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A MODEL OF ENERGY-EFFICIENT HOUSING AND PROPENSITY TO ADJUST

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Abstract

The purpose of this study was to develop and test the structural model of energy-efficient housing and propensity to adjust. The hypothesized structural model was estimated by using LISREL 7 in terms of its latent-variable approach to model testing. The results showed an acceptable fit of the hypothesized model with the data. To better understand the relationships among the variables used in the model, the effects were decomposed into direct and indirect effects. Major hypotheses regarding effects on propensity to adjust were supported. The findings that (a) the absence/presence of energy-efficient features are related to housing dissatisfaction/satisfaction, but not directly to the propensity to make energy-related adjustments and (b) dissatisfaction/satisfaction is directly related to the propensity to make energy-related adjustments, have policy implications. If energy-related adjustments are desired, then policies that create dissatisfaction with inefficient energy features would be instituted.

Introduction

The level of concern with impacting the extent of energy-efficient features within the housing stock tends to ebb and flow depending on energy costs, availability, and other national priorities. However, among researchers there is the acknowledgment that continued effort is needed to more fully understand factors related to the presence/absence of energy-efficient features within the housing stock. The accumulation of knowledge requires a relatively long time span in order to build theoretical models and test hypotheses. Therefore, research endeavors need to be continual rather than sporadic.

The purpose of this study was to develop and test a structural model that would provide insight in understanding energy conservation behaviors among households. The model of housing adjustment (Morris and Winter, 1975, 1978, 1985; Morris et al., 1990) has served as a basis for the study, specifically as it relates to attitude-behavior resulting in energy conserving features in a dwelling. The model of housing adjustment postulates that households are engaged in a dynamic process of evaluating their housing conditions in terms of cultural and family norms. A propensity to engage in adjustment behavior may occur when the household perceives a salient deficit creating dissatisfaction with current conditions. Whether or not desired action can occur is likely impacted by a variety of existing constraints.

Literature Review

Two studies in particular (Eichner and Morris, 1984; Niemeyer and Morris, 1986) have used the model of housing adjustment to gain a better understanding of energy conserving behavior. Both studies analyzed data collected in the winter of 1981-82 by personal interviews from 198 households residing in five cities, ranging from 8,000 to about 35,000 in population located in a midwestern state. Eichner and Morris (1984) adapted the housing adjustment model to investigate the relationship between the existence of energy conserving conditions (i.e., the features that augment the energy-efficiency of the house, such as double-pane, storm windows and doors, weatherstripping and caulking on doors and windows, ceiling insulation, floor and wall insulation, vapor barriers, foundation and band joist area insulation), and constraints that restrict a family's ability to engage in housing adjust-

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ment behavior. They found that the selected constraint variables (age, income, household income, employment status, and home ownership) explained 17% of the variance in the existence of energy-conserving housing conditions with home ownership accounting for most of the variance. Renters were found to have less energy-conserving housing features than owners. Household income also made a significant contribution. The lower the income, the less likely the existence of energy-conserving housing conditions. Age, household size, and employment status were not found to have a significant effect on the energy conditions of the house.

Niemeyer and Morris (1986) used a somewhat different set of constraint variables. They added education, sex of head, and subjective economic constraints and omitted employment status, plus six predisposition variables (i.e., personal factors which seem to have effects on consumer behavior; personal control, responsibility, optimism, flexibility, expectation of tensions, and expectation of solutions were used in their study), and a belief variable. They found that resource constraints (home ownership, age of head, sex of head, and education, but not household size or income) act as barriers to having an energy-efficient dwelling. Those less likely to live in energy-efficient dwellings were renters, younger, female heads, and those with lower educational levels. The predisposition variables were not significant determinants of the energy condition of the dwelling.

Eichner and Morris (1984) and Niemeyer and Morris (1986) also investigated determinants of satisfaction. Eichner and Morris (1984) found that energy-conserving conditions, but not constraint variables, were related to satisfaction with housing. (It should be noted that because of an interest in investigating the impact of air quality, other variables, such as health symptoms, pollution sources, and area of house were included in the model.) On the other hand, Niemeyer and Morris (1986) found that the level of satisfaction with the energy characteristics of the dwelling was significantly affected by the presence of those energy characteristics, along with subjective economic constraints, education, and household size.

In further testing the housing adjustment model, Niemeyer and Morris (1986) found that significant predictors of the propensity to move to save energy were: education of the household head, energy satisfaction, belief in the energy problem, and two predisposition constraints (personal control and expectation of tensions). As far as the propensity for conservation alterations was concerned, they found significant impacts of energy satisfaction, household size, age of the household head, and home ownership.

