THREE ESSAYS ON ENERGY EFFICICNY POLICY

by

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A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Department of Economics

2013

This thesis entitled:

Three Essays on Energy Efficiency Policy

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has been approved for the Department of Economics

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Date: October 8th, 2013

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Three Essays on energy efficiency Policy

Thesis directed by Associate Professor Scott J. Savage

This thesis is comprised of three essays which explore selected aspects of the demand side energy efficiency policy of International Energy Conservation Codes (IECC). The first essay models the adoption of IECC in the U.S. between 1998 and 2010. An ordered probit model with IECC adoption as the dependent variable is used to test if a set of socio-economics, political, spatial, and environmental factors predict the residential building energy code adoption. The results show that higher energy price, relative political extraction, climate extremes, pollution level, and population growth predict IECC adoption in the sample. The diffusion variable (share of neighbor states with IECC) is shown to have a large impact on the probability of adoption of IECC.

The next two essays examine the effect of IECC on residential electricity consumption. The second essay investigates the impact of IECC on per-capita residential electricity consumption for 44 U.S. states from 1981-2008. Applying the pooled mean group (PMG) model developed by Pesaran *et al*. (1999a), and controlling for energy specific demand factors such as: prices, income, heating degree days, and cooling degree days, I find that there is an overall 2% decrease in new residential buildings per-capita electricity consumption in the states which adopted any version of IECC. The new residential buildings per-capita electricity consumption has decreased by about 2.5% and 5% in the states with IECC 2000 and IECC 2003 respectively.

The third essay examines the impact of building energy code on the household electricity consumption in three states in U.S. To do so; I construct a pseudo panel using household level data from the American Community Survey (ACS) over the period 2005-2010. By constructing pseudo panel, we are able to track cohorts of relatively homogeneous individuals over time, and control for cohort unobserved heterogeneity that may bias the results of cross sectional estimates. The empirical analysis employs pseudo panel approach on pre- and post-code change comparisons method. I find that the increased stringency of energy code from IECC 2003 to IECC 2006 is associated with a 19% decrease in new house's electricity consumption.

Dedication

To my love, Mehdi, my beautiful sons, Rayan and Radeen, and my beloved Parents.

Acknowledgments

I would like to express my appreciation to Prof. Scott Savage for being an outstanding advisor throughout the years. His excellent guidance, kind encouragement and support made this work successful. He has been everything that one could want in an advisor. I would also like to thank my co-advisor, Prof. Donald Waldman for his encouragement and invaluable suggestion during this work.

I am deeply indebted to my committee member Prof. Jin-Hyuk Kim, Prof. Daniel Kaffine, and Prof. Harrison Fell for their time and helpful comments for this work.

Without the unconditional love and support of my husband Mehdi and encouragement of my family, this work would not have been possible.

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Chapter 1

Introduction

Energy efficiency policies and their potential impacts on energy consumption and greenhouse gas emission have been an increasingly discussed in the literature. The energy efficiency policies encourage people to consume less energy and achieve the national energy goal at low or no cost. The building energy code is one of the demand side-management energy efficiency policies. The following three essays address selected aspects of the residential building energy code in different approaches. From one point of view, identifying the factors affecting the adoption of the building energy code by states are taking place. In particular, the analysis focuses on the newest version of the building energy code IECC. The IECC are applicable on new constructions and sometimes it is so expensive or even impossible to apply the codes on the old houses. On the other hand, the impact of these building energy codes on energy consumption is analyzed. The last two essays in the dissertation examine how residential electricity consumption has changed in response to adopting of the IECC in macro- and micro-level in U.S.

One of the implications of IECC adoption by states, established in the first essay, is that there is no uniform rule for adopting the building energy code in U.S. It is not clear why some states adopt or intend to adopt IECC and others do not. The impact of most of the Socio-economics, political, spatial, and environmental variables on probability of adoption of IECC are found to be consistent with theories and previous studies. Furthermore, the empirical results suggest that, the odds of adopting of IECC are increasing for the states with higher level of energy price, climate extremes, relative political extraction, population growth, and pollution level. It is shown that the impact of neighbor state on adoption of IECC is highly significant and IECC diffuses among these neighborhoods quickly.

One of the main goals of the residential building energy code is decreasing the energy consumption in new constructions. This outcome is explored empirically in chapters 3 and 4 using state level data and household level data for U.S. it is shown that per-capita electricity consumption of new houses has declined in the states which adopted any version of IECC.

The third essay (chapter4) shifts the focus from macro level data to household level data. As we expected the new buildings electricity consumption has decreased in three states which updated their building code from IECC 2003 to IECC 2006.

Chapter 2

What Drives IECC Adoption?

2.1 Introduction

Since 1970's, most of the states in U.S. have adopted several state- and federal- level energy efficiency policies for the purpose of reducing the amount of energy consumption of appliances, vehicles, and buildings. International Energy Conservation Codes (IECC) is their most recent residential building energy policy choices. IECC typically focus on thermal resistance requirements of the wall and windows, minimum air leakage, and minimum efficiency for heating and cooling systems in a building. Adopting the IECC's by states has several energy, economics, and environmental advantages for the nation. The building energy code saves on energy bills by decreasing the peak demand for energy. Motamedi *et al.* (2004) show that the building energy code saved residence and businesses about $158 billion in electricity and natural gas cost since 1975 in California. Adoption of energy efficient technologies in residential and commercial buildings could also slow down the associated emission of energy consumption at low cost or at a net savings (Prindle *et al.* (2006)). States and jurisdictions gain benefits from investment in energy efficient capital equipment, job creation from installing the equipment, and monitoring building compliance. Dollars saved from energy efficient building codes offset the expenditures on energy services typically sends money out of the states (Kushler *et al* (2005)).

The number of state-level adoption of IECC has been growing since it was introduced for the first time as building energy code in the late 1990's, with 52 adoptions of different levels of IECC occurring just from 2008 to 2013. Heretofore, there are a few studies have focused on adoption of building energy code, and none so far consider the adoption of IECC.[1] Oster *et al.* (1977) investigate the diffusion pattern of four particular improved techniques in residential construction for U.S. They find that the education level of chief building official, the extent of utilization, and the relative size of house building companies in a jurisdiction impact the diffusion of innovations in the residential buildings. Kok *et al*. (2012) analyze the diffusion of building certificates for energy efficiency in commercial offices. They find that diffusion was rapid in the metropolitan areas which had higher income, and energy price. The diffusion of green space is facilitated by professional education program and governmental policies as well. Nelson (2012a) and (2012b) conduct a Cox proportional hazards model for adoption of commercial and residential building energy codes in U.S. He finds that colder climate and energy price do not predict more frequent code adoption for both residential and commercial buildings. He shows that wealthier states are more likely to adopt commercial codes while he cannot find significant relationship between wealth and code adoption for residential building. He also shows there is no evidence of political ideology in a state driving commercial and residential building energy codes adoption.

The purpose of this study is to investigate the factors affecting the adoption of IECC by states in U.S. This paper employs ordered probit and instrumental variables ordered probit models with IECC adoption as the dependent variable and a set of socio-economics, political, spatial, and environmental factors to meet the objective. To test for the validation of empirical model choice I compare the results of ordered probit model with those of a Poisson regression and two-stage least-square models and confirm that the ordered probit model is supported by data. The findings

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[1] There is a growing literature on adoption of different laws and regulations such as renewable portfolio standards (Carcamo et al. (2010), Chandler (2009), and Huang (2007)), and banking system (Kroszner et al. (1999))

suggest that factors such as energy price, climate extremes, relative state funding, pollution level, and population growth have positive impact on the odds of building energy code adoption. The diffusion variable (share of neighbor states with IECC) is an important factor in adoption of IECC by states. It is also shown that the Democratic Governor in a state drives the adoption of IECC. In the next section, I explain the IECC and its adoption process in the U.S. Section 3, describes the model used to evaluate the adoption of IECC. Section 4, discuss the data. Results are provided in section 5. Conclusions are offered in the last section.

2.2 International Energy Conservation Code (IECC)

IECC is one of the 14 model codes developed by the International Code Council (ICC) which provides the foundation for a complete set of building construction regulations. The IECC regulates energy conservation requirements for new residential and commercial construction at minimum level, using performance and prescriptive plans. The IECC impacts energy usage of heating and ventilation, water heating, air-conditioning, power usage for appliance and building systems, and electrical lighting in a construction. It also requires minimum level of mechanical duct system insulation, water distribution system insulation, and building systems insulation such as walls, roofs, windows, and doors.

The building energy code can significantly impact design, and sometimes more than the actual requirements. The building designers can choose the appropriate designs such as prescriptive-based, performance-based, or trade-off approaches. Their choices depend on the complexity and uniqueness of the building, time, and the available money for demonstrating compliance.[2] The U.S. Department of Energy (DOE) and the Building Energy Code Program (BECP) develop and implement the energy efficient codes and standards in buildings. They provide technical assistance to states and localities for adoption and enforcing the building energy code.

The first version of IECC was released in 1998 and it is updated every three years since 2000. Once the revised code are published, each state should declare that it has reviewed its residential building energy code regarding energy efficiency and make a decision as to adopt it in full, adopting it with amendments or taking no action at all. The states and local governments often can make changes on the IECC before adoption in order to reflect their building practices or state-specific energy efficiency goals. The building energy codes are adopted either directly through the legislative process, the codes are updated by a bill which is passed by the state legislature and signed by the governor; or a regulatory process, a state agency is granted by legislatures to issue a coed; or most commonly through a combination of both legislative and regulatory process. Table 2.1 shows detail code change process for each state.

As of May 2013, 44 states and the District of Colombia have adopted the different versions of IECC (Table 2.2). Maryland and Illinois have adopted the most stringent version (IECC 2012) and California, Washington, and Utah have plans to increase the stringency of their building energy codes (Figure 2.1). There are no uniform rules for states to adopt these energy efficient standards. California, Florida, Iowa, Nebraska, Alaska, and New York were the first states

[2] The prescriptive-based approach is a set of prescribed requirements that tells what to do exactly without trading off anything or trying to evaluate how the building performs. The performance-based allows to comparing the designers proposed design to a reference design and indicates that if it at least as efficient as the baselines in terms of usual energy use. A trade-off approach allows trading enhanced energy efficiency in one component against reduced energy efficiency in another component.

adopted IECC or revised their state-developed codes based on the IECC. Since that time, these states have been updated their building codes based on the latest edition of the IECC.

While the incentive for adopting IECC is growing across the nation, it is not clear why some states adopt or intend to adopt IECC and others do not. The IECC decreases building energy consumption, reducing power demand, and has less of an environmental impact. Therefore, IECC can be considered as an innovation that can be resulting in significant cost savings in both the private and public sectors of the U.S. economy. It is important to determine the factors influencing the adoption of this efficient building code and the scare resources which can be allocated more efficiently for a wider diffusion of IECC (Rogers, 1995).

2.3 Empirical Model

To analyze the factors that affect adoption of IECC by states in the U.S., I formulate an econometric model using a ranked discrete dependent variable which represents the different versions of IECC adopted by each state. Because there are more than two versions of IECC, an ordered probit model is chosen to address the ranked form of the dependent variable. The ordered probit model used to predict IECC adoption is specified as follows:

$$y_{it}^* = \beta' x_{it} + \varepsilon_{it} \tag{1}$$

for $i = 1, \ldots, N$, and $t = 1, \ldots, T$ where y_{it}^*, unobserved dependent variable reflects the desirability of a state to adopt energy saving building codes which is the most appropriate for their locale; β is a vector of coefficient to be estimated; x_{it} is a vector of independent variables, including the relative political extraction, energy cost, population growth, Governor Ideology, share of bordering states with IECC, coastline states, and natural log of per-capita disposable income, degree days, and pollution level; and ε_{it} is the error term. The variable y_{it}^* itself is not observed but y_{it} the observed counterpart of y_{it}^*, taking one of the values $\{0,1,\ldots,5\}$, and is related to y_{it}^* as follows:

$y_{it} = 0 \quad if \quad y_{it}^* < \alpha_0$

$y_{it} = 1 \quad if \quad \alpha_0 \leq y_{it}^* < \alpha_1$

$y_{it} = 2 \quad if \quad \alpha_1 \leq y_{it}^* < \alpha_2$

$y_{it} = 3 \quad if \quad \alpha_2 \leq y_{it}^* < \alpha_3$

$y_{it} = 4 \quad if \quad \alpha_3 \leq y_{it}^* < \alpha_4$

$y_{it} = 5 \quad if \quad \alpha_4 \leq y_{it}^*$

where α_j is the threshold variable such that $\alpha_0 < \alpha_1 < \cdots < \alpha_4$ and are treated as parameters to be estimated. The range of y_{it}^* is partitioned into 6 mutually exclusive and exhaustive intervals. The ordinal variable y_{it} takes a value of j if y_{it}^* falls into jth category. The probability of particular observation $y = j$ is equal to:

$$\begin{aligned} \Pr[y_{it} = j] &= \Pr\left[\alpha_{j-1} \leq y_{it}^* < \alpha_j\right] \qquad (3) \\ &= \Pr[\alpha_{j-1} - \beta' x_{it} \leq \varepsilon_{ti} < \alpha_j - \beta' x_{it}] \\ &= F\left(\alpha_j - \beta' x_{it}\right) - F(\alpha_{j-1} - \beta' x_{it}) \end{aligned}$$

where F is the cumulative standard normal distribution function. The ordered probit model coefficients do not directly represent the effect of a one-unit change in the explanatory variable on the ordered dependent variable. These coefficients can be translated into a probability of being in each of the five levels of dependent variable.

