote 5).

The net-of-tax price term for the western sample is again positive and in this case is statistically significant. Residents of western states that allowed relatively large tax credits were less likely to have made a "major" improvement, ceteris paribus. The coefficient on the net-of-tax price term in the non-"west" is positive but is not statistically significant.

For the "west" households the results for the other variables are essentially the same as those of the other regressions. In this specification, however, western households with higher incomes are significantly more likely to make a major improvement. For the non-"west" households, all variables except the net-of-tax price term, expected future fuel price and cooling degree days are statistically significant.

An additional caveat is warranted when interpreting the net-of-tax price coefficients from all the reported regressions. Because the data used here only reflect improvement activity that occurred between mid-1980 and early 1982, improvement activity that occurred before this time period is ignored. It may be the case that those eligible for larger tax credits made improvements prior to this time period. Indeed, households eligible for larger tax credits may have made "major" improvements before the time period considered here, thus they would be less likely to make a major improvement during the later time period. The data used are useful for a static cross-section analysis, but may yield invalid conclusions if the actions taken in earlier time periods are ignored.

None of the results presented above provides evidence to support the hypothesis that households eligible for larger conservation tax credits are more likely to make conservation improvements or that they tend to make larger improvements. Indeed, residents of states that allow the largest tax credits are, ceteris paribus, less likely to make a major improvement. As discussed above, this result may be due to some unmeasured characteristics unique to households living in the west, but even when western households are isolated, those eligible for larger tax credits are not more likely to make a conservation improvement and do not tend to make larger improvements. Also, the econometric findings are consistent with the hypothesis that ρ, the tax credit perception accuracy factor, is less than one. It may be the case that the low rates of conservation improvement in western states prompted officials in those states to adopt a tax credit with the hope of stimulating conservation activity.

The absence of evidence to support the hypothesis that larger tax credits lead to more conservation improvement activity suggests that ρ, the factor used to represent the accuracy of perception of available tax credits, is less than one. If the conclusion that tax credits do not influence improvement activity is correct but is not explained by the lack of perception of the credits, some other effect not considered here explains the above conclusions.

ADDITIONAL EVIDENCE

Internal Revenue Service Statistics of Income figures from 1981 indicate that 4.2% of all tax returns had an energy conservation credit claim. The 1981 RECS summary document indicates that 33% of sample households made some kind of improvement in that year. Around 95% of improvement actions were eligible for a federal tax credit, so only 13% of eligible actions were claimed on the federal form. A similarly low proportion of actual claims to eligible claims occurred in 1983.[6] Assuming the RECS survey was representative, it can be concluded that most taxpayers were unaware of the credit, did not find it worthwhile to file form 5695 ("Residential Energy Credit") or were not willing to file the "long" form (1040) in order to claim the credit. Although 19.6% of 1981 federal returns were not taxable, these were low income filers who were less likely to have made a conservation improvement, so this does not explain much of the difference between the proportions of improvement taxpayers and credit claim taxpayers.[7]

The average expenditure reported by those who did claim a credit was $600 to $700 in various years, far above the average expenditure reported by the U.S. Census Bureau.[8] Two main reasons probably explain the differences between the expenditure levels reported by the Census Bureau and those reported to the IRS. First, taxpayers may have overstated their true expenditures on tax credit forms.

---

[6] Energy Information Administration, 1985.

[7] It is possible that some taxpayers had hit the ceiling for maximum federal credits allowed during the life of the program, but it is unlikely that enough households claimed the $2,000 year-to-year limit imposed by this ceiling, to explain the low claim rates discussed here.

[8] U.S. Bureau of the Census/U.S. Department of Housing and Urban Development, 1981.

The second reason for the difference is that credits tended to be claimed by those who spent more. As discussed above, the likelihood of claiming the credit (or citing it as a reason for improvement) is greater the larger its value; i.e. the larger the improvement. Because the magnitude of improvements (likelihood of making a "major" improvement) has a strong positive association with income, the benefits of the credit are skewed towards those having incomes above the median (see Table 13).

Table 13

% OF ALL 1981 FEDERAL TAX RETURNS HAVING AN ENERGY CONSERVATION CREDIT CLAIM BY INCOME CATEGORY

INCOME	% WITH CONSERVATION CLAIM
$1 - $5000	.2%
$5001 - $10,000	1.1%
$10,001 - $15,000	2.1%
$15,001 - $20,000	4.0%
$20,001 - $25,000	6.3%
$25,001 - $30,000	7.3%
$30,001 - $40,000	9.7%
$40,001 - $50,000	9.8%
$50,001 - $75,000	11.2%
$75,001 - $100,000	10.6%
$100,001 - $200,000	9.2%
$200,001 - $500,000	7.1%
$500,001 - $1,000,000	5.1%
> $1,000,000	4.1%
overall proportion:	3.9%
median AGI (approximate):	$15,000

Source: Internal Revenue Service, Statistics of Income, 1981.

The federal claim percentages are also useful for making interstate comparisons. Column 1 of Table 14 shows the percentage of households who claimed a federal energy conservation tax credit for states with conservation credits or deductions and nearby, climate-similar states in 1981. Column 2 shows claim percentages adjusted so that all the claimed credits are assumed to be claimed by taxpayers who own their residences. Statewide average adjusted gross incomes are also shown because improvement activity and the likelihood of claiming a credit rise with income.

TABLE 14

PERCENTAGE OF ALL TAX RETURNS HAVING AN ENERGY CONSERVATION TAX CREDIT BY STATE FOR SELECTED STATES

"Adjusted" proportion assumes all claims are taken by owner-occupants.

