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Evidence of Rational Market Valuations for Home Energy Efficiency

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Evidence of Rational Market Valuations for Home Energy Efficiency

According to this study, residential real estate markets assign to energy-efficient homes an incremental value that reflects the discounted value of annual fuel savings. The capitalization rate used by homeowners was expected to be 4%–10%, reflecting the range of after-tax mortgage interest rates during the 1990s and resulting in an incremental home value of $10 to around $25 for every $1 reduction in annual fuel bills. Regression analysis of American Housing Survey data confirms this hypothesis for national and metropolitan area samples, attached and detached housing, and detached housing subsamples using a specific fuel type as the main heating fuel.

Investments in high-efficiency heating and air conditioning equipment, insulation, and other energy-efficient home features have historically been justified and promoted based on the investment payback to the homeowner. The payback period is the number of years needed to fully recover energy efficiency investments through reduced fuel costs. More recently, the U.S. Environmental Protection Agency initiated a marketing program called "ENERGY STAR Homes." This effort teaches that energy-efficient homes produce immediate positive cash flow for home buyers because the reduction in monthly fuel bills more than offsets the higher monthly mortgage payment needed to finance such investments. Some home buyers, however, still hesitate to invest in energy efficiency because they are uncertain that they would stay in their homes long enough to recover their investment through lower fuel bills and that they could recover an investment in energy efficiency when they sell their homes. Standard underwriting criteria for home mortgages can also increase the down payment requirements or mortgage insurance

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costs on these homes because energy efficiency investments raise the upfront price of a new home. Underwriting criteria may even prevent home buyers from qualifying for mortgages if the appraised value of the home does not fully reflect the value of energy efficiency investments. Home appraisals may not always reflect the cost of energy efficiency investments because research has never clearly demonstrated or quantified the relationship between energy efficiency and market value.

Underwriting criteria may prevent home buyers from qualifying for mortgages if the appraised value of the home does not fully reflect the value of energy efficiency investments.

ENERGY-EFFICIENT HOMES AND STANDARD MORTGAGE UNDERWRITING CRITERIA

Even if energy-efficient home investments pay for themselves in energy savings, the cost of such investments can adversely affect the qualifying ratios for a home mortgage, including the front-end and back-end income ratios and the loan-to-value ratio. The front-end ratio (or housing-cost-to-income ratio) is monthly housing expenses (principal, interest, taxes, and insurance, or PITI) divided by gross monthly income. The back-end ratio (or total debt-to-income ratio) is total monthly obligations (including auto loans, for example) divided by gross monthly income. The loan-to-value ratio is the amount of the mortgage divided by the lower of the appraised value or price of the home.

Standard underwriting criteria for 30-year, fixed-rate mortgages include a 28% constraint for the front-end ratio and a 36% constraint for the back-end ratio. Neither of these standard criteria account for utility costs as part of monthly housing expenses (PITI) or total monthly obligations. Therefore, the cost of energy-efficient upgrades for a new home can increase the home buyer's monthly PITI or total obligations beyond the qualifying constraints, even when the savings in monthly fuel bills more than offsets the higher mortgage interest. This income ratio anomaly was substantially addressed when the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac) responded to the energy crises of the 1970s by establishing energy-efficient mortgage (EEM) guidelines that allow for a "2% stretch" over normal income ratio criteria for energy-efficient home mortgages.[1] The 2% stretch means that the front-end ratio for an EEM is raised to 30%, and the constraint for the back-end ratio is raised to 38%. For a household earning $60,000 per year, the 2% stretch can accommodate up to about $100 per month for higher mortgage payments related to cost-effective energy efficiency upgrades.

The 2% stretch gives lenders more flexibility with income ratios for energy-efficient homes but does not allow any flexibility with the loan-to-value ratio. Home buyers generally must pay for mortgage insurance to qualify for a 30-year fixed-rate mortgage with a loan-to-value above 80%. They also pay higher rates for mortgage insurance if their loan-to-value exceeds 90%, and often cannot qualify for the mortgage if their loan-to-value exceeds 95%. For a typical $160,000 house, an 80% loan-to-value loan requires 20% down, or $32,000, resulting in a mortgage loan amount of $128,000. If $5,000 of energy-efficient upgrades are included in the purchase of the home, the price increases to $165,000, and a higher down payment is needed to maintain the same loan-to-value ratio. At best, if the appraised value for the home is $165,000, the home buyer must add $1,000 to the down payment to maintain an 80% loan-to-value. At worst, if the appraiser does not recognize any additional value for energy efficiency and estimates the appraised value at $160,000, then the home buyer must add the entire $5,000 to the down payment in order to maintain the 80% loan-to-value.