The marginal effect for each value of dependent variable provides an estimate of the magnitude of the impact that each explanatory variable has on each level of the dependent variable, compared with the other groups. The marginal effect of explanatory variable on the probability of the jth level is given by:

$$\partial \Pr(y = j)/\partial x = \beta[f(\alpha_{j-1} - \beta' x_{it}) - f(\alpha_j - \beta' x_{it)}] \quad (4)$$

where f is the standard normal density function. The model is estimated by maximum likelihood function approach in order to have consistent and efficient estimated parameters.

Some econometric problems may arise from estimating of Eq. (1). First, energy price and pollution level could be endogenous and yield biased and inconsistent estimated coefficient. To account for the endogeneity problems I use lagged value of energy price and pollution level (up to two lags) to instrument for current energy price and pollution level (Arellano *et al.* (1995) and Blundell *et al*. (1998)). The lagged values make the endogenous variables pre-determined and, therefore, not correlated with the error term in Eq. (1).[3] Second, one limitation of ordered probit model is that it specifies several thresholds. In this paper I have used five level of IECC as a threshold. For robustness of the ordered probit model results to the thresholds, I estimate Poisson and two-stage least-square regressions on the total number of IECC level.

2.4 Data

To estimate the model, this paper uses panel data of 51 states from 1998-2010. Table 2.3 summarizes the descriptive statistics for all independent variables in whole sample data.

2.4.1 Dependent Variable

The dependent variable is the whether or not a state has adopted any version of IECC in a particular year. The dependent variable ranked from 0 to 5, 0 for the states with no code, 1 for states with IECC 1998, 2 for IECC 2000, 3 for IECC 2003, 4 for IECC 2006, and 5 for IECC

[3] The paper uses pooled instrumental variables ordered probit mode developed by Roodman (2008, 2009) in STATA.

2009. Data to construct the ordered ranked IECC has been provided by Building Code Assistance Project (BCAP 2013).

2.4.2 Independent Variables

The independent variables and their expected relationship with IECC adoption are provided below. These variables are divided into four categories: socio-economics, political, spatial and environmental.

2.4.2.1 Socio-Economics Variables

It is expected that wealthy states have more tendency to adopt the building energy code and are be able to fund the high level of human and capital expenditure of energy efficient policies. Kok *et al.* (2012) finds that personal income positively impacts the adoption of energy efficient (Energy Star) and sustainable construction practices. Per-capita disposable income is used as a measure of wealth. This variable is in logarithm format to keep it from being much larger or smaller than the other independent variables. The range of per-capita disposable income is between $11,308 in Mississippi and $30,061 in District of Colombia, with an average value of $15,589 (Table 2.2). The state per-capita disposable income data comes from Bureau of Economic Analysis and are adjusted for inflation.

The other factor which may lead to a successful energy code adoption is the ability of a state to finance implementation of energy code program. The relevant U.S. census category expenditure for building energy code is not necessarily a good way to measure the capacity of a state to adopt a building energy code. Huang *et al*. (2007) show that natural resource expenditure has a negative impact on the adoption of renewable portfolio standards (RPS).

Following Nelson (2012b) this paper uses relative political extraction (RPE) which controls for population and level of development rather costs of administering the natural resource expenditures within the states. RPE measures the relative state and local government tax efforts. There are three steps to calculate the RPE based on the tax effort of the states. First step; obtain ordinary least squares estimates for the following specification:

$$TaxEffort/GSP_{it} = \alpha_0 + \alpha_1 Year_{it} + \alpha_2 GSP_{it} + \alpha_3 Mining/GSP_{it} + \alpha_4 Oli\&Gas/GSP_{it} + \alpha_5 Ag/GSP_{it} + \alpha_6 Population_{it} + e_{it} \quad (5)$$

Where, $year$ is the data field year, GSP is the per-capita Gross State Product (GSP), $Mining/GSP$ is the share of mining output to GSP, $Oil\&Gas/GSP$ is the share of oil and gas output to GSP, Ag/GSP is the share of agricultural output to GSP, and $Population$ is the natural logarithm of current year population. Second step; get the predicted value for TaxEffort/GSP from Eq. (5). Last step; calculate RPE from the following ratio:

$$Political\ Capacity_{it} = STR_{it}/\widehat{STR}_{it} \quad (6)$$

Where STR represents the observed value for state tax effort and $\widehat{STR}$ is the predicted value obtained from Eq. (5).[4] The mean value of this variable is shown to be 1.00, with the lowest value for Tennessee (0.59) and the highest value for Alaska (2.33). These data are obtained from U.S. Census State and Local government Finances data set.

Costa *et al.* (2011) show that there is a strong empirical evidence that houses built during periods of higher energy price is more energy efficient. Therefore, I expect that states which experience higher energy price are more likely to adopt the building energy code. The measure of energy cost is the average residential energy price for each state. Utah has the lowest energy

[4] The observed value of tax effort is defined as: Tax effort: Total own Source revenue less (utility revenue, social security contribution, and liquor store revenue) plus (liquor store net income)

price of 5.03 $\$/mBTU$ in 1999 and Hawaii has the highest energy price of 40.34 $\$/\mathrm{mBTU}$ in 2008. Energy cost is measured in current value and is from the Energy Information Administration.

It is hypothesized that a state with higher population growth will need more new residential buildings and investigates on recent and aggressive codes. The growth rate of population changes from negative growth rate of 0.059 for Louisiana to positive growth rate of 0.05 for Nevada.

The percent of the population 25 years and older with at least a bachelor's degree is used as economic development factor. Huang *et al*. (2007) conclude that high education level has a positive and great impact on probability to adopt RPS in a state. He argues that a person with higher education level is informed the negative consequences of fossil fuels consumption and political problems of dependency on foreign energy sources. Nelson (2012a) also finds a positive and significant effect of high school graduate level on adopting new residential code vintages. The average bachelor's degree is 26.2%, with the lowest in West Virginia (6.6%) and the highest in District of Colombia (50.1%). The education data comes from U.S. Census.

2.4.2.2 Political Variable

Political variables may also impact adoption of building energy code by states. Literature on American history shows that the state policy makers' percentage of pro-environmental laws in particular occurred in both Republican and Democratic parties. Huang *et al*. (2007) and Carcamo (2010) find that the states with majority of Republican representatives are less likely to adopt an RPS policy. Nelson (2012a) finds no evidence of voters voting for the Republican candidates in the presidential election on the adoption of residential building energy code. The binary variable is created and it is one if states Governor is Republican and zero otherwise.[5] The summary statistics shows that more than half of the state-year observations are dominated by the Republican Party.

2.4.2.3 Spatial Variables

The building energy code in a jurisdiction could have delay or speed up the adoption of these codes in neighbor jurisdictions. Nelson (2012a) argues that the adoption of building energy code are slow in the jurisdictions which are in competition with neighbor states to attract local commercial business or residence who care about the buildings initial cost. The operating and maintenance costs are lower than initial cost in energy efficient buildings. In the other hand, the adoption might be speed up by the diffusion of building practices by interstate construction companies, or by policy networks of code officials and policy makers. He finds a potential race to the bottom for residential building energy code. Chandler (2009) shows the share of neighbor states with Sustainable Energy Portfolio Standards (SEPS) positively impact the probability of adoption of this policy in a jurisdiction. The policy diffusion variable in this study is the share of bordering states for which adopted IECC. This variable changes from zero for the states with no neighbor state adopted IECC to one for the states surrounding by states which already have adopted any version of IECC.

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[5] In 1871, Congress created a territorial government for the entire District of Columbia, which was headed by a governor appointed by the President of the United States to a four-year term. Due to alleged mismanagement and corruption, including allegations of contractors bribing members of the District legislature to receive contracts, the territorial government was discontinued in 1874. Currently, the Mayor of the District of Columbia is popularly elected to a four-year term with no term limits. Even though Washington, D.C. is not in a state, the city government also has certain state-level responsibilities, making some of the mayor's duties analogous to those of United States governors. Source: http://en.wikipedia.org/wiki/List_of_mayors_of_Washington,_D.C.

Climate has an important impact on the energy consumption in residential building. The buildings in jurisdiction located in a cold or hot climate zones consume more energy for heating and cooling therefore the jurisdiction prefers to adopt building energy code. I use state's cooling degree days (CDD) and heating degree days (HDD) as a measure for climate variable. The data for CDD and HDD are obtained from National Oceanic and Atmospheric Administration and are population weighted. Value of degree days (sum of CDD and HDD) ranges from 3287 (California) to 15231 (Alaska) with an average value of 6346. Another factor which may influence adoption of building energy code is the geographic location of states. Figure 2.1 shows that most of the states located in coastlines prefer more recent and aggressive version of IECC. A binary variable is created. If the state is located in the coastline, a value of one is assigned and zero otherwise.[6]

2.4.2.4 Environmental Variable

Lastly, this study considers pollution level in states as an environmental factor which may influence the adoption of building energy code. One of the main targets of implementation of building energy code is reducing the level of greenhouse gas emission. A state with high level of greenhouse gas emission is more likely to adopt energy efficient building code. Bishwa *et al*. (2013) show that if all homes apply IECC 2003 and IECC 2006 effectively the greenhouse gas emission decrease by 7.54 million metric tons per year. The data for greenhouse gas emission comes from Energy Information Administration.

[6] There are 23 states which have an Ocean/Gulf of Mexico coastline, and 8 states that only have a Great Lake coastline.

Table 2.4 provides summary statistics for state-year observations which adopted any version of IECC and not adopted. These data suggest that states with any version of IECC experience higher energy price, income, RPE, and pollution level. These states also are located more on the coastlines and in the neighborhood of states which already adopted any version of IECC.

2.4.3 Evidence on the Adoption of IECC

Figure 2.2 presents a series of scatter plots and fitted regression line reporting the bivariate relationships between adoption of IECC and lagged values of the explanatory variables. Panel (A) shows income is positively related to the adoption of IECC. This positive correlation confirms the positive relationship between wealth and willingness to pay for environmental goods (Roe *et al.* 2001). Panel (B) presents the bivariate relationship between energy price and the adoption of IECC. The positive association between residential energy price and the adoption of IECC is consistent with conventional investment theory which says higher energy price improves the economic return to energy efficient investments, *ceteris paribus.*

Panel (C) relates adoption of IECC to climate variable. One would expect the adoption of IECC to be positively and directly related to degree days, but it seems that surprisingly the building energy codes are unrelated to sever climate conditions. Panel (D) shows there is a positive correlation between states located on the coastal lines and adoption of IECC. This relationship confirms that coastal states are more temperate and are more likely to adopt building energy code. In Panel (E), RPE is associated positively and strongly to the diffusion of energy efficiency technology in residential buildings. This relationship confirms that RPE is a superior measure of government effectiveness on adoption of IECC because it controls for population, wealth, and economic structure.

Panel (F), share of neighbor states with IECC is related directly and positively to the adoption of the building energy code, which is consistent with diffusion theory—neighbor states with energy efficacy policy increase the probability of adoption of the policy in a jurisdiction. In Panel (G), I relate education level to the adoption of IECC. Quite clearly, there is a positive correlation between education level and diffusion of IECC. This is consistent with the work of Huang *et al.* (2007) and Nelson (2012a), who document a positive effect of education on the adoption of energy efficiency policies.

