Housing Market Institutions Drive Race and Ethnicity Differences in Energy Consumption

Michael Edwards
James Woods

April 9, 2015

Abstract

When socio-demographic factors are considered in any kind of analysis of household electric and gas utility data, it is common to observe differences in energy use between households with different self-reported race and ethnicity compositions. These differences persist controlling for structure type, e.g., single family dwelling, age and size of housing units, and, other common control variables. Without the information necessary to better explain these differences, they are commonly summarized simply as cultural differences. This paper demonstrates that these differences can be partially explained by differential sorting by structure and ownership, i.e., endogenizing housing choice and rental decisions. We will show that these differences in energy consumption may be because of housing market institutions and restrictions.

1 Introduction

The choice of housing, differentiated between renters and owners: owners and those households making payments towards ownership are treated as the same. Homes are categorized by structure type.

Housing choices may be linked to fundamental characteristics of the heads of households as a dependent variable that has implications as to utility, and in this respect it is assumed that owning a detached home is of greatest use. The choice of homes is considered cardinal, where a house is of greatest value and the mobile home is treated as the least appealing choice. A townhome, row house, in a desirable location such as an urban area, may be a highly desirable good, in general that is not treated as the norm. Structures other than detached houses may be considerably more perishable. This assumption is made regardless of variations within the desirability of particular detached houses. The choice of purchasing or renting a home is relevant within the structure types. An individual may choose to forego ownership of a townhouse in favor of renting a house, or forego owning a mobile home in favor of renting an apartment. Here, both from a utilitarian perspective of the need for one domicile over another is considered as well as prestige that comes from both the structure type as well as what utility may derive from ownership.

The value of structure type may have implications as to future wealth. Homeowners tend towards greater wealth over time, related to home ownership itself(Di 2007). Homeowners have the opportunity to use their wealth for investment or paying off higher interest debts, such as credit cards, by using home equity. Homeowners have access to a safety net in terms of debt, and they also have the opportunity of reducing the lifetime costs of debts. Homeowners may also choose to liquidate their homes, or pass on wealth at at or near the end of their lives. One source found homeowners held more wealth compared to their contemporary counterparts. The growth of wealth was also appreciably higher(Di 2007).

The effect of home ownership and structure choice may have implications for future outcomes of the children of the suggested households. In that respect, it can be said that there is evidence of children having better outcomes, in terms of education and income, than their peers in households that choose to rent (Boehm 2014). It is plausible that the outcome benefits are coming from a causal relationship with parental characteristics rather than that of the housing choice, and are co-variables, rather than having an internal causal relationship. While it is beyond the scope of this paper, it is also plausible that housing choice is indicative of neighborhood choice, though it should be stated that there is no assertion on this statement to be found here.

Households choice of structure type, payment method, and location are often very difficult to change based on the history of a household (Darrah 2014). Households that have tended towards renting have difficulty, or at least choose not to, buy in the future. Community attitudes and behaviors in relation to housing are often sticky in changing, and this is of importance as related to the outcomes of children; often mirroring the characteristics of their parents.

This paper explores the relationship between the household characteristics and the choice of housing structure, and suggests that there is reason in particular of choosing housing structures based on wealth and needs as a proxy for utility, which not only has immediate effects but those that have persistent effects on the legacy of households. While the utility of a particular domicile cannot be measured directly, it is assumed that the choice of structure is indicative of the value that the household places on one choice over another.

1.1 Race and Ethnicity in Conditional Demand

1.2 How Race and Ethnicity are Interpreted

2 RECS

The 2009 Residential Energy Consumption Survey (RECS) was the main source of data. 12083 observations are included in the data, of which 11905 are used for most of the models. Because of the complex sampling scheme, which involves both cluster sampling and over sampling of odd cells, weights are used in all analysis. The reason that the majority of the observations were dropped was because the households were living on premises for free, neither owning or renting the property. We also dropped a few observations because they were under-sampled and the post-stratification weights were so large to as not be credible.

The RECS data set contains information on both the dwelling structure type, and an indicator if they own the property. The dwelling types are divided into the six common categories: single family detached house, single family attached (including duplexes and row house, small apartment complexes, large apartment complexes, and mobile homes.

The RECS survey contains an enormous number of variables, 931, for each household including: income, resident ages, education, rental assistance, appliance and building characteristics, thermostat set-points, householder ethnicity and race. Income was recorded in categories but midpoints of the categories were used for most analysis.

Table 1 shows the count of observations by Race/Ethnicity and structure after the basic data handling described above. Please note the dominance of single family detached homes, shown as SFDetached in the table and non-Hispanic Caucasians, shown as FALSEWt in the table. These counts are unweighted and do not take into account the stratified sampling scheme used to collect the data.

Table 1: Count of Observations by Race and Structure Type

	Mobile	SFDetached	SFAttached	SmApartment	LgApartment
FALSEWt	371	5694	544	430	951
FALSEAfAm	24	754	121	174	382
FALSEAsian	1	231	48	52	113
FALSEMulti	6	87	14	12	27
FALSENativeAm	7	35	9	7	15
FALSEOther	2	59	8	13	29
FALSEPacific	1	22	1	2	10
TRUEAfAm	3	8	10	5	8
TRUEAsian	0	5	0	0	1
TRUEMulti	1	10	2	4	4
TRUENativeAm	2	17	3	6	9
TRUEOther	6	41	12	16	24
TRUEPacific	0	2	1	1	0
TRUEWt	97	730	105	184	332

Many of the structure type/ race and ethnicity combinations are relatively rare, e.g., Hispanic Asians living in mobile homes. We have not collapsed any of these categories. Future research will look at collapsing some of the rare cells so that there are a more manageable number of both structure types and race/ethnicity combinations.

Table 2 gives a further description of the data is distributed around the country. Please note that both the Western and North Eastern area have a larger fraction of large apartment buildings, LgApartment in the table, than the other two regions.

Table 2: Count of Observations by Region and Structure Type

	NE	MidWest	South	West
Mobile	47	92	245	137
SFDetached	1173	2080	2685	1757
SFAttached	218	162	257	241
SmApartment	326	145	226	209
LgApartment	470	323	603	509

The table shows the range of climate zones and housing law covered by the survey. It also shows the reasonableness of our hypotheses that location and structure type choices are endogenous.

Figure 1 shows a smooth approximation of the distribution of annual household electricity use in kWh per year. The columns indicates the various self-identified race and the columns indicate if the the household self identifies as Hispanic and if the home is owned or rented. The blank cells indicate that there are too few observations to generate a reliable smooth approximation of electricity consumption.

Please note that households that rent tend to have lower annual electricity consumption and a smaller variance in that consumption. This is normal given that rented apartments which are typically smaller and of more uniform size than single family dwellings.

2.1 Race and Ethnicity Differences in Equipment and Structure

There are many choices that are frequently thought of as exogenous in conditional demand models that could account for differences electricity consumption by race and ethnicity. One of the most obvious is the location of the residence. At the most basic level, choosing to locate a household drives energy consumption.

Figure 2 shows the one of the most basic locational choices, residing in an urban or rural area. Race is represented by the columns and the two rows, labeled FALSE and TRUE, indicate if the household self identifies as Hispanic, TRUE, or not. The bars represent the fraction of each race and ethnicity combination that reside in rural and urban areas.

Non-Hispanic Caucasian and Native American households are more likely to reside in a rural area while those that identify as Hispanic are, in each category, almost always more likely to live in urban areas than those that don't self-identify as Hispanic. The connection to energy consumption is through the correlation between rural households having larger residences that are more likely to be single family detached houses.

Some of the large differences in those self-identified Hispanic categories are because of very sparse cells. There are only four Hispanic Pacific Islanders in the survey.