The Federal Housing Administration (FHA) offers an EEM that allows the incremental cost of energy-efficient, cost-effective upgrades to be added directly to the mortgage, as long as these additional costs do not exceed the greater of $4,000 or 5% of the property's value (not to exceed $8,000). The FHA EEM is designed so that someone who qualifies to buy a home without energy efficiency investments would also qualify for the FHA EEM without any increase in the required down payment. The FHA EEM defines "cost effective" to include energy efficiency investments with a total cost that is less than the present value of the energy saved over the useful life of the investment.

1. William Prindle, "Energy-Efficient Mortgages: Proposal for a Uniform Program," 1990 Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, D.C., August 1990, 7.155.

This EEM, however, is subject to the FHA maximum single-family mortgage limits, which can be as low as $86,317 and go up to $170,362.

Fannie Mae and Freddie Mac are currently engaged in pilot programs that allow the incremental cost of energy-efficient, cost-effective upgrades to be added to the appraised value of a home. Under these programs, the home buyer must provide only the additional down payment associated with the increase in appraised value in order to maintain the same loan-to-value ratio (e.g., an additional $1,000 down with a $5,000 upgrade to maintain an 80% loan-to-value). The Fannie Mae and Freddie Mac EEMs would provide substantial relief from loan-to-value constraints on energy-efficient homes that exceed FHA limits, but these programs are not generally available outside the pilot program areas at this time.

Review of Literature on Market Valuation of Energy-Efficient Homes

Seven studies provide some insight into the relationship between residential housing values and energy costs (see table 1). Six of these studies were published between 1981 and 1986, and the most recent study was published in 1990. The data for these studies were collected over a time period of considerable variation in fuel prices and mortgage interest rates. The first four studies are also not directly comparable because some drew relationships between home value and fuel type, while others linked home value to specific energy efficiency characteristics (e.g., the amount of insulation).

The research results are qualified by sample size limitations, narrow regional or local data sets, and/or the absence of data on key regression variables affecting residential housing values. It is significant, however,

TABLE 1 Published Research on Market Value of Energy-Efficient Homes

Study	Sample Size	Time Period	Key Findings
a	269	1970–1975	The 1974 spike in relative cost of fuel oil raised price differential between gas- and oil-heated houses to $761 in 1974, and up to $4,597 in first half of 1975.
b	100	1978–1979	Value of energy-efficient homes (with lower structural heat loss) was $3,248 higher than inefficient homes.
c	81	1980	Home value increased by $2,510 for each one-point decrease in thermal integrity factor.
d	505	1971–1978	A one-inch increase in wall insulation increased home value by $1.90 per square foot; a one-inch increase in ceiling insulation increased home value by $3.37 per square foot; high-quality (energy-efficient) windows increased home value by $1.63 per square foot.
e	1,317	1978	Home value increased by about $20.73 for every $1 decrease in annual fuel bills.
f	234	1982	Home value increased by $11.63 per $1 decrease in fuel expenditures needed to maintain house at 65° F in average heating season.
g	67	1983-1985	Home value increased by about $12.52 per $1 decrease in electric bills, consistent with home buyers discounting savings at after-tax mortgage interest rate.

a Robert Halvorsen and Henry O. Pollakowski, "The Effects of Fuel Prices on House Prices," *Urban Studies*, v. 18, no. 2 (1981): 205–211.

b John B. Corgel, Paul R. Geobel, and Charles E. Wade, "Measuring Energy Efficiency for Selection and Adjustment of Comparable Sales," *The Appraisal Journal* (January 1982): 71–78.

c Joseph Laquatra, "Housing Market Capitalization of Thermal Integrity," *Energy Economics* (July 1986): 134–138.