	(1)	(2)	(3)
STATE	PROPORTION WITH CREDIT CLAIMS	PROPORTION WITH CLAIMS ADJUSTED BY HOME OWNERSHIP	AVERAGE AGI
Arizona **	2.46%	3.61%	$17,842
New Mexico	2.82%	4.14%	$16,259
Texas	1.76%	2.73%	$19,775
Oregon **	3.75%	5.74%	$17,412
Washington	4.61%	7.01%	$19,701
California **	2.08%	3.73%	$19,817
Nevada	2.11%	3.54%	$18,547
Colorado **	6.52%	10.1%	$19,581
Utah	4.59%	6.48%	$17,755
Nebraska	4.88%	7.14%	$16,633
Idaho *	4.95%	6.88%	$16,159
Montana *	4.23%	6.17%	$15,891
Wyoming	2.52%	3.62%	$20,460
North Dakota	3.78%	5.48%	$16,370
Arkansas *	2.55%	3.62%	$14,898
Oklahoma	3.18%	4.50%	$18,555
Missouri	3.36%	4.83%	$17,612
Indiana *	4.37%	6.08%	$17,933
Illinois	4.86%	7.72*	$19,924
Ohio	4.01%	5.86%	$18,328
Massachusetts	6.41%	11.1%	
Rhode Island	5.81%	9.9%	
Connecticut	5.40%	8.4%	
National average:	4.17%	6.39%	

*: state allowed a tax credit for energy conservation expenditures
**: state allowed a tax deduction for conservation expenditures

Source: Internal Revenue Service, Statistics of Income, 1981.

Claim rates in Arizona and California are well below the national average and are not significantly different than rates in neighboring states where no state level tax incentives are available. The claim rate in Oregon is considerably below that of Washington although the significance of this difference is unclear as the mean AGI in Washington is well above that of Oregon. Claim rates in Idaho and Montana exceed those of their similar-climate neighbors even though the mean AGI in these two states is less than that of Wyoming and North Dakota. This difference is even greater if all credits are assumed to be claimed by owner-occupants. The claim rate in Colorado far exceeds that of its neighbors although the higher mean AGI in Colorado may explain part of this difference. Nevertheless, relatively high claim rates in Colorado, Idaho and Montana could be construed as some evidence that tax incentives have helped stimulate conservation improvement activity in these states.

Another explanation for the results just presented is that conservation improvement rates are equal among the compared states, but availability of state tax incentives made taxpayers more aware of energy tax credits in general, thus making them more likely to claim the federal credit. If, however, the proportion of improvement households that made a credit claim is constant across states, residents of Colorado, Idaho and Montana did make more energy conservation improvements and this difference might be attributable to the presence of state tax incentives. In general, absolute and owner-adjusted claim rates were highest in New England, where a relatively high proportion of residences are heated with fuel oil, the fuel that had the largest price increase in the late seventies and early eighties. Comparisons of claim rates in Arkansas and Indiana with those of their neighbors gives no indication that the availability of income tax deductions for conservation expenditures in those states have led to more widespread improvement activity.

CONCLUSIONS

Regression analysis indicates that the behavioral model developed in chapter two is useful for explaining conservation improvement activity, but indicates that fewer residents of high tax credit states made improvements. Comparison of the RECS survey data with IRS tax return data suggests that most households who made energy conservation improvements did not claim a federal tax credit. This, and the fact that claims are made by those spending relatively large amounts strongly suggests those who do claim a credit experience a windfall and claim the credit because it is more valuable, i.e., "because it was there".

The absence of evidence to support the hypothesis that larger available tax credits lead to more widespread or more extensive energy conservation improvement activity should not be construed as evidence that "prices don't matter", i.e. that lower prices for conservation improvement do not lead to a greater quantity demanded. Rather, the evidence should be interpreted as an indication that tax credits are not effective in causing perceived net price reductions. That is, the lower net prices implied for a perfectly informed and eligible taxpayer do not represent price reductions for all taxpayers. Several possible explanations for this result are discussed in the next chapter.

CHAPTER FOUR

CONCLUSIONS AND POLICY IMPLICATIONS

Survey evidence compiled by other researchers and reviewed in Chapter 3 indicates that only a small proportion of taxpayers understand the energy tax credit or state that its availability strongly influenced their decision to improve the energy efficiency of their dwelling. Similarly, among the RECS participants who made conservation improvements, only 9.6% cited tax credits as one reason for doing so. Econometric estimates of the influence of various factors on the likelihood of making a conservation improvement had fairly good explanatory power but indicate that conservation improvement activity is actually less extensive in states which allow income tax credits or deductions in addition to the federal credit. The latter result appears to be due to the fact that larger tax credits are available in western states where conservation improvement rates were far below the national average. It may be that shorter expected home tenures or better initial thermal quality of western homes (both variables were measured by highly imperfect proxies), or some other omitted factor common to western households or homes caused the lower conservation improvement rates. Even when western households are separated from the rest of the sample to allow for the differences in conservation behavior those households seem to exhibit, no discernible influence from the presence of state level tax credits can be identified.

These findings and the other empirical evidence presented suggest that only a small percentage of conservation improvement activity, if any, has been caused by the availability of energy tax credits. To the extent that claimed tax credits did not cause improvements to be made, th

by

th

Se

sh

on

su

re

ef

in

rep

the

abo

abo

mos

rap

con

yea

con

imp

Thus

seem

to s

been

the tax savings (and revenue loss from government treasuries) generated by the credit programs were a windfall to taxpayers.

As discussed in Chapter 3, the 1982 RECS data set does not report the extent of energy conservation improvement made on dwellings before September 1980. Thus the conclusion that larger tax credits cannot be shown to be associated with more widespread or extensive improvements only applies strictly to the time period covered by the 1982 RECS survey. Households eligible for a larger tax credit may have acted in response to the credits soon after (1978 or 1979) the credits became effective and would thus not report an improvement if they participated in a later survey. If that is the case the econometric evidence reported in Chapter 3 is less convincing because the true effects of the credits would have occurred before the time period considered here.

Conversely, because the participants in the 1982 RECS were asked about improvements made since September 1980, the survey did inquire about improvement activity when (according to available evidence) it was most widespread. Because residential energy prices were rising more rapidly in 1980 than they had during the energy "crisis" of the 1970's, conservation improvement activity during 1980 was greater than any other year for which data are available. Survey evidence that unanimously concluded that energy tax credits were not effective for stimulating improvement activity was gathered at several different points in time. Thus the possibility that the 1982 RECS "missed" what really occurred seems less likely.