Figure 1: Annual kWh by Rent/Own and Race

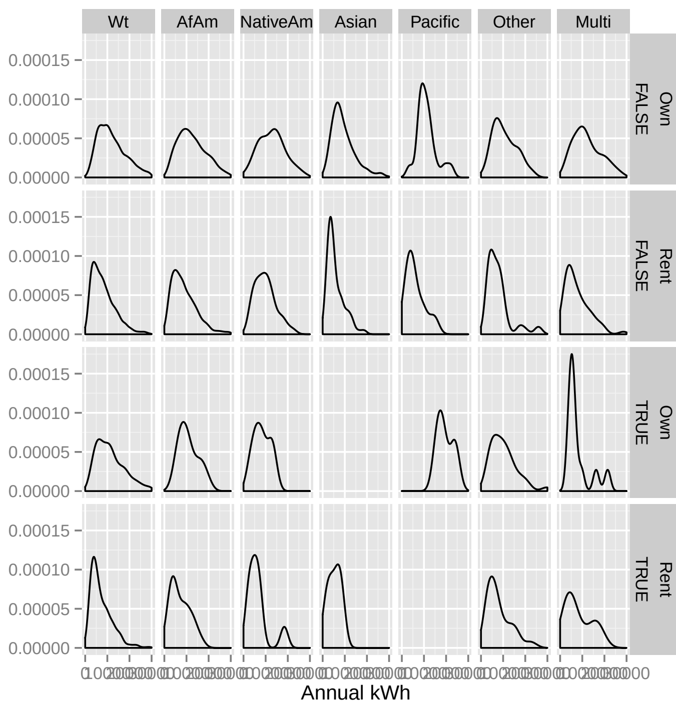
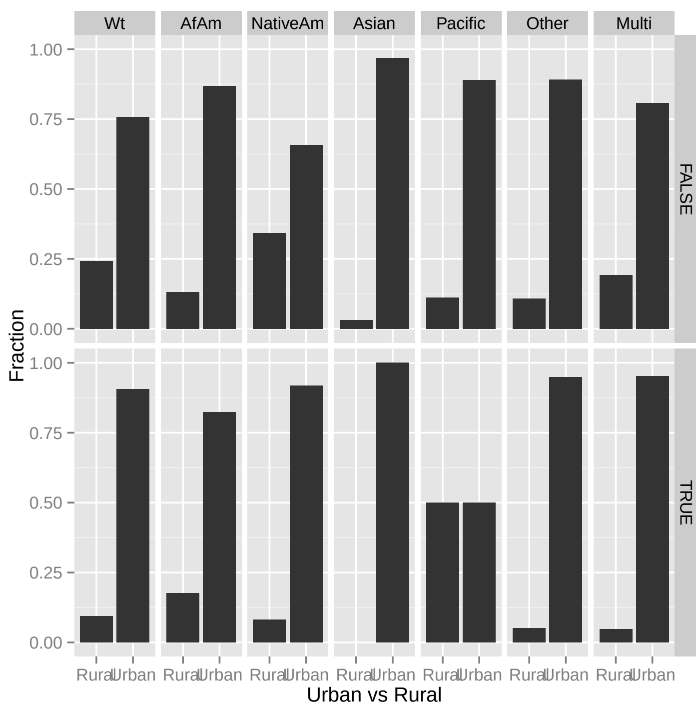


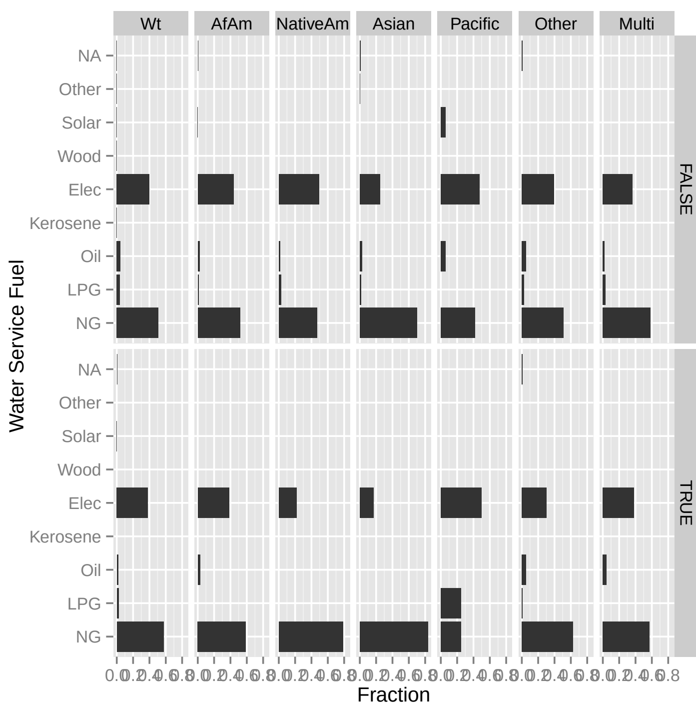
Figure 2: Urban vs Rural by Race and Ethnicity



Both the water and space heating fuel show significant differences across race and ethnicity combinations. The fuel choice something controlled by the owner of the structure. For households that rent this choice more likely to be electric heating and water service. While electric heat and water service is often very expensive on a month-to-month basis, the installation costs are typically quite low. The installation cost is what is faced by the landlord. The month-to-month cost is faced by the lessee.

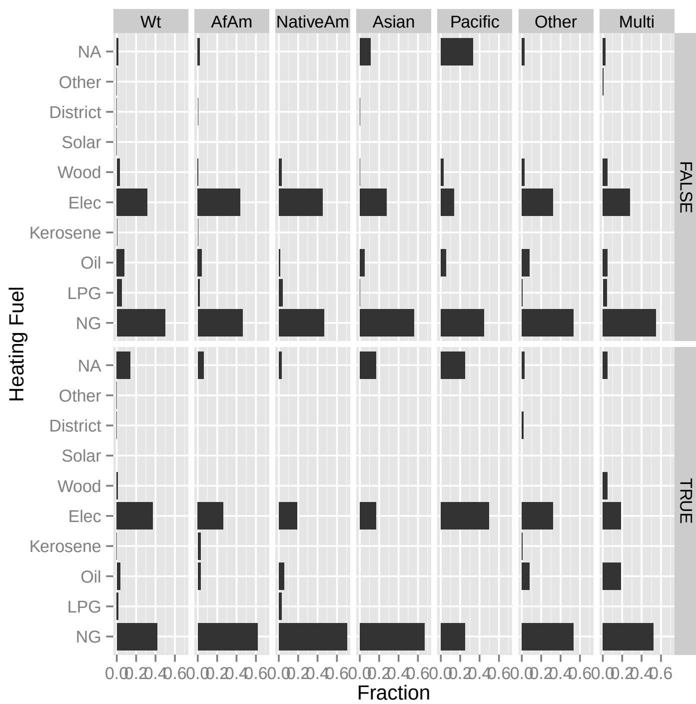
Figure 5 shows the distribution of heating fuel by race and ethnicity. It is very clear that Natural Gas is the most common fuel for hot water service but there are some differences based on race and ethnicity. Excluding the less common self-identified Hispanic categories, native Americans and pacific islanders are more likely to have electric hot water service than non-Hispanic Caucasians and households with a head of household that identifies as multi-racial is less likely to have electric hot water service.

Figure 3: Water Service by Race and Ethnicity



Again, electric hot water service is more common in extreme rural areas and rental housing. Figure 5 shows a similar figure for heating fuel. Non-Hispanic African Americans and Native Americans are more likely to have electric heat than non-Hispanic Caucasians, while Asian and Pacific Islanders have a large, “Not applicable”, response category. Again, Hispanic Caucasians are more likely to have electricity as their heating fuel than non-Hispanic Caucasians.

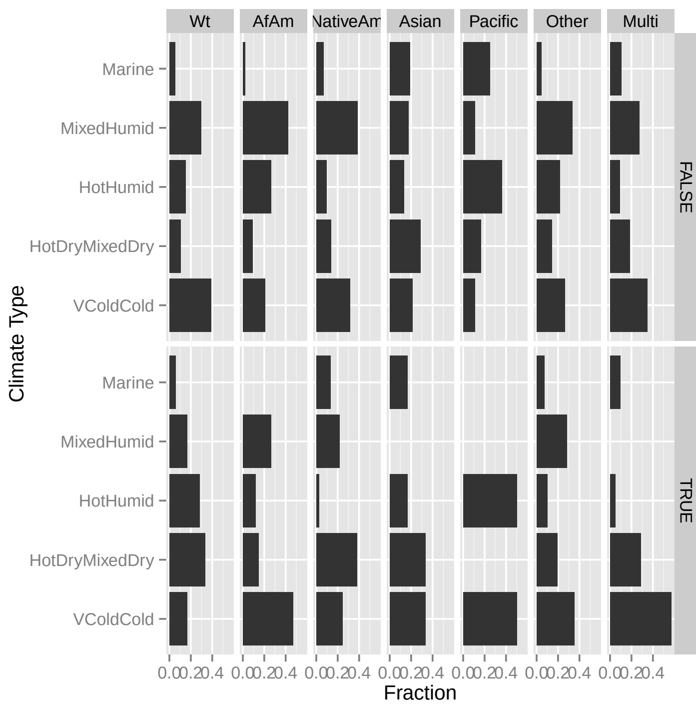
Figure 4: Heating Fuel by Race and Ethnicity



Many of these different fuel choices can be partially explained by the locational choice made by the households. Figure 5 shows the climate type by race and ethnicity. Non-Hispanic pacific islanders are more likely than non-Hispanic Caucasians to be in hot humid and marine environments and may explain the large number of not applicable responses for heating fuel. Hispanic Caucasians are also more likely to live in hot dry/mixed dry or hot humid climes that the other groups. While these climate types will still have some heating load, heating behavior and heating fuel is less likely to be a strong determinant of total electricity use. Heating is just less an issue than cooling.