Panel (H) relates political preferences in the states to the adoption of IECC. The importance of government ideology in the states seems unrelated to the adoption of IECC in residential sector. Panel (I) presents the simple correlation between pollution level and the diffusion of technologies resulting in IECC. There is a fairly positive association between greenhouse gas emission and the adoption of IECC, which is consistent with public interest theory of regulation—regulation is consequence of the need to protect the public from the negative effects of market failures, such as pollution (Lyon *et al.* 2010). In Panel (J), population growth is positively related to the adoption of IECC—as suggested in literature that environmental policies are consequence of overconsumption of common pool resources and perceptions of scarcity (Lubell *et al.* 2005)

Of course, all these inferences above ignore the presence of other observables that may impact the variation in adoption of IECC.

2.5 Estimation Results

This section examines the effect of socio-economics, political, spatial and environmental variables on the adoption of any version of IECC by states. First column on Table 2.5 shows the pooled ordered probit model results. Energy price has a positive and significant effect on the adoption of IECC with those states with higher levels of energy price are more likely to adopt any version of IECC. The predicted probabilities for a state's climate extremes and the odds of adopting IECC are positive and indicate that the more number of days that need energy for heating and cooling are positively correlated with more efficient building energy code. The positive coefficient on coastline confirms the hypothesis that the states located on coastline are more likely to adopt the IECC than the interior states, but these coefficients are not statistically significant.

The coefficient on wealth shows no statistically significant relationship between per-capita income and probability of adopting IECC by a state. Another economic development factor can be used as a measure of wealth is per-capita Gross State Product (GSP). Appendix A shows the ordered probit model estimation results with per-capita gross state products. The coefficient on GSP is also positive but not statistically significant. The coefficient on RPE variable is found to be positively related to the IECC and statistically significant at five percent significant level, indicating that the more relative tax effort a state has the more that state is likely to adopt the building energy code. Nelson (2012a) and (2012b) also find that RPE is an important predictor of building energy code adoption for residential and commercial buildings.

The diffusion variable shows a potential race to the top for residential building energy code. A state surrounded by neighbor states which have already adopted any version of IECC is more likely to adopt the building energy code. The negative sign on political variable suggests that states with Republican Party Governor are less likely to adopt the building energy code relative to states with Democratic Party Governors. The positive coefficient on pollution indicates that the more a state is concerned about pollution level, the more is likely to adopt the IECC.

Educational attainment has been found to be insignificant with positive sign. High level of fertility or in-migration in a states increase the odds of adopting building energy code. Estimates of the five threshold parameters (α) are significant at the one percent level.

Second column on Table 2.5 reports the second stage of pooled instrumental variables ordered probit estimation results. The instrumental variables estimation results are very similar to the results of ordered probit model. The instruments are discussed in section 3. The first stage of instrumental variables method shows that two lagged energy price and pollution level instruments are positive and highly significant (see Appendix B).

Table 2.6 shows the outcomes of testing for the choice of empirical model by comparing the results from the ordered probit and instrumental variables ordered probit models with those of a Poisson regression and two-stage least-square equation. The estimated results are comparable to the ordered probit and instrumental variables ordered probit model coefficients. This confirms our beliefs in the robustness of our result to the type of model fitted to the data.

Marginal effects for ordered probit model are presented in Table 2.7, and give insight into the factors that are most important in the adoption of IECC. For example, the states experience higher energy prices have a probability of adopting IECC 2003 six points higher compared with the other adoption level of IECC. The probability that these states adopt IECC 2006 is five points higher and the probability that they adopt IECC 2000 is three points higher compared with other adoption groups. Similarly, states with more extreme degree days have a probability of adopting IECC 2003 that is 9.4 points higher than others, and a probability of adopting IECC 2006 that is 8.2 points higher than others. States which have Republican Governor are 4.1 points less likely to adopt IECC 2003 than the other groups. PRE, diffusion variable, pollution level, and population growth also impart relatively large changes in the probability of adoption of IECC 2003 across all level of IECC. For a state adopted IECC 2003, an increase of one $\$/mBTU$ in the energy price is equivalent to approximately 15.6 degree days, 4 million metric tons of greenhouse gas emission, and $ 9.5 per-capita income all else equal.

2.6 Conclusion

The adoption and diffusion of newest version of building energy code "IECC" has been widespread and rapid in U.S. since introduced to the nation for first time in the late 1990's. This paper identifies which factors are critical for states in adopting any version the IECC. By May 2013, about 45 states have adopted different versions of IECC at state level. The probability of adoption is high in the states with higher energy price, relative political extraction, climate extremes, pollution level, and population growth. A state's motivation to adopt the building energy code is also due to Democratic Governor. It has shown that diffusion of IECC among neighbors is important for state adoption. The result for energy price makes important contribution to the policy and decision makers. As opposed to previous studies I found that higher energy price drives to more efficient buildings. If the policy makers would like to encourage the states to adopt the IECC, focus should be more on the states with lower energy price, pollution level and population growth. The policy makers should also increase the relative resource in a state to finance the adoption process of codes. Ceteris paribus, those states that did not adopted IECC but have Republican Party Governor should find out whether political factors are posing challenges to the adoption of IECC.