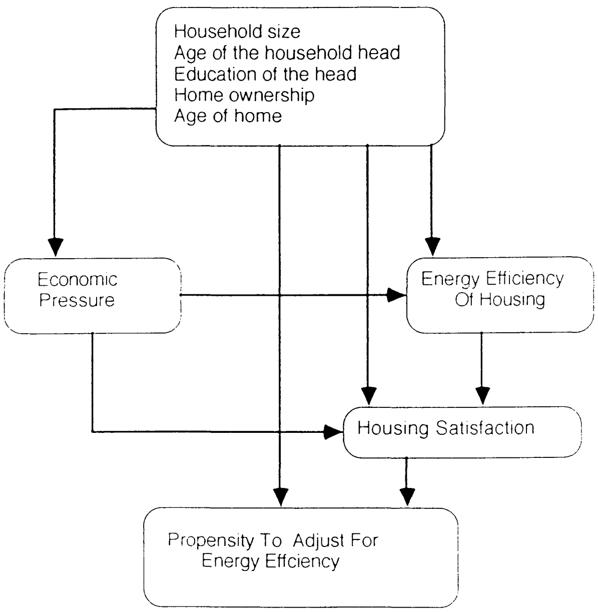
On the other hand, Johnson-Carroll, Brandt, and Olson (1987) analyzed the factors influencing energy conservation alterations in Oregon households, expanding the energy adjustment model by Niemeyer and Morris (1986). In the tested model, propensity for conservation alteration was divided into the propensity for two types of conservation alteration (energy curtailment and energy efficiency), and compared energy efficiency was used instead of energy satisfaction. Also, some variables, such as size of dwelling as an exogenous variable and two types of conservation alteration behaviors as the dependent variables, were added. Using path analysis, they found that age, sex, tenure, dwelling size, and energy conditions had significant direct effects on propensity for energy efficiency alteration.

Even though few studies look at resulting satisfaction and adjustment plans for the future, some findings provide insights on possible constraints impacting on the energy conserving features of housing. They include the following: homeowners are much more likely to implement conservation measures than are renters (Counihan and Nemtzom, 1981; Junk et al., 1984, 1988; Tienda and Aborampah, 1981); those at lower income levels are less likely to invest in conservation measures (Dillman et al., 1983; Junk et al., 1987, 1988; Macey, 1982; Stern, 1984); older homes do not contain as many energy-efficient features as newer homes (Junk et al., 1987, 1988); individuals with higher levels of education are more likely to take conservation measures (Junk, et al., 1984, 1988; Macey, 1982; Yergin, 1980); the older the participant, the lower the participation in conservation (Brandt and Guthrie, 1984; Junk et al., 1984); families with eight or more members are more likely to retrofit their home to make it more energy-efficient (Tienda and Aborampah, 1981).

Theoretical Model

Derived from previous research and inductive reasoning, Figure 1 depicts the structural model of energy-efficient housing and propensity to adjust. There are three categories of variables in the model: exogenous variables, intervening variables, and dependent variables. The five exogenous variables (serving as controls) represent household characteristics. They include household size, age of the household head, education of the household head, home ownership, and age of home. The dependent variable is propensity to adjust for energy efficiency. For the intervening variables, between the exogenous variables and the dependent variable, economic pressure, energy efficiency as housing deficit, and housing satisfaction are considered.

Figure 1. Structural model of energy-efficient housing and propensity to adjust.



Hypotheses

It is hypothesized that propensity to adjust for energy efficiency is directly affected by housing satisfaction when the exogenous variables, economic pressure, and energy efficiency of housing are controlled. Energy efficiency is hypothesized to have an indirect effect on propensity to adjust through housing satisfaction rather than a direct effect. Energy efficiency is projected to have a direct effect on housing satisfaction.

Economic pressure is hypothesized to have an indirect effect on propensity to adjust through energy efficiency of housing and/or housing satisfaction. Economic pressure is projected to have a direct effect on energy efficiency of housing and housing satisfaction respectively.

On the other hand, each of the exogenous variables (as a control) is hypothesized to have a direct effect on economic pressure, energy efficiency, housing satisfaction, and propensity to adjust for energy efficiency respectively.

Procedures

Data

The data used for this study came from the North Central Regional Research Project NC178, "The Economic, Social, Psychological, and Health Consequences of the Housing

Decisions of Rural Families." Within six states (Illinois, Iowa, Minnesota, Missouri, Nebraska, and Wisconsin), a multi-stage random sample was selected from the population of interest (rural) which consisted of all households outside Standard Metropolitan Statistical Areas and outside incorporated cities with populations of 20,000 or more.

