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INTERACTIONS OF PRICES AND HOUSEHOLD CHARACTERISTICS AND RESIDENTIAL ENERGY CONSERVATION

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ABSTRACT

The analysis identifies the determinants of residential energy consumption by 95 households between 1973-74 and 1977-78. The data are from households surveyed in 1974 and 1976. Changes in consumption from year to year are treated as dependent on the initial level of consumption, changes in energy prices, current family income, family life cycle status and family employment structure, type and size of dwelling, reported attempts to conserve and exposure to energy conservation information. Yearly variations in weather are incorporated by expressing consumption in British Thermal Units (Btu) per heating degree day.

Mean family consumption declined by 21.6 percent between 1973-74 and 1977-78. The majority conserved by more than two percent in three of four seasons and 59 percent had conserved at least 20 percent after four seasons. Energy prices, family income, family size, employment structure and dwelling size measures were all statistically significant predictors of annual consumption. The primary determinants of conservation were price change and prior consumption level. Family characteristics determined consumption, but had little relation to conservation. People who were at work all day used less energy and conserved more, reinforcing the importance of thermostat reduction measures for conservation.

INTRODUCTION

This paper advances three arguments:

1. There is evidence that families learn to conserve, and that more of them adopt the habit over time.

2. Numerous features of the physical dwelling and of a family's economic, social and demographic circumstances make independent contributions to the annual level of consumption, and these factors seem quite stable over time.

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3. These features of families and dwellings make comparatively little contribution to the explanation of conservation, which can be accounted for primarily in terms of changes in price and the adoption of certain specific conservation measures.

Evidence for the first point will be drawn from tables showing rates of conserving from 1973 through 1978. The second and the third points will be argued by brief reference to tables of multiple regression results where first consumption and then conservation are the dependent variables. Finally, a path analysis model is presented that illustrates points 2 and 3 in a summary fashion. It also contains evidence of the operation of feedback over time, with high rates or levels of consumption in one period contributing to conservation (independent of the effect of price changes and other variables) in the subsequent period.

THE DATA

The data come from 216 households interviewed in May, 1974 and 263 households interviewed in May, 1976. Of those original households, 159 were re-interviewed in 1976. The sample was an area probability sample of the Lansing, Michigan SMSA. The sampling procedures were those used by Zuiches et al. (1976) and Gladhart et al. (1983). Energy consumption data were collected from the utilities and fuel dealers serving each household for the heating seasons of 1973-74 through 1977-78. Five continuous years of consumption records are available for 99 families, with shorter stretches of data available for 125 to 186 families. For the sample analyzed here, 143 received natural gas service in 1974 and 44 received fuel oil. There were 134 natural gas customers in 1976 and 65 users of fuel oil. Consumption of each energy source was converted to Btus and totaled for each heating season, June through May.

ENERGY PRICES

Since marginal prices are those which a rational consumer would use in decision making, monthly marginal prices for electricity and natural gas were calculated from the utilities' complete rate structures using procedures outlined by Taylor (1975). A computer program was developed to examine the monthly billing and then assign the appropriate price (including any cost or fuel purchase adjustment factor) for the last kilowatt or cubic foot consumed, excluding the fixed block or billing charge. The price of fuel oil used was the price-per-gallon at the time of each delivery as reported by fuel oil dealers. Weighted average prices for each season were calculated for each energy form based on the quantity billed or delivered at each billing. Summer fills of fuel oil were generally allocated as consumption in the prior heating season. Finally, a weighted energy price in cents per therm (100,000 Btu) was computed to permit aggregation of prices for electricity, fuel oil and natural gas. The sample was served by two electric utilities, Consumer's Power Company and Lansing Board of Water and Light, with distinct rate structures. Both variations in the price of electricity as well as the proportions of oil or natural gas and electricity consumed contributed to variations in the price of energy faced by families.

Energy prices moved steadily upward for the subsample of families over the entire period. The mean price per therm for the 99 households with 5 years of continuous data was 21.6 cents in 1973-74 and 38.5 cents in 1977-78. The average price rise from season to season for all energy was 5.6 cents per therm for the first year, 5.4 cents the second, 2.4 cents the third and 3.7 cents the fourth. The mean price of all energy rose by approximately 78 percent over the five year period with annual increases of 7 to 26 percent.

The sample of 99 families consumed an average of 26,863 Btu per degree day in 1973-74 and 21,058 Btu per degree day in 1977-78, a decline of 21.6 percent. Mean consumption declined in three of the seasons, but rose 440 Btu per degree day from 1974-75 to 1975-76. In this analysis, Btu are computed as direct energy used at the residence, disregarding any generation or transmission losses.

