Are Home Buyers Myopic? Evidence From Housing Sales

Erica Myers*

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Abstract

This paper explores whether home buyers are myopic about future energy costs. I exploit variation in energy costs in the form of fuel price changes in Massachusetts where there is significant overlap in the geographic and age distributions of oil-heated homes and gas-heated homes. I find that relative fuel price shifts cause relative changes in housing transaction prices that are consistent with full capitalization of the present value of future energy cost differences under relatively low discount rates. These findings are consistent with home buyers being attentive to energy costs and are not consistent with myopia.

Keywords: Myopia, Efficiency Gap, Undervaluation, Housing Prices
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*Assistant Professor, Department of Agricultural and Consumer Economics, University of Illinois. Email: ecmyers@illinois.edu. I am grateful to Severin Borenstein, Maximilian Auffhammer, Meredith Fowlie, and Catherine Wolfram for their invaluable advice, and to Judson Boomhower, Benjamin Crost, Lucas Davis, Walter Graf, Koichiro Ito, and seminar participants at the University of Illinois for helpful comments. Data support from the CoreLogic Academic Research Council (CLARC) Grant is gratefully acknowledged. I am also thankful for financial support from the Joseph L. Fisher Doctoral Dissertation Fellowship by Resources for the Future and from the Fisher Center for Real Estate & Urban Economics PhD Fellowship.

1 Introduction

Consumers are often more responsive to changes in purchase price than to less salient product costs such as shipping and handling expenses (Hossain and Morgan, 2006), sales tax (Chetty et al., 2009), and operating costs of appliances (e.g., Hausman, 1979). This type of consumer inattention has important implications for policy measures such as taxation, since in order to affect behavior, policies need to target costs to which people pay attention. In recent years, governments around the world have become interested in designing successful policy instruments for reducing greenhouse gas emissions. Whether price based instruments such as taxes or cap-and-trade programs will be effective crucially depends on whether consumers are responsive to fuel prices in markets for energy-using durables.

This paper asks whether consumers are responsive to heating fuel prices in the housing market. An increasing proportion of U.S. carbon dioxide emissions, around 40%, come from the residential and commercial buildings sector.[1] As end uses, space heating and cooling contribute almost as much to U.S. greenhouse gas emissions annually (13%) as personal vehicles (15%).[2]

The EPAs proposed Clean Power Plan (CPP), the first national program aimed at reducing U.S. greenhouse gas emissions, is designed to reduce carbon by changing relative energy prices. Many states will likely comply with the CPP by pricing carbon through cap-and-trade programs. How effective the CPP will be at achieving the first-best policy outcome will depend crucially on how responsive consumers are to changes in energy price, since a significant share of the emissions reductions from the CPP are projected to be met by low-cost efficiency investments (ICF, 2014). If people lack information about changes in energy prices or are myopic about the resulting changes in the operating costs of energy using durables, carbon pricing may not induce them to undertake these investments. In this

[1] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2011 Buildings Energy Data Book (2012) pp. 1-1.

[2] EPA: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012 and EIA: Residential Energy Consumption Survey 2009, Commercial Buildings Energy Consumption Survey 2003.

case, other more traditional policy instruments, such as information campaigns, efficiency standards for appliances, or building codes, may be more effective at improving market efficiency.

It can be challenging to estimate whether home buyers are attentive to energy costs. Previous attempts have used hedonic approaches to see if utility bills (Johnson and Kaserman, 1983), measures of efficiency (Dinan and Miranowski, 1989), or efficiency letter grades (Brounen and Kok, 2011) are capitalized into housing sales. In general, these studies find that more efficient homes with lower fuel costs receive premiums in the housing market, which are consistent with relatively low implied discount rates. One limitation of this approach is that home efficiency is not randomly assigned, so that more efficient homes may be more likely to have renovations or other improvements that are unobservable to the researcher. Therefore, the observed premium for efficient units may be due to unobserved differences in homes rather than the causal effect energy cost savings.

This study is the first to estimate the effect of plausibly exogenous variation in energy costs on housing prices. I use changes in the relative fuel prices of heating oil and natural over time as a source of variation in energy costs.[3] For this study, I focus on the state of Massachusetts, where there is significant overlap in the geographic and age distributions of oil-heated homes and gas-heated homes. I compare the transaction price of oil-heated versus gas-heated homes for the period 1990-2011, during which there is significant variation in the relative fuel prices. With two dominant heating fuels I am able to control for unobserved variation in the macroeconomic environment with year fixed effects. In addition, I observe multiple sales of homes, which allows me to control for time-invariant characteristics of a home with unit fixed effects. As the relative fuel price of a home increases, it should sell at a discount compared to homes with less expensive fuel. If home buyers are not myopic about future fuel costs, this discount should reflect the net present value of the difference in

[3]Natural gas is used to heat homes in most parts of the United States where substantial heating is required. However, in the northeastern United States 30-40% of households still heat with heating oil. See American Housing Survey National Summary Table 2-5: Fuels-Occupied Units, years 2005, 2007, and 2009.

consumer surplus.

I find little evidence that home buyers are systematically "under-valuing" future fuel costs. Increases in relative fuel prices cause decreases in relative transaction prices in ways that are consistent with full capitalization of the present value of consumer surplus differences under a 9-10% discount rate.[4] It appears that home buyers are paying attention not only to whether a home heats with oil or gas, but how the prices are moving relative to one another and further, how fuel price movements change the net present value of the future stream of payments.

These findings are relevant to the literature on consumer myopia in energy using durables, where evidence in other contexts has been mixed. Consistent with my findings, recent work in car markets suggests that consumers are relatively attentive to future fuel costs. Estimates of implied discount rates for automobile purchases range between 10% and 15% (Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2015). There is, however, reason to believe that consumers might be less myopic about gasoline purchases as opposed to residential fuels. Gasoline is one of the most salient products that consumers buy. Obtaining information about gasoline prices is relatively costless, since they are prominently posted at gas stations, and many people purchase gas one or more times in a week. In addition, people tend to know how much it would cost to drive from one place to another in car. Residential fuel costs may not be as well understood or salient for consumers. Households only receive bills on a monthly basis, making it harder to translate consumption of particular energy services into costs.

Consistent with the possible role of salience, evidence on consumer myopia has been more varied in the context of appliances, for which energy costs are less salient. For example, early work using a discrete choice framework that found that consumers substantially discount future energy costs (e.g., Hausman, 1979; Dubin and McFadden, 1984). Similarly, more recently, Allcott and Sweeney (2015) found that consumers are myopic about future

[4] As I describe in more detail in the conceptual framework, I assume that consumers use a no-change forecast for future energy prices and I use an infinite time horizon for net present value estimates.

energy costs in the context of water heaters. Rapson (2014), on the other hand, developed a structural model of air-conditioner demand and found that consumers value the stream of future savings from high efficiency units. Houde (2014) found that consumers are highly heterogeneous in how they value future energy prices in the context of refrigerators.