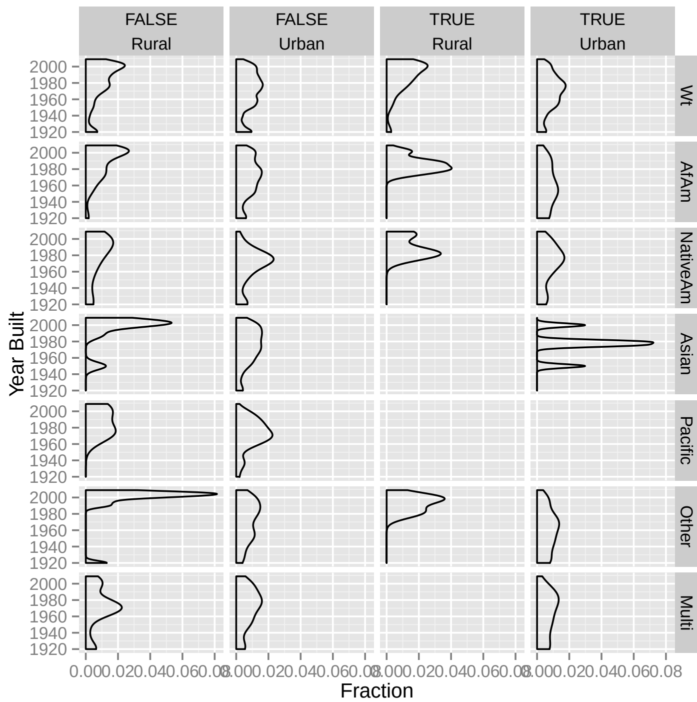
There are also differences in the age of structure depending on both the race and ethnicity reported and if the household lives in an urban or rural area. Figure 6 shows the distribution of the year the housing unit was built. Columns indicate urban and rural households with the two left, $FALSE$, columns breaking out the non-Hispanic households and the right two, $TRUE$, showing the Hispanic households. Rows are indicating the self-identified race. There are several blank cells, where a smooth histogram is not possible because of the

Figure 5: Climate Type by Race and Ethnicity



small number of observations.

Figure 6: Age of Structure by Rent/Own and Race/Ethnicity



What should be most apparent is that rural housing tends to be newer than urban housing. Urban households have a modal construction date in the 1980s while the rural areas are more likely to have a model construction date in the 2000s.

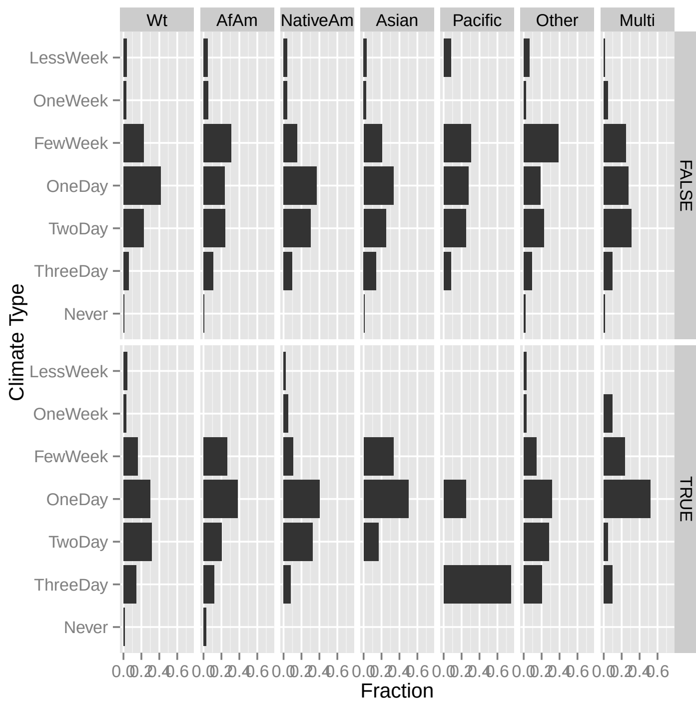
These diagrams should lead one to the conclusion that important variables, such as location and fuel choice differ significantly across race and ethnicity and should not be treated, without great consideration, as exogenous.

2.2 Differences in Reported Behavior

In spite of the evidence above that locational choice, tenure, and structure type decisions drive a great deal of energy use, there are still decisions, made after these choices that can be thought of as cultural differences. Some of these may be regional preferences, for example the North East preference for higher winter indoor air temperatures, but there may be some true differences in behavior by race and ethnicity.

Consider figure 7 which shows the number of meals cooked in the home by

Figure 7: Meals Cooked by Race and Ethnicity



race and ethnicity. Non-Hispanic Caucasian household report a strong mode of one meal cooked in the house per day. Non-Hispanic African Americans have a mode of one meal per week and Hispanic Caucasians have a mode of two a day. Many of these differences can be attributed to differences in income across groups, but functional kitchens are virtually universal.

The choice of thermostat setting is also made after the fact. The price of electricity, natural gas, square footage of the house, income, the presence of elderly residence can all have an effect on the choice of thermostat settings but these are all done after the equipment and location choices.

Figure 8 shows box and whisker plots with notches for self-reported daytime thermostat settings in winter when someone is home. The boxes show the 25%-75% interquartile range. The bold mark shows the median and the notches give a visual test of a difference in medians for the groups. If the notches overlap, you can not reject the null hypotheses that the thermostat settings are the same. Note that for some of the cells with few observations, Hispanic Asians, the notches are wider than the interquartile range.

The figure clearly shows that non-Hispanic African American households report a higher daytime winter thermostat setting than the other non-Hispanic

Figure 8: Daytime Temp and Race/Ethnicity (Winter)

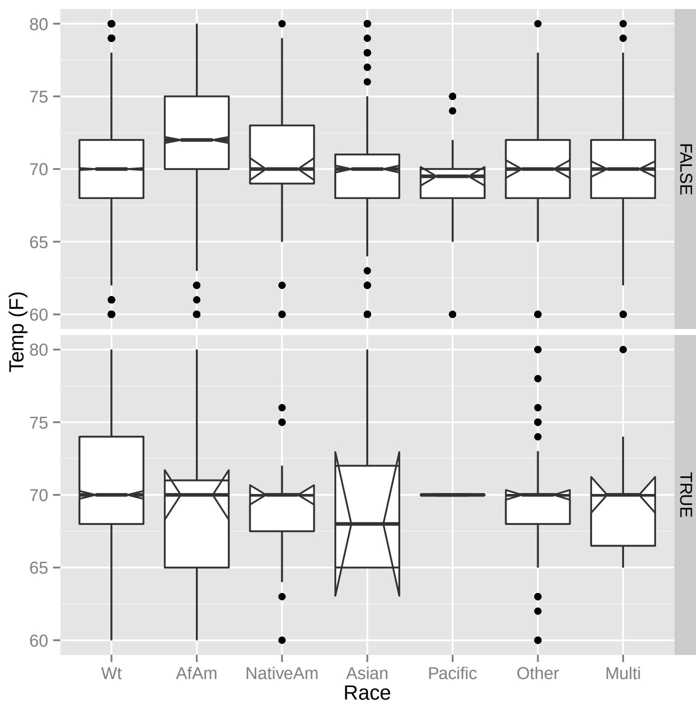
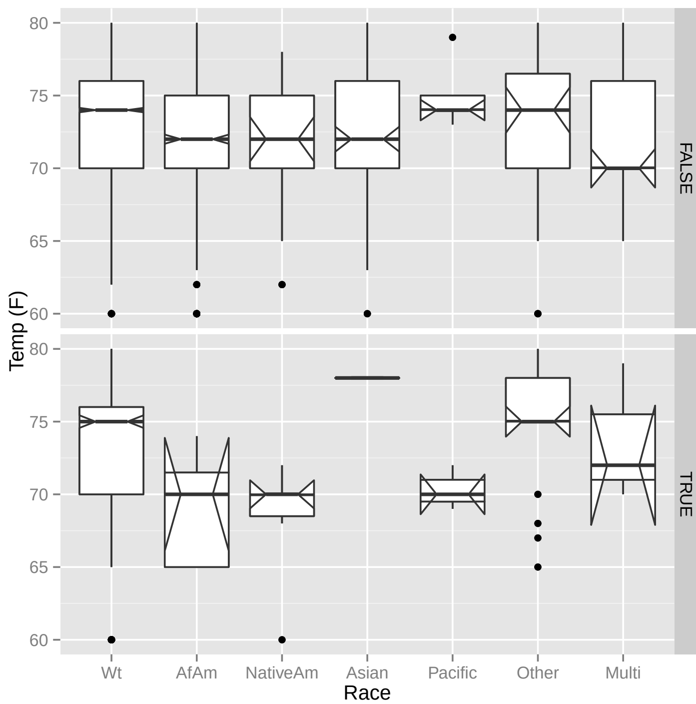


Figure 9: Daytime Temp Home by Race/Ethnicity (Summer)



groups. This could be locational. This could be cultural, but it is a behavioral difference that could make African American households more energy intensive in this end-use.

The effects of this higher thermostat setting may be offset by less electricity use for plug loads or hot water service or by having smaller residences, but it represents a different preference.

This difference in winter thermostat behavior follows through in summer thermostat preferences. Figure 9 shows a summary for similar summer thermostat settings. Note that non-Hispanic African Americans, Asian Americans and Native Americans all report lower summer thermostat settings than non-Hispanic and Hispanic Caucasian households.

*** TRANSITION TEXT NEEDED ***

2.3 HUD Complaints as a Measure of Discrimination

Part of our hypothesis is that housing market discrimination is forcing some race and ethnicity groups into rental, older and poorer quality housing and that discrimination is leading to differences in electricity consumption that is currently being captured and interpreted as cultural differences. Finding a state level index of housing market discrimination not easy. While there are plenty of studies that show experimentally that housing market discrimination exists, an index that shows the extent of the discrimination is unavailable.