Table 2.1 - States Code Change Process

State	Code Change Process
Alabama	**Regulatory & Legislative:** Legislation passed in March 2010 the Alabama Energy and Residential Codes (AERC) Board the authority to adopt mandatory residential and commercial energy codes for the entire state and residential building codes for jurisdictions that had not implemented a residential building code prior to March 2010.
Alaska	**Regulatory:** Proposed changes to the standards for residential buildings can be submitted to the Alaska Housing Finance Corporation, which reviews and acts on the proposals. Public hearings are required before changes are adopted.
Arizona	**Legislative & Regulatory:** Arizona is a home rule state, thus codes are adopted and enforced on a local level. The State Energy Code Advisory Commission reviews the state energy code through an open, voluntary and consensus process, performs cost-benefit analyses of potential state incentives for the use of energy saving devices and methods, and provides annual reports on its findings. At present, statewide adoption of energy code, residential and/or commercial, must be mandated by the legislature.
Arkansas	**Regulatory:** After the approval of Act 802 in 2011, the Arkansas Energy Office (AEO) has been granted authority to promulgate rules to update the Arkansas Energy Code. Rules must be approved by Administrative Rules and Regulations Subcommittee of the Arkansas General Assembly.
California	**Regulatory:** The first statewide energy requirements were established in 1975 by the Department of Housing and Community Development for all low-rise residential buildings. In 1974 the California legislature passed the Warren-Alquist Act establishing the California Energy Commission and authorizing the Commission to establish energy requirements for both residential and commercial buildings.
Colorado	**Legislative:** Local jurisdictions can and do adopt their own energy code requirements, but a statewide energy code would have to be promulgated by the state legislature. The legislature meets in regular session on the second Wednesday of January each year, unless the previous year's legislature amends the date of next convening through a joint resolution.
Connecticut	**Legislative & Regulatory:** The local Building Official in each jurisdiction enforces the Connecticut State Building Codes. Codes are said to be updated no more than every four years, by the Connecticut General Assembly who approves codes, and legislature that sets the implementation dates.
Delaware	**Regulatory:** The Delaware Energy Office will adopt the latest versions of the IECC and ASHRAE Standard 90.1. It shall promulgate procedures for certification of compliance with these codes and standards to be utilized by respective local governments.
District of Columbia	**Regulatory & Legislative**: The District of Columbia Construction Codes Coordinating Board (CCCB) advises the mayor and D.C. government on all matters pertaining to the D.C. building codes, and meets regularly throughout the year. The District of Columbia City Council has final approval of all proposed code changes.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
Florida	**Regulatory:** The Florida Building Commission (FBC) is directed to adopt, revise, update, and maintain the Florida Building Code in accordance with Chapter 120 of the state statutes. The code is a mandatory uniform statewide code and need not be adopted by a local government to be applicable at the local level. Local jurisdictions may not adopt more or less efficient codes. Visit the Florida Building Commission website for a detailed overview of the code modification process.
Georgia	**Regulatory:** A rulemaking process is used to adopt new codes and to change existing codes. When a proposed code change is forwarded to the Department of Community Affairs, it is first reviewed by a task force consisting of engineers, architects, builders, and contractors. The task force evaluates the proposal and forwards it to the State Codes Advisory Committee if deemed appropriate. The Advisory Committee also evaluates the proposal and submits it for public hearing. If approved, the proposal is adopted by the Board of Community Affairs for inclusion into the next edition of the code. The Department of Community Affairs is responsible for final rulemaking.
Hawaii	**Legislative & Regulatory:** The Hawaii Building Code Council is tasked with developing the state's building codes, including the state energy conservation code. After soliciting input from the community through small business review and several public hearing and comment periods, the Council publishes a draft recommendation. This recommendation is the subject of public hearings on each of the four counties (Oahu, Maui, Hawaii, and Kauai) as well as announced in public notices published in the state's largest local newspapers. The recommendation is then filed as an Administrative Directive and approved by the Governor. It is then filed with the Office of the Lt. Governor and becomes effective ten days later.
Idaho	**Legislative & Regulatory**: Updated codes are adopted every three years by the Idaho Legislature as they are revised by the International Code Council. Code amendments are adopted by the Idaho Building Code Board.
Illinois	**Legislative & Regulatory**: The Illinois Energy Conservation Code is overseen by the Capital Development Board (CDB) Division of Building Codes & Regulations. The Illinois Energy Code Advisory Council (IECAC) meets regularly to evaluate energy code issues and provide advice to CDB. CDB reviews and adopts the latest edition of the IECC within a year of its publication by approving an administrative rule. The rule adopting the new code must then be approved by the General Assembly's Joint Committee on Administrative Rules (JCAR).
Indiana	**Regulatory**: Proposed changes initially proceed through code committee meetings, and it approved, notice of intent is published in the Indiana Register. Proposed rules are published 60 days after notice, and two public hearings are held. The first is held 75 days after publication of the rules, and the second hearing is held 45 days after the first hearing. The Attorney General then has 45 days to review the rules before they proceed to the Governor. If the Governor signs off on the rules, they are effective not less than 30 days after being filed with the Secretary of State. Learn more about the Indiana administrative rule review process.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
Iowa	**Regulatory:** Code updates are initiated by the Iowa Building Code Commission within the Building Code Bureau of the Fire Marshal's Division of the Department of Public Safety.
Kansas	**Legislative:** Adoption and changes to the statewide energy code proceed through the state legislature.
Kentucky	**Legislative & Regulatory:** Changes to building codes by the state of Kentucky are submitted to the Board of Housing for review by the Office of Housing, Buildings, and Construction Division of Building Codes Enforcement. The changes are approved in this forum and are forwarded to the Legislative Research Committee for public comment and further review. During the three-year cycle, proposed changes to the KBC may be submitted for consideration and voted upon by the board. The Division of Building Codes and Enforcement is responsible for complying with code changes and amendments. Once changes and amendments are adopted and entered as part of the state requirements, they become state law by state statute.
Louisiana	**Regulatory:** Building codes for 1- and 2-family residential buildings are promulgated through the Louisiana State Uniform Code Council. Because the state adopts the International Residential Code (IRC), changes to the IRC are reviewed and recommended by an IRC review subcommittee, then a Technical Advisory Committee, then by the full Code Council. The final decisions of the Code Council are must then proceed through the state's administrative rules review process before becoming law. Building codes for other residential buildings and all commercial buildings are developed by the State Fire marshal's office.
Maine	**Legislative & Regulatory:** Code adoptions and amendments originate from the Maine Public Utilities Commission (PUC). The PUC issues a final provisional rule and the order approving the rule through the PUC's rulemaking process. This also means that the Legislature must approve its final version. The next step is the drafting of a bill that adopts the provisional rule. The rule must be approved by the Attorney Generals' office before it goes to Utilities and Energy Committee which will then hold a public hearing on the bill. Comments are submitted in writing or in person. The Committee and ultimately the full Legislature revises the rule, accepts it as is or rejects it completely.
Maryland	**Regulatory**: Updates to the MBPS and MPC proceed through the rulemaking authority of the Maryland Department of Housing and Community Development (DHCD) Codes Administration. Public notice, public hearings, and a public comment are required before a new rule updating the codes can be published in the Maryland Register.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
Massachusetts	**Regulatory:** Code amendment cycles occur twice a year, as required by statute, and include a public hearing process. The Board of Building Regulations & Standards has sole authority to promulgate the Massachusetts State Building Code (MSBC). Anyone can submit code change proposals to the Board. Adopted code changes are typically promulgated during the year of adoption.
Michigan	**Regulatory:** The Michigan Uniform Energy Code (MUEC) is promulgated by the Department of Licensing and Regulatory Affairs (LARA, formerly DELEG) Bureau of Construction Codes and is evaluated for revisions or modifications every three years.
Minnesota	**Regulatory**: Authority for adopting the state energy codes has been given to the Department of Labor & Industry. The state's Administrative Procedures Act provides for a minimum update process of 18 months. Its procedures require a formal public hearing only if requested by 25 or more individuals. The Building Codes and Standards Division delivers an executive summary of the proposed rule changes to the office of the Governor. After the Governor and State Reviser's Office approve the rule changes, a Notice of Adoption is published in the state register.
Mississippi	**Legislative**: The promulgation of a statewide mandatory energy code would have to proceed through the state legislature. Mississippi is a home rule state.
Missouri	**Legislative**: In Missouri, only the General Assembly is authorized to enact legislation to establish statewide building construction regulations and/or authorize a state agency to do so. However, there currently is no state regulatory agency authorized to promulgate, adopt, or update construction codes on a statewide basis.
Montana	**Regulatory:** The energy codes are reviewed on a three-year cycle corresponding to the adoption of new versions of the International Code Conference (ICC) Uniform Codes. Proposed changes are submitted to the Building Codes Bureau, which must file its proposed rules with the Secretary of State within six months of adoption.
Nebraska	**Legislative**: In Nebraska, the authority to update the state's energy code lies with the Unicameral Legislature. Before a bill is introduced, NEO staffs consult with the Governor's office and community stakeholders as they develop legislative language. When the language is deemed satisfactory, the Governor's office selects a legislator to introduce the bill, which is assigned to a committee by the Speaker of the Legislature. Successful legislation would be approved by the committee and the full chamber, ultimately being signed into law by the Governor. In general, non-emergency laws become effective 90 days after the Legislature adjourns *sine die*.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
Nevada	**Regulatory**: Before 2009, the state legislature was required to authorize the Nevada State Energy Office (NSOE) to make changes to the state energy code. However, after the establishment of NRS 701.220 through SB 73 in 2009, NSOE is required to promulgate rules to adopt the most recent version of the IECC every three years. Many local jurisdictions like Southern Nevada and the City of Las Vegas have adopted their own energy codes beyond the statewide minimum code.
New Hampshire	**Regulatory**: The New Hampshire Building Code Review Board has the authority (NH RSA XII, 155-A:1) to change the standards within the code. The procedure consists of public hearings held by the Review Board followed by public adoption or rejection of proposed amendments. Through ratification legislation, the New Hampshire General Court (the state legislature) must concur with any amendments adopted by the Board within two years of their effective date or the code reverts to the prior version.
New Jersey	**Legislative & Regulatory**: The New Jersey Uniform Construction Code Act stipulates that model codes and standards publications not be adopted more frequently than once every three years. The Commissioner of Community Affairs may make an amendment if it is found that an imminent peril exists to the public's health, safety, or welfare, or that the current code is contrary to the intent of the legislation mandating the code. The Department of Community Affairs (DCA) itself does not have the legislative authority to amend the code to include new material from codes not yet adopted.
New Mexico	**Regulatory**: The codes are adopted or amended by the Construction Industries Division, on recommendation of the various trade bureaus that have been created under its auspices. As part of the process, the new code or code amendments are reviewed by the general construction technical advisory council and a code change committee. Once approved, comments are solicited at public hearings. The final version is prepared by Construction Industry Division staff and sent to the Construction Industry Commission. If approved, the changes are sent to archive and become effective after a thirty day waiting period.
New York	**Regulatory:** The State Fire Prevention and Building Code Council maintains and periodically updates New York's Uniform Fire Prevention and Building Code and the ECCCNYS, as well as adopting higher or more restrictive standards upon the recommendation of local governments. The council is comprised of 17 members, appointed by the Governor. A quorum of nine members must be present in order to adopt any proposed code changes.
North Carolina	**Regulatory & Legislative**: New code editions are generally promulgated by rule after being reviewed by the North Carolina Building Code Council. The state legislature, however, also retains the power pass legislation updating the state's building codes.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
North Dakota	**Legislative & Regulatory**: The North Dakota Department of Commerce, in cooperation with the Building Code Advisory Committee (page 7), shall adopt rules to implement, amend, and periodically update the state building code. Rules and regulations associated with a new code are established through the Administrative Practices Act.
Ohio	**Legislative & Regulatory**: An energy subcommittee of the Residential Codes Advisory Committee (RCAC) provides recommendations on proposed updates to the RCO, which then must be approved by a vote of the full RCAC. Those recommendations are then submitted for approval by the Ohio Board of Building Standards (BBS), then by the Ohio legislature's Joint Committee on Agency Rule Review (JCARR), and finally the state's administrative review procedures before any code update would be effective.
Oklahoma	**Regulatory & Legislative**: In June 2009, the Oklahoma Legislature passed a bill (SB 1182) creating the Oklahoma Uniform Building Code Commission that would be charged to review and recommend building codes (including energy codes) for residential and commercial construction for adoption. Under the revised Oklahoma Administrative Code, Title 748, the codes and standards recommended by the Commission would go before the Oklahoma Legislature. Should the Legislature not act to disapprove the recommendations, they will be submitted to the Secretary of State (SOS) for filing. Local governments would be allowed to adopt "higher" standards than those recommended by the Commission.
Oregon	**Regulatory**: Changes to the energy conservation requirements are submitted on code change forms to the Oregon Building Codes Division (BCD). The Residential Structures Board reviews proposed changes that are applicable to residential code. The Building Codes Structures Board reviews changes that are applicable to the structures code. The BCD administrator, under delegated authority from the Director of the Department of Consumer and Business Services, makes a final determination about acceptance of the proposal. Once the administrator accepts a proposal, rulemaking begins.
Pennsylvania	**Regulatory:** The Pennsylvania Department of Labor and Industry (DLI) has the authority to promulgate and upgrade the Pennsylvania Uniform Construction Code (UCC). Legislation requires that by December 31 of the year in which is issued "a new triennial BOCA National Building Code, or its successor building code", and/or "a new triennial ICC International One and Two Family Dwelling Code, or its successor building code", the department promulgate regulations adopting the new codes. Modifications to the code are reviewed through a series of public meetings and hearings.
Rhode Island	**Regulatory:** The State Building Codes Standards Committee (SBCSC) is responsible for adopting and amending the state building code, including the energy code.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
South Carolina	**Regulatory & Legislative:** While the South Carolina Building Codes Council (BCC) is charged with adopting and amending most statewide construction codes, including the IRC and IBC, the ultimate authority to adopt and update the South Carolina Energy Standard is left to the South Carolina General Assembly. A group of technical experts and other stakeholders comprises the Energy Advisory Council (EAC), which is part of the South Carolina Public Utility Review Commission (PURC). The EAC reviews code proposals and develops amendments which it may recommend to the PURC. Should the full Commission approve the proposals, they are then submitted to the Public Utility Review Committee of the South Carolina General Assembly, where legislative language is drafted and the bill then proceeds through regular legislative order. If passed into law, a code update will generally become effective on the first day of January or July, whichever date is sooner but not less than six months from the adoption date of the new code.
South Dakota	**Legislative:** Promulgation of a statewide energy code would have to proceed through the state legislature.
Tennessee	**Legislative**: Changes to the state's energy code proceed through the state legislature.
Texas	**Legislative & Regulatory*:*** The Texas State Energy Conservation Office (SECO) has authority over the adoption of building codes for state-funded buildings, and the Texas Legislature has control over the adoption of statewide energy codes.
Utah	**Regulatory & Legislative:** The Utah Uniform Building Code Commission is charged with forming advisory committees and recommending code adoptions and amendments for adoption to the Utah Legislature.
Vermont	**Legislative & Regulatory*:*** RBES Revisions go through a process specified in the State Administrative Procedures Act (3 V.S.A. Chapter 25), including public notification, public hearing, testimony, and comments. The Vermont Department of Public Service must provide technical assistance and expert advice to the Commissioner of Labor and Industry on the interpretation of the RBES and in formulating specific revisions to the RBES. At least one year prior to adopting required revisions to the RBES, the Department of Public Service must convene an advisory committee to provide recommendations to the commissioner.
Virginia	**Regulatory:** The Virginia Board of Housing and Community Development (a Governor-appointed board) has authority to adopt changes to the Uniform Statewide Building Code (USBC), and the adoption process for modifications may take up to 12 months. All meetings of the board and its three committees are open to the public, and there is a public comment session at the beginning of each business meeting to allow the public to address the board on any issue. The board generally meets monthly but there are some months that the board does not meet. Meeting dates and times are posted to the Department of Housing and Community Development website and the Virginia Regulatory Town Hall website.

Table 2.1 - States Code Change Process (Continued)

State	Code Change Process
Washington	**Regulatory:** The Washington State Building Code Council (SBCC) reviews and amends the state energy code for residential and nonresidential buildings respectively.
West Virginia	**Legislative and Regulatory**: The West Virginia State Fire Commission is responsible for adopting, promulgating, and amending statewide construction codes. The Administrative Procedures Act requires public hearings on the adoption of all codes by the State Fire Commission.
Wisconsin	**Regulatory & Legislative:** The code is adopted by the Department of Commerce after a code development and public hearing process. The state code provisions are first developed within the Department of Commerce's Office of Codes and Applications, which is part of the Safety and Buildings Division. Modifications to the code are developed in accordance with Chapter 227 of the Wisconsin Statutes.
Wyoming	**Legislative & Regulatory**: Proposed changes to the state energy code may be submitted to the Wyoming Department of Fire Prevention and Electrical Safety, which reviews changes and submits recommendations to the Governor-appointed Building Codes Council.

Source: Building Codes Assistance Project (BCAP 2013)

Table 2.2 - Status of Residential Building Energy Code 1998-2013

State	IECC 1998	IECC 2000	IECC 2003	IECC 2006	IECC 2009	Code Notes
Alabama					Effective on Oct 1, 2012	
Alaska			Effective on Jan 1, 1992	Effective on Nov 8, 2006	Effective on Mar 9, 2011	
Arizona						Jurisdictions adopted different versions of IECC
Arkansas			Effective on Oct 1, 2004			
California	Effective on 1998	Effective on 2001	Effective on 2004	Effective on 2007	Effective on 2010	
Colorado						Jurisdictions adopted different versions of IECC
Connecticut			Effective on Dec 31, 2005	Effective on Aug 1, 2009		
Delaware		Effective on Jul 1, 2004			Effective on Jul 1, 2010	
District of Columbia		Effective on Jan 9, 2004			Effective on Dec 26, 2009	
Florida	Effective on 1997	Effective on Jan 1, 2002	Effective on Jan 1, 2005	Effective on Mar 1, 2009	Effective on Mar 15,2012	
Georgia		Effective on Jan 1, 2003		Effective on Jan 1, 2008	Effective on Jan 1, 2011	
Hawaii				Effective on May 24, 2010		
Idaho		Effective on Jan 1, 2003	Effective on Jan 1, 2005	Effective on Jan 1, 2008	Effective on Jan 1, 2011	

Table 2.2 - Status of Residential Building Energy Code 1998-2013 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	IECC 2009	Code Notes
Illinois					Effective on Jan 29, 2010	
Indiana					Effective on Apr 5, 2012	
Iowa	Effective on 1998	Effective on Jan 1, 2001	Effective on Jan 1, 2004	Effective on Jan 1, 2007	Effective on Jan 1, 2010	
Kansas						State energy code
Kentucky		Effective on Jul 1, 2005		Effective on Aug 1, 2007	Effective on Jun 1, 2011	
Louisiana				Effective on Jun 22, 2007		
Maine					Effective on Jun 1, 2010	
Maryland			Effective on Sep 20, 2004	Effective on Jul 1, 2007	Effective on Jan 1, 2010	
Massachusetts					Effective on Jan1, 2010	
Michigan			Effective on Oct 24, 2008		Effective on Mar 9, 2011	
Minnesota				Effective on Jun 1, 2009		
Mississippi						State energy code Precedes IECC 1998
Missouri						No statewide energy code
Montana			Effective on Sep 3, 2004		Effective on Mar 26,2010	

Table 2.2 - Status of Residential Building Energy Code 1998-2013 (Continued)