The finding that home buyers are paying attention to fuel prices and how those price movements translate into a stream of future cost differences suggests that fuel costs are well-understood and salient at the point of sale. One possible reason home buyers are well-informed is that it is relatively low cost to obtain the information by requesting previous utility bills. This has important implications for carbon policy since an increasing proportion of U.S. carbon dioxide emissions come from the residential and commercial buildings sector. Because home buyers appear to be informed about and paying attention to fuel prices, pollution pricing will create incentives to reduce the amount of energy people choose to consume, to convert to cleaner heating fuels, and possibly to increase the efficiency of building shells and appliances.

This paper proceeds as follows. Section 2 describes the data, Section 3 lays out the conceptual framework for estimating implied discount rates, Section 4 details the empirical approach and results for the capitalization of energy costs into housing transaction prices, and Section 5 concludes.

2 Data

The real estate data firm, CoreLogic, provided the housing transaction and unit characteristic data with over 1,000,000 transactions in the state of Massachusetts between 1990 and 2011. The unit characteristic data contain information on the number of bedrooms, bathrooms, stories, square feet, year built, exterior wall type, heating fuel, and heating system type. The unit characteristic data and the transaction data were compiled by CoreLogic from different sources. As a result, the unit characteristic data provide one snapshot of a home and do not necessarily reflect the attributes at the point of sale. I carefully address this potential for measurement error in the empirical analysis.

In addition, housing units were designated to 491 geographic units in order to protect the proprietary nature of the data. Each geographic unit is made up of 3-41 census block groups, with a mean size of 10 census block groups. The criteria used to group census block groups into geographic areas were (1) to allow no fewer than 10 sales within a geographic area in a year and (2) not to let the geographic areas cross natural gas utility or county boundaries. The larger geographic areas are less densely populated with fewer transactions.

I drop observations if a unit is sold more than once in a year, or more than 4 times over the 21 year sample period, indicating special circumstances such as foreclosure (about 13% of observations). In property records, the "effective age" of a building is adjusted for significant renovations or neglect. Over 99% of adjustments to property age in the sample were for improvements, so that the "effective year built" is later than the actual year built. I drop another 8% of the remaining sample for these types of large renovations or improvements. I use the middle 99% of the distribution of non-zero housing transactions, dropping the top and bottom 1/2% most extreme values. The remaining data used have 909,434 transactions with 604,807 housing units sold between 1 and 4 times. About 50% of the sample heats with oil and 50% heats with gas. Over half of the sample (60%) were sold only once during the sample period.

Massachusetts was chosen for this study because there is good geographic overlap between oil and gas houses. Figure 1 shows the proportion of oil homes by the geographic units described above. The white areas are Berkshire and Plymouth counties for which no transaction data were available. The darker areas represent geographies where a higher proportion of homes heat with gas. Very few of the geographies have less than 10% of homes heating with oil. This means that even where utility natural gas is available, there are still many houses that heat with oil. In western Massachusetts more homes are heated with oil because there is less population density, and in some areas, there is no utility gas available.

Figure 2 displays which towns had utility natural gas service as of 2008.

Table 1 displays the results of t-tests comparing the means of the characteristics of oil and gas homes. Gas homes differ from oil homes in predictable ways. On average, gas homes are slightly younger, larger, and more expensive than oil homes. In addition, gas heating systems are most likely to use forced air, while oil heating systems are most likely to use forced hot water. Figure 3 displays the distribution of the numbers of bedrooms, bathrooms, square feet, and year built for oil vs. gas units. Importantly, there is good overlap in the covariates between the two heating types, so there are good counterfactual comparisons in terms of characteristics as well as geographies.

The natural gas price data are state-level average annual residential retail prices calculated as the consumption weighted average of state-level monthly prices reported by the EIA. The heating oil price data are the average annual New England (PADD 1A) number 2 heating oil residential retail prices calculated as the consumption weighted average of monthly prices reported by EIA. I inflated all prices to 2012 dollars using the consumer price index. Both natural gas and heating oil prices were converted into \$/MMBTU in order to make them comparable. Figure 4 displays the price variation in residential natural gas and heating oil prices from 1990 to 2012. In the mid-1990s, heating oil was less expensive than natural gas. But, starting in the mid-2000s, the price of heating oil began to rise, driven by world oil demand. The price of natural gas was rising in the early 2000s, until the use of hydraulic fracturing techniques began to drive prices down after 2006. Figure 5 shows the price difference (price of oil-price of gas) between the two fuels over the time period. Importantly, the price difference follows a “U” shape rather than a simple linear trend allowing me to identify the effects of fuel price variation rather than other trending variables on housing prices.

3 Conceptual Framework

The purpose of the empirical exercise is to investigate whether home buyers are myopic about energy costs. All else equal, lower fuel prices increase consumer welfare. When it costs less to heat, households save money, which they can spend on other things including more energy services. Under the hedonic framework, the difference in equilibrium housing prices caused by relative shift in fuel prices reflects buyers' willingness to pay for the net present value of the difference in consumer surplus caused by the relative fuel price change (Rosen, 1974). In the following section, I will calculate home buyers implied discount rate for energy costs based on the estimated willingness to pay for a change in fuel price. This requires me to make assumptions about consumers' beliefs about future fuel prices and the lifespan of the house as well as an estimate of how fuel price changes affect consumer surplus.

3.1 Beliefs About Future Fuel Prices

For this analysis, I will assume that consumers believe that fuel prices follow a no-change forecast, so that contemporaneous fuel prices are the best predictor of future fuel prices. A recent study by Anderson et al. (2013) finds that consumers believe that gasoline prices follow this type of pattern. A no-change forecast is a reasonable belief for home buyers, particularly in the case of heating oil, since a no-change forecast predicts future crude oil prices as well or better than forecasts derived from futures markets or surveyed experts (Alquist and Kilian, 2010; Alquist et al., 2012).

Another possibility is that consumers are more sophisticated, using information from crude oil and natural gas futures markets to make projections about fuel prices going forward. Figure 6 shows the spot and forward curves for crude oil (panel A) and natural gas (panel B). The natural gas forward curves reflect seasonality in prices, whereas the crude oil forward curves are much smoother. Figure 6 Panel C shows the difference in the spot and forward prices between the two fuels (price of oil - price of gas).