d Molly Longstreth, "Impact of Consumers' Personal Characteristics on Hedonic Prices of Energy-Conserving Durable Good Investments," *Energy*, v. 11, no. 9 (1986): 893–905.

e Ruth C. Johnson and David L. Kaserman, "Housing Market Capitalization of Energy-Saving Durable Good Investments," *Economic Inquiry* (July 1983): 374–386.

f Terry M. Dinan and John A. Miranowski, "Estimating the Implicit Price of Energy Efficiency Improvements in the Residential Housing Market: A Hedonic Approach," *Journal of Urban Economics*, v. 25, no. 1 (1989): 52–67.

g Marvin J. Horowitz and Hossein Haeri, "Economic Efficiency v. Energy Efficiency," *Energy Economics* (April 1990): 122–131.

Although home buyers are not likely to make present-value calculations or fuel bills, they will look at average fuel bills and energy efficiency features before buying a home.

that all seven studies report higher home values associated with energy efficiency. Comparable results shown for the last three studies suggest that home value increases by $11–$21 for every dollar reduction in annual fuel expenditures. The last study also suggests consistent criteria that could be used in home appraisals to quantify the increase in market value associated with energy efficiency. Specifically, the higher market value associated with energy efficiency in this study appears to reflect projected fuel savings discounted at the home buyer's after-tax mortgage interest rate.

Rational Market Hypothesis

The hypothesis presented here is that rational home buyers should bid more for energy-efficient homes as long as the incremental cost of the energy-efficient home does not exceed the present value of its expected fuel savings. Further, the discount rate used to determine the present value of expected fuel savings should be the home buyer's after-tax mortgage interest rate.

Throughout the 1990s, the interest rate on 30-year fixed-rate mortgages has ranged from just under 7% to just over 9%. A home buyer paying a 7% mortgage rate and using the mortgage interest deduction in the top marginal income tax bracket will pay an after-tax interest rate of approximately 4%. At the other extreme, home buyers with a 9% mortgage rate could pay a total financing cost of almost 10% if they pay an additional percentage rate for mortgage insurance and cannot benefit from the mortgage interest deduction (because their standard deduction exceeds their itemized deductions). Using the range of 4%–10% for after-tax interest rates, the hypothesis for the regression analysis can be stated as follows:

> *With after-tax interest rates between 4%-10% and stable fuel price expectations, home buyers should pay $10-$25 more for every dollar reduction in annual fuel bills resulting from energy efficiency.*

If home buyers expect stable fuel prices, then paying $10 for every $1 reduction in annual fuel bills is an energy efficiency investment having a 10% return, and paying $25 per $1 reduction in annual fuel bills yields a 4% return. Although home buyers are not likely to make present-value calculations on fuel bills, they are likely to look at average fuel bills before buying a home and obtain information about insulation and other energy efficiency features. Fuel costs may be considered just one of many complex factors affecting the decision to buy a home, but the same can be said about other determinants of home value—from number of bedrooms to the quality of local schools. In a rational, competitive market, the value of energy efficiency, like the value of any other housing characteristic, should reflect its marginal value to home buyers. If home buyers expect stable fuel prices, then the marginal value of energy efficiency in recent years should be $10–$25 for every dollar reduction in annual fuel bills.

Data

The rational market hypothesis was tested for energy-efficient home values using 1991, 1993, and 1995 American Housing Survey (AHS) national data, and for 1992 through 1996 metropolitan statistical area (MSA) data. The AHS is a unique data source for this research in that it includes both house characteristic data (home value, number of rooms, square feet, lot size, and other key housing characteristics) as well as utility expenditure data. These data are reported by homeowners in lengthy interviews with the Census Bureau. Although independent data measurement (e.g., actual sales prices for homes) is preferable to self-reported values, the AHS provides a relatively large sample to ease concerns about random reporting error. Further, the AHS includes Census Bureau weights indicating the universe of owner-occupied housing units represented by each sample unit.

A complete set of national AHS data is collected every two years, while the MSA data are collected on a staggered cycle. The national sample includes data on rural housing not included in the MSA data and non-MSA urbanized areas, but the MSA data provides larger sample sizes within each specified MSA. The MSA data also provides a completely separate set of survey respondents (i.e., there is no overlap with the national sample). The period 1992–1996 reflects a complete cycle of MSA surveys, with a few MSAs surveyed in both 1992 and 1996. The MSA analysis here examines each of these five years of data and a merged MSA sample, including the complete cycle of MSA surveys. In the case of the few MSAs surveyed in both 1992 and 1996, the merged sample includes only the 1996 data.