There are several reasons that may explain why tax credits failed to stimulate conservation improvement activity. Households may have been unaware of the credits; this is true to some extent, as was found in other studies. If one is aware of the credits, the time and effort involved in obtaining and filing tax credit forms reduces the net benefit of doing so. Because the price-reducing effect of a tax credit actually occurs several months after making an improvement (when tax forms are filed or tax returns received), taxpayers may not have considered a tax credit to truly represent a price reduction as they would a cut in the retail price. Also, the lack of complete understanding of the credits introduces uncertainty into the computation of the net-of-tax price of improvements, thus suggesting a further discounting of the value of the credit. Finally, while a tax credit reduces the net price of conservation improvements, the gross (retail) price of conservation materials increased much faster than the overall rate of inflation in the late seventies and early eighties.[1] Thus, the effect of tax credits on the net <u>relative</u> price of improvement materials may have been overwhelmed by retail price inflation. Sellers of conservation equipment may have raised prices as demand for this equipment increased. To the extent that the availability of tax credits contributed to the increase in demand for conservation materials, the credits benefitted sellers if the supply of conservation materials is less than perfectly elastic.

It appears that tax credits caused only a very small fraction, if any, of the conservation improvements that occurred during the life of the tax credit program. A simple estimate of the total amount of fuel savings caused by conservation improvements installed from 1978 through 1985 is now computed. Various hypothetical values for the maximum value of fuel savings "caused" by the availability of energy tax credits are

---

[1]National Association of Home Builders, 1977, p. 2.

then computed. This allows determination of the required levels of "causation" needed to achieve various payback levels. The required levels of causation are then compared with the most extreme assumptions regarding the effect of the credits (i.e. that some improvement was caused by the availability of tax credits).

The U.S. Department of Energy reports that 75% of households living in single-family dwellings (58 million of the total 83 million housing units in 1980) made some conservation improvement between 1978 and 1982. Nationwide improvement rates were falling quickly in 1981 and 1982 and most households who desired improvements probably made them prior to 1983, so the total proportion of improvement households from 1978 through 1985 (the life of the tax credit program) is probably around 80%. A reasonable estimate of the proportion of multiple-family housing units that received improvements is 20%. Keeping the analysis simple, 20 years of fuel savings for these 51.5 million households are applied against a heating and cooling fuel consumption base of 100 Mbtu/year at a weighted average price of $7.50 per Mbtu. Hirst, et. al., (1981b) estimated that the median proportion of energy savings due to conservation improvements was around 25% of pre-improvement energy consumption. Because they looked at more equipment types and did not adjust downward their savings estimate to reflect the "comfort buy-back"[2] effect of lower marginal heat costs, their fuel savings estimate is probably too high. These adjustments and other sources of information regarding energy savings potential suggest a reasonable estimate for the effective proportion of energy saved by RECS

---

[2] see Hirst, et. al., 1984.

improvement households is around 15%. An average extent of improvement in the current study is approximately the energy-saving equivalent of the purchase an automatic thermostat and door and window caulking. Savings resulting from these improvements are probably closer to the 15% figure than to the 25% estimate.

Using the estimates just discussed, the total value of savings in this scenario is:

(20 years)x(51.5 million)x(100)x($7.50)x(.15) = $115.8 billion.

If the $3 billion outlay of the federal conservation tax credit program "caused" 2.6% of this total savings to occur, the value of savings to households experiencing the savings would just equal the value of the tax expenditures allowed to tax credit claimants. This would be the case if 1.34 million households made a median improvement because the tax credit was available. The latter implies 4.8% of all federal tax credit claims over the life of the program (a total of 1.33 million or 167,000 claims per year) were made by taxpayers who made a median conservation improvement because the federal energy tax credit was available. Although the available evidence suggests the federal credit did not lead to this many median improvements, the 4.8% "causation" figure is not implausible as it is similar to the proportion of respondents in Petersen's survey (see Chapter 3) that said they definitely or probably would have spent less for improvements if the credit was not available. The 1.33 million total is also the approximate number of tax returns that had a conservation claim in 1982. Thus, if around one-eighth (12%) of all federal claims were made by house

of th

discu

subs

valu

gene

tota

prog

cons

assu

caus

valu

revi

fede

savi

prog

of s

high

savi

reve

OTHE

occu

prese

were

overc

households that would not have made a median improvement in the absence of the tax credit, the program would have achieved the "private payback" discussed above. If this is the case, the program may have simply subsidized energy savings for some taxpayers with an outlay of equal value by other taxpayers.

Presumably the public policy goal of the tax credit program was to generate a positive externality by reducing energy consumption. The total value of externalities is the amount of savings caused by the program multiplied by the per unit public value of reduced energy consumption. If the public value of energy savings is 20% of the assumed market price of fuel, 13% of all savings would have to have been caused by the federal tax credit program to generate an "externality" value equal to the amount of tax expenditures. All the evidence reviewed in the current study indicate it is extremely unlikely that the federal tax credit program caused 13% of all the residential fuel savings that resulted from improvements made during the life of the program. Thus, even with the extreme assumption that 20% of the value of saved energy is a "public" benefit or positive externality, it is highly unlikely that the federal tax credit program caused enough energy savings to generate a payback to society equal to the amount of tax revenue that was redistributed by the tax credit program.

OTHER POLICY IMPLICATIONS

While a large amount of capital improvements for energy efficiency occurred during the late seventies and early eighties, evidence presented here indicates that improvements in rental housing by tenants were relatively rare. Thus direct grants, such as those financed by oil overcharge fines, and other programs to encourage landlords to improve

the
imp
ren
enc
cor
co

fu
en
dw
ap
re
re
do
pr
u
u
h
T
p
e

e
r
f
c
r

the energy efficiency of rental units may be necessary if such improvements are considered a desirable public policy goal. Apparently renters who pay their fuel bills directly do not anticipate a high enough return on improvement expenditures and owners that include fuel costs in the rent do not fear the prospect of being unable to shift fuel costs to renters.