There are two things to note about the relationship between the spot and future curves of these two fuels. First, the forward curves do not deviate substantially from spot prices. Therefore, even if home buyers were more sophisticated and paying attention to trends in futures prices, their beliefs about fuel prices going forward would not differ significantly from no-change beliefs. Second, the price difference between oil and natural gas is in backwardation in a significant part of the sample, particularly when oil is most expensive compared to natural gas. In periods of backwardation, the assumption that consumers believe prices follow a no-change forecast when in fact consumers are truly sophisticated and paying attention to futures markets, would bias me toward finding myopia.

3.2 Time Horizon

In order to calculating the implied discount rate from the estimated willingness to pay for change in fuel price, I need to make an assumption about the time horizon for discounted flow of consumer surplus from energy consumption. Houses are long lived assets with some houses in the sample being over 300 years old. Because the assets are so long lived, I assume an infinite time horizon. If consumers were truly considering a shorter time horizon, assuming an infinite time horizon would lead to higher estimates of implied discount rates and again bias me toward finding myopia.

3.3 Effect of Fuel Price Movements on Consumer Surplus from Energy Consumption

Further, in order to estimate the extent of consumer myopia, I need an estimate of the annualized loss in consumer surplus caused by changes in fuel price. Figure 7 depicts the loss in consumer surplus from a price increase. There are two components of the change in consumer surplus. First, when price goes up the fuel consumed costs more and second, home owners will consume less fuel and experience a loss of energy services. Assuming a locally linear demand curve for heating fuel, the loss in consumer surplus from a \$1 fuel price increase from P^0 to P^1 would be the sum of these two components, $Q^1 + \frac{1}{2}(Q^0 - Q^1)$.

Estimates of demand elasticity for heating fuel such as natural gas tend to be fairly inelastic, suggesting that when there is a price change, changes in the level of fuel consumption are likely a small component of the overall change in consumer surplus (e.g., Bernstein and Griffin, 2006). Nonetheless, for the purposes of this study, I will estimate the change in quantity of fuel demanded from a \$1 increase in fuel price using data from the repeated cross-sectional Residential Energy Consumption Survey (RECS), 1990-2009. I limit the sample to single family homes in the northeast census division, which primarily heat with oil or gas, and whose energy usage and expenditure information were verified with the local utility.[5] With this sample, I estimate the following model:

$$\mathrm{Q}_{it} = \beta_1 + \beta_2 \mathrm{P}_{it} + \beta_3 \mathrm{I}_{it}^{\mathrm{oil}} + \mathbf{X}_{it}'\beta + \alpha_t + \epsilon_{it} \tag{1}$$

The fuel price, P_{it}, for housing unit i in period t, is the average price the consumer faces, calculated by dividing the households' measured annual expenditure by its measured annual usage. There is strong evidence that customers respond more to changes in this type of average price rather than marginal price when faced with non-linear energy prices (Ito, 2014). Whether a unit heats with oil as opposed to gas is indicated by $\mathrm{I}_{it}^{\mathrm{oil}}$. The vector of covariates, $\mathbf{X}_{it}$, includes flexible controls indicating decade built, number of stories, number of bedrooms, number of bathrooms, and square footage binned for every 500 square feet. Year fixed effects, α_t are included to control for trends in energy usage common to both oil and gas homes over time, and ϵ_{it} is the error term.

The coefficient of interest, β_2, is an estimate of the effect of a \$1 increase in relative fuel price on the quantity of energy consumed in MMBTU, Q_{it}. Table 2 shows result of this estimation in column 1. The point estimate indicates a reduction of 1.8 MMBTU/year

[5] The northeast census division is comprised of 5 states: Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.

for a \$1 increase in fuel price. Single family homes in the northeast that heat with oil or gas use 94 MMBTU/year on average, so a \$1/MMBTU increase in fuel price results in a 2% reduction in fuel use.[6] While this linear estimation of the effect of a \$1 increase in fuel price on energy use is most useful for this analysis, it is typical to report the effect of price increases on demand in terms of elasticity. As a point of comparison, column 2 shows the result of estimating the log-log form of equation 1. The point estimate is $-.15$ with a 95% confidence interval of $-.33$ to $-.03$. This short-run elasticity estimate for heating oil and natural gas consumption is close in magnitude to empirical estimates of short-run elasticities for electricity, which range from $-.1$ to $-.5$ (e.g., Reiss and White, 2008; Ito, 2014; Jessoe and Rapson, 2014).

With an average annual fuel consumption of 94 MMBTU, the lost consumer surplus from a \$1/MMBTU fuel price increase can be approximated as $\$94 + \frac{1}{2}(\$1.8) \approx \$95$/year. Table 3 displays the net present value of the \$95 surplus difference over an infinite time horizon at various discount rates. The difference in the NPV of consumer surplus caused by a \$1 increase in fuel price ranges from around \$570 at a 20% discount rate to over \$9,595 at a 1% discount rate.

3.4 Cost of Conversion from Oil to Natural Gas

If the price of oil gets high enough compared to natural gas, it could be the case that the net present value of the consumer surplus difference between heating with oil and heating with natural gas exceeds the typical cost of conversion. In that case, economic theory would predict that the housing transaction price differential would not exceed the cost of conversion.

The cost of converting from oil to gas can vary widely from a few thousand dollars to over \$10,000 (Notte, 2012). The cost of conversion depends on several factors including the system you choose to install, whether or not you have an underground oil tank that needs to be removed, and the cost of connecting to the main supply line. Conversion can be much

[6] Residential Energy Consumption Survey: Table CE2.2 "Household Site Fuel Consumption in the Northeast Region, Totals and Averages, 2009"

more costly in areas that do not have access to the main supply line for natural gas. In many cases, utilities will extend the supply line only if residents are willing to pay for it.

If the conversion cost ceiling were a large biasing factor in this analysis, the cost of conversion would act as a limit on the level of pass-through of the surplus differential, particularly in later years when the fuel price difference is large. This would attenuate my estimates toward zero, thus biasing me toward finding consumer myopia. However, as I will show in the results section, the housing transaction price differential curve does not appear to flatten out relative to the fuel price difference in these later years. This suggests that the conversion cost ceiling is likely not a important biasing factor.

4 Empirical Strategy and Results

4.1 Basic Specification

In this section, I estimate the short-run equilibrium effects of relative fuel price shifts on relative transaction price and calculate the implied discount rates from the estimates. As the relative fuel price of a home increases, it should sell at a discount compared to homes with less expensive fuel, reflecting the net present value of the difference in consumer surplus.