Data were collected during the fall of 1985 and the spring of 1986 by the trained interviewers administering a personal interview schedule to the heads of household in the sample. A total of 702 households were originally identified within the 280 area segments. About 16% of the identified households were not eligible for the interviews. Finally, 506 interviews were completed out of the 589 eligible households for a response rate of 85.9 percent.

Measurement of Variables

The description of latent variables and their indicators with factor loadings is presented in Table 1. The latent variables are hypothesized common causes of the nonerror variation in the indicators. Significant ($p < .01$) factor loadings indicate confirmation of this relationship, supporting the construct validity of the latent variables.

Household size is the number of persons currently living in the household. Age of the household head refers to the age in years of the head in the household. Education of the household head is the number of years of formal schooling completed by the household head. Home ownership refers to whether or not the household owns the dwelling in which they live. Age of home refers to the number of years since the dwelling was built.

Economic pressure refers to the emotional, cognitive, and behavioral responses of household members experiencing difficulties in making household resources meet household needs. It reflects both objective economic conditions and household expectations re-

Table 1. Description of latent variables and corresponding loadings of manifest indicators.

Latent variable and manifest indicator	M	SD	Factor[a] loading
Propensity to adjust (PROPADST)			
PLANENGY	1.79	1.26	0.762
PLANHEAT	1.42	1.02	0.599
Housing satisfaction (HOUSAT)			
SOVERALL	5.62	1.18	0.546
SATEFF	5.10	1.48	0.824
SPAY	4.23	1.72	0.348
SUMMER	5.71	1.06	0.501
WINTER	5.62	1.16	0.771
Energy efficiency (ENNEFFCY)			
ENEFFIND[b]	8.26	2.26	0.771
Economic Pressure (ECONPRES)			
THIRATIO	0.32	0.62	0.230
RATING	3.69	1.37	0.788
ADQUACY	2.90	1.05	0.728
Household size (HHSIZE)	2.69	1.41	-
Age of the head (AGEHED)	50.73	18.83	-
Education (EDHED)	11.90	2.93	-
Home ownership (HOMEOWN)	81.2%[c]	-	-
Age of home (AGEHOME)	47.11	34.31	-

[a]Factor loadings were estimated as standardized Lambday's in LISREL, based on pairwise present cases (minimum N=490, maximum N=560). All factor loadings were significant at the .01 level.

[b]Reliability of the scale was .5936, using Cronbach's alpha.

[c]This represents the percent of home owners rather than the mean value.

garding a necessary or desired standard of living. It was measured by (a) housing expenditure/income ratio (THIRATIO), (b) respondent's subjective rating of economic and financial situation (RATING), and (c) respondent's subjective rating of adequacy of household income (ADEQUACY).

Energy efficiency of housing was measured by a summated scale (ENEFFIND) of 15 energy efficiency items, which include storm windows, storm doors, interior window coverings, ceiling/attic insulation, wall insulation, basement/foundation insulation, caulking, glass to south, shade trees, windbreak, awning, attic vent/fan, cross ventilation, ceiling fan, and solar unit. Each of the energy efficiency items was coded 0 for not present and 1 for present. An energy efficiency index was created by adding together the features that were present within the dwelling, and the reliability of the index was tested by using Cronbach's alpha (alpha = .5936).

Housing satisfaction refers to a state of contentment with current housing conditions. It was measured by five indicators: (a) satisfaction with overall housing condition (SOVERALL), (b) satisfaction with energy efficiency (SATEFF), (c) satisfaction with the amount you pay for energy for heating and cooling (SPAY), (d) satisfaction with the comfort inside your home in summer (SUMMER), and (e) satisfaction with the comfort inside your home in winter (WINTER). Each of the five indicators of satisfaction was measured by using a 7-point Likert scale: 1=lowest, 7=highest.

Propensity to adjust for energy efficiency refers to desires, expectations, or plans for future alterations and additions to improve energy efficiency of the dwelling. It was measured by two indicators: (a) plan to add energy efficiency features (PLANENGY), (b) plan to alter heating or cooling system (PLANHEAT). Five responses were possible to each of these indicators: (a) not going to do it, (b) thought about, (c) want to, (d) expect to, (e) have definite plans.

Analytical Procedures

The hypothesized structural model as well as the measurement model used for each latent variable were estimated by using LISREL 7 (Jöreskog & Sörbom, 1989). Also predicated on pairwise-present cases (minimum N=490, maximum N=506), a covariance matrix was created by PRELIS (Jöreskog & Sörbom, 1988) in order to estimate the model fit and parameters in LISREL.