State	IECC 1998	IECC 2000	IECC 2003	IECC 2006	IECC 2009	Code Notes
Nebraska	Effective on 1999		Effective on Jul 1, 2005		Effective on Aug 27, 2011	
Nevada					Effective on Jul 1, 2012	
New Hampshire		Effective on 2002		Effective on 2007	Effective on Apr 1, 2010	
New Jersey				Effective on Feb 20, 2007	Effective on Sep 7, 2010	
New Mexico			Effective on Jul 1, 2004	Effective on Jan 1, 2008	Effective on Jan 1, 2012	
New York	Effective on Jul 29, 1999	Effective on Jul 1, 2002	effective on Jan 1, 2008		Effective on Dec 28, 2010	
North Carolina		Effective on Dec 31, 2001	Effective on Jul 1, 2006	Effective on Mar 11,2008	Effective on Jan 1, 2012	
North Dakota						Precedes IECC 1998
Ohio			Effective on Mar 1, 2005	Effective on Jan 1, 2008	Effective on Jan 1, 2013	
Oklahoma			Effective on Jun 1, 2004	Effective on Jul 15, 2011		
Oregon		Effective on 2002	Effective on Oct 1, 2005	Effective on Jul 1, 2008	Effective on Jul 1, 2011	
Pennsylvania			Effective on Apr 1, 2004	Effective on Dec 31, 2006	Effective on Dec 31, 2009	
Rhode Island				Effective on 2006	Effective on Jan 1, 2010	
South Carolina		Effective on Jul 1, 2001	Effective on Jan 1, 2005	Effective on Jul 1, 2009	Effective on Jan 1, 2013	
South Dakota						State energy code

Table 2.2 - Status of Residential Building Energy Code 1998-2013 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	IECC 2009	Code Notes
Tennessee		Effective on Jul 1, 2003	Effective on Jan 1, 2009	Effective on Jul 1, 2011		
Texas		Effective on Jun 1, 2002			Effective on Apr 1, 2011	
Utah				Effective on Jan 1, 2007	Effective on Jul 1, 2010	
Vermont		Effective on Jan 1, 2005			Effective on Oct 1, 2011	
Virginia		Effective on Oct 1, 2003		Effective on May 1, 2008	Effective on Mar 1, 2011	
Washington			Effective on Jul 1, 2002	Effective on Jul 1, 2007	Effective on Jan 1, 2011	
West Virginia			Effective on Jan 1, 2009			
Wisconsin				Effective on Apr 1, 2009		IECC 2006 is mandatory for one- and two-family dwellings and IECC 2000 for multifamily dwellings
Wyoming						Precedes IECC 1998

Source: Building Codes Assistance Project (BCAP 2013)

Table 2.3 - Summary Statistics for all States

Variable	Observation	Mean	Std. Dev.	Min	Max
Energy Price ($\$/mBTU$)	663	9.464	3.434	5.038	40.346
Degree Days	663	6346	167	3287	15231
Coastal State	663	0.569	0.496	0	1
Income	663	15589	2397	11308	30061
RPE	663	1.000	0.156	0.597	2.340
Share of Neighbor States with IECC	663	0.423	0.344	0	1
Education	663	0.262	0.059	0.066	0.501
Pollution ($MMTCO_2$)	663	113.53	114.72	3.133	712.93
Governor	663	0.548	0.493	0	1
Population Growth	663	0.009	0.008	-0.060	0.050

Table 2.4 - Summary Statistics by Adoption of IECC

	No IECC (n=370)				Any Version of IECC (n=293)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Energy Price	9.04	3.93	5.04	40.35	10.00	2.58	5.71	35.33
Degree Days	6357	1343	4217	10307	6335	2018	3287	15231
Coastal State	0.48	0.50	0	1	0.68	0.47	0	1
Income	15024	2070	11308	23908	16304	2588	12754	30062
RPE	0.99	0.13	0.60	1.35	1.02	0.19	0.62	2.34
Share of Neighbor States with IECC	0.31	0.30	0	1	0.57	0.34	0	1
Education	0.25	0.06	0.07	0.46	0.27	0.06	0.07	0.50
Pollution	100.44	92.38	3.92	704.92	130.06	135.19	3.13	712.93
Governor	0.61	0.48	0	1	0.46	0.49	0	1
Population Growth	0.01	0.01	-0.06	0.05	0.01	0.01	-0.01	0.03

Table 2.5 - Order Probit and IV- Ordered Probit Models

Variables	Ordered Probit	IV - Ordered Probit
Energy Price	0.039**	0.035**
	(0.0164)	(0.017)
Degree Days	0.623**	0.617**
	(0.252)	(0.246)
Coastline States	0.188	0.186
	(0.116)	(0.115)
Income	0.38	0.371
	(0.503)	(0.249)
RPE	0.686**	0.677**
	(0.331)	(0.331)
Share of Neighbor States with IECC	1.493***	1.493***
	(0.152)	(0.150)
Governor	-0.271***	-0.263**
	(0.096)	(0.095)
Pollution	0.156***	0.165***
	(0.0572)	(0.0571)
Education	1.014	1.103
	(1.161)	(0.992)
Population growth	13.18**	13.17**
	(6.438)	(6.472)
Observations	663	663
Threshold Variables		
	11.97***	11.86***
	12.12***	12.00***
	12.53***	12.42***
	13.18***	13.07***
	14.20***	14.10***

Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Table 2.6 - Poisson and Two-Stage Least-Square Models

Variables	Poisson	Two-Stage Least-Square
Energy Price	0.0399***	0.0426**
	(0.0120)	(0.0203)
Degree Days	0.574***	0.553*
	(0.205)	(0.322)
Coastline States	0.205**	0.283**
	(0.0902)	(0.143)
Income	0.247	-0.0902
	(0.371)	(0.624)
RPE	0.659***	0.894*
	(0.246)	(0.467)
Share of Neighbor States with IECC	1.422***	1.784***
	(0.110)	(0.186)
Governor	-0.263***	-0.344***
	(0.0742)	(0.122)
Pollution	0.121***	0.156**
	(0.0420)	(0.0704)
Education	0.567	1.756
	(0.855)	(1.422)
Population growth	15.88***	17.99**
	(4.99)	(7.776)
Constant	-9.779	-5.993
	(3.447)	(5.606)
Observations	663	612

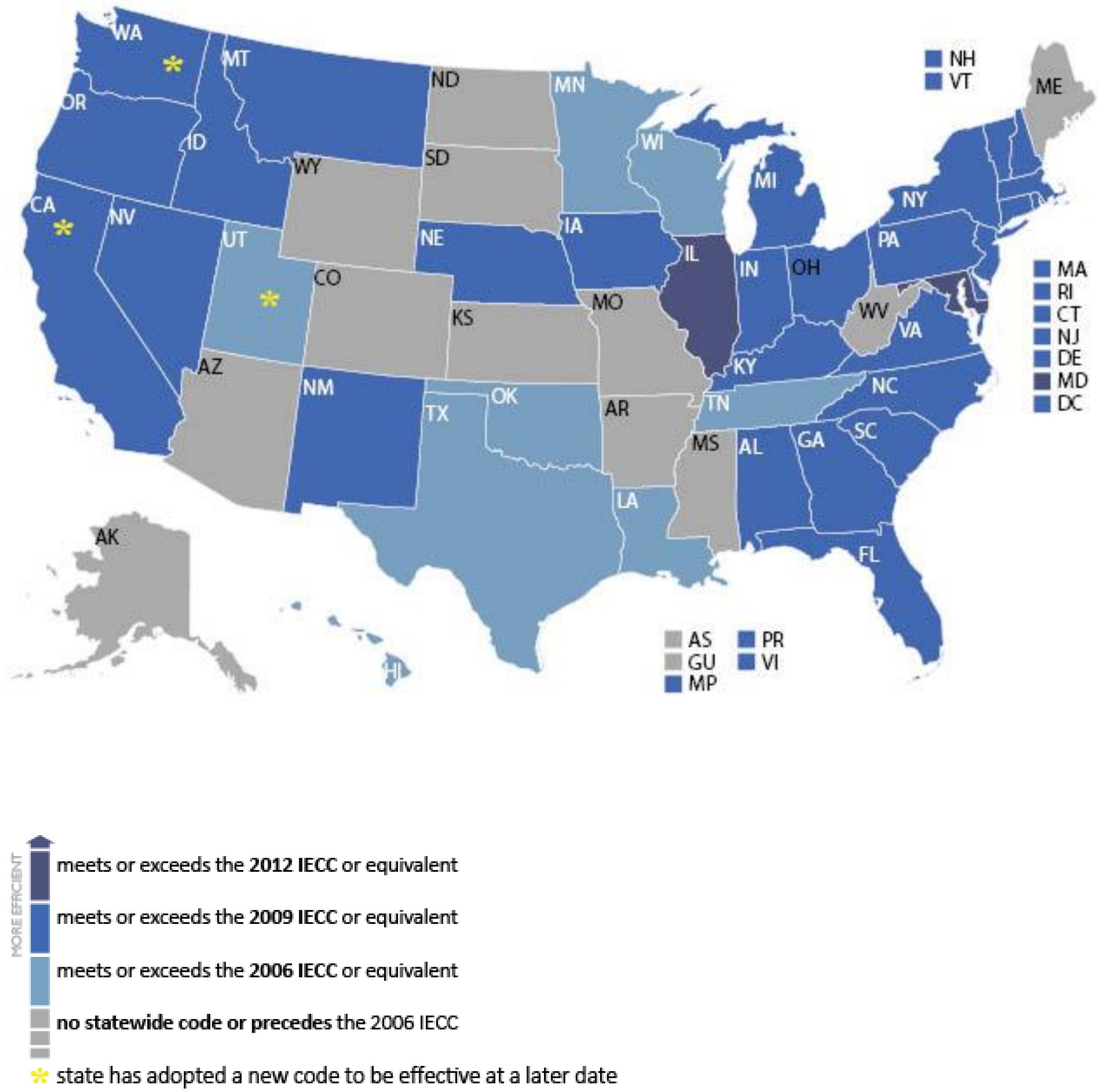
Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Table 2.7 - Marginal Effects of Ordered Probit Model

Variables	Prob(IECC=0)	Prob(IECC=1)	Prob(IECC=2)	Prob(IECC=3)	Prob(IECC=4)	Prob(IECC=5)
Energy Price	**-0.015**	**0.001**	**0.003**	**0.006**	**0.005**	**0.001**
Degree Days	**-0.245**	**0.009**	**0.046**	**0.094**	**0.082**	**0.014**
Coastline States	-0.074	0.003	0.014	0.028	0.024	0.004
Income	-0.149	0.005	0.028	0.057	0.050	0.008
RPE	**-0.270**	**0.010**	**0.051**	**0.103**	**0.090**	**0.015**
Share of Neighbor States with IECC	**-0.587**	**0.021**	**0.110**	**0.225**	**0.197**	**0.033**
Governor	**0.106**	**-0.004**	**-0.020**	**-0.041**	**-0.036**	**-0.006**
Pollution	**-0.061**	**0.002**	**0.012**	**0.024**	**0.021**	**0.003**
Education	-0.399	0.014	0.075	0.153	0.134	0.023
Population growth	**-5.181**	**0.185**	**0.975**	**1.988**	**1.739**	**0.295**

Notes: Bold values show the statistically significant variables.