Until we construct a better index we are using a simple measure of the number of discrimination complaints filed with the U.S. Department of Housing and Urban Development as reported in their annual fair housing report [12]. There are problems with using complaints as an index of discrimination.

Complaints are only investigated if are reported to an agency that participates in the Federal Fair Housing Assistance program. That program has a requirement that they enforce housing rights similar to the Fair Housing Act [12, p. 17]. The data is accumulated in the Title Eight Automated Paperless Office Tracking System (TEAPOTS) system. The majority of the complaints were because of disabilities but race is a close second in the number of complaints recorded [12, p. 20] with the most common violations being, "Discriminatory Terms, Conditions, Privileges, Services, and Facilities in the Rental or Sale of Property".

We treat complaints as evidence that there is housing market discrimination but it could be thought of as a compound event. A complaint has as a prerequisite, an agency that enforces laws similar to the Fair Housing Act and the belief that a complaint will be acted upon. You can have a low number of complaints if there is no discrimination but also because no one believes that a complaint is effective. Until we construct a better index, which includes local law, field experiments similar to ***CITE*** this is as close as we can get to a statewide measure of housing market discrimination.

Table 3 shows the number of HUD complaints per 100,000 population by state. States are aggregated the same way that location is reported in the RECS data set. This means that, for example, states in the North East, Vermont, Rhode Island, New Hampshire, Connecticut and Maine share the same 20.50 complaints per 100,000, the highest reported complaint rate. Other nearby states have a much lower rate, e.g., Pennsylvania with only 1.87 complaints per 100,000 population.

The fact that some states with a historical reputation for discrimination on the basis of race, Georgia and Illinois for example, have a very low complaint rate, highlights some of the difficulty in using HUD complaints as a measure of housing market discrimination. The pre-condition for a HUD complaint investigation does not exist.

There is also the possibility that housing market discrimination may not be equally applied within the state to each to each of the race and ethnicity combinations. It may be that one state has a lot of housing market discrimination against Hispanic Caucasians but none for African Americans. Another state could have the reverse situation. We may also have the circumstance where some ethnic groups have given up on HUD complaints and does not use that mechanism within that state.

In either case, HUD complaints by state is our current best measure of housing market discrimination.

Table 3: HUD Complaints per 100,000 Population

State	Population	Reports (per 100,000)
Alabama	4,677,464	7.50
Alaska	688,125	13.01
Arizona	6,499,377	3.68
Arkansas	2,867,764	9.26
California	36,580,371	3.03
Colorado	4,935,213	1.97
Connecticut	3,502,932	20.50
Delaware	876,211	14.00
District of Columbia	590,074	14.00
Florida	18,423,878	3.93
Georgia	9,697,838	2.06
Hawaii	1,287,481	13.01
Idaho	1,527,506	9.94
Illinois	12,842,954	2.88
Indiana	6,388,309	9.14
Iowa	2,993,987	19.92
Kansas	2,797,375	10.31
Kentucky	4,287,931	7.50
Louisiana	4,451,513	9.26
Maine	1,319,691	20.50
Maryland	5,658,655	14.00
Massachusetts	6,543,595	4.51
Michigan	10,002,486	4.97
Minnesota	5,230,567	19.92
Mississippi	2,940,212	7.50
Missouri	5,956,335	4.99
Montana	968,035	9.94
Nebraska	1,781,949	10.31
Nevada	2,615,772	5.08
New Hampshire	1,321,872	20.50
New Jersey	8,663,398	2.34
New Mexico	1,986,763	5.08
New York	19,467,789	4.60
North Carolina	9,247,134	4.22
North Dakota	641,421	19.92
Ohio	11,528,072	9.14
Oklahoma	3,644,025	9.26
Oregon	3,782,991	13.01
Pennsylvania	12,566,368	1.87
Rhode Island	1,053,502	20.50
South Carolina	4,503,280	4.22
South Dakota	804,532	19.92
Tennessee	6,240,456	2.61
Texas	24,304,290	4.18
Utah	2,727,343	9.94
Vermont	621,049	20.50
Virginia	7,795,424	2.03
Washington	6,566,073	13.01
West Virginia	1,814,873	14.00
Wisconsin	5,627,610	1.81
Wyoming	532,981	9.94

3 Conditional Demand Estimation

Modern conditional demand models of the kind commonly created as part of the process of data collection of large residential appliance and use surveys such as RECS, include a mix of engineering estimates, survey responses and analyst best estimates to produce energy end-use estimates. For example, survey respondents will give an age range on the furnace they have installed, the square footage of the residence, and some indication of heating set points. The analyst will assign a likely efficiency for the furnace based on the average of the age ranges and then estimate hours used based on set points, weather, and the reported thermostat settings. This produces estimates that are closer to a Statistically Adjusted Engineering (SAE) model than what is normally regarded as a conditional demand model outside of the energy community.

Our model is based more on the traditional conditional demand models, and includes terms for electricity use contingent on: the age of the home, which is a proxy for building code requirements and insulation; the weather, in the form of Heating and Cooling degree days with a base temperature of 65F; Meals cooked at home, to indicate energy use related to food preparation; the number and age of refrigerators, a major end-use; the number of and types of TVs and computers, as a proxy for major plug loads; the existence of a well pump; weather the residence has electric hot water service; the existence of pools and hot tubs as well as if they are electrically heated; the kind of windows installed, as another indication of shell quality; the number of people in the home; and finally the income, race and ethnicity of the residents.

Model: Multinomial logit

As a point of clarity, surveys with questions not filled in were coded with 97, to differentiate between responses that were left blank and those where the value coded was not applicable. For the purpose of this paper 97s were recoded to not and were dropped from the analysis.

Results:

The first and most likely indicator of home ownership within the structure type is income. Here, we find in the results that the effect of income is statistically significant in each category accept the renting of townhomes. Theory may suggest that, as mentioned earlier, row houses and townhomes in highly desirable neighborhoods especially historic neighborhoods are often rentals and as such might be rented by those with high incomes. This question will remained unanswered within the scope of this study.

More importantly, the sign of the coefficient for income is positive for house ownership (approx. .22). Continuing down the coefficients it is negative for townhouse rental (insignificant), positive for townhouse ownership, and the trend continues until that of mobile homes. The income coefficient for mobile homes is negative for both rental and ownership, suggesting that a positive change in income has a negative effect on the probability of a household choosing a mobile home regardless if they are choosing to rent or buy. It could be suggested that living in a mobile home is considered an inferior good, and households might choose to forego ownership or renting a mobile home in favor of choosing any other domicile.

The education variable is estimated, and is found to be statistically insignificant in the ownership of houses and the renting of townhouses and small complex apartment units. Based on its coefficient, its value as an explanatory variable appears to be weak, yet as we go down the list of owndwel values the education coefficient moves from a positive to a negative at mobile homes. That is to say that here, education appears to have an effect mostly positive between the owndwel values of 3-8, and negative thereafter.

Race, the dummy for being white, is statistically significant everywhere except in the rental of apartments in large small complexes. Note that for mobile homes the dummy for race takes on a value of approximately 1 and 1.57 for renters and owners respectively. This would suggest, while not realistic probabilities, that overwhelmingly whites have a higher probability of choosing mobile homes in comparison to non-self-reporting whites. Notably, no results of interest were found regarding the stereotype of Native-Americans dwelling in mobile homes within the data. Also race in this case appears to be linked to ownership of homes in each of the categories, within the bootstrapped version of the model it is statistically significant in each of the ownership owndwel categories.

When the model as specified first, is ran using a multinomial logit vce bootstrapping the results are slightly different with regards to children. Now, while in places not statistically significant (see appendix) there does appear to be a trend towards the results are the same. Further examination is needed.

The parameter estimates of the full model can be found in appendix , partial results are shown in table .

Table 4: Orthodox kWh Model

	Estimate	Std. Error	t value	Pr(>|t|)
Income	0.0086	0.0016	5.3662	0.0000
Income:EthRaceFALSEAfAm	0.0031	0.0027	1.1389	0.2548
Income:EthRaceFALSEAsian	-0.0243	0.0034	-7.1646	0.0000
Income:EthRaceFALSEMulti	-0.0168	0.0069	-2.4259	0.0153
Income:EthRaceFALSENativeAm	0.0117	0.0123	0.9493	0.3425
Income:EthRaceFALSEOther	-0.0249	0.0083	-2.9909	0.0028
Income:EthRaceFALSEPacific	-0.0163	0.0138	-1.1807	0.2378
Income:EthRaceTRUEAfAm	-0.0120	0.0165	-0.7271	0.4672
Income:EthRaceTRUEAsian	-0.0365	0.0454	-0.8032	0.4219
Income:EthRaceTRUEMulti	-0.0291	0.0212	-1.3745	0.1693
Income:EthRaceTRUENativeAm	-0.0187	0.0148	-1.2599	0.2077
Income:EthRaceTRUEOther	-0.0262	0.0099	-2.6335	0.0085
Income:EthRaceTRUEPacific	-0.0122	0.0380	-0.3221	0.7474
Income:EthRaceTRUEWt	-0.0192	0.0031	-6.2907	0.0000
StrTenureOwnSFDetached:TOTSQFT_EN:HDD65	0.0001	0.0000	4.1043	0.0000
StrTenureOwnLgApartment:TOTSQFT_EN:HDD65	-0.0001	0.0001	-0.9580	0.3381
StrTenureOwnMobile:TOTSQFT_EN:HDD65	0.0004	0.0001	5.9838	0.0000
StrTenureOwnSFAttached:TOTSQFT_EN:HDD65	-0.0000	0.0000	-0.5516	0.5812
StrTenureOwnSmApartment:TOTSQFT_EN:HDD65	0.0000	0.0001	0.5438	0.5866
StrTenureRentLgApartment:TOTSQFT_EN:HDD65	-0.0002	0.0001	-4.0031	0.0001