PATTERNS OF CONSERVATION

With the sample average of 21 percent between the first and the fifth season, this is an uncompounded rate of conservation of about 5 percent per season for four periods of change. Since one would not expect that any two years' measured consumption per degree day would be identical, a range of plus or minus 2 percent was selected to simplify the search for families who conserved and those who did not. Families within the range were classified as not changing consumption. On this basis, 35 families never increased their consumption by as much as 2 percent; 52 increased once, 11 increased twice and one family had an increase in three of the four periods. On the conservation side, three families showed just one decrease as large as 2 percent, 34 families had two decreases, 54 had three decreases and 9 families conserved by more than two percent in every period.

Table 1 contains evidence of a "learning" effect. Fourteen percent showed an increase over the first period and 79 percent showed a decrease. This was the first season following the 1973-74 oil embargo and the first season after the interviewers had raised the awareness of these families with several hours of questions about energy and conservation. Between the second and third seasons, conservation efforts fell off dramatically. Thirty percent showed an increase and only 50 percent showed a decrease. Increases dropped to 19 percent for the third period and 14 percent for the fourth, while decreases rose to 64 and 73 percent of the sample, respectively. On the average, the sample was back to the same proportion making a conservation effort in 1978 as right after the oil embargo. They may have decided that the new energy situation was a long-term problem. A similar upturn in 1976 consumption appears in the national level residential natural gas data analyzed by Harris et al. (1984).

Table 1. Proportions of Conservers and Non Conservers by Season

Period	Up 2% or more (%)	Down 2% or more (%)
1973-4, 1974-5	14	79
1974-5, 1975-6	30	50
1975-6, 1976-7	19	64
1976-7, 1977-8	14	73

Further evidence of increasing homogeneity of behavior over time is provided by the variances of the consumption measures and the regression analysis of conservation. Examining the mean change for each period, one can see that the ratio of the mean to its standard deviation rises over time. That is, there is less variance. Taking the case of the average annual change for the first two periods, the last two and all four periods combined, the ratio of mean to standard deviation rises from .16 to .72 to 1.15. The means and standard deviations for consumption change (conservation) appear as the first two rows of Table 5. The R square for total consumption and for consumption change rises over each period. Thus, the power of the explanatory variables increases as the sample's behavior becomes more more homogeneous, suggesting that average sensitivity to price increased. The ratio of mean consumption change to mean price change rises over time. The absolute levels of conservation associated with changes in price change rise over time. This is evidenced by the increasing size of the unstandarized coefficients when conservation is the dependent variable. It reinforces the interpretation that price sensitivity becomes more common. All these coefficients are found in Table 5.

It is evident that every year more families attained a given level of conservation. The conservation of the entire sample is presented in Table 2. The average conservation over four periods was 21.6 percent. Six percent of the families had conserved at least 20 percent at the end of the first period, 13 percent by the end of the second, 27 percent by the third and 59 percent by the fourth. Three percent of the families conserved 30 percent of their energy in the first season and 25 percent had reached this level by the end of the fourth. Conservation of ten per cent or better was reached by 41 percent of the sample after the first period. This rose to 84 percent after the fourth period.

Examination of the records of those who had three periods of conservation in Table 3 shows the pattern is more extreme. Eleven percent had conserved at least 20 percent at the end of the first period, 21 percent at the end of the second, 34 percent by the third and 70 percent by the fourth period.

Table 2. Conservation Achievements by 99 Families Below 1973-74 Base Period

Conservation Level % Reduction	Cumulative Achievement Percentile Period 1	2	3	4
45	--	1	3	4
40	--	1	6	9
35	1	4	7	13
30	3	7	9	25
25	4	8	13	37
20	6	13	27	59
15	15	25	46	73
10	41	44	66	84
5	65	70	76	88
0	84	82	83	92
Increases >2% .	16	18	17	8

Table 3. Conservation Achievements Below 1973-74 Base Period By 53 Families Who Made Three Decreases Of At Least Two Percent

Conservation Level % Reduction	Cumulative Achievement Percentile Period 1	2	3	4
45	--	2	2	6
40	--	2	8	13
35	2	6	9	15
30	6	9	11	26
25	8	11	17	47
20	11	21	34	70
15	19	32	57	83
10	43	49	83	93
5	70	77	89	94
0	89	85	94	98
Increases >2%	11	15	6	2

In summary, most families conserved incrementally, the mode being three times in four seasons. The conservation level attained by a given proportion of families rose twice as fast between the third and fourth periods as it did between the first three (10 percentage points compared to 5), and the variance in conservation decreased as the level of conservation rose. While more families conserved, and conserved more over time, their apparent sensitivity to energy prices rose as well.