Figure 2.1 - Residential State Energy Code Status, as of May 2013



Source: Building Codes Assistance Project (BCAP 2013)

Figure 2.2 - Correlates of the Adoption of IECC with Explanatory Variables

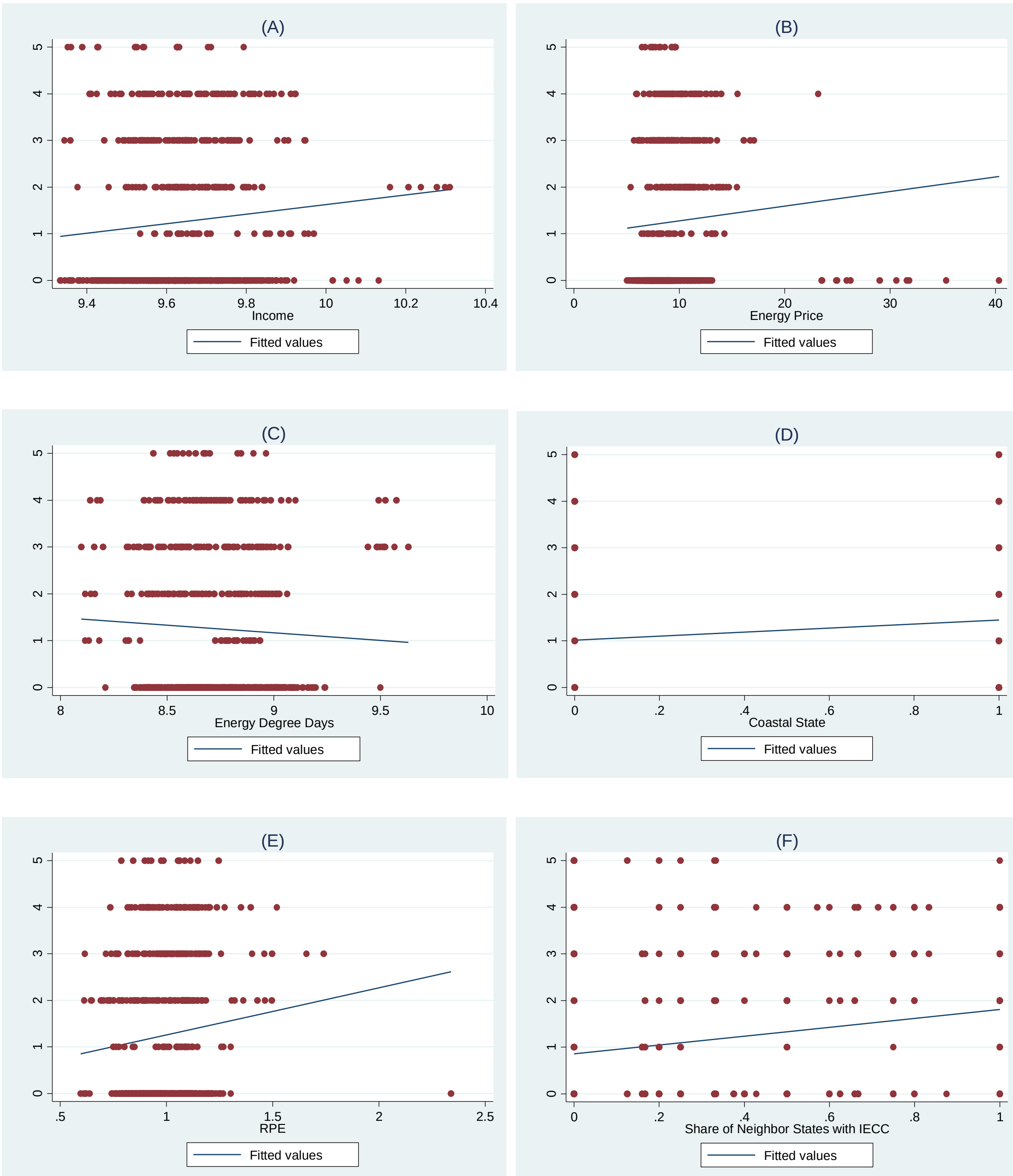
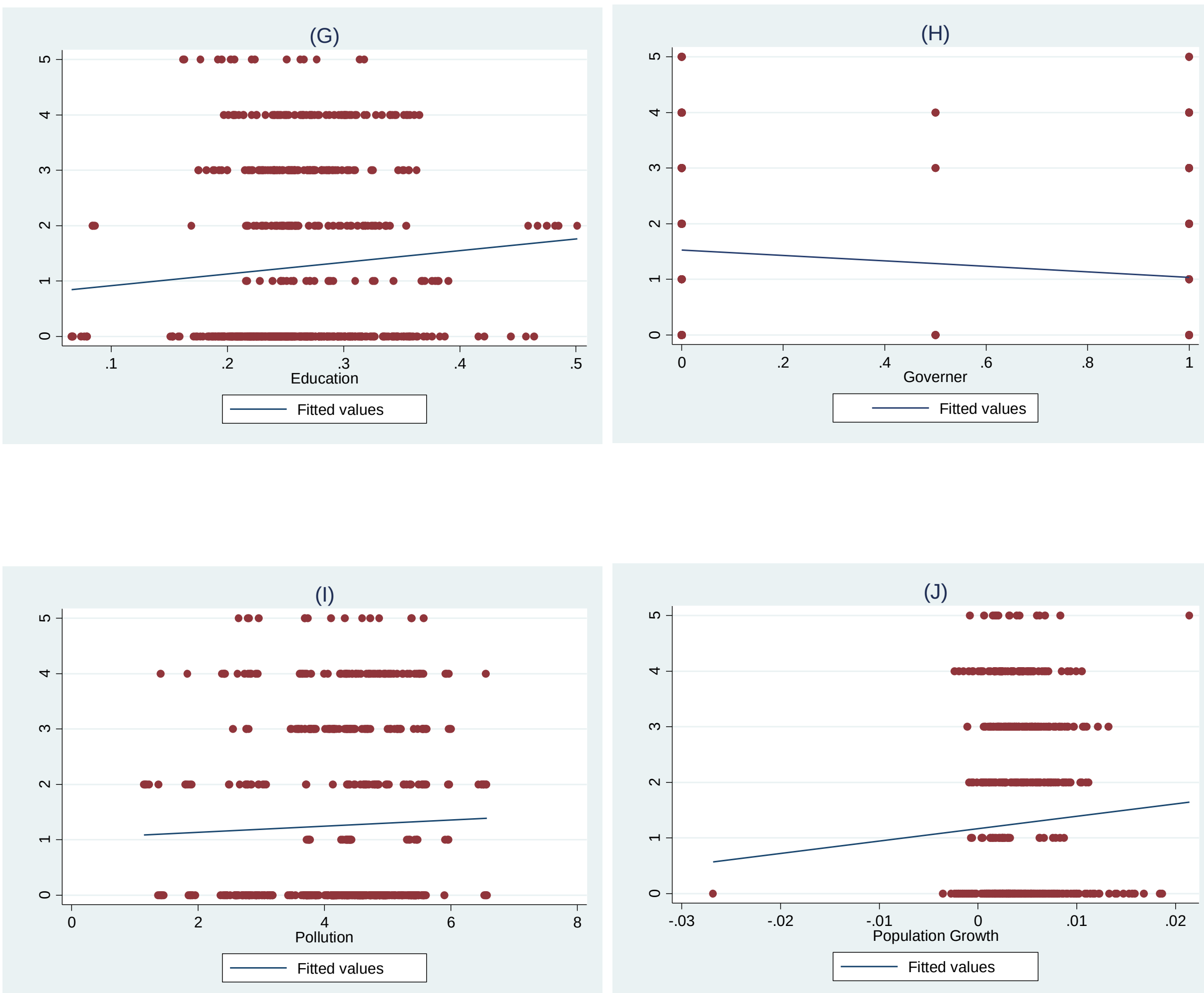


Figure 2.2 - Correlates of the Adoption of IECC with Explanatory variables (Continued)



Appendix A: Order Probit and IV- Ordered Probit Models with Gross State Product

Variables	Ordered Probit	IV - Ordered Probit
Energy Price	0.0407**	0.041**
	(0.016)	(0.0169)
Degree Days	0.661***	0.652***
	(0.243)	(0.198)
Coastline States	0.19	0.189
	(0.116)	(0.115)
GSP	0.114	0.111
	(0.253)	(0.179)
RPE	0.666**	0.663**
	(0.33)	(0.329)
Share of Neighbor States with IECC	1.518***	1.519***
	(0.148)	(0.147)
Governor	-0.277***	-0.270***
	(0.0957)	(0.0955)
Pollution	0.167***	0.176***
	(0.0564)	(0.0505)
Education	1.323	1.407
	(1.06)	(1.007)
Population growth	12.88**	12.94**
	(6.489)	(6.554)
Observations	663	663
Threshold Variables		
	9.975***	9.869***
	10.12***	10.04***
	10.53***	10.45***
	11.18***	11.11***
	12.20***	12.14***

Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Appendix B: First-Stage of Instrumental Variable Estimation Results

Variables	First-Stage Instrumental Variable for Energy Price	First-stage Instrumental Variable for Pollution
Energy Price		-0.00184**
		(0.000882)
Degree Days	-0.615***	-0.00656
	(0.180)	(0.0141)
Coastline States	-0.0377	0.000537
	(0.0808)	(0.00627)
Income	0.665*	-0.0387
	(0.354)	(0.0269)
RPE	0.454*	-0.0239
	(0.250)	(0.0203)
Share of Neighbor States with IECC	0.0166	-0.0539***
	(0.107)	(0.00813)
Governor	-0.00398	-0.000215
	(0.0683)	(0.00533)
Pollution	-0.0318	
	(0.0392)	
Education	-1.529*	0.0735
	(0.801)	(0.0615)
Population growth	4.483	1.198***
	(4.184)	(0.341)
Two lagged Energy Price	0.925***	
	(0.0109)	
Two Lagged Pollution		0.998***
		(0.00309)
Constant	-0.455	0.472*
	(3.178)	(0.245)
Observations	612	612

Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Chapter 3

The Role of International Energy Conservation Codes in Managing Energy Consumption

3.1 Introduction

Nationwide, energy efficiency policies play an important role in U.S. energy policy debate because future national energy needs can be met by increasing energy supply or decreasing energy demand. The exclusive focus on increasing energy supply is an undesirable way to meet growing demand.[7] The demand-side energy efficiency policies encourage consumers and manufactures to use less energy and manage the national energy need efficiently at low or no cost. These energy efficiency policies on the contrary could decrease the unit cost of energy services and encourage consuming more energy service, which is called rebound effect and offsets the efficiency gain in energy use.[8] The demand side-management energy efficiency policies include categories of energy efficiency standards (such as Federal/State appliance standards, building codes, professional codes, and corporate average fuel economy standards), financial incentives, information and voluntary programs, and the management of government use.

In 2008, the residential building sector consumed 6% of the nation's primary energy and produced 1,220.1 million metric tons of carbon dioxide (20% of total U.S. emissions) which

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[7] Gillingham, K., Newell, R.G., Palmer, K., (2004) "Retrospective Examination of Demand-side Energy Efficiency Policies" Resource for the Future

[8] Although the rebound effect exists, Manne *et al.*(1992) and Kemfert (1998) show there are net energy savings from adoption of energy efficient technologies in commercial building sector.

grows by an average of 1.6% each year.[9] In order to regulate the emissions from buildings, Congress has passed several legislations during the last 35 years. The newest series of building energy code is the International Energy Conservation Code (IECC). The state-level policy IECC provides a good opportunity to significantly improve energy performance of a new building like reducing peak energy demand, and greenhouse gas emissions. The IECC is applicable to all new residential and commercial buildings and covers the building's ceilings, walls, and floors/foundations, lighting, and power systems which decrease the energy consumption used for cooling and heating systems in the buildings.

Recently, the importance and the expected effects of building energy code have been examined by two different types of studies. One group of studies which is based on engineering perspective looks at a typical heating, cooling, or ventilation system device installed in the building. They simulate energy consumption before and after installation of the efficient devices and develop scenarios of carbon dioxide emissions reductions and cost-effectiveness of the program.[10] These studies find that a substantial reduction in future greenhouse gas emission can be achieved through the investment and use of more energy-efficient technologies.

The other groups of studies focus exactly on the building's energy efficiency policies and specify how these codes affect the consumption per-capita of electricity and natural gas in residential sector. Arroonruengaswat *et al*. (2009) estimate the impact of state level residential building codes on per-capita electricity consumption for 48 states in U.S. from 1970-2006. They show that the states that adopted building codes experienced a noticeable reduction in their electricity consumption which is about 3-5% in the year 2006. Costa *et al.* (2010) use micro data

[9] Energy Information Administration, Annual Energy Review, October 2011
[10] Koomey *et al.* (1999), Wiel *et al.* (1998), Chan *et al.* (2005), Yu *et al.* (2007), and Asdrubali *et al.* (2008)

to determine the electricity demand for California. They find that development of building codes in California accounts for flat electricity consumption but they don't see the full impact of the codes on electricity consumption yet. Jacobsen *et al.* (2013) use household level data for Florida and compare energy consumption of residential construction just before and after increasing stringency of energy code in 2002. They find that the consumption of electricity decreases by 4% and natural gas by 6% as the stringency of building codes increases in 2002.