My preferred specification for the estimating equation is as follows:

$$\mathrm{H}_{igt} = \beta_1 + \beta_2 \mathrm{P}_{it} + \gamma_{gt} + \delta_i + \epsilon_{it} \tag{2}$$

where H_{igt} is the transaction price for house i in geographic area g in year t. The fuel price, P_{it}, is the annual residential retail fuel price for Massachusetts and varies whether unit i is oil or gas. House fixed effects are indicated by δ_i, geographic area by time fixed effects are indicated by γ_{gt} and ϵ_{it} is the idiosyncratic error term.

The coefficient of interest, β_2 is the estimate of the effect of a \$1/MMBTU heating fuel price increase on the housing transaction price. Since there is no cross-sectional variation in price, year fixed effects are collinear with one fuel price, so that the identifying variation is the difference in price between oil and gas. The identifying assumption is that oil units do not systematically differ from gas units in unobservable or inadequately controlled for ways that are correlated with the difference between the price of oil and the price of gas.

Table 4 displays the results from the estimation of the preferred specification (column 5) as well as several models with less flexible controls (columns 1-4). The first two columns show estimates for a model that includes year fixed effects with and without housing attribute controls. Housing attribute controls include flexible controls for decade built, number of stories, number of bedrooms, number of bathrooms, exterior wall type, heating system type, and square footage binned for every 500 square feet for unit i. I_i^{oil} indicates whether unit i heats with oil. The estimates in columns 3-4 come from models with geographic area by year fixed effects and housing unit FE respectively. The estimates in column 5 for the preferred specification include both geographic area by year and housing unit fixed FE. The results indicate that when the relative cost of heating goes up by \$1/MMBTU, it leads to a \$1000-\$1200 discount in relative housing transaction price. The last two rows of the table show the implied discount rate for the point estimate and 95% confidence interval of the point estimate, assuming a drop in consumer surplus of \$95 per \$1/MMBTU increase in fuel price over an infinite time horizon.

The results imply that home buyers use a 9-10% discount rate, which suggests that they are not strongly myopic regarding future heating fuel costs when purchasing houses. These results are consistent with recent work on automobile purchases that also find no evidence of strong myopia. Recent estimates of implied discount rates for automobile purchases range between 10% and 15% (Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2015).

Figure 8 displays the relationship between the housing transaction price difference for oil versus gas homes and the the net present value of the consumer surplus from heating with gas as opposed to oil. The left side of Figure 8 plots this relationship over the sample period. I estimate the NPV of the difference in consumer surplus between heating with oil and gas over an infinite horizon using the estimate of a loss of $95 in consumer surplus per $1 difference in relative fuel price and a 10% discount rate from the preferred estimation in Table 4. In addition, I depict the housing transaction price difference between gas and oil homes from the preferred specification with geographic area by year fixed effects and unit fixed effects by plotting coefficients on the year-specific gas intercepts ($\beta_1 - \beta_{22}$) from the following regression.

$$\mathrm{H}_{igt} = \sum_{t=1}^{22} \beta_t \mathrm{I}_i^{\mathrm{gas}} + \gamma_{gt} + \delta_i + \epsilon_{it} \quad (3)$$

The housing transaction price H_{igt} for house i in geographic area g in year t is regressed on house fixed effects, δ_i, geographic are by time fixed effects, γ_{gt}, and year-specific gas intercept terms where $\mathrm{I}_i^{\mathrm{gas}}$ indicates the home heats with gas and ϵ_{it} is the idiosyncratic error term. In the left side of Figure 8, the variation in housing price difference tracks the NPV of the consumer surplus difference closely over the sample period.

The right side of Figure 8 plots the fuel price difference against the corresponding NPV of the difference in consumer surplus for each year in the sample. If the housing transaction price difference was precisely the estimated NPV of the difference in consumer surplus, each dot would fall on the 45 degree line. The fitted line through the scatter plot shows that the NPV estimate of the consumer surplus difference using a 10% discount rate is a close fit for the housing transaction price difference.

4.2 Robustness Tests

One potential worry with this approach is that the pattern in relative housing transaction prices are caused by a differential trend in homes with a particular heating fuel rather than by the relative fuel price variation. For example, since oil homes are older on average, the results might be explained by the declining value of a vintage over time. In other words, when oil is getting most expensive relative to natural gas in later years, oil homes are also getting older on average compared to natural gas homes. This trend in age difference might partially explain some of the observed discount for oil homes compared to natural gas homes.

However, in Figure 8, the housing transaction price difference closely follows the U-shape of the NPV of the difference in consumer surplus. In early years, the transaction price difference falls when it is less expensive to heat oil homes as compared to gas homes. Then in later years, the transaction price difference increases as oil homes get more expensive to heat than gas homes. The relationship does not appear to be driven just by the later years, where one might worry that the difference in housing transaction prices were being driven by differential trends in fuel type.

In order to address the issues of differential trends more rigorously, columns 1 and 2 of Table 5 display results for two robustness tests of the identifying parallel trends assumption between oil and gas houses. First, for the estimates in column 1, I included an oil-heat linear trend. If my results were the result of a differential trend in homes that heat with oil rather than fuel price variation, the inclusion of the trend would substantially change my estimates. However, the estimates do not change substantially with the inclusion of an oil specific linear trend.

Second, for the estimates in column 2, I flexibly control for the age of the home with age fixed effects where age is defined by the sales year minus year built. Age fixed effects allow me to control flexibly for trends in value of houses as they age. Homes are grouped in 5 year bins for homes that are 20 years or older, because there are relatively few observations for each vintage in early years. For homes younger than 20 years, I use the actual year built, because there are more observations for each vintage year and the value of newer homes is likely much more sensitive to smaller age differences. Here too, the coefficients of interest change little, suggesting that differences in the capitalization rates are driven by the price variation and not by unobservable trends in the age of the structure.

Another potential concern with my approach is the measurement error introduced by the housing unit characteristic data. As is the case with most real estate transaction data, the unit characteristic data provide only a snap shot of a house's attributes even though the transaction data span over 20 years. Therefore, there is a potential for measurement error in the characteristics at the point of sale. Measurement error, particularly in the heating fuel, could potentially bias my estimates.

If the measurement error were standard, it would attenuate my estimates toward zero and make me more likely to find evidence consistent with myopia. However, in this context it is likely that the measurement error is non-standard. The more recent housing transactions are more likely than earlier transactions to have the correct housing characteristics. In later years as the price of oil increases compared to natural gas, people maybe converting from oil to gas. This has the potential to bias me toward finding high levels of capitalization and away from finding myopia. The intuition is that in early years, when there is more likely to be measurement error, the estimate of the mean difference in housing transaction prices is more likely to be attenuated, while in later years, the difference in housing transaction price is likely to be more precise. Since the biggest change in fuel prices is in later years, some of the difference in housing transaction price attributed to change in fuel price may be driven instead by the increasing precision of the estimates.