A REGRESSION MODEL OF ENERGY CONSUMPTION

A regression model of consumption employing family lifestyle, dwelling and price variables was estimated for each of five years of consumption data. Annual family income, family size and employment status were the three lifestyle variables used. Employment status was represented by a dummy variable that took the value one if both husband and wife or the single head of the household were employed full time. The dummy variable took zero in other cases. The hypothesis represented by this variable is that families with the adults employed full time will be more likely to have their homes empty during the day with consequent lower energy consumption. Twenty-five to 32 percent of the sample had the heads employed full time in each season analyzed. Family income was taken from the response to a survey question listing total household income in $1,000 intervals. Income was entered in the analysis as a continuous variable using the midpoint of the reported interval. Employment and family size were both expected to be positively related to income.

The dwelling was represented in the model by four measures of size of heating and cooling load: the number of windows, the number of doors, the number of rooms heated and the number of rooms air-conditioned. A second dummy variable was employed that took the value one if the dwelling was a mobile home. Six families in the sample analyzed lived in mobile homes during the 1974 season, five in each of the next three seasons and two families in 1977-78. Since the rooms of mobile homes are usually smaller than those of standard dwellings, the hypothesis was that mobile home dwellers would consume less energy, independent of the effects of the other measures of dwelling size.

Results

The results of this analysis are presented in Table 4. The table contains, for each year of the analysis, the unstandardized regression coefficients with their t values and probability levels, the means of the dependent variables and summary statistics. Between 135 and 194 cases were available for analysis in the different years, 95 cases are common to all five years. The most striking aspect of the results are the high degree of uniformity and stability of the coefficients and their t values from year to year. The coefficients for a majority of the variables are efficient and of high statistical significance: the t values for energy price range from 4.7 to 7.7. Most of those for income, family size, windows, doors, and rooms lie between 2.0 and 4.0. With the exception of the mobile home variable, all the coefficients are of similar magnitude from year to year and they have the sign predicted by the hypotheses. While the mobile home coefficient is not interpretable due to small sample size,

Table 4. Regression Coefficients for Total Annual Energy Consumption, Lansing, Michigan, 1974-1978

Variables		1973-74	1974-75	Consumption Year* 1975-76	1976-77	1977-78
Price		-2.548	-1.62	-1.852	-1.804	-1.715
Cents/therm	t	(5.32)	(4.73)	(7.71)	(5.73)	(6.36)
	sig.	.000	.000	.000	.000	.000
Income		1.311	1.585	.941	1.427	.664
$1,000	t	(3.30)	(3.01)	(2.18)	(2.74)	(1.36)
	sig.	.001	.003	.030	.007	.177
Family Size		8.971	5.535	9.728	8.553	7.332
	t	(3.93)	(1.99)	(4.03)	(2.96)	(2.42)
	sig.	.000	.049	.000	.004	.017
Number of Windows		2.949	4.086	2.097	3.398	2.539
	t	(4.52)	(5.01)	(3.10)	(3.89)	(3.03)
	sig.	.000	.000	.002	.000	.003
Number of Doors		16.560	8.980	18.014	12.866	17.208
	t	(3.88)	(1.60)	(3.99)	(2.32)	(3.18)
	sig.	.000	.111	.000	.022	.002
Rooms Heated		4.185	5.570	2.840	3.274	3.933
	t	(2.90)	(2.25)	(1.47)	(1.36)	(1.69)
	sig.	.038	.026	.144	.177	.094
Rooms Air Conditioned		.308	1.084	1.874	2.922	1.025
	t	(.15)	(.43)	(1.19)	(1.53)	(.57)
	sig.	.882	.666	.237	.128	.571
Mobile Home		-46.216	-9.780	-1.974	-16.866	38.330
Yes = 1	t	(2.15)	(.30)	(.10)	(.70)	(1.09)
	sig.	.033	.768	.923	.485	.277
Full Time		-13.877	-19.441	-10.664	-9.493	-9.825
Employed	t	(1.83)	(2.01)	(1.26)	(.93)	(1.00)
Yes = 1	sig.	.070	.046	.208	.352	.319
Constant		86.259	87.986	100.580	108.018	113.628
Dependent Variable million Btu		196.275	201.744	183.643	204.201	191.374
N		179	157	194	152	135
R Square		.55	.49	.50	.52	.49
Overall F		23.42	16.01	20.51	17.28	13.3

* Consumption years measured June-May.
t values in parenthesis followed by significance levels.

it was retained in the model to reduce bias in the estimate of other coefficients. The full employment coefficient is less stable than desirable. Its connection to the underlying consumption reducing behavior is imprecise, as indicated in the discussion of the variable. This overall stability suggests that variations in sample composition and measurement error do not seriously limit the ability to generalize about the importance of the variables employed for the samples studied.

A large proportion of the total energy consumed in each year was not related to the variables included in the model. The constant terms are between 44 and 59 percent of the respective means of the dependent variables. About half of the total variance in each equation is explained by the included variables, the R square statistic ranges from .49 to .55. Part of this is, of course, due to the inability to include precise measures of the weather conditions at each home, the thermal properties of the dwelling, the efficiency of equipment, and the daily habits of people themselves. Part is surely due to the fact that much of the energy consumed in a household occurs because of essentially fixed costs of operation.