The Autoregressive Distributed Lag (ARDL) model is widely used for estimating energy demand relationship recently (Pesaran *et al.* (1999a), Bentzen *et al.* (2001), Dergiades (2008)). The ARDL model estimates the long-run cointegration relationship by focusing on the dynamic of one single equation, while the short-run dynamics and long-run relationship are estimated simultaneously. There are different approaches to estimate the ARDL model. One can pool the data with state-specific dummies (fixed- or random-effects models) and get a single estimate for whole sample, but imposing homogeneity across states and ignoring the potential differences between them can be inappropriate. Such traditional method of estimation can produce inconsistent estimates of the average values of the coefficients in dynamic panel data models.

The other approach is to estimate the regression for each state separately which is not precise method estimation since there is small number of observation for each state. Maddala *et al.* (1997) introduce the shrinkage estimator model which is an intermediate case between two extremes of homogeneity and heterogeneity of coefficient models. The estimated parameter is a weighted average of the overall pooled estimate and the separate time series estimates based on each cross-section. Each cross-section estimate is shrunk toward the overall pooled estimate.

Pesaran *et al.* (1999a) introduce another useful intermediate alternative, the pooled mean group (PMG) model. The PMG estimator allows for homogeneous long-run coefficients, and heterogeneous short-run coefficients and error variance across cross-sections. This weak homogeneity assumption is preferable to the other methods such as, fixed effects, generalized method of moments (GMM), and instrumental variables which are based on the strong homogeneity assumption across the groups. It is reasonable to consider the long-run coefficients of energy demand to be similar across states, due to common energy price shocks or technologies. While it is not promising to consider the short-run coefficients to be the same across states due to pattern of investment in energy efficient policies or supply constraints in each state.

The current study makes several contributions to the literature. First, it uses PMG estimator of Pesaran *et al.* (1999a) framework to estimate the residential electricity demand for U.S. for the first time. Second, I specifically identify the impact of all versions of IECC on per-capita electricity consumption which is the newest and strongest version of building code introduces by Department of Energy (DOE) to the nation since 1998.

I use a panel data for 44 U.S. states from 1981-2008. The results show an overall 2% decrease in new residential buildings per-capita electricity consumption for the states which adopted any version of IECC. The states with IECC 2000 and IECC 2003 experienced a reduction in their new residential buildings per-capita electricity consumption ranging from 2.5-5%.

The next section discusses the international energy conservation codes in U.S. Section 3 describes the empirical model and the data. Section 4 provides the methodology. Section 5 discusses the results. Section 6 concludes.

3.2 The Building Energy Code

The regulation of building energy code began in the 1970s in U.S. due to the energy crisis. The Energy Policy and Conservation Act (EPAC) was the first public policy passed by the U.S. Congress in 1975 in order to decrease the use of energy in buildings through the building code process. The next one was the Energy Policy Act (EPAct) of 1992 which created the Building Energy Codes Program (BECP) and required DOE to develop a model codes for buildings and support state adoption. The Council of American Building Officials (CABO) issued the first residential model code as Model Energy Code (MEC) in 1992 with two updates in 1993 and 1995. In 1998, the CABO joined to several other buildings associations to create the International Code Council (ICC). IECC is part of the family of International Codes developed by ICC.

The IECC is a required minimum level of energy efficiency in new residential and commercial buildings and it covers the building's ceilings, walls, and floors/foundations; and the mechanical, lighting, and power systems. Since it is written in mandatory and enforceable language, the state and local jurisdictions can easily adopt the model as their energy code. Before adopting the code, state and local governments often make some changes to reflect regional building practices.

Federal laws require the DOE to determine whether revisions to the residential part of the IECC would improve energy efficiency in the nation's residential buildings. After the DOE's improvement, each state has two years to review the energy provisions of its residential building code and has determined whether it is appropriate for the state to revise its residential building code to meet or exceed the IECC. If a state determines that it is not appropriate to revise its residential code to meet or exceed the IECC, the state is required to explain why in writing to the

Secretary of Energy. By the end of 2008, about 37 states had adopted any version of IECC with amendments on the state level. There is not a penalty for the states if they do not adopt it. However the DOE State Energy Program (SEP) provides grants and technical assistance to states and U.S. territories based on a yearly appropriation by Congress.

The first version of IECC was released in 1998. The next ones are IECC 2000 with its 2001 supplement, IECC 2003 with its 2004 supplement, IECC 2006, IECC 2009, and the recent one is IECC 2012. The codes promulgate once each three years, with amendments and supplements made available in between edition. Table 3.1 and Figure 3.1 display status of adoption of IECC by residential sector for all states in U.S. by end of 2008.

The primary goal of the IECC is to decrease building energy consumption and greenhouse gas emissions from burning the fossil fuels. The average lifespan of a building is about 50 years or even more in U.S. therefore these building codes will affect building energy consumption until 50 years and beyond. In this study, I try to estimate the residential electricity demand function by incorporating the IECC's and find out how the consumption of electricity and greenhouse gas emission will be affected by implementing these codes.

3.3 Model and Data

The electricity demand equation to be estimated in this study is the following,

$$\mathrm{CON_{it}} = f(\mathrm{P^{e}_{it}}, \mathrm{P^{ng}_{it}}, \mathrm{I_{it}}, \mathrm{HDD_{it}}, \mathrm{CDD_{it}}, \mathrm{NUACC_{it}}, \mathrm{IECC_{nit}}, (\mathrm{NUACC_{it}} * \mathrm{IECC_{nit}}), \mathrm{AP_{it}}) \qquad (1)$$

$$\forall\ 1 \le \mathrm{i} \le 44\ ,\ \ 1981 \le \mathrm{t} \le 2008$$

$$n = IECC\ 1998, 2000, 2003, and\ 2006$$

The dependent variable $\mathrm{CON_{it}}$ is state *i*'s per-capita residential electricity consumption (million Btu) in year *t*. The explanatory variables are: $\mathrm{P^{e}_{it}}$ is the real average price of electricity for residential customers ($ per million Btu), P_{it}^{ng} is the real average price of natural gas ($ per million Btu). which is the main substitute source for electricity [11], I_{it} is real per-capita disposable income for a typical household, HDD_{it} is heating degree days, CDD_{it} is cooling degree days, $NUACC_{it}$ is the accumulation of new privately owned housing unit, $IECC_{nit}$ is dummy variable for *n* different building codes, and AP_{it} is the dummy variable for appliance and equipment standards. I will estimate Eq. (1) using panel data from 44 U.S. states for the sample period of 1981-2008. I exclude Arizona, Colorado, Illinois, Massachusetts, Missouri, Nevada, and Wisconsin which have adopted different versions of IECC in their jurisdictions.[12]

The consumption and price of electricity and natural gas for residential sector were obtained from the Energy Information Administration. Figure 3.2 and 3.3 display trends in per-capita electricity consumption for U.S. and the 44 states. Electricity consumption per-capita in states such Alaska, California, and Hawaii has stayed nearly constant, while increasing steadily for the other states and U.S. as a whole.[13] The data on per-capita disposable income of typical household for each state were obtained from the Bureau of Labor Statistics. To remove the effects of inflation all prices and incomes are deflated by the consumer price index.

HDD and CDD are quantitative indices designed to reflect the demand for energy needed to heat or cool a home or business. The indices are derived from daily temperature observation, and

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[11] Natural gas is the main substitute in consumption for electricity. Beierlein *et al*. (1981) and Kamerschen *et al.* (2004) find that natural gas and electricity are substitute in consumption in residential sector in U.S.

[12] Arizona, Colorado, Illinois, and Missouri do not have a mandatory statewide energy code. Local jurisdictions can adopt their own energy code requirements. For instance in Colorado, Boulder, Boulder County, Broomfield, and Broomfield County adopted the IECC 2003 and Adam County, Arvada, Aurora, and Denver adopted the IECC 2006 in Colorado. Massachusetts and Wisconsin have their own mandatory statewide code adoption for one- and two-family dwelling. Nevada has mandatory statewide code adoption and some local jurisdictions have adopted their own energy codes beyond the statewide minimum code.

[13] Usually zero growth rates in per-capita electricity consumption are called “Rosenfeld Curve”. Sudarshan *et al.* (2008) show that up to 23% of the overall difference between California and U.S. electricity consumption is due to policy measures and remaining by structural factors.

the heating (or cooling) requirements for a given structure at a specific location are considered to be directly proportional to the number of heating degree days at that location. The number of heating degrees in a day is defined as the difference between a reference value of 65°F (18°C) and the average outside temperature for that day. The value of 65°F is taken as a reference point because experience shows that if the outside temperature is this value then no heating or cooling is normally required. Heating and cooling degree days can be added over period of time to provide a rough estimate of seasonal heating and cooling requirements. The data on HDD and CDD were obtained from the U.S. National Climate Data Center.

New privately owned housing units which are just over one percent of the total housing units in U.S. represent a good opportunity to impact energy consumption in residential sector. Once a new building is constructed, it is very expensive and often impossible to achieve the energy efficiency that can be built in economically at the time of construction. There are two leading indicators for new privately owned housing units, housing starts and building permits. Housing starts are counted as the actual breaking of ground for footings or foundations and building permits are defined as of when those units authorized and granted to be built. I use housing starts as a measure of new constructions since housing starts covers the entire U.S. not the areas requiring building permits. The number of housing units constructed in non-permit areas is about 2.5% of the total and those are almost single family houses.[14] Data for housing starts have been collected from the U.S. Census Bureau data base.

The data of implementation and adoption of IECC's is from the Building Code Assistance Program (BCAP 2008). It provides maps and detail information on the state overviews of current

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[14] U.S. Department of Commerce, United States Census Bureau, New Residential Construction, Data Relationship between Permits, Starts, and Completions

building codes and their history. Table 3.1 shows the dates of implementation of building codes for each state by the end of 2008. Four dummy variables were created, one for each of IECC 1998, IECC 2000, IECC 2003, and IECCC 2006. The variables are coded one if the state has adopted the code, and zero otherwise.

The appliance and equipment efficiency standards are one of the other policies used by state and federal governments to save the energy. These standards require that all producers of appliances meet the minimum energy efficiency levels for all products and purge the most inefficient products form the market. California introduces the appliance standards in 1974 for the first time. Soon after California, other states such as New York and Massachusetts have adopted these codes. National Appliance Energy Conservation Act 1988 (NAECA) was passed by federal government in 1988 and institutes the national standards based on the California's standards. ACEEE (2008) scores states based on the number of adoption of appliance standards. I create an indicator variable for appliance standards which gets a score of 0 to 4; 4- for the state with more than 10 product standards; 3- seven to ten product standards; 2- four to six product standards; 1-one to three product standards and; 0- for no standards.

Table 3.2 shows the summary statistics. The states which adopted IECC at any point in the sample have higher per-capita electricity consumption and lower electricity price versus states that never did. As the stringency of IECC increases the price of natural gas is raising as well. In the other hand, the states with no IECC experience lower per-capita income and number of new housing starts. Table 3.2 also indicates that states which adopted any version of IECC have higher mean value of appliances standards than the states which have not.

3.4 Methodology

This section presents a panel econometric model that not only deals with any possible endogeneity issues concerning electricity demand regression, but also improves the possible dynamic heterogeneity of this relationship across states. These requirements can be accomplished with an ARDL model. In ARDL model, dependent variable (per-capita electricity consumption) is explained by lags of itself and current and lagged values of explanatory variables such as income, price, temperature, etc. The lagged value of dependent variable captures the slow adjustment that often characterizes electricity consumption in response to change in the explanatory variables. The main advantage of ARDL specification is that effectively corrects for reverse causality running from the consumption of electricity to the explanatory variables (possible endogeneity problem) by including at least one period lagged of explanatory variables (Pesaran *et al.* (1999b)). The other benefit of this model is to allow for heterogeneity in the adjustment dynamic across states, because the various parameters in Eq. (1) are not constrained to be the same across sates. Another benefit of ARDL model is that avoids the uncertainty raised from unit root test. Since there is a unique long-run relationship between the variables the corresponding estimator will results in consistent estimates regardless of whether the variables are I(0) or I(1), or a mixture of I(0) and I(1) (Pesaran *et al.* (1999b)).