If renters pay heating and cooling bills, an efficiently functioning market for rental housing would presumably force owners of energy inefficient units to either accept lower rents or insulate the dwelling if rents are to be sustained. Renters would avoid high rent apartments that have high utility bills, thus forcing the owner to reduce rents or improve the fuel efficiency of the dwelling. Although renters may seek information about past utility bills, that information does not fully describe the thermal quality of a dwelling because previous occupants may have had different levels of temperature control, used other appliances differently and may have experienced unrepresentative weather conditions. Thus renters typically do not have reliable information about the energy efficiency of a rental unit. The above considerations suggest that the market efficiency required to provide sufficient incentive for landlords to improve the energy efficiency of rental units is not likely to be present.

Because renters tend to be lower income households, the absence of energy efficiency improvements in rental housing helps perpetuate the relatively high proportion of incomes that lower income people spend on fuel bills. Also, the presence of state and local taxes on heating and cooling fuel implies a regressive tax burden that for the most part remains so as rental unit energy efficiency improves only as new rental units are constructed. The lack of efficiency improvements in rental housing also suggests that if reduction of the relatively high energy expenditures of lower income consumers is a goal, minimum standards for energy efficiency in new rental units or other policies may be necessary. Of course the costs of meeting such standards may end up being passed on to renters and the disproportionate burden they bear for energy-related expenses may not be alleviated.

As mentioned in a note at the end of chapter two, it is not clear why purchases of new, more efficient furnaces and several other energy saving improvements were not eligible for the (federal) tax credit. If the goal was simply to save energy there is no obvious reason why these items should be excluded from the program.

CONCLUDING COMMENTS

While the RECS data set is not ideal for analysis of state-level variations in tax credits and fuel prices, it does provide a large and sufficiently detailed sample for examination of the economics residential energy consumption. Regional variations in energy efficiency improvement activity were identified, and useful estimates of energy demand and other relationships can be generated by the data. It was necessary to also consider other data sources in order to support the findings based on the Residential Energy Consumption Survey. Although the designers of the survey wisely included questions about the reasons households made conservation improvements, more specific questions regarding the act of claiming state and federal tax credits would have made investigation of this issue easier and more conclusive.

APPENDICES

APPENDIX A: ANALYSIS OF COMPARATIVE STATIC DERIVATIVES OF THE OPTIMUM CONSERVATION IMPROVEMENT MODEL FROM CHAPTER 2.

Total utility is defined to be (from expression 11.):

A-1 $$U = Y_0^a + DY_1^b T^{(1-b)}$$

where: Y_0 is current period gross income Z_0 minus expenditures for conservation improvement, $P_R R'$, which is the net-of-tax price of a unit of multiplied by R', the "quantity" of R purchase in the current period.

D is the discount factor, 1/(1+r)

Y_1 is future period gross income, Z_1, minus expenditures for fuel consumption, $F(R_1,T,E)P_f$

where: fuel consumption is a negative function of both R_1, thermal integrity of the home in period 1, and E, external temperatures and is a q positive function of T, temperature control consumed in period 1.

and: $R_1 = R_0 + R'$, i.e. thermal integrity in the future period is the initial level of thermal quality plus R', the increase in R.

T= temperature control in the future period,

$= |T^* - T_{actual}|/T^*$

where $|T^* - T_{actual}|$ is the absolute value of the difference between "ideal" indoor temperatures and the one actually chosen, T_{actual}.

Consumers choose R' and T to maximize U. Because income constraints are incorporated into U, an unconstrained maximum of U with respect to the choice variables yields:

A-2: $$F^1 = \partial U/\partial R' = (\partial U/\partial Y_0)(\partial Y_0/\partial R') + (\partial U/\partial Y_1)(\partial Y_1/\partial F_1)(\partial F_1/\partial R'|T = 0$$

A-3: $$F^2 = \partial U/\partial T + (\partial U/\partial Y_1)(\partial Y_1/\partial T) = 0$$

where the { } term at the end of F^1 represents fuel savings from the R' increase in R.

The specific functions for F^1 and F^2 are:

A-4: $$F^1 = aY_0^{a-1}(-P_R) + bdY_1^{b-1}(-P_f)[-TT^*-E)Ah/R_1^{\,2} + (T^*Ah/R_1)(\partial T/\partial R')] = 0$$

A-5: $$F^2 = (1-b)DY_1^{\,b}T^{-b} + bDY_1^{\,b-1}T^{1-b}(-P_f)(T^*Ah/R_1) = 0$$

As discussed in Chapter 2, the optimum temperature control level in period 1 is an implicit function of R_1 which is a function of R'. Thus implicit functions prevent the derivation of a single expression to represent the optimum value of R'. The qualitative influence of the various exogenous and policy variables on optimum R' can be determined by treating F^1 and F^2 as a system of implicit functions. The sign of derivatives of optimum R' can be found by working through a total derivatives of F^1 and F^2 with respect to each exogenous variable and solving for the appropriate derivative which, for exogenous variable i is:

A-6: $$\underline{d}R'/\underline{d}i = \frac{\begin{vmatrix} -F^1{}_i & F^1{}_T \\ -F^2{}_i & F^2{}_T \end{vmatrix}}{\begin{vmatrix} F^1{}_R & F^1{}_T \\ F^2{}_R & F^2{}_T \end{vmatrix}}$$

where | | terms are determinants, $F^n{}_j$ is the partial derivative of expression F^n with respect to choice variable j and the determinant in the denominator can be assumed to be positive in fulfillment of second-order conditions for a maximum. Thus to determine the direction of influence that exogenous variable i has on the optimum increase in R, it is only necessary to determine the sign of:

A-7: $$(-F^1{}_i)(F^2{}_T) - (-F^2{}_i)(F^1{}_T).$$

It was shown in Chapter 2 that $F^2{}_T$, the second derivative of U with respect to T, is negative. Because the derivatives of optimum R' with respect to the exogenous variables are partial derivatives, all other variables are held constant when signing the derivatives. Thus the partial $\partial T/\partial R'$ in F^1 and F^2 can be removed from those expressions.