With this type of non-standard measurement error, one might expect that the slope of the housing transaction price difference in Figure 8 would get steeper compared to the NPV of the difference in consumer surplus in the later years relative to early years. However, the housing transaction price difference follows the NPV of the difference in consumer surplus fairly uniformly for the entire sample period, indicating that non-standard measurement error is unlikely to be a significant driver of my results.

Further, in columns 3 and 4 of Table 5, I estimate the same two models as in columns 1 and 2, except that I limit my sample to homes that are 18 years and younger by 2011. The average lifetime of a furnace is 18 years.[7] If the furnace would not need to be replaced yet, homeowners may be less likely to convert heating fuel, thus reducing the chance measurement

[7] The life cycle cost estimator developed by the EPA and the DOE for evaluating savings from Energy Star Furnaces assumes an 18-year life for conventional furnaces.

error of fuel type in newer houses. The results for the newer houses have higher point estimates than those for the full sample. However, with a smaller sample size the effects are not as precisely estimated, and the standard errors are relatively large. Consistent with the full sample estimates, when the sample is limited to newer houses that are less likely to have measurement error in fuel type, consumers do not appear to be particularly myopic about fuel costs in housing purchases.

4.3 Instrumental Variables Approach

Another source of potential bias stems from the fact that homeowners may be improving other aspects of the home that are unobserved in the data when they are changing heating fuel. For example they may choose to put in new flooring or new kitchen appliances such as a gas stove. Then houses may have an unobservably higher quality after they convert than before. If conversions are correlated with the price difference and are accompanied by other major renovations, it will exacerbate the non-standard measurement error problem, biasing my estimates away from zero, making me more likely to find evidence of capitalization. If these types of upgrade were driving the results, one would again expect that the slope of the housing transaction price difference in Figure 8 would be steeper compared to the NPV difference in later years as compared to earlier years. Since this is not the case, it is unlikely that endogenous upgrades are a significant issue. In addition, as stated in the data section, in the initial data construction, I removed any houses that appear to have had major upgrades. This removes houses where the characteristics changed significantly over time, possibly reducing the prevalence of homes with major endogenous upgrades.

However, in order to address this issue more rigorously, I consider an instrumental variables approach, creating an instrument for heating fuel, in order to mitigate the effects of measurement error and the possibility of endogenous fuel switching with upgrades. I exploit temporal variation in the fuel type of new construction in order to isolate variation in fuel choice that is exogenous to the fuel price difference. Figure 9 displays the proportion of homes in the sample built with oil for each vintage year from 1900 to 2011. It is clear that there is variation in fuel choice that is separable from a linear trend in vintage. Figure 9 depicts several clear breaks in the data, which are associated with policy changes that are exogenous to the local housing market. Starting in 1954, wellhead price controls were introduced in the United States for natural gas, resulting in low retail prices for consumers. There is a sharp kink in the proportion of homes build with oil starting in 1954. After 1954, more and more homes are built with gas until about 1974. The price control policy lead to shortages in supply in the mid-1970's. The way that many utilities dealt with these shortages was to restrict access to new customers rather than by rationing existing consumers (Davis and Kilian, 2011). Between 1974 and 1978, there was an increase in homes built with oil due to supply shortages of natural gas. In 1978, wellhead price controls were lifted, which increased natural gas supply, and the proportion of homes built with oil dropped. Since then, natural gas has been getting more common with the exception of a brief increase in homes built with oil in the mid-1980's following the crude oil price collapse of 1986.

Using this variation, the instrument for price is the proportion of homes built with oil in the year a particular house was built times the oil price in the year it was sold plus the proportion of homes built with gas in the year a particular house was built times the gas price in the year it was sold. Using this instrument, the local average treatment effect will come from a comparison of vintages when gas was more or less readily available. As with my approach in the robustness tests, I include an oil specific trend and flexibly control for the age of the house.

The results from this estimation are displayed in Table 6. The first column shows the results of the first stage estimation. The coefficient on the instrument is close to one since on average, the instrument closely predicts fuel price. Column 2 shows the results of the two-staged least squares estimation. The point estimate of the price coefficient using two-staged least squares is much larger than that using OLS. This suggests that the measurement error, even though it is non-standard, may have served to attenuate rather than bias the estimates upward. The implied discount rate for the two-staged least squared estimate is around 3%, close to recent mortgage interest rates. However, given the 95% confidence interval on the point estimates, I cannot rule out the implied discount rates from the OLS estimation. With these results taken together, it seems unlikely that home buyers are strongly myopic regarding future heating fuel prices.

5 Conclusion

This paper explores how shifts in energy costs affect housing transaction prices to see if home buyers are myopic about energy costs. I use shifts in natural gas and heating oil prices over time to isolate exogenous variation in home energy costs. I use housing transaction data from Massachusetts, where roughly an equal number of homes heat with oil as heat with natural gas. This allows me to estimate the effect of a change in relative energy costs on a change in relative housing prices, while controlling for changes in the macroeconomic environment and in the value of different housing characteristics over time.

I find that home buyers are relatively attentive to future fuel costs. They are paying attention to shifts in relative fuel prices and are aware of how changes in fuel price translate into changes in the net present value of the future stream of payments. The implied discount rates from the estimates range between 9 and 10%, which are consistent with recent work on automobile purchases (Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2015).

My findings suggest that since home buyers are attentive to and informed about fuel prices, pollution pricing policies such as taxes and cap-and-trade programs will create incentives not only to reduce the amount of energy people choose to consume, but to convert to cleaner heating fuels, and possibly increase the efficiency of building shells and appliances as well.

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Tables

Table 1: Covariate Comparison Between Fuel Type

	Gas	Oil	P-value of Diff
sale price	$342,104	$322,718	0.00***
bedrooms	3.32	3.36	0.00***
bathrooms	2.37	2.21	0.00***
stories	1.78	1.73	0.00***
square ft.	1922.51	1902.47	0.00***
year built	1956.59	1947.94	0.00***
exterior wall			
wood	45%	46%	
vinyl	32%	33%	
aluminum	11%	12%	
other	13%	9%	
heat type			
forced air	50%	26%	
forced hot water	38%	60%	
steam	8%	13%	
other	3%	1%	
Observations	303,802	301,005	

Notes: Characteristic and transaction data are from CoreLogic for the state of Massachusetts (1990-2011). All prices are inflated to 2012 dollars.