In the model estimated, a difference of family income of $1,000 dollars implies a difference of .7 million to 1.6 million Btu. While the coefficients were positive and all but one statistically significant, the calculated elasticities were negligible, .07 to .13. The coefficients imply a consumption difference equivalent to six to twelve gallons of fuel oil annually for every $1,000 difference in family income (1 gallon=125,000 Btu). It is evident that in heating a home and feeding and washing a family, the effects of wealth are expressed through the energy using properties of the structure itself. Pure income effects are not visible.

Family size is revealed in Table 4 as an important contributor to consumption. Each person in the family accounts for six to ten million BTUs. The net effect of having both household heads employed full time was to reduce consumption on the average by about 13 million BTUs. While these estimates are not as reliable as others in the model, they do suggest that many families were leaving their homes unheated all day while they were at work.

While measures of dwelling size each contributed positively to energy consumption during all five years, the coefficients for rooms air-conditioned fell short of statistical significance. This should not be surprising in the climate of Lansing, where over 60 percent of the sample reported no air-conditioning. This variable is really a report of capacity, not use. By contrast, the report of the number of rooms heated is apparently quite a good indicator of use.

In summary, the lifestyle and structural measures of consumption determinants were quite stable in their effects over the period of analysis. Both types make substantial and distinct contributions to the explanation of consumption. There are other important (perhaps idiosyncratic) factors not included in this model since only 49 to 55 percent of the variance was explained by the variables included. These results reflect the strengths and suggest the limitations of survey research to answer these types of questions.

CONSERVATION MODELS

The basic elements of family lifestyle formed the core components of the models of energy conservation tested here. Other variables representing reported attempts to conserve energy were introduced as appropriate. In addition to income and family size, the ratio of annual energy costs to per capita family income for the base period expressed as a percent was included to capture the relative importance of energy to the family's budget. This ratio varies dramatically between families in different circumstances. It was expected that the variable would measure effects, not captured by income and prior consumption independently. The hypothesis was that families experiencing costs as a higher proportion of their budget would make greater attempts to conserve.

The family life cycle is represented in the models by two dummy variables, YoungFam and OldFam, for people under 40 with no children and people over 40 with no children at home. Both types of families have notably lower levels of consumption compared to families in the middle life cycle stages. The variables were included to see if life cycle measures would make an independent contribution to conservation.

The number of windows, outside doors and rooms heated were all strong predictors of consumption and were initially introduced in the conservation models. Since no theoretical significance was attached to these variables, those that did not improve the fit of the equations were dropped after initial trials. Doors was eliminated entirely and windows only appears in the model for 1973-4, 1974-5.

Three major technical conservation actions reported in 1976 were included for models involving 1975 and subsequent years: installed ceiling insulation, wall insulation, or a clock thermostat within the previous two years. An index of conservation practice adoption, ConBehavior, was also included. This reflects the reported adoption ("all" or "most" of the time) of nine conservation practices, weighted by whether one or both spouses reported adoption of the practice. Finally, dummy variables were included for reported installation of ceiling, wall and crawlspace insulation between spring and fall of 1977. This information was gathered as part of an experiment to deliver conservation information to families in different ways (Zuiches, 1978). A dummy variable was included if the family received the information and weatherization analysis in person or if the family had refused to participate in the experiment when contacted in the spring of 1977.

Results

The results of the conservation analysis are displayed in Table 5. Table 5 contains the analysis of a group of 95 households with complete data for each period. An identical analysis was performed in which the 95 cases of Table 5 were augmented to the maximum available for each analysis period. In the case of Table 5, the equations explain 20 to 25 percent of the variation in conservation for the first two periods, 59 to 69 percent for the last two. Only 16 percent of the variance in mean change from 1973-74 to 1975-76 is

Table 5. Regression Coefficients, t Values (in parentheses) and Significance Levels for Energy Conservation: Sample A, 94 Repeated Cases, Lansing, Michigan