F^1_T can be shown to be:

A-8: $F^1_T = \{P_f AhbD/(R_1)^2\}[(b-1)Y_1^{b-2}T^{1-b}P_f(TT^*-E)T^*Ah/(R_1) + (1-b)Y_1^{b-1}T^{-b}(-(TT^*-E)) + Y_1^{b-1}T^{1-b}(-T^*)]$.

Thus it can be shown that F^1_T is positive.

It was shown in Chapter 2 that the optimum increase in R′ is a negative function of P_R.

The derivative of optimum R′ with respect to Z_0, current period gross income, has the same sign as $(-F^1_{Z0})(F^2_T)$ because $(-F^2_{Z0})$ equals zero. From above:

$$F^1_{Z0} = (a-1)a[Z_0 - P_R R']^{a-2}(-P_R).$$

Because a<1 this expression is positive. Thus with $F^2_T<0$, the derivative of optimum R′ with respect to current period gross income is positive if improvement expenditures do not exceed gross income.

The influence of D, the discount factor, on optimum R′ can also be found by examining only the first half of A-7 because in equilibrium, the two components of A-5 (F^2) sum to equal zero, thus making F^2_D equal to zero. To sign the derivative, it is necessary to sign $-F^1_D$. It is clear from A-4 that F^1_D is positive. Thus ∂R′/∂D is positive. As r, the household's discount rate increases, D decreases, as D decreases optimum R′ also decreases. Thus higher discount rates applied to the future imply lower optimum increases in R.

The influence of "a", the current period utility parameter on optimum R′ can also be found by looking only at the first half of A-7. From A-4 it can be shown (and it is fairly obvious) that F^1_a is negative. Thus ∂R′/∂a is negative, i.e. a larger weight on current period "net" income implies a smaller optimum conservation improvement.

The sign of $\partial R'/\partial P_f$ depends on the magnitude of each portion of A-7 because the first half of the sum is positive while the second is negative. Substantial manipulation of the relevant products of A-7 does not make it possible to clearly see the conditions under which the derivative would have a particular sign. As discussed in the text, an indeterminate sign of the influence of future fuel prices on optimum R′ arises because a higher fuel price implies a lower optimum level of temperature control and the latter implies a lower optimum level of R. (In a single period utility-maximization model where temperature control is traded-off against net income, the optimum amount of R to have for that single period is a positive function of the amount of temperature control consumed.)

The derivatives of optimum R′ with respect to E, external temperatures and A, area of the dwelling, are also indeterminate and also do not yield identifiable conditions under which the derivative is signable. As E rises, the optimum level of R in a static model declines, but optimum temperature control increases as E increases and the latter dictates a higher optimum level of R in a static model. The opposite holds for A.

APPENDIX B: IDENTIFICATION OF STATE OF RESIDENCE FOR RECS HOUSEHOLDS

State of residence for each household was not reported in the RECS data. In order to assign the appropriate state energy tax credit or deduction to each household, it was necessary to indirectly identify residents of state where these policies apply. The states that were identified are: Arizona, California, Colorado, Idaho, Montana and Oregon, New Mexico, Washington and Wyoming were also identified. There were no Nevada residents in the sample. A census region identifier is included in the RECS data, so all residents of the above states were designated as "Pacific" (CA,OR,WA) or "Mountain" region inhabitants.

The Energy Information Administration (EIA) provided a list of the Primary Sampling Units (PSU's) (counties) from which RECS households were chosen. This information indicated the approximate number of households surveyed in each state and their location within each state. U.S. Weather Service data on actual heating- and cooling-degree days for weather stations in or near each PSU for 1981 are used for comparison with the relevant annual climate data reported in the RECS.

The table B-1 shows the steps and data used in the state identification process.

TABLE B-1: STEPS USED IN STATE IDENTIFICATION PROCESS

Residential Energy Consumption Survey Data	compared with....
Census region identifiers	--
SMSA-City/SMSA-non-city/ non-SMSA location	list of sample locations (PSU's)
heating- and cooling-degree-days	U.S. Weather Service data at nearby stations in same time period (U.S Weather Service)
marginal electricity prices for three customer sizes and average electricity prices for each household	marginal electricity prices for three customer sizes and average prices for local retail utilities ("Typical Electric Bills", January 1, 1982.)
average natural gas price for each household	state level natural gas prices (U.S. DOE, State Energy Price and Expenditure Report, 1970-1982)
average fuel oil prices	state level fuel oil prices (U.S. DOE, State Energy Price and Expenditure Report, 1970-1982)
average LPG prices	state level LPG prices (U.S. DOE, State Energy Price and Expenditure Report)

APPENDIX C: RESULTS OF FUEL CONSUMPTION AND TAX CREDIT IMPORTANCE REGRESSIONS

TABLE C-1

Fuel Demand Regression

Ordinary Least Squares regressions run on RECS households

Dependent variable: natural logarithm of heating and cooling fuel consumption (in thousands of Btu's).

INDEPENDENT VARIABLE	COEFFICIENT (standard error)
ln(square feet heated area)	.46 (.02)
ln(weighted fuel price adjusted for furnace efficiency)	-.61 (.03)
ln (year made) (lower values of this variable imply older homes)	-.14 (.01)
ln(heating degree-days)	.30 (.02)
ln(cooling degree-days)	.12 (.01)
ln(income)	.05 (.01)
ln(number of household members)	.15 (.02)
"house" dummy (= 1 for single-family dwelling)	.09 (.02)

All coefficients are statistically significant at the .01 level.