StrTenureRentMobile:TOTSQFT_EN:HDD65	0.0004	0.0002	1.7633	0.0779
StrTenureRentSFAttached:TOTSQFT_EN:HDD65	0.0000	0.0001	0.6010	0.5479
StrTenureRentSFDetached:TOTSQFT_EN:HDD65	0.0000	0.0000	0.5515	0.5813
StrTenureRentSmApartment:TOTSQFT_EN:HDD65	-0.0001	0.0001	-1.8580	0.0632
StrTenureOwnSFDetached:TOTSQFT_EN:CDD65	0.0008	0.0000	19.2068	0.0000
StrTenureOwnLgApartment:TOTSQFT_EN:CDD65	-0.0002	0.0002	-0.8168	0.4140
StrTenureOwnMobile:TOTSQFT_EN:CDD65	0.0009	0.0001	7.3167	0.0000
StrTenureOwnSFAttached:TOTSQFT_EN:CDD65	0.0006	0.0001	5.0127	0.0000
StrTenureOwnSmApartment:TOTSQFT_EN:CDD65	0.0001	0.0003	0.4022	0.6875
StrTenureRentLgApartment:TOTSQFT_EN:CDD65	0.0000	0.0001	0.3926	0.6946
StrTenureRentMobile:TOTSQFT_EN:CDD65	0.0024	0.0004	6.3205	0.0000
StrTenureRentSFAttached:TOTSQFT_EN:CDD65	0.0007	0.0002	4.0210	0.0001
StrTenureRentSFDetached:TOTSQFT_EN:CDD65	0.0008	0.0001	9.2680	0.0000
StrTenureRentSmApartment:TOTSQFT_EN:CDD65	0.0005	0.0002	2.8365	0.0046

The top parameter, Income, shows the estimate for annual kWh per dollar of income for a household headed by a non-Hispanic Caucasian. The remaining income related variables show the deviations from this case for Hispanic headed households, labeled TRUE in the table, and by the other self reported races. Note that in all cases, with the exception of non-Hispanic Native Americans, the parameter estimates show less electricity used than non-Hispanic Caucasian households. Only a few of these differences are statistically significant, non-Hispanic Asian and multi-ethnic households, as well as Hispanic Caucasian households and households that reported some other race.

The remaining items shown in the table show the electricity use per square foot for each of the structure types, e.g., Single Family Detached, and tenure, i.e., Rent or Own, per annual heating and cooling degree days. Aside from the negative and significant estimate for the heating load in large Rented apartments, the results are unremarkable.

3.1 Endogenizing Structure and Other Variables

Treating structure type and square footage as endogenous is our first step in estimating conditional demand for many end uses treating the choice of things like, EnergyStar appliances, refrigerator size and design. The current standard, treating these as exogenous drivers of energy use biases or estimates of energy use in unknown ways.

Focusing on tenure, i.e., the decision to own or rent, structure and square footage decisions allows us to see if other housing market institutions are driving energy use differently depending on ethnicity. At this early stage of research we are focusing only on these major drivers but we can expand the analysis to other choices including clothes washing, hot water service and other large energy drivers.

As stated in section 2.3, using HUD complaints as a measure of housing market discrimination based on race and ethnicity is less than optimal measure, but at this early stage is an adequate measure to determine the scale of the effect.

Table shows only the discrimination related results for our model of square footage. Full results can be seen in appendix . Note that the square footage model includes structure type and tenure as an exogenous variable. This model of square footage will be included later as part of a system estimation of electricity use.

The key discrimination variable, reporttot, is the count of complaints received by HUD per 100,000 people in the state where the household is located. We interacted this variable with race and ethnicity to allow for different effects groups but we do not allow the discrimination to vary by state. Note that the effects of HUD reports on square footage are rarely significant, only strongly significant for Hispanic Caucasian households. In this case incidences of HUD complaints per 100,000 of state population results in a reduction in the square footage for Caucasian Hispanics by 22.73 square feet.

This model is in general not very good at explaining square footage; the adjusted R^2 is only .3897. This weakness will plague us later when we jointly estimate this model with structure type, tenure and electricity use, but illustrates one of the ways we can endogenize the choices that lead to electricity consumption.

While the impact of housing market discrimination has some effect on the size of residences, the effects on the ownership and structure type decision is expected to be more dramatic. Housing market discrimination can be expected to push some people away from owned property and into the rental market, which is rife with split incentives for conservation and energy efficiency investments.

Discrimination can also push some households into structure types, where even when owned, that have significant split incentives for energy efficiency investments. Take, for example, small and large apartment buildings. While the householder may have control over some appliances, the building shell and some of the heating and cooling equipment decisions are made by others.

Our model of structure type and tenure includes categories for both owned and rented: Large Apartments, Small Apartments, Mobile Homes, Single Family Detached, and Single Family Attached. We explain the joint tenure and structure type with: the square footage of the structure, if the household receives rental assistance, income, number of people in the household, education level of the head of household, the HUD reports per 100,000 in that state and whether the household is in a rural or urban location. As in the square footage model, HUD reports are interacted with the race and ethnicity variables to allow for separate discrimination effects for each.

All parameter estimates for the models are statistically significant at the 1% level, with the exception of the income variable which is highly correlated with the education variables, and are displayed in appendix.

Since all the parameters are statistically significant it is easier to show the effects of our measure of housing market discrimination on the probability of each structure and tenure choice for the race and ethnicity combinations. The HUD reports run from 1.81249 complaints per 100,000 to 20.496 complaints per 100,000. Figure shows the reaction to HUD complaints over the 1 to 21 complaint range.

Lots of explanation goes here

3.2 System Estimation

The single equation results discussed in section 3.1 show strong promise for endogenizing some of the decisions made about structure and equipment within the conditional demand model as well as the potential importance of housing market discrimination in structure choice. In this section we treat square footage, tenure and structure type as endogenous and estimate estimate the electricity, structure/tenure, and square footage model as a system.

It is unclear how this can be accomplished in a full information, so we chose a two-stage least squares technique, estimating first the square footage model, then using forecasted values to estimate tenure and structure type model. Forecasts from that model were used to resestimate and produce a new round of forecasts for the square footage model. Both the forecasts of the structure tenure model and square footage model were then used to estimate the conditional demand model.

This should produce consistent results but the variance of the parameter estimates are biased. It is unclear how to make the usual corrections to the variance of the parameter estimates given that the structure and tenure model is estimated as a multinomial logit. The best alternative is to bootstrap the system. There are a few caveats.

First, the bootstrap sampling is stratified so that all parameter estimates in all models can be estimated. This is particularly important in the structure and tenure model. We had to ensure enough observations of the rare endogenous cells, rented mobile homes being the most restricted, and exogenous variables, e.g., Hispanic Pacific Islanders. This was accomplished by simple rejection sampling rather than assigning different probabilities of selection to each of the cells.

Second, we did not censor non-positive square footage forecasts. The square footage model is weaker than expected and it was quite possible to have negative forecasts. Alternative models, such as Tobit, would not be effective, but we are considering transformations of square footage as we move forward.

Finally, only 400 bootstrap replicates were evaluated. This is usually enough to produce adequate estimates of the standard deviations of the parameter estimates in the electricity model but insufficient for BCa, percentile, or even basic bootstrap confidence intervals.

The full set of parameter estimates for the electricity model can be found in the appendix. We will focus on a subset of the parameter estimates, focusing on the effects of race and ethnicity separately and the effects of the other endogenous variables, structure and tenure and square footage.

Table 5: System Estimation of kWh Model: Race and Ethnicity

	Estimate	Std. Error	t value	Sig
Income:EthRaceFALSEAfAm	0.0052	0.0029	1.7791	
Income:EthRaceFALSEAsian	-0.0230	0.0035	-6.4831	***
Income:EthRaceFALSEMulti	-0.0157	0.0057	-2.7584	*
Income:EthRaceFALSENativeAm	0.0092	0.0211	0.4382	
Income:EthRaceFALSEOther	-0.0237	0.0082	-2.9038	*
Income:EthRaceFALSEPacific	-0.0129	0.0230	-0.5625	
Income:EthRaceTRUEAfAm	-0.0173	0.0139	-1.2454	
Income:EthRaceTRUEAsian	-0.0375	0.0101	-3.7155	**
Income:EthRaceTRUEMulti	-0.0331	0.0192	-1.7208	
Income:EthRaceTRUENativeAm	-0.0163	0.0107	-1.5276	
Income:EthRaceTRUEOther	-0.0274	0.0080	-3.4318	**
Income:EthRaceTRUEPacific	-0.0240	0.0659	-0.3647	
Income:EthRaceTRUEWt	-0.0185	0.0033	-5.5782	***

Table shows similarities with the results from the orthodox electricity model. Non-Hispanic Asians, and Hispanic Caucasians and Hispanic heads of households that identify as some other race all show lower electricity use per dollar of income. This is consistent in sign with the parameter estimates in table , but the statistically significant deviations from non-Hispanic Caucasians for non Hispanic multi-ethnic heads of household has vanished. The scale of the significant parameter estimates are also roughly the same magnitude but attenuated towards zero.