Table 2: Estimation of the Effect of Fuel Prices on Heating Fuel Consumption

	Consumption	Log Consumption
price	-1.769***	
	(0.674)	
log price		-0.150*
		(0.0895)
oil	-3.449	-0.0697***
	(3.459)	(0.0240)
Year FE	Yes	Yes
N	1130	1130

Notes: Data are from the Residential Energy Consumption Survey (RECS), northeast census division, survey years 1990, 1993, 1997, 2001, 2005, and 2009. RECS probability sampling weights are used. The unit of observation is housing unit × year. Fuel price is estimated by dividing expenditure by usage (MMBTU) as verified from the utility. All prices are inflated to 2012 dollars. All specifications control flexibily for the house age, number of rooms, bedrooms and bathrooms, and square footage. Standard errors are robust to heteroskedasticity and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 3: Net Present Value of $95 Surplus Difference: Infinite Horizon

Discount Rate	NPV
1%	$9,595
5%	$1,995
10%	$1,045
15%	$728
20%	$570

Table 4: Estimation of the Effect of Relative Fuel Prices on Relative Transaction Prices

	sales price	sales price	sales price	sales price	sales price
fuel price	-1186.4***	-1106.2***	-1163.2***	-1074.7***	-1064.7***
	(317.7)	(284.0)	(161.1)	(286.0)	(208.1)
I^{oil}	-15334.4**	-10535.4**	323.9		
	(6522.4)	(4114.6)	(1127.1)		
Year FE	Yes	Yes	No	Yes	No
Attribute Controls	No	Yes	Yes	No	No
Geo. AreaxYear FE	No	No	Yes	No	Yes
Unit FE	No	No	No	Yes	Yes
N	909434	863480	863416	529156	529008
Implied Discount Rate	8.7%	9.4%	8.9%	9.3%	9.8%
95% Confidence	5.5-20.3%	6.1-21%	6.9-12.7%	6-20.3%	6.9-16.9%

Notes: Regressions are based on transaction and unit characteristic data for the state of Massachusetts from CoreLogic, years 1990-2011. Price is the average annual residential retail fuel price for oil or natural gas in $/MMBTU. All prices are inflated to 2012 dollars. Standard errors are clustered at the geographic unit level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 5: Estimation of the Effect of Relative Fuel Price on Relative Transaction Price: Robustness Tests

Dep. Var. Sales Price	Full Sample	Full Sample	Newer	Newer
price	-793.5***	-751.9***	-2375.9**	-1327.7
	(195.5)	(174.4)	(933.1)	(818.5)
Unit FE	Yes	Yes	Yes	Yes
Geo. AreaxYear FE	Yes	Yes	Yes	Yes
Oil Linear Trend	Yes	Yes	Yes	Yes
Year FExVintage FE	Yes	Yes	Yes	Yes
fixed4	No	No	No	No
N	529008	528642	90532	90532
Implied Discount Rate	13.6%	14.5%	4.2%	7.7%
95% Confidence	8.8-30.3%	9.5-30.4%	2.3-21.3%	3.3-100%

Notes: Regressions are based on transaction and unit characteristic data for the state of Massachusetts from CoreLogic years 1990-2011. The Full Sample includes all housing vintages and Newer includes homes built between 1994 and 2011. Price is the average annual residential retail fuel price for oil or natural gas in $/MMBTU. All prices are inflated to 2012 dollars. Standard errors are clustered at the geographic unit level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 6: IV Estimation of the Effect of Relative Fuel Price on Relative Transaction Price

(dep. var.)	First Stage (fuel price)	2SLS (sales price)
fuel price IV	1.080***	
	(0.0471)	
fuel price		-3544.8***
		(1313.8)
F-stat	264.9	
R^2	0.886	
Unit FE	Yes	Yes
Geo. AreaxYear FE	Yes	Yes
Oil Linear Trend	Yes	Yes
Age FE	Yes	Yes
N	528642	528642
Implied Discount Rate		2.8%
95% Confidence		1.5-11%

Notes: Regressions are based on transaction and unit characteristic data for the state of Massachusetts from CoreLogic years 1990-2011. Price is the average annual residential retail fuel price for oil or natural gas in $/MMBTU. The instrument for price is the proportion of homes built with oil in the year a particular house was built times the oil price in the year it was sold plus the proportion of homes built with gas in the year a particular house was built times the gas price in the year it was sold. All prices are inflated to 2012 dollars. Standard errors are clustered at the geographic unit level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Figures

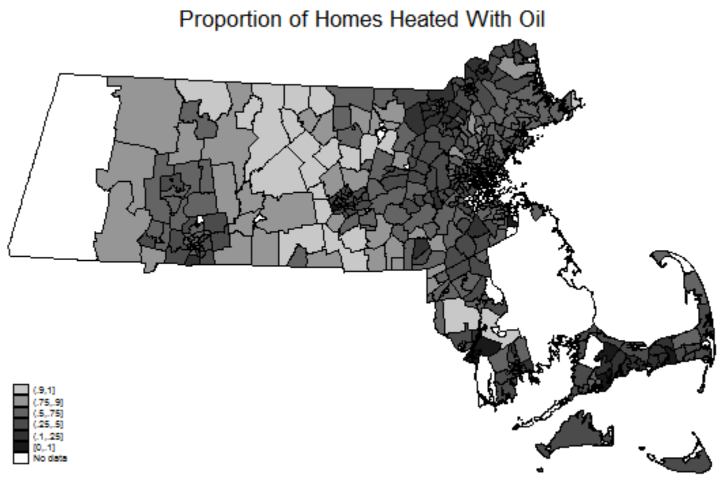

Figure 1: Proportion of Homes Heated With Oil

Notes: Housing characteristic data for the state of Massachusetts are from CoreLogic

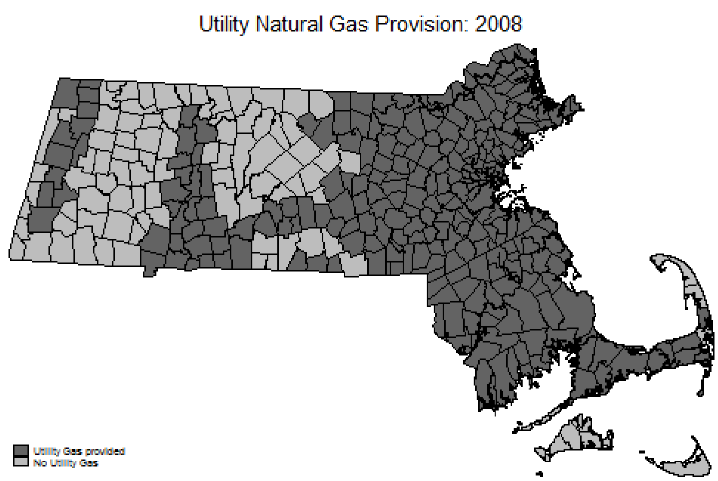

Figure 2: Utility Natural Gas Provision: 2008

Notes: Natural gas utility territory data for the state of Massachusetts are from MassGIS