A major strength of LISREL is its latent-variables approach to model testing, whereby multiple indicators of each concept are obtained. Multiple indicators improve construct validity of measurements and reduce measurement errors. Furthermore, LISREL provides the following features for model testing: full information of maximum likelihood estimation, statistical assessments of model fit, and indications for improving the model, and relaxation of classical regression assumptions (i.e., no measurement error, no error term correlations).

Results

The results for the hypothesized structural model showed an acceptable fit with the data (chi-square = 150.60 with df=73, p =.000, GFI =.963, AGFI =.932). Inspection of the structural coefficients (Gamma's and Beta's in LISREL model), however, revealed that some hypothesized effects were negligible and statistically nonsignificant (Table 2).

Decomposition of Effects

To better understand the relationships among the variables used in the model, the effects are decomposed into direct and indirect effects. As indicated in Figure 2, the model has both direct and indirect effects. A direct effect is an unmediated relation between two variables. An indirect effect is a relation between two variables that is mediated by one or more other variables. The sum of these effects is the total effect. Table 3 shows the result of the decomposition of significant effects among the variables.

Three exogenous variables were found to have significant direct effects on economic pressure: age of the head, education of the head, and age of home. Household size, education of the head, and home ownership had significant direct effects on energy efficiency

Table 2. Standardized coefficients for structural model of energy-efficient housing and propensity to adjust (N=490).

VARIABLES	ECONPRES	ENNEFFCY	HOUSAT	PROPADST
HHSIZE	0.83	2.45**	-.217**	.064
AGEHED	-.162*	.108	.062	-.363**
EDHED	-.287**	.155*	-.126*	-.016
HOMEOWN	-.046	.419**	-.054	.324**
AGEHOME	.219**	-.059	-.188**	.172**
ECONPRES		-.109	-.313**	-.147
ENNEFFCY			.447*	.031
HOUSAT				-.361**

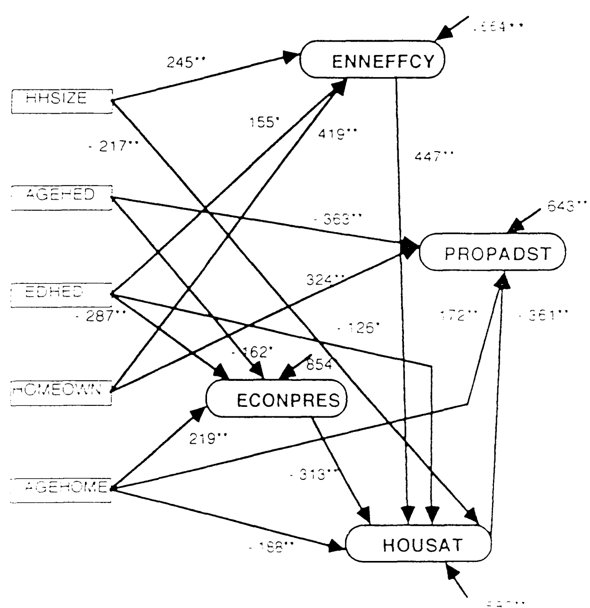
Chi-square	150.60
df	73
P	.000
Goodness of fit index (GFI)	.963
Adjusted GFI	.932

*p<.05; 88p<.01.

of housing. However, there was no significant effect between economic pressure and energy efficiency.

With regard to the effects on housing satisfaction, the hypothesized direct effects of economic pressure and energy efficiency were found. Among exogenous variables, education of the head had the strongest direct effect, followed by household size and age of home. Three exogenous variables (age of the head, home ownership, and age of home) and hous-

Figure 2. Structural model with significant standardized coefficients.



Note: Unattached arrows for each construct are unexplained variances, estimated as standardized Psi's. *p <.05; **p <.01.

ing satisfaction were found to have significant direct effects on propensity to adjust for energy efficiency. Age of the head was the strongest determinant of propensity to adjust, followed by housing satisfaction. As expected, economic pressure and energy efficiency had significant indirect effects through housing satisfaction. No significant direct effects of economic pressure and energy efficiency on propensity to adjust for energy efficiency was found.

Discussion

This study tested a model of energy efficiency housing. Propensity to adjust for energy efficiency was the final interest stage. The unique contribution of this study is the elaboration of the model in terms of the measurement models for theoretical constructs.