N = 2941 adjusted R^2 = .50 F = 373

TABLE C-2

Regression Results: Likelihood of citing tax credits as one reason for making an improvement

Sample: households who made conservation improvements

Dependent variable = 1 if the household cited the availability of a tax credit as one reason for making an improvement

= 0 if tax credits were not cited

VARIABLE	LOGIT COEFFICIENT (std. error)	LINEAR PROBABILITY REGRESSION COEFFICIENT (std. error)
net-of-tax price	-4.48 (1.65)	--
income	.75 (.20)	.0000012 (.0000004)
"major" (=1 if a major improvement was made)	.44 (.07)	.11 (.02)
age of household head	-1.05 (.42)	-.0011 (.0005)
"west" (=1 for western region residents)	--	.04 (.018)

all coefficients are statistically significant at the .01 level

Logit variables are natural log transformations

adjusted R^2	--	.057
F-statistic	--	20.5

APPENDIX D: DESCRIPTIVE STATISTICS OF INDEPENDENT VARIABLES USED IN CHAPTER THREE REGRESSIONS

Format: Means
: (Standard deviations)
: [minimum, maximum]

Sample:	Whole	West	Non-West
Variable Annual Household Income (categorized raw data)	$24,397 (18,087) [2,500, 100,000]	$24,121 (17,707) [2,500, 100,000]	$24,500 (18,228) [2,500, 100,000]
Net-of-tax price of conservation improvements	.822 (.068) [.61,1.06]	.737 (.084) [.61,1.0]	.853 (.013) [.80,1.0]
Year Dwelling constructed (categorized raw data) (See page 56)	3.45 (2.07) [1,8]	3.67 (2.07) [1,8]	3.36 (2.06) [1,8]
Age of household head	49.1 (17.0) [18,95]	47.8 (17.4) [18,93]	49.6 (16.8) [18,95]
Square foot area of home	1631 (898) [151,7880]	1469 (815) [240,6312]	1691 (920) [151,7880]
Future fuel price ($/million Btu)	15.4 (6.6) [3.3,47.3]	13.0 (4.4) [6.6,39.3]	16.3 (7.0) [3.3,47.3]
Heating-degree days (65° F base)	4840 (1998) [119,12664]	4876 (2118) [1185,12493]	4826 (1952) [119,12664]
Cooling-degree days (70° F base)	893 (782) [1,4618]	474 (548) [1,3522]	1048 (799) [55,4618]
% renters	21.2%	29.2%	18.2%
% Living in single-family dwellings	84.2%	81.7%	85.2%

BIBLIOGRAPHY

Allen, C. T., "Self-Perception Based Strategies for Stimulating Energy Conservation," Journal of Consumer Research, Vol. VIII, Mar. 1982, pp 381-390.

Amemiya, T., "Qualitative Response Models: A Survey," Journal of Economic Literature, Vol. XIX, December 1981, pp. 1483-1536.

Ansberry, C., "States Seek to Help the Poor By Preventing Heat Shut-Offs," The Wall Street Journal, Feb. 25, 1986, p 31.

Arizona Department of Revenue, Statistics of Energy Tax Credit Claims, Phoenix, Az., April 1985.

Arkansas Department of Finance and Administration, Statistics of Energy Conservation Deduction Claims, Little Rock, Ark., March 1985.

Arthur D. Little, Inc., Measuring the Impact of Residential Conservation: Volume III. An Econometric Analysis of General Public Utilities Data, Report to the Electric Power Research Institute, EA-3606, Project 1587, Sept., 1984.

Arthur D. Little, Inc., Measuring the Impact of Residential Conservation: Volume IV. A Comparison of Alternative Methods, Report to the Electric Power Research Institute, EA-3606, Project 1587, May 1985.

Berg, M. R. and Hassett, M. L., "Conservation and Solar Energy in Residential and Commercial Buildings: The Northern Industrialized U.S.A.," Energy Policy, Vol. 12, No.2, Mar. 1984, pp 93-101.

Bureau of the Census, Annual Housing Survey: 1980. General Housing Characteristics for the United States and Regions. U.S. Department of Commerce, Series H-150-80, 1981.

California Franchise Tax Board, Statistics of Energy Tax Credit Claims, Sacramento, Ca., June 1985.

Cameron, T. A., "A Nested Logit Model of Energy Conservation Activity By Owners of Existing Single Family Dwellings, "The Review of Economics and Statistics, Vol. MXVII, No, 2, 1985. pp 205-211.

Capper, G. and Scott, A., "The Economics of House Heating: Further Findings", Energy Economics, Vol. IV, No. 2, April 1982, pp 134-138.

Carpenter, E. H. and Chester, S. T., "Are Federal Energy Tax Credits Effective? A Western United States Survey," The Energy Journal, Vol. V, No. 2, 1984, pp 139-149.

Carpenter, E. H. and Durham, C., "Again, Federal Tax Credits Are Found Effective: A Reply," The Energy Journal, Vol. VI, No. 3, 1985, pp 127-135.

Collins, R. A. and Gray, J. K., "Derivation of a Theoretical Form of a Production Function for Home Temperature," Energy Economics, Vol. V, No. 4, Oct. 1983, pp 273-278.

Colorado Department of Revenue, Statistics of Energy Tax Credit Claims, Denver, Co., March 1985.

Dildine, L. L. and Massey, F. A., "Dynamic Model of Private Incentives To Housing Maintenance," Southern Economic Journal, Vol XV, No. 4, 1974, pp 631-639.

Energy Information Administration. Residential Energy Consumption Survey: Housing Characteristics, 1981. Washington D.C.: U.S. Department of Energy, 1983. DOE/EIA-0314(81).

Energy Information Administration. Typical Electric Bills, 1981. Washington D.C.: U.S. Department of Energy, 1982.

Energy Information Administration. Natural Gas Annual, 1982. Washington D.C.: U.S. Department of Energy, 1983, DOE/EIA-0131(82).

Energy Information Administration. Residential Energy Consumption Survey: Housing Characteristics 1982. Washington D.C.: U.S. Department of Energy, 1984. DOE/EIA-0314(82).

Energy Information Administration. Energy Conservation Indicators, 1983. Washington D.C.: U.S. Department of Energy, 1984. DOE/EIA-0441(83).