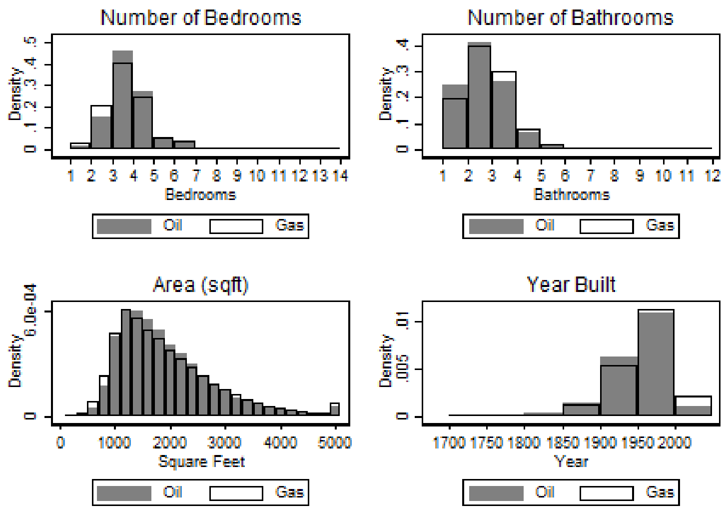

Figure 3: Overlap of Covariates

Notes: Housing characteristic data for the state of Massachusetts are from CoreLogic

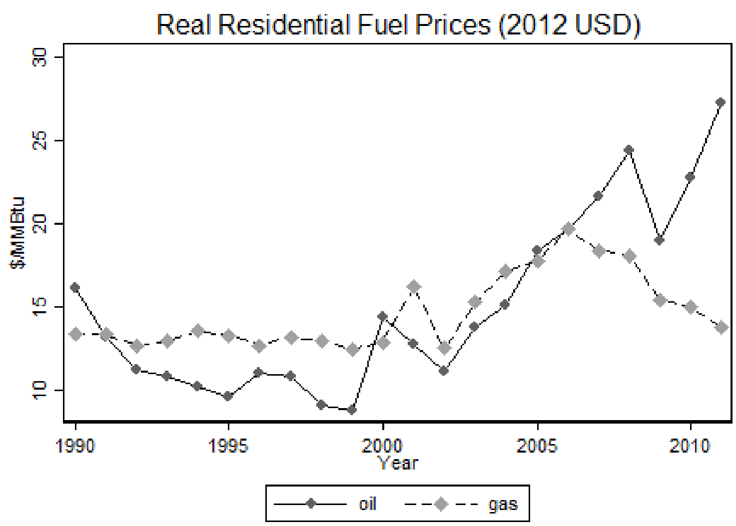

Figure 4: Real Residential Fuel Prices (2012 USD)

Notes: The prices are average annual retail prices ($/MMBTU) for the state of Massachusetts from EIA. All prices are inflated to 2012 dollars.

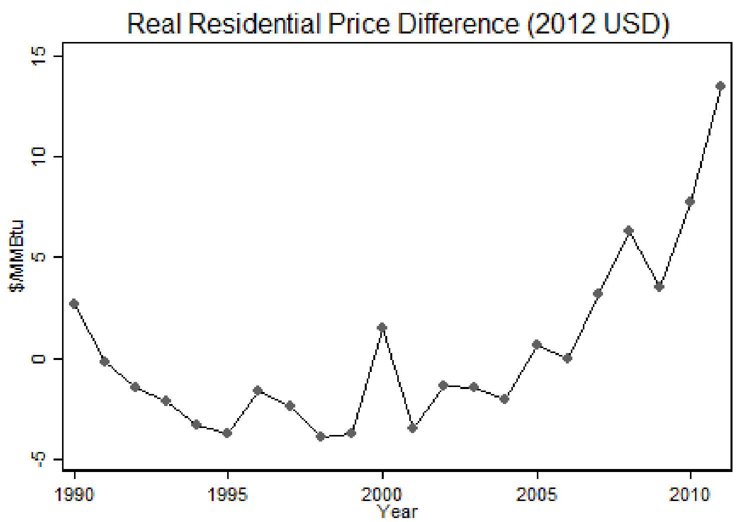

Figure 5: Real Residential Price Difference (2012 USD)

Notes: This figure displays the price of oil minus the price of natural gas. The prices are annual retail prices ($/MMBTU) for the state of Massachusetts from EIA. All prices are inflated to 2012 dollars.