	Change Periods			
Dependent Variable	1	2	3	4
Consumption	1973-74	1974-75	1975-76	1976-77
(100 Btu/DD)	1974-75	1975-76	1976-77	1977-78
mean	-16.699	6.473	-27.146	-21.452
standard dev.	36.185	60.557	57.779	32.38
Independent Variables				
Base Consumption	-.119	.036	-.446	-.160
(100 Btu/DD) t	(2.06)	(.445)	(10.78)	(3.77)
sig.	.042	.657	.000	.000
Price	3.965	-6.804	-2.013	-5.467
(Cents/Therm) t	(2.76)	(2.81)	(1.10)	(5.71)
sig.	.007	.006	.274	.000
Income	.249	-.880	1.640	-.031
($1,000) t	(.519)	(1.26)	(2.91)	(.759)
sig.	.605	.209	.005	.940
Cost/INC-Person	.177	-.254	.120	-.863
(Percent) t	(.824)	(1.13)	(.210)	(.248)
sig.	.412	.263	.834	.805
Family size	-5.129	13.254	.778	5.089
t	(1.38)	(2.25)	(.185)	(1.75)
sig.	.171	.027	.854	.084
Young Family	-18.807		49.625	-10.70
(Yes=1) t	(.528)		(1.95)	(.599)
sig.	.599		.055	.551
Old Family	-5.561	-2.995	24.037	-5.364
(Yes=1) t	(.493)	(.159)	(2.17)	(.724)
sig.	.623	.874	.033	.471
Both Employed	2.963	-22.607	-4.289	-15.267
(Yes=1) t	(.364)	(1.70)	(.505)	(2.71)
sig.	.717	.093	.615	.008
Rooms Heated	4.967	-6.756	6.183	-3.406
t	(2.31)	(1.91)	(3.42)	(2.43)
sig.	.024	.060	.001	.017
Windows	.970			
t	(1.25)			
sig.	.215			
New Furnace		-22.878		
t		(.986)		
sig.		.327		

New House		35.895		
t		(.005)		
sig.		.996		
Insulation Ceiling			-21.458	
74-76 (Yes=1) t			(1.68)	
sig.			.098	
Insulation Wall		-23.112	34.119	
74-76 (Yes=1) t		(1.28)	(2.39)	
sig.		.206	.019	
ConBeh		2.499	-.821	-.310
74-76 t		(1.72)	(.986)	(.542)
sig.		.090	.327	.590
Insulation Ceiling				-.954
'77 (Yes) t				(.976)
sig.				.922
Insulation Wall				23.017
'77 (Yes=1) t				(1.80)
sig.				.076
Insulation Basement				-30.918
'77 (Yes=1) t				(2.70)
sig.				.009
Personal Info.				1.112
Delivery (Yes=1) t				(.192)
sig.				.843
Dropout by '77				1.019
(Yes=1) t				(.149)
sig.				.882
Constant	13.993	49.771	5.378	50.012
Number of Cases	94	94	95	95
R Square	.198	.254	.694	.589
Overall F	2.048	2.304	15.527	7.577
Significance	.038	.014	.000	.000

Table 5. Regression coefficients, t values (in parentheses) and Significance Levels for Energy Conservation: Sample A, 94 Repeated Cases, Lansing, Michigan

Dependent Variable		Mean Changes	
	1-2	3-4	1-4
Consumption	1973-74	1975-76	1973-74
(100 Btu/DD)	1975-76	1977-78	1977-78
mean	-5.113	-24.299	-14.730
standard dev.	32.019	33.903	12.818
Independent Variables			
Base Consumption	-.108	-.281	-.119
(100 Btu/DD) t	(.215)	(12.58)	(7.60)
sig.	.830	.000	.000
Price	-4.898	-4.052	-3.327
(Cents/Therm) t	(2.83)	(3.08)	(4.79)
sig.	.006	.003	.000
Income	-.330	.826	.373
($1,000) t	(.851)	(2.65)	(2.38)
sig.	.397	.010	.020
Cost/INC-Person		.139	.247
(Percent) t		(.473)	(.169
sig.		.638	.095
Family Size	3.522	2.500	1.067
t	(1.077)	(1.06)	(.928)
sig.	.289	.291	.356
Young Family	-22.947	20.119	5.056
(Yes=1) t	(.703)	(1.44)	(.727)
sig.	.484	.154	.469
Old Family	-3.376	7.247	1.835
(Yes=1) t	(.324)	(1.18)	(.610)
sig.	.747	.241	.544
Both Employed	-6.253	-7.562	-3.823
(Yes=1) t	(.835)	(1.67)	(1.71)
sig.	.406	.099	.192
Rooms Heated	-1.795	1.118	-.417
t	(.939)	(1.01)	(.762)
sig.	.351	.316	.443
New Furnace	-11.699		
74-76 (Yes=1) t	(.891)		
sig.	.376		
New House	14.883		
74-76 (Yes=1) t	(.402)		
sig.	.689		