Table 6: System Estimation of kWh Model: Square Footage

	Estimate	Std. Error	t value	Sig
PSQFT:OwnSFDetached:HDD65	0.0001	0.0000	4.4109	***
PSQFT:HDD65:OwnLgApartment	0.0000	0.0001	0.8450	
PSQFT:HDD65:OwnMobile	0.0004	0.0001	4.6205	***
PSQFT:HDD65:OwnSFAttached	0.0000	0.0000	1.3603	
PSQFT:HDD65:OwnSmApartment	0.0001	0.0000	1.1709	
PSQFT:HDD65:RentLgApartment	-0.0001	0.0000	-1.3292	
PSQFT:HDD65:RentMobile	0.0005	0.0003	2.0238	
PSQFT:HDD65:RentSFAttached	0.0001	0.0001	1.0923	
PSQFT:HDD65:RentSFDetached	0.0001	0.0000	1.7233	
PSQFT:HDD65:RentSmApartment	-0.0000	0.0000	-0.2465	
PSQFT:OwnSFDetached:CDD65	0.0007	0.0000	16.3870	***
PSQFT:OwnLgApartment:CDD65	0.0000	0.0002	0.2207	
PSQFT:OwnMobile:CDD65	0.0011	0.0002	6.7660	***
PSQFT:OwnSFAttached:CDD65	0.0005	0.0001	5.3085	***
PSQFT:OwnSmApartment:CDD65	0.0003	0.0002	1.8671	
PSQFT:RentLgApartment:CDD65	0.0003	0.0001	2.5551	.
PSQFT:RentMobile:CDD65	0.0020	0.0009	2.2066	
PSQFT:RentSFAttached:CDD65	0.0009	0.0002	4.9470	***
PSQFT:RentSFDetached:CDD65	0.0008	0.0001	8.8123	***
PSQFT:RentSmApartment:CDD65	0.0005	0.0001	3.5753	**

Table shows the relationship between heating and cooling degree days per square foot on electricity use for each of the tenure and structure type combinations. These results are particularly troublesome because heating and cooling degree days, in conjunction with square footage, are one of the most reliable explanatory variables for electricity use. Space heating and cooling are two major end-uses in most households. The parameter estimates show that these reliable explanatory variables are only significant in a few rare cases. There is a strong relationship heating and cooling degree days for owned single family detached structures, but only rented mobile homes show statistically significant reactions to heating loads and only large apartments, owned or rented, for cooling loads.

This is very strong evidence that our square footage choice model needs improvement if it will be used as part of this electricity consumption system.

4 Summary and Conclusions

The model set out to provide some explanation of housing choices based on relevant variables. In doing so it is apparent that income places a significant role in the formation of house choices both to own/rent and what type of structure is chosen. Further education played a less significant role than anticipated, thought it could be said that the role of education is actually channeled through income. As such its placement in the model is suspect in its current form.

The race variable appears to suggest that whites tend towards ownership of their homes, and that whites are more likely to live in mobile homes than other races. Further examination of race within this model framework would be an interesting and possibly useful endeavor.

The model would likely benefit by an expansion of the explanatory variables in an effort to provide a better fit. It is relevant to point out that this is a model in progress whose ultimate goal is that of modeling household characteristics on energy consumption.

As well, the location of a structure type to needs such as: employment, school districts, entertainment, and public services etc., may play a role in choice of homes. This last point is not considered within the scope of the model.

[2]

References

[1] Joseph M Burgett and Abdol R Chini. Using building and occupant characteristics to predict residential residual miscellaneous electrical loads: a comparison between an asset label and an occupant-based operational model for homes in florida. *Journal of Building Performance Simulation*, (ahead-of-print):1–17, 2015.

[2] Angelo Canty and Brian Ripley. *boot: Bootstrap R (S-Plus) Functions. R package version 1.3-9.* R Foundation for Statistical Computing, Vienna, Austria, 2013.

[3] David B. Dahl. *xtable: Export tables to LaTeX or HTML*, 2014. R package version 1.7-4.

[4] Lucas W Davis. Evaluating the slow adoption of energy efficient investments: are renters less likely to have energy efficient appliances? In *The Design and Implementation of US Climate Policy*, pages 301–316. University of Chicago Press, 2011.

[5] DOE EIA. Residential energy consumption survey (recs), 2008.

[6] Hossein Estiri. 21 percent: The role of socioeconomics and housing characteristics on co2 emissions from the us residential sector. *Available at SSRN 2196984*, 2012.

[7] Hossein Estiri. Building and household x-factors and energy consumption at the residential sector: A structural equation analysis of the effects of household and building characteristics on the annual energy consumption of us residential buildings. *Energy Economics*, 43:178–184, 2014.

[8] Hossein Estiri. A structural equation model of energy consumption in the united states: Untangling the complexity of per-capita residential energy use. *Energy Research & Social Science*, 6:109–120, 2015.

[9] Hossein Estiri, Ryan Gabriel, Eric Howard, and Li Wang. Different regions, differences in energy consumption: Do regions account for the variability in household energy consumption? *Differences in Energy Consumption: Do Regions Account for the Variability in Household Energy Consumption*, 2013.

[10] Chao Li. *HOME ENERGY CONSUMPTION ESTIMATION BY END USE AND ENERGY EFFICIENCY UPGRADE RECOMMENDATIONS*. PhD thesis, Duke University, 2014.

[11] Kelly Hellman Miller, Francesca Colantuoni, and Christine Lasco Crago. An empirical analysis of residential energy efficiency adoption by housing types and occupancy. 2014.

[12] U.S. Department of Houseing and DC Urban Develpment, Washington. Annual report of fair housing, fy 2010, 2010.

[13] Gary Pivo. Unequal access to energy efficiency in us multifamily rental housing: opportunities to improve. *Building Research & Information*, 42(5):551–573, 2014.

[14] R Core Team. *R: A Language and Environment for Statistical Computing.* R Foundation for Statistical Computing, Vienna, Austria, 2013.

[15] Thomas F Sanquist, Heather Orr, Bin Shui, and Alvah C Bittner. Lifestyle factors in us residential electricity consumption. *Energy Policy*, 42:354–364, 2012.

[16] DC U.S. Energy Information Administration, Washington. Residential energy consumption survey, doe/eia- forms eia 457a-g, 2009.

[17] W. N. Venables and B. D. Ripley. *Modern Applied Statistics with S*. Springer, New York, fourth edition, 2002. ISBN 0-387-95457-0.

[18] Gregory R. Warnes, Ben Bolker, and Thomas Lumley. *gtools: Various R programming tools*, 2014. R package version 3.4.1.

[19] Hadley Wickham. *ggplot2: elegant graphics for data analysis.* Springer New York, 2009.

[20] Hadley Wickham. The split-apply-combine strategy for data analysis. *Journal of Statistical Software*, 40(1):1–29, 2011.

[21] Hadley Wickham. *stringr: Make it easier to work with strings.*, 2012. R package version 0.6.2.

A Full Regression Results

Table 7: Orthodox kWh Model

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2181.1197	1792.3947	1.22	0.2237
ElecMealsThreeDay	1338.6588	297.7217	4.50	0.0000
ElecMealsTwoDay	1644.3185	185.0764	8.88	0.0000
ElecMealsOneDay	1685.3404	159.1570	10.59	0.0000
ElecMealsFewWeek	1451.1356	183.7584	7.90	0.0000
ElecMealsOneWeek	1726.8842	406.3322	4.25	0.0000
ElecMealsLessWeek	992.8116	424.8594	2.34	0.0195
NUMFRIG	1574.9574	120.8432	13.03	0.0000
AgeFridge2to4Years	49.6457	195.1174	0.25	0.7992
AgeFridge5to9Years	312.9075	183.1243	1.71	0.0875
AgeFridge20PlusYears	282.4503	328.6753	0.86	0.3902
AgeFridge10to14Years	392.2705	207.4396	1.89	0.0587
AgeFridge15to19Years	3.4299	283.6629	0.01	0.9904
NUMPC	345.0370	64.3126	5.37	0.0000
TIMEON1OneTo3Hrs	-142.2026	160.6198	-0.89	0.3760
TIMEON1ThreeTo6Hrs	-5.9463	186.4186	-0.03	0.9746
TIMEON1SixTo10Hrs	224.2810	239.0840	0.94	0.3482
TIMEON1Gr10	823.2281	214.7291	3.83	0.0001
WELLPUMPTRUE	1501.4018	183.5027	8.18	0.0000
ElecWaterSmall	4421.9192	256.3522	17.25	0.0000
ElecWaterMed	4658.3555	163.9114	28.42	0.0000
ElecWaterLrg	5809.5827	189.7584	30.62	0.0000