Energy Information Administration. Energy Conservation Indicators 1984 Annual Report. Washington D.C.: U.S. Department of Energy, 1985. DOE/EIA-0441(84).

Energy Information Administration. State Energy Price and Expenditure Report 1970-1982. Washington D.C.: U.S. Department of Energy, 1985. DOE/EIA-0376 (82).

Energy Information Administration. An Economic Evaluation of Energy Conservation and Renewable Energy Tax Credits, (Service Report: unofficial at time of writing). Washington D.C.: U.S. Department of Energy, 1985.

Federation of Tax Administrators. Preferential Tax Treatment For Alternative Energy Devices and Energy Conservation. Research Report No. 82, Washington D.C.: Federation of Tax Administrators, April, 1979.

Feiveson, H. A., and Rabl, A., "Subsidy Strategies For Energy Technologies," Energy Policy, Vol. X, No. 4, Dec. 1982, pp 322-336.

Fishelson, G., "Measuring the Benefits From An Innovation: An Application To Energy," Energy Economics, Vol. I, No. 1, Jan. 1979, pp 47-52.

Frieden, B. J. and Baker, K., "The Market Needs Help: The Disappointing Record of Home Energy Conservation," Journal of Policy Analysis and Management, Vol. II, No. 3, 1983, pp 432-448.

Garbacz, C., "Residential Demand For Fuelwood," Energy Economics, Vol. VII, No. 3, July 1985, pp 191-193.

Gates, R. W., "Investing in Energy Conservation," Energy Policy, Vol. XI, No. 2, March 1983, pp 63-71.

Geller, E. S., "Evaluating Energy Conservation Programs: Is Verbal Report Enough?," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 331-334.

Gibbons, J. C., "Energy Prices and Capital Obsolescence: Evidence from the Oil Embargo Period," The Energy Journal, Vol. V, No.1, 1984, pp 29-43.

Harris, T., "Improving Insulation Standards in Existing Dwellings," Energy Policy, Vol. X, Mar. 1982, pp 61-62.

Hausman, J. A., "Individual Discount Rates and the Purchase and Utilization of Energy-using Durables," The Bell Journal of Economics, Vol. X, Spring 1979, pp 33-54.

Hirst, E. and Jackson, J., "Energy Demand and Conservation in U.S. Residential and Commercial Buildings: Impact of the U.S. National Energy Plan," Energy Policy, Vol. VII, Sept. 1979, pp 208-214.

Hirst, E., Berry, L. and Soderstrom, J., "Review of Utility Home Energy Audit Programs," Energy, Vol. VI, No. 7, 1981, pp 621-630.

Hirst, E., Goeltz, R. and Carney, J., "Residential Energy Use and Conservation Actions: Analysis of Disaggregate Household Data," Oak Ridge National Laboratory, Oak Ridge, TN, 1981.

Hirst, E., Goeltz, R. and Carney, J., "Residential Energy Use: Analysis of Disaggregate Data," Energy Economics, Vol. IV, April 1982, pp 74-82.

Hirst, E., Fulkerson, W., Carlsmith, R. and Wilbanks, T., "Improving Energy Efficiency: The Effectiveness of Government Action," Energy Policy, Vol. X, June 1982, pp 131-142.

Hirst, E., White, D. and Goeltz, R., "Indoor Temperature Changes In Retrofit Homes," Oak Ridge National Laboratory, Oak Ridge, TN, July 1984.

Hirst, E. and Goeltz, R., "Estimating Energy Savings Due to Conservation Programmes: The BPA Residential Weatherization Pilot Programme," Energy Economics, Vol. VII, Jan. 1985, pp 20-28.

Hutton, R. B. and McNeill, D. L., "The Value of Incentives in Stimulating Energy Conservation," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 291-298.

Idaho Department of Revenue & Taxation, Statistics of Energy Conservation Deduction Claims, Boise, Id., April 1985.

Indiana Department of Revenue, Statistics of Energy Conservation Deduction Claims, Indianapolis, In., April 1985.

Internal Revenue Service, Statistics of Income 1978 through 1982: Individual Income Tax Returns. Washington D.C.: U.S. Government Printing Office, 1979-1983. Library of Congress Card No. 61-37567.

Isakson, H. R., "Residential Space Heating: An Analysis of Energy Conservation," Energy Economics, Vol. V, Jan. 1983, pp 49-57.

Johnson, R. C. and Kaserman, D. L. "Housing Market Capitalization of Energy-saving Durable Good Investments," Economic Inquiry, Vol. XXI, July 1983, pp 374-386.

Judge, G. G., Griffiths, W. E., Hill, R. C., Lee, T.C., The Theory and Practice of Econometrics. New York: John Wiley and Sons, 1980.

Karp, L., "Demand For Energy and Insulation," Energy Economics, Vol. VI, July 1984, pp 208-210.

Kempton, W. and Montgomery, L., "Folk Quantification of Energy" Energy, Vol. VII, No. 10, 1982, pp 817-827.

Kempton, W., Harris, C. K., Keith, J. G. and Weihl, J. S. "Do Consumers Know "What Works" In Energy Conservation?", Presented at the 1982 Summer Study, American Council for an Energy-Efficient Economy, Santa Cruz, CA, Aug. 23, 1982.

Kain, J. F. and Quigley, J. M., "Measuring the Value of Housing Quality," Journal of the American Statistical Association, Vol. MXV, No. 330, June 1970, pp 532-548.

Labay, D. G. and Kinnear, T. C., "Exploring the Consumer Decision Process in the Adoption of Solar Energy Systems," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 271-278.

LeBel, P. G.. Energy Economics and Technology. Baltimore: The Johns Hopkins University Press, 1982.

Lubick, D. and Brannon, G., "Stanley Surrey And The Quality Of Tax Policy Argument," National Tax Journal, National Tax Institute-Tax Institute of America Symposium: "Emerging Issues In Tax Policy" May, 1985, in Vol. XXXVIII, No. 3, Sept. 1985, pp 251-259.

Maddala, G. S.. Limited-dependent and qualitative variables in econometrics. Cambridge: Cambridge University Press, 1983.