Insulation Ceiling 74-76 (Yes=1)		-3.174	-2.408
t		(.453)	(.696)
sig.		.652	.488
Insulation Wall 74-76 (Yes=1)	-2.465	18.824	8.336
t	(.245)	(2.13)	(2.06)
sig.	.307	.036	.042
CLOCK Therm 74-76 (Yes=1)		5.213	3.256
t		(.341)	(.438)
sig.		.734	.663
CON Behavior 74-76	.848	-.682	-.295
t	(1.04)	(1.51)	(1.27)
sig.	.30	.135	.207
Insulation Ceiling '77 (Yes=1)		-1.576	.948
t		(.182)	(.233)
sig.		.856	.816
Insulation Wall '77 (Yes=1)		21.174	4.436
t		(2.04)	(.864)
sig.		.045	.391
Insulation Basement '77 (Yes=1)		-16.83	-6.785
t		(1.81)	(1.49)
sig.		.075	.140
Personal Info Delivery (Yes=1)		-1.155	-3.353
t		(.247)	(1.44)
sig.		.806	.155
Dropout by '77 (Yes=1)		4.739	-.184
t		(.859)	(.065)
sig.		.393	.948
Constant	28.952	25.227	21.217
Number of Cases	94	95	94
R Square	.166	.772	.609
Overall F	1.341	14.292	6.601
Significance	.212	.000	.000

explained. However, the R square values were of similar magnitude for the augmented sample. They were slightly larger for period 2 and slightly smaller for the other periods. In general, the principal effect of the additional observations was to increase the t ratios for individual coefficients at the expense of modest declines in total variance explained. In the interest of economy, the augmented results are not presented separately here.

Price Change and Consumption

Price change and prior consumption are about equally important in explaining change in consumption from one season to the next. The standardized regression coefficients (not shown in the table) for Price are larger than those for Consumption in the second and fourth period and the same size in the first period. Consumption has the largest standardized coefficient in the third period. With the exception of the coefficients for the second period and the first two-year average, the t ratios for Consumption range from 2.0 to 12.6. The majority of the single period coefficients as well as that for the fourperiod mean are in the range of .11 to .18 They imply that consumption declined by 12 to 18 percent of its prior level and other factors held constant. An explanation for the coefficient of .44 for base consumption in 1975-76 is most likely to be found in the behavior of the coefficients for Family Size and Rooms Heated, two variables correlated with total consumption whose effects are discussed below.

Price change is the most stable variable in explaining consumption change in these models. The coefficients suggest a change in consumption of 200 to 800 Btu per degree day for every one cent change in the price of a therm. With mean price changes ranging from 2.36 cents to 5.56 cents, the mean consumption change attributable to change in price ranges from 460 Btu per degree day in period three to 3,670 Btu per degree day in period two. This is equivalent to 3.2 million Btu in period three and 25.7 million Btu in period two when a 7000 degree day heating season is assumed.

Family Lifestyle Variables

The family variables are, in general, less stable in their effects across the various models than are price and consumption. Only a few reach a level of statistical significance of .05. Overall they are much less interpretable and dependable than they were in the models explaining total consumption. Income has a positive sign for the third period; both the 76-77 mean and the four-year mean are simple dilutions of the effect. The coefficient for the four-year mean implies a 37 Btu per degree *increase* for every $1,000 dollars of Family Income, about three cubic feet of natural gas in a heating season of 8,500 degree days. The ratio of cost to per-capita family income only attained a modest level of significance (.095) for the four-year mean analysis. Inclusion of the variable in most cases enhanced both the size and the t statistic of the coefficients of consumption, income and family size in a marginal way. The same effect was true in the case of the augmented sample, but the larger number of observations permitted the estimation of more efficient coefficients. The generally positive sign of this variable may mean that families with high incomes and, therefore, low cost to income ratios had more funds to commit to energy conserving investments. This is only speculation.

The key to understanding the results for the family and dwelling variables of Family Size, Young Families, Old Families and Rooms appears to consist in the correlation of both family size and number of rooms with total consumption. The effects of total consumption upon other coefficients in the equations also figure in this correlation. In Table 5, Family Size and Rooms Heated have opposite signs in each of the three one-year periods when the coefficient for consumption is small, .12 to .17. They, thus, tend to balance one another, particularly since Family Size has a larger coefficient in two of the three periods. Moreover, the signs change from period to period. For period three, 1975-76 to 1976-77, the coefficient for consumption is very large and those for *both* Family Size and Rooms Heated are positive. Furthermore, the coefficients for both Young Family and Old Family are large, positive and significant in this period, the only time this occurs. Clearly, other factors besides the level of prior consumption are involved in the conservation achieved by these samples. The data, however, do not permit isolation of these factors with any certainty.

The variable of Both Employed has a large negative coefficient in the fourth period that is significant at the level of .008. The strength of the effect persists for the two period and four period means as well. The coefficient for the second period is also negative and significant at the level of .093. The evidence suggests that dual earner families were able to achieve greater conservation than their single earner counterparts, perhaps by simply leaving the thermostat lower during the day when they are at work.