ElecWaterTankless	3251.7517	755.3718	4.30	0.0000
SWIMPOOLTRUE	3228.7285	222.3292	14.52	0.0000
ElecPoolTRUE	4604.1557	837.0574	5.50	0.0000
RECBATHTRUE	1013.4653	426.3413	2.38	0.0175
ElecTubTRUE	1218.8041	486.6005	2.50	0.0123
NHSLDMEM	952.0720	42.5506	22.38	0.0000
Income	0.0086	0.0016	5.37	0.0000
TVONWD1LessHour:TVTYPE1Standard	-3266.1101	1800.2730	-1.81	0.0697
TVONWD1OneTo3Hrs:TVTYPE1Standard	-3010.1255	1775.5111	-1.70	0.0900
TVONWD1ThreeTo6Hrs:TVTYPE1Standard	-2516.9211	1772.6818	-1.42	0.1557
TVONWD1SixTo10Hrs:TVTYPE1Standard	-1794.7156	1778.9345	-1.01	0.3131
TVONWD1Gr10:TVTYPE1Standard	-1290.6207	1784.9518	-0.72	0.4697
TVONWD1LessHour:TVTYPE1LCD	-2896.8097	1807.2466	-1.60	0.1090
TVONWD1OneTo3Hrs:TVTYPE1LCD	-2313.1891	1773.9814	-1.30	0.1923
TVONWD1ThreeTo6Hrs:TVTYPE1LCD	-1955.8036	1770.9445	-1.10	0.2695
TVONWD1SixTo10Hrs:TVTYPE1LCD	-1593.9919	1777.1898	-0.90	0.3698
TVONWD1Gr10:TVTYPE1LCD	-485.7205	1785.6404	-0.27	0.7856
TVONWD1LessHour:TVTYPE1Plasma	-1497.7500	1988.0024	-0.75	0.4512
TVONWD1OneTo3Hrs:TVTYPE1Plasma	-1664.7504	1800.8346	-0.92	0.3553
TVONWD1ThreeTo6Hrs:TVTYPE1Plasma	-2001.8306	1788.6852	-1.12	0.2631
TVONWD1SixTo10Hrs:TVTYPE1Plasma	-940.8541	1815.7684	-0.52	0.6044
TVONWD1Gr10:TVTYPE1Plasma	418.9083	1846.1024	0.23	0.8205
TVONWD1LessHour:TVTYPE1Projection	-2094.9059	2146.9297	-0.98	0.3292
TVONWD1OneTo3Hrs:TVTYPE1Projection	-1639.6049	1851.1064	-0.89	0.3758
TVONWD1ThreeTo6Hrs:TVTYPE1Projection	-2152.3377	1812.9470	-1.19	0.2352
TVONWD1SixTo10Hrs:TVTYPE1Projection	-925.1902	1837.7040	-0.50	0.6147
TVONWD1Gr10:TVTYPE1Projection	1530.2305	1911.2140	0.80	0.4234
TVONWD1LessHour:TVTYPE1LED	-4513.1128	2901.1001	-1.56	0.1198
TVONWD1OneTo3Hrs:TVTYPE1LED	-1678.7884	2013.2805	-0.83	0.4044
TVONWD1ThreeTo6Hrs:TVTYPE1LED	-2106.7446	1923.5912	-1.10	0.2735
TVONWD1SixTo10Hrs:TVTYPE1LED	-3418.0720	2390.7609	-1.43	0.1528
TOTSQFT_EN:TYPEGLASSSinglePane	-0.1921	0.1586	-1.21	0.2259
TOTSQFT_EN:TYPEGLASSDoublePane	-0.0336	0.1540	-0.22	0.8271
TOTSQFT_EN:TYPEGLASSTriplePane	0.0093	0.2093	0.04	0.9644
Income:EthRaceFALSEAfAm	0.0031	0.0027	1.14	0.2548
Income:EthRaceFALSEAsian	-0.0243	0.0034	-7.16	0.0000
Income:EthRaceFALSEMulti	-0.0168	0.0069	-2.43	0.0153
Income:EthRaceFALSENativeAm	0.0117	0.0123	0.95	0.3425
Income:EthRaceFALSEOther	-0.0249	0.0083	-2.99	0.0028
Income:EthRaceFALSEPacific	-0.0163	0.0138	-1.18	0.2378
Income:EthRaceTRUEAfAm	-0.0120	0.0165	-0.73	0.4672
Income:EthRaceTRUEAsian	-0.0365	0.0454	-0.80	0.4219
Income:EthRaceTRUEMulti	-0.0291	0.0212	-1.37	0.1693
Income:EthRaceTRUENativeAm	-0.0187	0.0148	-1.26	0.2077
Income:EthRaceTRUEOther	-0.0262	0.0099	-2.63	0.0085
Income:EthRaceTRUEPacific	-0.0122	0.0380	-0.32	0.7474
Income:EthRaceTRUEWt	-0.0192	0.0031	-6.29	0.0000
StrTenureOwnSFDetached:TOTSQFT_EN:HDD65	0.0001	0.0000	4.10	0.0000
StrTenureOwnLgApartment:TOTSQFT_EN:HDD65	-0.0001	0.0001	-0.96	0.3381
StrTenureOwnMobile:TOTSQFT_EN:HDD65	0.0004	0.0001	5.98	0.0000

StrTenureOwnSFAttached:TOTSQFT_EN:HDD65	-0.0000	0.0000	-0.55	0.5812
StrTenureOwnSmApartment:TOTSQFT_EN:HDD65	0.0000	0.0001	0.54	0.5866
StrTenureRentLgApartment:TOTSQFT_EN:HDD65	-0.0002	0.0001	-4.00	0.0001
StrTenureRentMobile:TOTSQFT_EN:HDD65	0.0004	0.0002	1.76	0.0779
StrTenureRentSFAttached:TOTSQFT_EN:HDD65	0.0000	0.0001	0.60	0.5479
StrTenureRentSFDetached:TOTSQFT_EN:HDD65	0.0000	0.0000	0.55	0.5813
StrTenureRentSmApartment:TOTSQFT_EN:HDD65	-0.0001	0.0001	-1.86	0.0632
StrTenureOwnSFDetached:TOTSQFT_EN:CDD65	0.0008	0.0000	19.21	0.0000
StrTenureOwnLgApartment:TOTSQFT_EN:CDD65	-0.0002	0.0002	-0.82	0.4140
StrTenureOwnMobile:TOTSQFT_EN:CDD65	0.0009	0.0001	7.32	0.0000
StrTenureOwnSFAttached:TOTSQFT_EN:CDD65	0.0006	0.0001	5.01	0.0000
StrTenureOwnSmApartment:TOTSQFT_EN:CDD65	0.0001	0.0003	0.40	0.6875
StrTenureRentLgApartment:TOTSQFT_EN:CDD65	0.0000	0.0001	0.39	0.6946
StrTenureRentMobile:TOTSQFT_EN:CDD65	0.0024	0.0004	6.32	0.0000
StrTenureRentSFAttached:TOTSQFT_EN:CDD65	0.0007	0.0002	4.02	0.0001
StrTenureRentSFDetached:TOTSQFT_EN:CDD65	0.0008	0.0001	9.27	0.0000
StrTenureRentSmApartment:TOTSQFT_EN:CDD65	0.0005	0.0002	2.84	0.0046

Table 8: Orthodox Square Foot Model

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1944.2850	75.4800	25.76	0.0000
RENTHELPTRUE	182.1575	82.5453	2.21	0.0274
StrTenureOwnLgApartment	-1374.2383	67.6666	-20.31	0.0000
StrTenureOwnMobile	-1095.7710	47.1356	-23.25	0.0000
StrTenureOwnSFAttached	-493.4629	52.5900	-9.38	0.0000
StrTenureOwnSmApartment	-776.3654	87.1475	-8.91	0.0000
StrTenureRentLgApartment	-1393.2440	30.1078	-46.28	0.0000
StrTenureRentMobile	-1202.7143	95.8133	-12.55	0.0000
StrTenureRentSFAttached	-807.0103	62.9410	-12.82	0.0000
StrTenureRentSFDetached	-561.3334	38.9760	-14.40	0.0000
StrTenureRentSmApartment	-1142.2015	41.4263	-27.57	0.0000
Income	0.0079	0.0003	30.04	0.0000
reporttot	11.6455	2.0454	5.69	0.0000
EDUCATIONNoHS	45.4843	77.6015	0.59	0.5578
EDUCATIONHS	77.1327	73.4168	1.05	0.2935
EDUCATIONSomeCol	131.9180	74.1386	1.78	0.0752
EDUCATIONAA	123.6675	77.9407	1.59	0.1126
EDUCATIONBA	330.4375	75.4797	4.38	0.0000
EDUCATIONMA	334.8239	80.7072	4.15	0.0000
EDUCATIONProf	585.2435	104.0935	5.62	0.0000
EDUCATIONPHD	436.0771	115.7913	3.77	0.0002
URUrban	-232.6741	24.4942	-9.50	0.0000
reporttot:EthRaceFALSEAfAm	-6.9645	4.4105	-1.58	0.1143
reporttot:EthRaceFALSEAsian	-6.5949	8.0953	-0.81	0.4153
reporttot:EthRaceFALSEMulti	-18.6324	10.3186	-1.81	0.0710
reporttot:EthRaceFALSENativeAm	-11.9507	11.6925	-1.02	0.3068
reporttot:EthRaceFALSEOther	0.1925	14.9557	0.01	0.9897

reporttot:EthRaceFALSEPacific	-34.7044	19.0077	-1.83	0.0679
reporttot:EthRaceTRUEAfAm	-18.4892	31.5771	-0.59	0.5582
reporttot:EthRaceTRUEAsian	-24.6105	43.8328	-0.56	0.5745
reporttot:EthRaceTRUEMulti	4.1417	17.6508	0.23	0.8145
reporttot:EthRaceTRUENativeAm	-19.0098	37.4768	-0.51	0.6120
reporttot:EthRaceTRUEOther	5.9743	13.0668	0.46	0.6475
reporttot:EthRaceTRUEPacific	-19.2825	57.2286	-0.34	0.7362
reporttot:EthRaceTRUEWt	-22.7295	5.5102	-4.12	0.0000