For each national and MSA sample, the analysis examined subsets of the weighted AHS data on owner-occupied housing in adequate condition reporting electricity, piped gas, or fuel oil as the main heating fuel. The 8% of housing units using wood and other fuel types were excluded from the analysis because they provided incomplete data on fuel expenditures. Rental units were excluded because survey data on property values and fuel expenditures for rental units are probably distorted by reporting errors. Units in "adequate condition" are defined by the Census Bureau as having none of a series of major flaws or some combination of moderate flaws that make the unit substandard in quality. Substandard units were excluded from the analysis. These include houses experiencing electricity and heating equipment failure, which could obviously lower total fuel bills. Even when units were classified as substandard for another reason, their low fuel bills were attributed to uncomfortable internal temperatures.

The AHS data were separated into detached housing and attached housing to account for differences in their valuation models and consumption patterns. The detached housing sample was large enough to permit the analysis of homes in each category of main heating fuel (electricity, piped gas, or fuel oil). This further segmentation was intended to reveal any variation by fuel type.

Model Specification

Table 2 lists the variables in the regression model for single-family detached home values in the national AHS sample. Beside each independent variable description is the expected sign of the coefficient; also, the range anticipated by the hypothesis for the total utility variable is shown.

Established indicators of home value. The model incorporates independent variables for lot size, unit square feet, age of unit, and number of rooms, plus dummy variables to indicate whether the unit has a porch (or deck, balcony, or patio), garage (or carport), and/or central air conditioning. The coefficients for lot size, unit square feet, and number of rooms are all expected to be positive because home buyers are expected to pay more for additional living space. The coefficients for porch, garage, and central air conditioning are also expected to be positive because home buyers are expected to pay more for these amenities. Finally, the coefficient for age is expected to be negative be-

TABLE 2 Variables in Regression Model for Detached Home Values

Variable	Variable Description	Expected Value
House Value	This is the owner's reported value of the house. It is not the purchase price, nor is it the assessment for tax purposes.	Dependent variable
Intercept	Constant/intercept.	
Lot	Lot size in square feet.	+
Age	Age of property in years.	–
UnitSf	Size of unit in square feet.	+
Rooms	Number of rooms.	+
Totutil	Sum of reported household expenditures on fuel oil, gas, and electricity, including the total consumption of these fuels (There is no way to distinguish how much electricity was used for heating and cooling as opposed to lighting and other electricity consumption.).	-10 to -25
Lot2-MM	Lot size square feet squared, in millions.	–
Unitsf2-K	Size of unit square feet squared, in thousands.	–
SFUtil-K	Unit square feet multiplied by total utility, in thousands. This is to account for more space requiring more utility consumption.	+
RMUtil	Number of rooms multiplied by total utility. This is to account for more rooms requiring more utility consumption.	+
Garage	Whether or not a garage or carport was present.	+
Porch	Whether or not a porch or deck was present.	+
AirCond	Whether or not the house had central air conditioning.	+
South	If unit is in the South.	
West	If unit is in the West.	
Midwst	If unit is in the Midwest.	
Urban	If unit is in an urbanized area but not inside the central city.	
Rural	If unit is in a rural area.	

cause home buyers are expected to pay less for older homes.

Second derivative variables. The model incorporates variables for the squared values of lot size and unit square feet. Negative coefficients are anticipated for these variables due to diminishing marginal values for additional space.

Total annual fuel expenditures. The rational market hypothesis anticipates a negative coefficient for total annual fuel expenditures. Further, the expected value for this coefficient is between -10 and -25, indicating that home values decreased by $10–$25 for every dollar increase in annual fuel bills.