Reported Conservation Actions

Performance of the various specific conservation actions was decidedly mixed in these models. Installation of ceiling insulation before 1976 was associated with a decrease in consumption in the succeeding period at a significance level of .088. The effect was strong enough to appear in the final two-period and four-period mean models, but at much smaller values and at a significance of .5 or greater. Families who reported insulating their ceiling between 1974 and 1976 showed a net decrease of 2,200 Btu per degree day between 1975-76 and 1976-77, a change of about 10 percent of the base consumption. There was no effect at all for the period ending in 1976 and the variable was dropped. Insulating the ceiling in 1977 has a negative coefficient, but there is no significance to the estimate.

Many unmeasured factors could be responsible for this result. Ideally, one would like to know the area receiving the insulation and the net increase in the R value for that area. A report, "We added insulation to the ceiling," can include such a wide range of possible actions that statistical discrimination of the effect is impossible for this sample. The effect of insulation may have been counter-balanced by a shift in the thermostat setting, or some other change in energy management practices.

Adding insulation to a basement or crawlspace in 1977 did produce a statistically significant impact in the following winter's consumption for both samples, but adding wall insulation has a positive sign in that year. Addition of wall insulation prior to 1976 has a negatively signed coefficient of low significance for the period ending in 1976. It is a positive coefficient for the next period that is significant statistically for both samples. Once again, it may simply be the case that a family's report, "We insulated our walls," is too inadequate a measure of the relative improvement of the dwelling to permit statistical discrimination.

The variable, ConBehavior, has the wrong sign for the period to which it should apply, 1974-75 to 1975-76. The coefficient is negative for succeeding periods. It achieved statistical significance for the augmented sample in the fourth period, so the results are difficult to interpret. The results may be simply the consequence of the low level of total variance explained for the second period compared to the fourth. One is tempted to infer that the variable is not merely a report of recent activities, but that it indexes an underlying commitment to conserving energy on the part of families.

In summary, the primary determinants of conservation that appear in this analysis are the absolute level of prior consumption and the increases in prices of energy. Various features of a family's lifestyle have modifying effects. They seem to have their influence through the determination of total consumption. The one exception to this is the case of dual earner households, who seem to have conserved more effectively than others, by whatever means. The analysis provides tentative support for the idea that comprehensive behavioral indexes of conservation may indeed tap a real commitment on the part of families. The implications of these findings will be drawn out in the discussion of the path model of consumption that follows.

A PATH ANALYSIS OF FIVE YEARS OF CONSUMPTION

With the evidence of the preceding analysis as a guide, a path model of five years of consumption was estimated in an attempt to integrate the findings concerning both consumption and conservation. The resulting path diagram appears in Figure 1. The path coefficients shown are standardized regression coefficients. The model provides evidence of recursive effects between the amount consumed in one period and the amount conserved in the next. The variables are a subset of those that have already been discussed above.

At the left of the model is an entirely structural equation. BTUPDD74 is determined by the current price of energy, the rooms heated and air-conditioned, the number of exterior doors, windows, rooms heated, family size, income, mobile homes and BOTHFUL (whether or not both spouses were employed full time outside the home). The coefficients are significant at the .05 to .01 level, except for mobile home and air-conditioning.

Proceeding to the right, ENROOM4 is the ratio of BTUPDD74 to rooms heated in 1974. The rationale for the variable is that consumption per room is a measure of intensity or inefficiency of use. There is a strong positive path from consumption to ENROOM4, a modest negative path from ENROOM4 to BTUPDD75. CPRICE45 is the change in energy price from 1973-74 to 1974-75.

In 1976, the sign for the path from ENROOM6 to BTUPDD76 has reversed and is positive. Table 1 shows that 30 percent of the sample had an increase of over 2 percent for this season and only 50 percent showed a decline. Nevertheless, the absolute level of 1975 consumption is positively related to reports in 1976 that families had insulated their ceilings or their walls between 1974 and 1976. These in turn have small, negative paths to consumption in 1976 and, for ceiling insulation, for consumption in 1977 as well.