The created model was subjected to a LISREL analysis using the maximum likelihood method for estimating the model fit and parameters. The measures of fit indicate that the model fits the data moderately. In order to improve the model fit, some of the constrained parameters were considered to be freed as suggested by the modification indices. However, relaxing those parameters did not seem to make sense from a substantive point of view nor did it greatly improve the model fit.

Major hypotheses regarding effects on propensity to adjust were supported. Age of the head, home ownership, age of home, and housing satisfaction had direct effects, whereas economic pressure and energy efficiency had indirect effects through housing satisfaction. Households with a young head and households living in an owned dwelling tend to have higher levels of propensity to adjust for energy efficiency. Also households with lower housing satisfaction and households living in older structures are likely to have higher levels of

Table 3. Decomposition of standardized effects among the variables.

Explained variables	Explanatory variables	Direct effects	Indirect effects	Total effects
ECONPRES	HHSIZE		-	-
	AGEHED	-.162	-	-.162
	EDHED	-.287	-	-.287
	HOMEOWN	-	-	-
	AGEHOME	.219	-	.219
ENNEFFCY	HHSIZE	.245	-	.245
	AGEHED	-	-	-
	EDHED	.155	-	.155
	HOMEOWN	.419	-	.419
	AGEHOME	-	-	-
	ECONPRES	-	-	-
HOUSAT	HHSIZE	-.217	.110	-.107
	AGEHED	-	.051	.051
	EDHED	.324	.159	.483
	HOMEOWN	-	.187	.187
	AGEHOME	-.188	-.069	-.257
	ECONPRES	-.313	-	-.313
	ENNEFFCY	-.447	-	.447
PROPADST	HHSIZE	-	.038	.038
	AGEHED	-.363	-.018	-.381
	EDHED	-	-.012	-.012
	HOMEOWN	.324	-.068	.256
	AGEHOME	.172	.093	.265
	ECONPRES	-	.113	.113
	ENNEFFCY	-	-.161	-.161
	HOUSAT	-.361	-	-.361

Note: All effects were statistically significant at the .05 level. Dashes indicate nonsignificant effects.

propensity to adjust.

Economic pressure and energy efficiency had direct effects on housing satisfaction. The more severe economic pressure, the lower housing satisfaction. Households with more energy efficiency features are more likely to be satisfied with their housing. The households with a small household size, with a head who is highly educated, and living in a new home, tend to have higher levels of housing satisfaction.

Younger households with a less educated head tend to have more severe economic pressure than older household with a more educated head. The households living in older homes tend to have more severe economic pressure than those living in newer homes.

Larger households with a more educated head are more likely to have energy-efficient housing than are smaller households with a less educated head; homeowners are more likely to have energy-efficient housing than are renters. However, a hypothesized direct effect of economic pressure on energy efficiency was not supported.

The results indicate that the housing adjustment model by Morris and Winter is good at explaining energy-efficient housing and propensity to adjust. Energy-efficient housing serves as a societal norm (Gladhart & Roosa, 1983, Gmelch & Dillman, 1988). The absence or lack of energy efficiency features can be conceptualized as a housing deficit, having an impact on housing satisfaction and, through satisfaction, an impact on adjustment plans for the future.

Nevertheless, the application of the findings is limited because this study was based on a rural sample of the north-central region of the United States. For further research, it is recommended that replications of this study be necessary for generalization of the findings. Replications in other regional or geographic areas and with various types of populations would provide an even more reliable and valid theoretical framework on which to formulate conclusions.

Implications for Public Policy

Whether or not the home has energy-efficient features does not relate directly to the propensity to make energy-related adjustments. People first have to be dissatisfied with the energy-efficient features of their home before they have a propensity to make changes. This finding would suggest that, if society believes it is in its best interest to encourage families to make their homes more energy-efficient, it is important to put in place factors that create dissatisfaction with the current status which may in turn affect intent to adjust. This might be through the use of economic incentives (i.e. rising energy costs) or through the creation of social expectations (i.e. responsible citizens conserve energy) or perhaps through emphasizing physiological effects (an energy-efficient home is a more comfortable home). As suggested in the study of the diffusion of innovative housing (specifically solar and earth-sheltered housing) by Ha and Weber (1991), consumer education through a common communication system might be important for families to make energy-related changes. Through endeavors such as these, an energy-efficient home might become a stronger norm for society with more resulting deficits, and consequently, more energy-related changes.

While this study did not focus on identifying factors that predict the strength of a norm for energy-efficient housing, the finding that economic pressure does not appear to have a direct effect on the presence/absence of energy-efficient features suggests that economic factors (constraints) may not be as important as is often assumed, and that other factors should also be investigated.

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