A.1 System Estimation Results

Table 9: System Estimation of kWh Model

	Estimate	Std. Error	t value	Sig
(Intercept)	-547.7160	1505.7185	-0.3638	
ElecMealsThreeDay	1375.6512	440.4367	3.1234	*
ElecMealsTwoDay	1600.5524	212.9011	7.5178	***
ElecMealsOneDay	1686.5705	175.7809	9.5947	***
ElecMealsFewWeek	1470.9015	204.6759	7.1865	***
ElecMealsOneWeek	1702.6234	412.2076	4.1305	***
ElecMealsLessWeek	1040.6175	383.9259	2.7105	*
NUMFRIG	2041.4460	167.4981	12.1879	***
AgeFridge2to4Years	2.9750	216.7455	0.0137	
AgeFridge5to9Years	193.7201	211.8752	0.9143	
AgeFridge20PlusYears	248.7269	479.4517	0.5188	
AgeFridge10to14Years	358.7208	241.2085	1.4872	
AgeFridge15to19Years	-117.8308	320.5402	-0.3676	
NUMPC	418.1593	72.6452	5.7562	***
TIMEON1OneTo3Hrs	-69.0487	183.3079	-0.3767	
TIMEON1ThreeTo6Hrs	-13.1604	200.3356	-0.0657	
TIMEON1SixTo10Hrs	233.6172	289.5477	0.8068	
TIMEON1Gr10	889.8391	292.0892	3.0465	*
WELLPUMPTRUE	1411.7137	279.3720	5.0532	***
ElecWaterSmall	4275.4234	278.7125	15.3399	***
ElecWaterMed	4404.4543	180.8300	24.3569	***
ElecWaterLrg	5779.6329	300.7620	19.2166	***
ElecWaterTankless	3020.2905	995.0797	3.0352	*
SWIMPOOLTRUE	3627.7895	364.5886	9.9504	***
ElecPoolTRUE	5201.5011	1709.7956	3.0422	*
RECBATHTRUE	1882.7243	691.6599	2.7220	*
ElecTubTRUE	310.9469	794.7220	0.3913	
NHSLDMEM	1014.0356	56.8306	17.8431	***
Income	-0.0021	0.0032	-0.6434	
TVONWD1LessHour:TVTYPE1Standard	-2571.5913	1483.2943	-1.7337	
TVONWD1OneTo3Hrs:TVTYPE1Standard	-2304.5338	1463.4167	-1.5748	
TVONWD1ThreeTo6Hrs:TVTYPE1Standard	-1804.8250	1469.5580	-1.2281	
TVONWD1SixTo10Hrs:TVTYPE1Standard	-1136.4160	1452.3312	-0.7825	
TVONWD1Gr10:TVTYPE1Standard	-739.2962	1482.9861	-0.4985	

TVONWD1LessHour:TVTYPE1LCD	-2139.9144	1487.6184	-1.4385	
TVONWD1OneTo3Hrs:TVTYPE1LCD	-1526.1157	1472.2723	-1.0366	
TVONWD1ThreeTo6Hrs:TVTYPE1LCD	-1183.2819	1456.8798	-0.8122	
TVONWD1SixTo10Hrs:TVTYPE1LCD	-944.2670	1440.7984	-0.6554	
TVONWD1Gr10:TVTYPE1LCD	211.0419	1479.7559	0.1426	
TVONWD1LessHour:TVTYPE1Plasma	-387.6774	1879.4130	-0.2063	
TVONWD1OneTo3Hrs:TVTYPE1Plasma	-766.5487	1583.4746	-0.4841	
TVONWD1ThreeTo6Hrs:TVTYPE1Plasma	-1352.4175	1499.5147	-0.9019	
TVONWD1SixTo10Hrs:TVTYPE1Plasma	-402.8629	1514.6445	-0.2660	
TVONWD1Gr10:TVTYPE1Plasma	889.3760	1569.4195	0.5667	
TVONWD1LessHour:TVTYPE1Projection	-699.8204	1637.1732	-0.4275	
TVONWD1OneTo3Hrs:TVTYPE1Projection	-1218.5567	1534.0730	-0.7943	
TVONWD1ThreeTo6Hrs:TVTYPE1Projection	-1319.9761	1490.3811	-0.8857	
TVONWD1SixTo10Hrs:TVTYPE1Projection	-52.4928	1558.1229	-0.0337	
TVONWD1Gr10:TVTYPE1Projection	2109.5856	1775.7924	1.1880	
TVONWD1LessHour:TVTYPE1LED	-4069.8485	2205.6129	-1.8452	
TVONWD1OneTo3Hrs:TVTYPE1LED	-1017.3486	1706.4396	-0.5962	
TVONWD1ThreeTo6Hrs:TVTYPE1LED	-1379.6589	1638.8949	-0.8418	
TVONWD1SixTo10Hrs:TVTYPE1LED	-2980.6241	2057.1315	-1.4489	
TVONWD1Gr10:TVTYPE1LED				
PSQFT:TYPEGLASSSinglePane	0.5481	0.2887	1.8987	
PSQFT:TYPEGLASSDoublePane	0.7501	0.2804	2.6746	*
PSQFT:TYPEGLASSTriplePane	1.1070	0.3696	2.9950	*
Income:EthRaceFALSEAfAm	0.0052	0.0029	1.7791	
Income:EthRaceFALSEAsian	-0.0230	0.0035	-6.4831	***
Income:EthRaceFALSEMulti	-0.0157	0.0057	-2.7584	*
Income:EthRaceFALSENativeAm	0.0092	0.0211	0.4382	
Income:EthRaceFALSEOther	-0.0237	0.0082	-2.9038	*
Income:EthRaceFALSEPacific	-0.0129	0.0230	-0.5625	
Income:EthRaceTRUEAfAm	-0.0173	0.0139	-1.2454	
Income:EthRaceTRUEAsian	-0.0375	0.0101	-3.7155	**
Income:EthRaceTRUEMulti	-0.0331	0.0192	-1.7208	
Income:EthRaceTRUENativeAm	-0.0163	0.0107	-1.5276	
Income:EthRaceTRUEOther	-0.0274	0.0080	-3.4318	**
Income:EthRaceTRUEPacific	-0.0240	0.0659	-0.3647	
Income:EthRaceTRUEWt	-0.0185	0.0033	-5.5782	***
PSQFT:OwnSFDetached:HDD65	0.0001	0.0000	4.4109	***
PSQFT:HDD65:OwnLgApartment	0.0000	0.0001	0.8450	
PSQFT:HDD65:OwnMobile	0.0004	0.0001	4.6205	***
PSQFT:HDD65:OwnSFAttached	0.0000	0.0000	1.3603	
PSQFT:HDD65:OwnSmApartment	0.0001	0.0000	1.1709	
PSQFT:HDD65:RentLgApartment	-0.0001	0.0000	-1.3292	
PSQFT:HDD65:RentMobile	0.0005	0.0003	2.0238	
PSQFT:HDD65:RentSFAttached	0.0001	0.0001	1.0923	
PSQFT:HDD65:RentSFDetached	0.0001	0.0000	1.7233	
PSQFT:HDD65:RentSmApartment	-0.0000	0.0000	-0.2465	
PSQFT:OwnSFDetached:CDD65	0.0007	0.0000	16.3870	***
PSQFT:OwnLgApartment:CDD65	0.0000	0.0002	0.2207	
PSQFT:OwnMobile:CDD65	0.0011	0.0002	6.7660	***
PSQFT:OwnSFAttached:CDD65	0.0005	0.0001	5.3085	***

PSQFT:OwnSmApartment:CDD65	0.0003	0.0002	1.8671	
PSQFT:RentLgApartment:CDD65	0.0003	0.0001	2.5551	.
PSQFT:RentMobile:CDD65	0.0020	0.0009	2.2066	
PSQFT:RentSFAttached:CDD65	0.0009	0.0002	4.9470	***
PSQFT:RentSFDetached:CDD65	0.0008	0.0001	8.8123	***
PSQFT:RentSmApartment:CDD65	0.0005	0.0001	3.5753	**