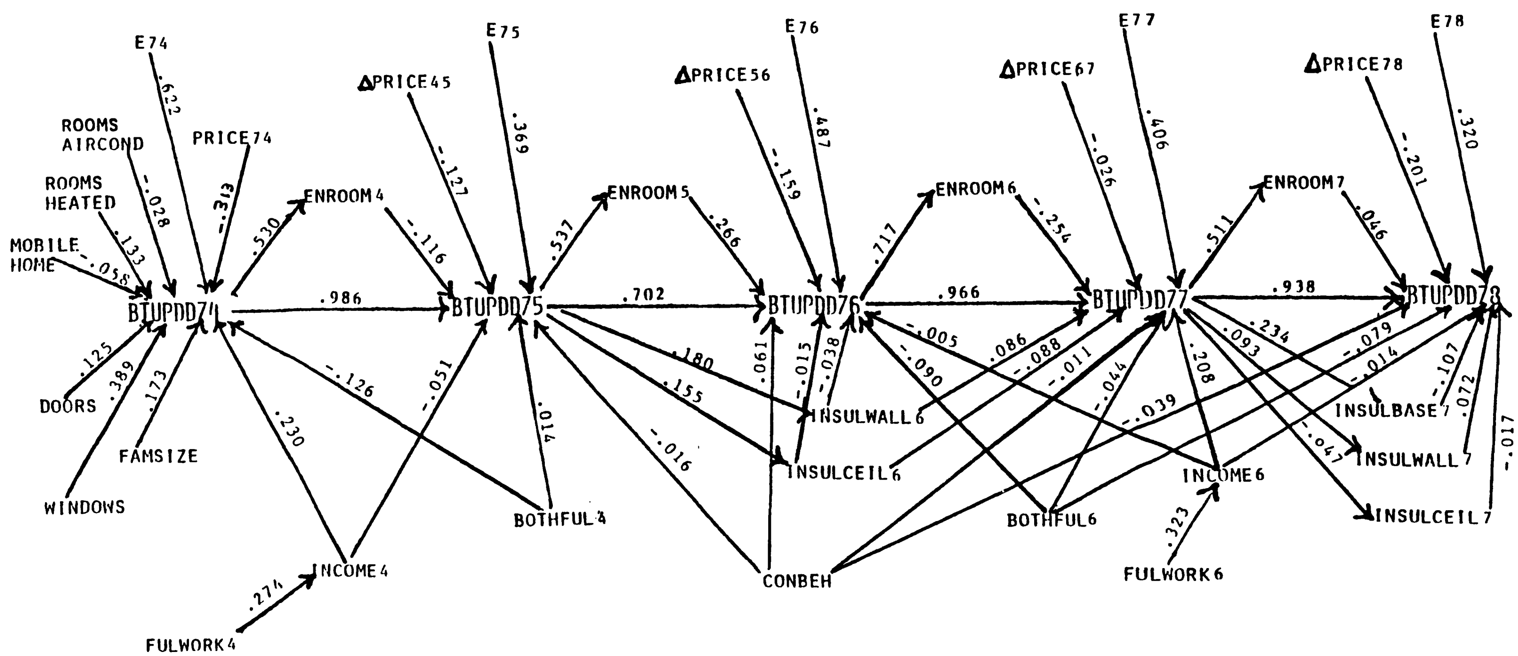

FIGURE 1. PATH MODEL OF CONSUMPTION DETERMINANTS THROUGH TIME.

The variable CONBEH (an abbreviation of the variable ConBehavior discussed in the preceding section) has a negative path to consumption of the previous year and negative paths to consumption in both 1977 and 1978. The effects of the variable extend well beyond the point of measurement. The positive path to consumption in 1976 is a humbling reminder of the nature of social data. As noted above, Harris et al. (1984) have shown a national backsliding effect for 1976.

A word about some variables: BOTHFUL, FULWORKS and INCOME appear twice in the model with suffixes 4 and 6 because they were measured twice, in 1974 and 1976. While the 1974 levels would be good predictors of those in 1976, there appears no *theoretical* reason to link the variables. So there is no path between them. Having both household heads employed full time makes a negative contribution to consumption in four of the five periods analyzed in the model.

For 1977, there is a negative path from ENROOM6 to BTUPDD77. While the path from ENROOM6 to BTUPDD78 is positive, the coefficient is small. This path from BUTPDD77 through ENROOM7 to BTUPDD78 is virtually balanced by a negative path through BASEMENT insulation--+.024 versus -.025. The paths through WALL and CEILING insulation 1977 are too small to contemplate.

One interesting element about the model consists in the absence of attitudinal measures. Initially, the model included paths from a series of attitude indexes to the insulation reports and CONBEH. These scales measure ecosystem awareness, human responsibility for the energy problem and flexibility of lifestyle, measures that have proved highly related to endorsement of conservation policies (Gladhart et al., 1978). The regressions of specific practice adoption with the attitude measures showed no relationship whatsoever. With R squares of less than .05, there seemed no justification for retaining the variables.

A possible explanation is provided by the Fishbein model (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1977) which suggests that the generality level of attitude and behavior variables should be closely matched. The global energy attitudes employed here may be too far removed from energy conservation actions to have much effect. Cramer et al. (1984) report an example of this effect in which thermal comfort attitudes were related to electricity use, but conservation and environmentalism attitudes were not.

SUMMARY

Families work at conservation year after year. As a group, they get more efficient and effective in conserving. Family characteristics determine consumption, but have little relation to conservation. People who are at work all day use less energy and conserve more, reinforcing the importance of thermostat reduction measures for conservation policy and the importance for research of getting better measures of the actual thermal conditions of homes. The combination of measurements such as electronic instrumentation of energy use along with careful interview and observational data gathering should give researchers a better understanding of the dynamics of family

energy management.

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