Fuel interaction variables. Two independent variables are included in the model to account for the interactions between fuel costs and living space (measured by square feet and number of rooms). The room utility variable was constructed by multiplying the number of rooms in a house by its annual fuel bill, and the square feet utility variable was constructed by multiplying the housing unit's square feet by its annual fuel bill. The inclusion of these variables in the model is intended to isolate the effect of energy efficiency in the coefficient for total annual fuel expenditures. For houses with equal living space, home buyers are expected to pay more for homes with lower fuel bills, but the two interaction variables are included to control for larger homes that have higher utility bills because they have more interior space. The expectation of positive signs for these two fuel interaction variables is that the preference for more space is generally stronger than the preference for lower utility bills.

Location variables. The model incorporates two types of location dummy variables: one set identifies region (the omitted category is the Northeast) and the other set defines urban status (the omitted category is Central City). Both the region and urban status categories are as defined by the Census Bureau.

Attached housing model. The attached housing model is exactly the same as the detached housing model, except that the lot size and lot squared variables are not included in the attached housing model because a substantial majority of the attached housing units in the AHS do not report any values for lot size.

MSA model. The attached and detached housing models for the MSA data are the same as the national AHS model, except that the location variables are dummy variables for each specific MSA.

Regression Results for Relationship Between Fuel Expenditures and Home Values

Table 3 shows the total utility coefficients from each of 15 national AHS regressions examining detached homes, attached homes, and the subsets of detached homes reporting their main heating fuel as electric, piped gas, and fuel oil. The total utility coefficients from the 30 MSA regressions are shown in table 4. Table 5 provides the approximate sample sizes for each type of AHS sample and subsample examined in the analysis, and table 6 shows the approximate R^2 values for the regressions associated with each type of sample and

TABLE 3 Total Utility Coefficients in National AHS Home Value Regressions

	1995	1993	1991
Detached homes	-23.41***	-20.00***	-21.16***
Attached homes	-20.49	-12.34	-18.88
Detached electric homes	-16.42**	-31.43***	-28.55***
Detached piped gas homes	-28.94***	-22.48***	-36.25***
Detached fuel oil homes	-21.92***	-5.05	+6.04

***Significance > 99%; ** significance > 95%.

TABLE 4 Total Utility Coefficients in MSA Home Value Regressions

	1996	1995	1994	1993	1992	1992–1996
Detached homes	-9.92***	-22.44***	-30.89***	-10.40**	-26.38***	-17.68***
Attached homes	-20.69	-15.35	-35.65**	-25.85	16.50	-23.18***
Detached electric homes	-36.73***	-12.53*	-33.66***	-13.11	-20.64**	-28.60***
Detached piped gas homes	-6.79*	-26.65***	-27.65***	-24.43***	-33.97***	-20.29***
Detached fuel oil homes	-10.07	-30.44**	-20.07	12.31	6.61	-2.64

*** Significance > 99%, ** significance > 95%, * significance > 90%.

TABLE 5 Approximate Sample Sizes for AHS Regressions

	National	MSA	Merged MSA
Detached homes	16,000	10,000	46,000
Attached homes	800	600	3,000
Detached electric homes	3,600	2,000	9,000
Detached piped gas homes	10,000	7,000	32,000
Detached fuel oil homes	2,400	1,000	5,000

TABLE 6 Approximate R^2 Values for AHS Regressions

	National	MSA	Merged MSA
Detached homes	0.41	0.55	0.59
Attached homes	0.28	0.47	0.53
Detached electric homes	0.38	0.55	0.58
Detached piped gas homes	0.43	0.57	0.61
Detached fuel oil homes	0.40	0.48	0.50

subsample (exact sample sizes and R^2 values vary by year). Detailed regression results for the national AHS data and the MSA regressions are available from the authors.

Discussion of Results

Forty-five regressions were conducted. All F values exceed the 99% level of significance. In the larger sample size regressions, almost all of the coefficients have the expected signs, and most are significantly different from zero at the 99% level. The limitations of the AHS data are reflected in R^2 values for the national sample regressions of about 0.40. This is not surprising because the AHS does not provide data that quantifies neighborhood crime rates or public school rankings, which certainly affect home price variations across different neighborhoods. Also, the variable in the national sample regression for urban status (urban, rural, or central city) provides only a discrete indicator variable to reflect the extent to which real estate values tend to increase in a continuous fashion for housing units closer to the city center. The region variable is also a discrete indicator variable that does not capture the extent of home value variation associated with different metropolitan areas within a region. Despite these limitations on the model's specification, the relatively large sample size from the AHS results in estimated values and the standard errors for the fuel expenditure coefficients that provide strong support for the rational market hypothesis.