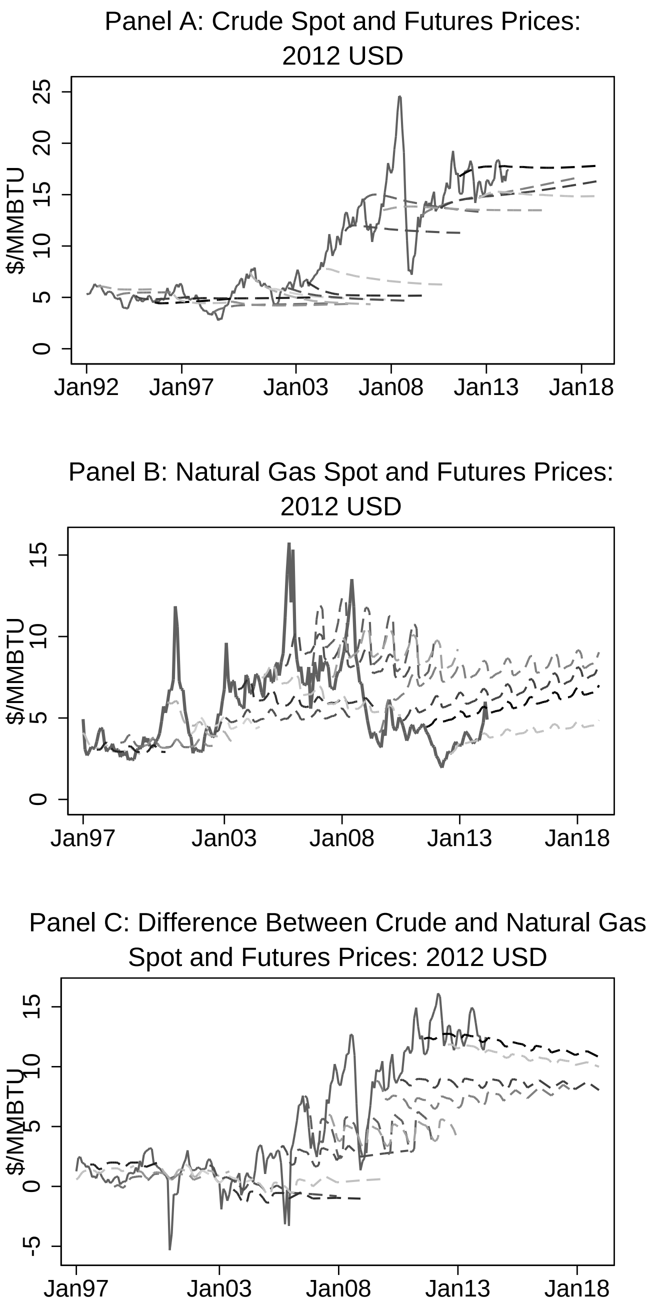

Figure 6: Spot and Futures Prices

Notes: The solid line in Panels A an B are the spot price and the dashed lines are forward curves taken every June. All prices are in 2012 dollars. Forward curves are inflated according to the trade date. Panel C displays crude spot and futures prices minus natural gas spot and futures prices. Source: NYMEX

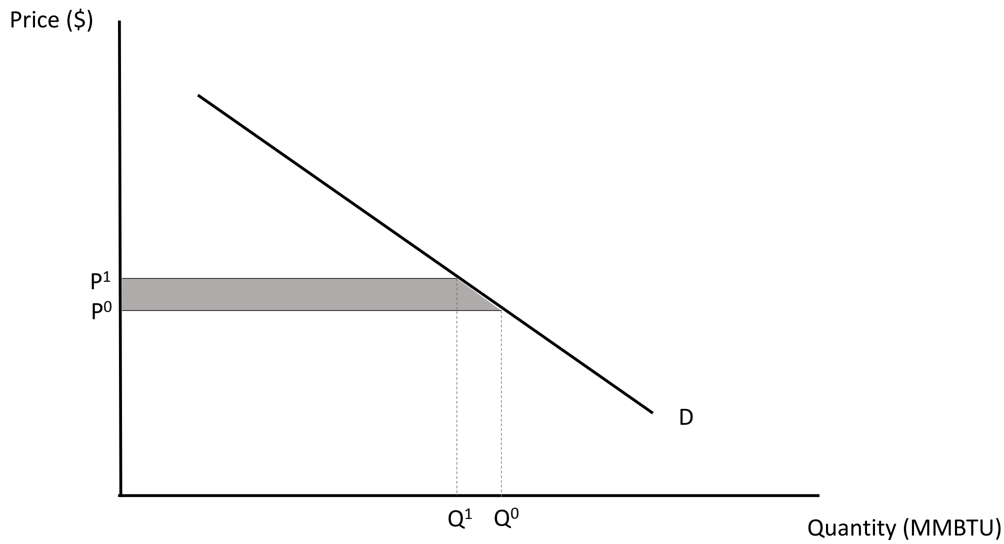

Figure 7: Lost Consumer Surplus from a Price Increase with Linear Demand

Figure 8: Net Present Value of the Surplus Difference For Oil vs. Gas Houses Over Infinite Horizon With 10% Discount Rate and the Difference in Housing Transaction Prices

Notes: The graph on the left depicts the difference in the net present value of consumer surplus between oil and gas houses and the difference in transaction prices. The graph on the right plots each mean difference in annual transaction price against the difference in the NPV of consumer surplus between oil and gas houses for each year. All prices are inflated to 2012 dollars

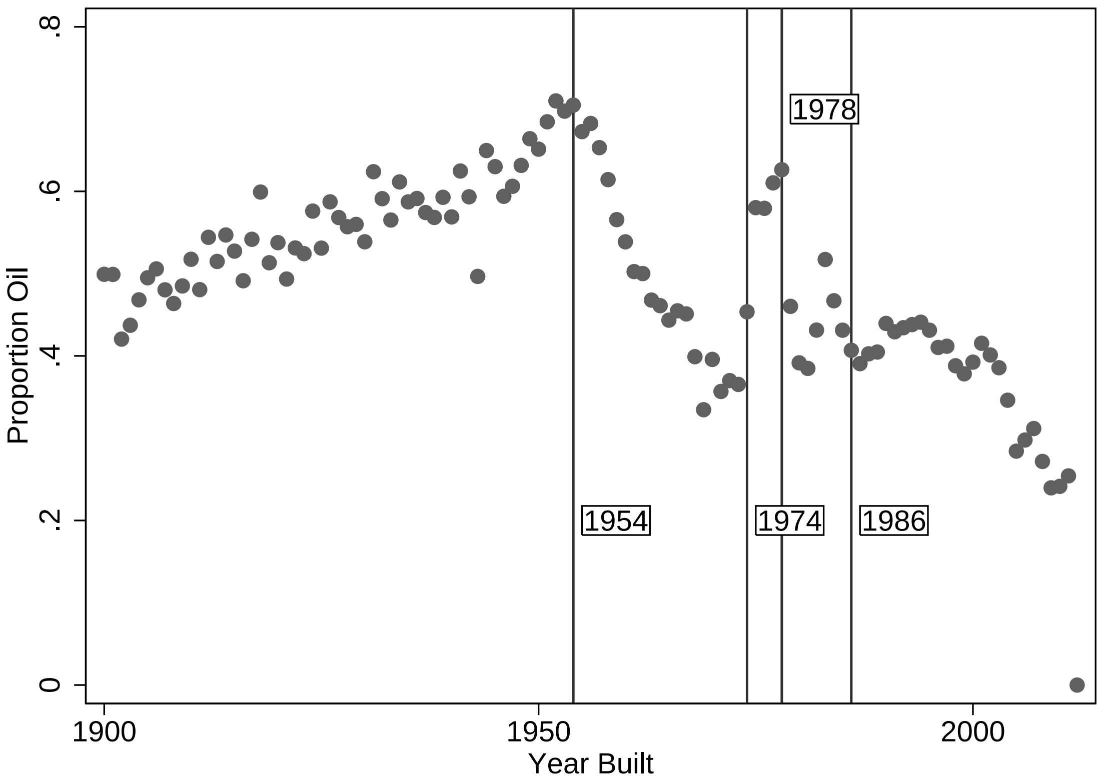

Figure 9: Proportion of Homes Built with Oil by Year Built

Notes: The graph on the left depicts the proportion of homes of built with oil for each vintage year between 1900 and 2011. The housing transaction price data are provided by CoreLogic for the state of Massachusetts.