Malloy, M., "The Solar Age 1984 State Tax Credit Survey," Solar Age, June 1984, pp 24-26.

Mathur, V. K., "Effectiveness of Building Energy Performance Standards to Curtail Household Energy Demand: A Theoretical Analysis," The Energy Journal, Vol. V, No. 1, 1984, pp 99-114.

McDougall, G. H. G. and Ritchie, J. R. B., "Consumer Energy Conservation Policy," Energy Policy, Vol. XII, No. 2, June 1984, pp 201-212.

McKelvey, Richard D. and Zavoina, William, "A Statistical Model For The Analysis of Ordinal Level Dependent Variables," Journal of Mathematical Sociology, 1975, Vol. 4, pp. 103-120.

Mendehlsohn, R., "Empirical Evidence on Home Improvements," Journal of Urban Economics, Vol. IV, 1977.

Montana Department of Revenue, Statistics of Conservation Deductions, Helena, Mont., April 1985.

National Association of Home Builders Journal-Scope, Shortages real now: insulation critical, lumber prices soaring, in "Economic News Notes," Washington D.C.: National Association of Home Builders, Oct. 1977.

Olsen, M. E. and Cluett, C., "Public Willingness to Invest in Household Weatherization," The Energy Journal, Vol. V, No. 1, 1984, pp 165-168.

Oregon Department of Revenue, Statistics of Energy Tax Credit Claims, Salem, Ore., April 1985.

Oviatt, A. E., "Optimum Insulation Thickness In Wood-Framed Homes," U.S.D.A. Forest Service General Technical Report PNW-32, Washington D.C.: U.S. Government Printing Office, 1975.

Owens/Corning Fiberglass, "Building and Commercial Insulation Price Table," Toledo, Oh., Aug. 1984.

Pindyck, R.S., and Rubinfeld, D.L.. Econometric Models and Economic Forecasts, second edition. New York, New York: McGraw-Hill Book Co., 1981.

Pitts, R. E. and Wittenbach, J. L., "Tax Credits as a Means of Influencing Consumer Behavior," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 335-338.

Penoyar, W. E. and Williams, F. E., "Survey of U.S. Residential Insulation Industry Capacity and Projections For Retrofitting U.S. Housing Inventory," Construction Review, Vol. XXIII, No. 5, August 1977. pp 4-14.

Proctor, R. J. and Tyner, W. E., "Assessing the Impact of Peak-Load Pricing and the Solar Tax Credits on the Adoption of Solar Energy," Land Economics, Vol. MX, No. 1, Feb. 1984, pp 49-55.

Ray, G. F., "Energy Economics--A Random Walk in History," Energy Economics, Vol. I, July 1979, pp 139-143.

Ritchie, J. R. B., McDougall, G. H. G. and Claxton, J. D., "Complexities of Household Energy Consumption and Conservation," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 233-242.

Rodberg, L. and Schachter, M.. State Conservation & Solar Energy Tax Programs: Incentives or Windfalls?. Washington D. C.: The Council of State Planning Agencies, 1980.

Rosson, P. J. and Sweitzer, R. W., "Home Heating Oil Consumption: Profiling "Efficient" and "Inefficient" Households," Energy Policy, Vol. IX, No. 3, Sept. 1981, pp 216-225.

Sawyer, S. W. and Friedlander, S. C., "State Renewal Energy Tax Incentives: Monetary Values, Correlations, Policy Questions," Energy Policy, Vol. XI, No. 3, Sept. 1983, pp 272-276.

Scott, A., "The Economics of House Heating," Energy Economics, Vol. II, July 1980, pp 130-141.

Sebold, F. D. and Fox, E. W., "Realized Savings from Residential Conservation Activity," The Energy Journal, Vol. VI, No. 2, 1985, pp 73-88.

Shama, A., "Energy Conservation in U.S. Buildings: Solving the High Potential/Low Adoption Paradox From A Behavioral Perspective," Energy Policy, Vol. VI, June 1983, pp 148-167.

Smith, V. K., "Estimating the Price Elasticity of U.S. Electricity Demand," Energy Economics, Vol. II, April 1980, pp 81-85.

SPSS Inc., SPSS-X User's Guide, Edition 2. New York, NY: McGraw-Hill Book Co., 1986.

Stelzer, I. M., "What Role Can Utilities Play in Energy Conservation Programs," Vol. III, No. 1, 1982, pp 90-94.

Stocks, K. J., "Discount Rate for Technology Assessment: An Application to the Energy Sector," Energy Economics, Vol. VI, July 1984, pp 177-185.

Sweeney, J. L., "Housing Unit Maintenance and the Mode of Tenure," Journal of Economic Theory, Vol. VIII, 1974, pp 111-138.

Talwar, R. and Hirst, E., "Energy Savings From the Minnesota Low-income Weatherization Programme," Energy Policy, Vol. IV, Mar. 1981, pp 48-51.

Tobin, J., "Estimation of Relationships for Limited Dependent Variables," Econometrica, Vol. XXVI, 1958, pp 24-36.

United States Government Budget, 1978-1982. Washington D.C.: U.S. Government Printing Office, 1979-1984.

University of Illinois Small Homes Council-Building Research Council, Council Notes: A1.61: Savings by Insulating Doors and Windows: A1.62: Savings by Insulating Ceilings, Walls and Foundations. Urbana-Champaign, Il., 1980.

Uri, N. D., "The U.S. Insulation Market," Energy Policy, Vol. I, Mar. 1978, pp 78-79.

Verhallen, T. M. M. and Van Raaij, W. F., "Household Behavior and the Use of Natural Gas for Home Heating," Journal of Consumer Research, Vol. VIII, Dec. 1981, pp 253-257.

Wene, C. O., "Communications on Energy: Limits to Energy Conservation Analysis," Energy Policy, Vol. IV, Mar. 1981, pp 47-48.

Williams, F. E., "Storm Doors and Windows," Construction Review, Vol. XXI, No. 2, March, 1975. pp 2-8.