The results for the MSA regressions confirm the findings from the national sample regressions. The R^2 values for the MSA regressions are also higher than the R^2 values for the national sample, with an R^2 value as high as 0.61 for the merged MSA regression for detached homes with piped gas. The higher R^2 values for the MSA regressions suggest that the dummy variables for each MSA capture more of the "location" value in residential real estate than the combination of region and urban status variables in the national sample. The remaining unexplained variance in the MSA regressions almost certainly reflects the importance of other more complex location variables (local schools, crime, and length of work commute) that are known to affect home values but are not detailed in the AHS data.

Beyond showing that the total utility coefficient is significantly different from zero, the MSA and national AHS regressions are remarkably consistent with respect to the specific value assigned to the total utility coefficient. For both the MSA and national samples, the total utility coefficients for attached and detached homes are very similar, with an average value of about -20, indicating that home buyers during this period discounted their future fuel savings at after-tax mortgage interest rates of about 5%. The smaller samples show more variation, but about half of the 45 regressions have total utility coefficients within one standard error of -20, consistent with random error around a normal distribution mean of –20. These findings provide strong evidence that the market value of energy-efficient homes reflects projected fuel savings discounted at the average home buyer's after-tax mortgage interest rate.

Detached Home National Samples

All three of the larger national samples for detached homes show total utility coeffi-

Home buyers in the 1990s have recognized market value for energy efficiency based on annual fuel savings discounted at 5% after-tax mortgage interest rate.

cients between -20 and -24, at the upper end of the range of –10 to -25 anticipated by the rational market hypothesis. Further, standard errors for these fuel expenditure coefficients are between 3.0 and 3.4, indicating a high probability that the true value of this coefficient is not only greater than zero but specifically in the upper end of the range anticipated by the hypothesis. The smaller single-year MSA samples for detached homes show more variation, but all five of these samples show total utility coefficients within or just outside of the anticipated range of -10 to -25, with a coefficient of -18 for the larger merged MSA sample.

Attached Home National Samples

The statistical significance of the results for the attached home national samples and single-year MSA samples are limited by small sample sizes, but the values for their total fuel expenditure coefficients are completely consistent with the detached housing analysis. The value of this coefficient in the larger merged MSA sample is -23, with a standard error of 8.3. This consistency in the fuel expenditure coefficients for attached and detached housing contrasts with two significant differences between these two housing types. First, the attached housing model has no independent variable for lot size. Second, the coefficients for the unit square feet variables indicate that the incremental market value associated with more living space is higher for attached homes than for detached homes, consistent with the fact that attached housing is disproportionately located closer to central cities where real estate values are higher.

In spite of the significant differences between attached and detached housing markets, the rational market hypothesis anticipates little or no difference in the fuel expenditure coefficient because the discounted value associated with every dollar reduction in annual utility bills should not be affected by other housing characteristics. Therefore, the consistency of the fuel expenditure coefficients in the attached and detached housing regressions is entirely supportive of the hypothesis.

Electric-Heat Detached Home National Samples

Regression analyses for the subset of detached housing units that identify electricity as their main heating fuel show national sample coefficients for the fuel expenditure variable that range from -16 to -31, with standard errors between 6.4 and 7.4. The smaller single-year MSA samples result in more variation in the total fuel expenditure coefficients for these samples, but these values are all roughly consistent with the hypothesis. The value of this coefficient in the larger merged MSA sample is –28.6, with a standard error of 3.9. Almost all of the national and MSA regressions show total fuel expenditure coefficients for electric homes within one standard error of the upper end of the -10 to -25 range anticipated by the rational market hypothesis, consistent with the results for all detached housing analysis. These consistent results for the electric home subsamples suggests that the market value associated with lower fuel expenditures does not simply reflect a premium paid for homes with a fuel type that may be more economical than other heating fuels in certain regions.

Gas Heat Detached Home Samples

The regression analyses for homes that identify piped gas as their main heating fuel reinforce the conclusions suggested by the analysis of electric homes. In the national sample regressions, the fuel expenditure coefficients range from -22 to -36, with standard errors between 4.0 and 4.6. The 1991 coefficient is the only estimate that is more than one standard error above the range anticipated by the rational market hypothesis, possibly reflecting the preference for gas heat over fuel oil following the spike in fuel oil prices in 1990. A similar pattern appears in the single-year MSA regressions. The larger merged MSA sample shows a fuel expenditure coefficient of -20, with a standard error of just 2.5, consistent with the results for all detached housing. These results indicate that the incremental home value of $20 per dollar reduction in annual fuel expenditures is evident both within and across subsets of housing using different fuel types as their main heating fuel.

Fuel Oil Heat Detached Home National Samples

The regression results for detached homes with fuel oil heat reflect the relatively small size of this subsample and appear to be distorted by extreme fluctuations in fuel oil prices in the early 1990s. Detailed results for this subsample show that some coefficients are not significantly different from zero and/or do not have the expected signs, especially in the regression analysis for the 1991 data. The 1995 coefficient for the fuel expenditure variable is -21, consistent with results for other fuel types, but the 1993 coefficient is -5, and the 1991 coefficient is +6. Also, the coefficient for unit square feet in the 1991 fuel oil regression is negative. Similar patterns are reflected in the MSA regressions, with positive values for the fuel expenditure coefficients in 1992 and 1993.

The anomalous results in the fuel oil regressions for the early 1990s almost certainly reflect the extreme spike in fuel oil prices following the invasion of Kuwait in the summer of 1990. AHS respondents in the 1991 survey were reporting annual fuel bills that reflected extraordinarily high fuel oil prices during the 1990–1991 winter. Further, the national AHS sample of detached homes reporting fuel oil as their main heating fuel declined by almost 30% between the 1991 and 1995 surveys, while the sample size for all detached homes declined by only 2% between these two samples. This finding suggests that a large percentage of homes with fuel oil heat were converted to gas or electric heat in the years following the 1990 spike in fuel oil prices. Homeowners with the most financial incentive for converting from fuel oil and those most likely to have the financial means to convert would tend to be upper-income households disproportionately concentrated in larger homes with higher property values. Because the 1991 survey was actually conducted from July 1991 through December 1991, a substantial number of households may have reported higher home values in 1991 based on fuel conversions that were already planned or underway. These same households, however, may have reported their main heating fuel and annual fuel expenditures based on the spike in fuel oil prices from the previous winter. These factors could have substantially distorted the regression results for this subsample in the early 1990s.

CONCLUSION

The 45 regressions collectively indicate a clear convergence for the value of home energy efficiency. Almost half of the fuel expenditure coefficients are within one standard error of –20. This suggests that home buyers in the 1990s have recognized market value for energy efficiency based on annual fuel savings discounted at a 5% after-tax mortgage interest rate. The major exception to these findings were the regressions for homes heated by fuel oil in the early 1990s. These outliers appear to reflect the sharp increase in fuel oil prices in 1990 and conversions to gas heat in subsequent years.

The convergence of the fuel expenditure coefficients around -20 is consistent with research findings that the selling price of homes increased by $20.73 for every $1 decrease in annual fuel bills.[2] Other research supports the underlying conclusion that energy efficiency increases home value by an amount that reflects annual fuel savings discounted at the prevailing after-tax mortgage interest rate.[3]

The implication for home buyers is that they can profit by investing in energy-efficient homes even if they do not know how long they might stay in their homes. If their reduction in monthly fuel bills exceeds the after-tax mortgage interest paid to finance energy efficiency investments, then they will enjoy positive cash flow for as long as they live in their homes and can also expect to recover their investment in energy efficiency when they sell their homes.

The implication for appraisers is that cost-effective energy efficiency investments *do* appear to be reflected in residential housing market values. Therefore, the appraised value of energy-efficient homes could understate their actual resale value if the comparables used in the appraisal do not reflect the value of a cost-effective energy efficiency investment.

2. Ruth C. Johnson and David L. Kaserman, "Housing Market Capitalization of Energy-Saving Durable Good Investments," *Economic Inquiry* (July 1983): 374–386.
3. Marvin J. Horowitz and Hossein Haeri, "Economic Efficiency v. Energy Efficiency," *Energy Economics* (April 1990): 122–131.