The ARDL $(p, q_1, \dots, q_k)$ model with dynamic panel specification where the dependent and independent variables have lags of order $p, q_1, \dots, q_k$, respectively, has the form of:

$$Y_{it} = \delta_i + \sum_{j=1}^{p} \theta_{ij} Y_{it-j} + \sum_{j=0}^{q} \gamma'_{ij} X_{it-j} + \varepsilon_{it} \qquad (2)$$

$$\forall\ 1 \leq i \leq N,\ 1 \leq t \leq T$$

where X_{it} is a $k \times 1$ vector of independent variables; γ_{ij} are the $k \times 1$ coefficient vectors; θ_{ij} are scalars; and δ_i is the group–specific effect. Eq. (2) can be reparameterized as:

$$\Delta Y_{it} = \delta_i + \alpha_i(Y_{it-1} - \beta_i' X_{it}) + \sum_{j=1}^{p-1} \theta_{ij}^{*\prime} \Delta Y_{it-j} + \sum_{j=0}^{q-1} \gamma_{ij}^{*\prime} \Delta X_{it-j} + \varepsilon_{it} \qquad (3)$$

where $\alpha_i = -\left(1 - \sum_{j=1}^{p} \theta_{jt}\right)$, $\beta_i = \sum_{j=0}^{q} \frac{\gamma_{ij}}{1-\sum_k \theta_{ik}}$, $\theta_{ij}^* = -\sum_{m=j+1}^{p} \theta_{im} \quad j = 1,2, \dots, p-1$, and $\gamma_{ij}^* = -\sum_{m=j+1}^{q} \gamma_{im} \quad j = 1,2, \dots, q-1$.

The parameter α_i, the error-correcting speed of adjustment measures the speed of adjustment of Y_{it} toward its long-run equilibrium following a given change in X_{it}. This parameter is expected to be negative and significant which ensures that such a long-run relationship exists. The vector β_i is the long-run or "equilibrium" relationship between Y_{it} and X_{it}. In contrast, θ_{ij}^* and γ_{ij}^* define the short-run coefficients relating Y_{it} to X_{it}.

There are several approaches to estimate Eq. (3). On one extreme, the MG estimator which known as an unrestricted individual-by-individual regression, separate ARDL regressions for each individual are estimated and a simple average of individual group coefficients could be obtained. These estimators are consistent estimates of the average of parameters. There are no cross-state coefficient constraints and all coefficients and error variances are fully heterogeneous. On the other extreme, the Dynamic Fixed Effect (DFE) approach could be estimated. In this model, the time series data for each group are pooled and allows to homogeneity of all slope coefficients (short-run and long-run) and error variances, except the intercepts. The homogeneity of the slope coefficients is a necessary assumption for DFE otherwise it produces inconsistent results.

The intermediate estimator PMG combines both averaging and pooling methods. The model allows for different speed of adjustment, error variances, intercepts, and short-run coefficients across the groups (as would the MG model) and homogeneity restriction for long-run parameters (as would be DFE model). Pesaran *et al.* (1999a) develop a maximum likelihood method to estimate the parameters since the Eq. (4) is nonlinear in parameters.

$$\text{PMG:} \quad \Delta Y_{it} = \delta_i + \alpha_i (Y_{it-1} - \beta' X_{it}) + \sum_{j=1}^{p-1} \theta_{ij}^{*\prime} \Delta Y_{it-j} + \sum_{j=0}^{q-1} \gamma_{ij}^{*\prime} \Delta X_{it-j} + \varepsilon_{it} \qquad (4)$$

The long-run homogeneity restriction of parameters can be tested by a standard Hausman-type or likelihood tests. If the long-run relationship exists, PMG estimates are efficient and consistent and we don't need to test whether variables are integrated. If the homogeneity doesn't hold, the MG approach is preferred and provides a consistent estimate of the mean of the long-run coefficients across individuals. The advantage of PMG approach over the DFE estimator is that it allows for the short-run dynamic specification varies across groups.

In order to estimate the effect of the IECC on the per-capita electricity consumption, I estimate the following equation:

$$\Delta \log(\mathrm{CON}_{it}) = \delta_i + \alpha_i \left(\log(\mathrm{CON}_{it-1}) - \beta_i' X_{it} - \beta_{ni}' \sum_{n=1}^{4} \theta_{ij}^{*\prime} (\mathrm{NUACC}_{it} * \mathrm{IECC}_{nit}) \right) + \sum_{j=1}^{p-1} \theta_{ij}^{*\prime} \Delta \log\left(\mathrm{CON}_{it-j}\right) + \sum_{j=0}^{q-1} \gamma_{ij}^{*\prime} \Delta X_{it-j}\, \varepsilon_{it} \qquad (5)$$

$\forall\ 1 \le i \le 44\ ,\ 1981 \le t \le 2008$

$n = IECC\ 1998, 2000, 2003, and\ 2006$

Where X_{it} includes energy specific demand factors such as: price of electricity and natural gas, income, cooling degree days, heating degree days, new housing starts accumulation, four dummy variables for the IECC's and one dummy for appliances. The parameter of interest is β_{ni}' which measures the mean effect of IECC on per-capita electricity consumption for new residential building units in the states which adopted the codes versus to other states which did not. I would expect the states with IECC experience decrease in per-capita residential electricity consumption.

Based on the law of demand an increase in the price of electricity decreases the consumption of electricity so the expected sign for electricity price is negative. Since electricity and natural gas are substitute in consumption the expected sing of natural gas price is positive. If income, heating degree days, and cooling degree days increase the consumption of electricity will increase (I assume that electricity is a normal good). A state with the appliance and equipment standards is supposed to have lower electricity consumption, so the expected sign of coefficient for this dummy variable is negative.

Using a panel data set for 44 states from 1981-2008 and PM method, I hope to answer the question of how per-capita electricity consumption would have change if one state adopts any version of the IECC.

3.5 Empirical Results

Models (1) through (4) in Table 3.3 show the results of Eq. (5) for PMG method. The estimated coefficients for prices, income, climate, and new housing unit accumulation should be interpreted as the short-run and long-run elasticities of electricity consumption, while the estimated coefficients for the indicator variable should be interpreted as the mean effect of electricity consumption for the states which have adopted the IECC or appliances standards. The model (1) is the electricity demand for residential sector using only the energy specific demand factors. The long–run coefficients are highly significant and have the right signs. The own price elasticity is -0.313, the cross price elasticity is 0.035, the income elasticity is 0.585, and the cooling and heating degree days elasticities are 0.234 and 0.233. The short-run coefficients are smaller than the long-run in magnitude with expected right sings for own price, heating and cooling degree days elasticities. The long-run and short-run elasticities of energy prices lie within the range of those found for electricity and natural gas in literature (e.g. Bernstein *et al.* (2006) and Maddala *et al.* (1997)). The pooled error correction coefficient estimate is significantly negative and lies within the unit circle for all three estimations, indicating evidence of mean reversion to a non- spurious long-run relationship and stationary residuals.

Model (2) controls for new housing unit starts. The prices, income, and climate elasticities have the right signs and are pretty close to those found in model (1). The coefficient on accumulated new unit starts is significant and shows that per-capita consumption of electricity has increased by almost 3% for new houses in all states.

Model (3) is the first model which includes the building codes and their interaction terms with new housing starts accumulation. The own price elasticity in now -0.262, the cross price elasticity is 0.024 and the income elasticity is 0.524 and all are smaller in magnitude than the model (1). The CDD and HDD elasticities decreases a little bit and the coefficient on accumulated new housing starts also has decreased. The coefficients on the interaction terms of IECC 2000 and 2003 with accumulated new unit starts are -0.023 and -0.049 respectively. These estimates indicate that if all houses in a given state have been built under IECC 2000 or 2003, per-capita electricity consumption in new buildings is about 2.5% or 5% smaller than in states without these codes. These results lie within the range of those found in Aroonruengsawat *et al.* (2009) and Jacobson *et al.* (2001).

The last model, model (4) includes the appliance and equipment standards. The estimated coefficients on energy specific demand factors and the building code policies remain roughly unchanged. The coefficients on the dummy variable for appliances are not significantly different from zero. These four models also are estimated with time trend included in Eq. (5) and the estimated results are pretty close to Table 3.3 which I do not display the estimations here.

Table 3.4 shows the overall effect of IECCs on per-capita electricity consumption. I include only one dummy variable for building codes in Eq. (5) which gets value one for the states which adopted any type of IECCs and zero otherwise. Models (1) and (2) are the same as Table 3.3. In model (3), the electricity price elasticity is -0.261, the natural gas price elasticity is 0.0325, the income elasticity is 0.502, and the cooling and heating elasticities are 0.180 and 0.162, and accumulated new unit starts coefficient is 0.025. All these long-run coefficients in model (3) are significant and smaller than models (1) and (2). The short-run elasticities are smaller than the long-run in magnitude with expected right sings for own price, heating and cooling degree days elasticities. The coefficient on interaction term of IECC with housing starts indicates that per-capita electricity consumption in new residential buildings has dropped by about 2% on average in the states which have adopted any version of IECC. By adding the appliance standards dummy variable to the model the estimated coefficients for three regressions in model (4) remains unchanged except IECC coefficient which declines significantly. All the error-correction coefficients are negative, less than one with the expected negative signs.

Appendix A and B show the results of Eq. (5) for MG and DFE methods. The Hausman test of long-run homogeneity is not rejected in any model and shows that the PMG regression which is the efficient estimator under the null hypothesis is more suitable than the MG regression.

3.6 Conclusion

This paper measures the International Energy Conservation Code effect on per-capita residential electricity consumption for the first time in U.S. by using Pooled Mean Group estimation. The key advantage of PMG estimation is dealing with short-run heterogeneity as well as the long-run homogeneity of estimated coefficients. It also corrects for any possible endogeneity problems of explanatory variables. The findings of this study along with my first paper are potentially important for the policymakers. The evidence in this paper shows that the new residential buildings per-capita electricity consumption has decreased ranging from 2.5-5% in the states which adopted IECC 2000 and 2003 from 1998 to 2008. As it shown on my first paper the states which experience higher level of energy prices, degree days, relative political extraction, pollution level, and population growth are more likely to adopt any version of IECC. These states also are located on the neighborhood of states which already had adopted IECC and have Democratic Governor. We can conclude that the Democratic Governor result in reduction of electricity consumption in the states with IECC 2000 and 2003. In these states, electricity consumption decreases as the states relative political extraction, pollution level, energy price, and degree days increases.

In 2009, there were 126.1 million homes in U.S. which on average each home consumed about 11280 KWh of delivered electricity and produced about 6.65 metric tons CO_2.[15] If all houses were constructed based on IECC 2000 or 2003, then the equivalence emission reductions from IECC 2000 and 2003 were about 2.2 million and 4.8 million metric tons carbon dioxide for one year.[16]

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[15] 2009 RECS Survey Data, EIA

[16] I use the Emission & Generation Resource Integrated Database (eGRID) U.S. annual non-baseload carbon dioxide emission rate to convert reductions of kilowatt-hours into avoided units of carbon dioxide emissions. The emission factor used for this paper is 7.0555×10^{-4} metric tons CO_2/ kWh. Source: www.epa.gov

Table 3. 1 - Status of Residential Building Energy Code 1998-2008

State	IECC 1998	IECC 2000	IECC2003	IECC2006	Enforcement Status	Residential Code Notes
Alabama					Voluntary	State- developed code effective on Jan 1, 2005
Alaska			Effective on Jan 1, 1992	effective on Nov 8, 2006	Mandatory statewide code	State- developed code similar to IECC 2003 and IECC 2006
Arizona					Voluntary Local wide code	Jurisdictions adopted different versions of IECC
Arkansas			Effective on Oct 1, 2004		Mandatory statewide code	
California	Effective on 1998	Effective on 2001	effective on 2004	effective on 2007	Mandatory statewide code	State-developed code Exceeds IECC 2003
Colorado					Voluntary Local wide code	Jurisdictions adopted different versions of IECC
Connecticut			Effective on Dec 31, 2005		Mandatory statewide code	
Delaware		Effective on Jul 1, 2004			Mandatory statewide code	
District of Columbia		Effective on Jan 9, 2004			Mandatory statewide code	
Florida	Effective on 1997	Effective on Jan 1, 2002	Effective on Jan 1, 2005		Mandatory statewide code	State-developed code Equivalent to IECC's
Georgia		Effective on Jan 1, 2003		Effective on Jan 1, 2008	Mandatory statewide code	

Table 3.1 - Status of Residential Building Energy Code 1998-2008 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	Enforcement Status	Residential Code Notes
Hawaii					Voluntary statewide code	Precedes IECC 1998
Idaho		Effective on Jan 1, 2003	Effective on Jan 1, 2005	Effective on Jan 1, 2008	Mandatory statewide code	
Illinois					Voluntary Local wide code	Jurisdictions adopted different versions of IECC
Indiana					Mandatory statewide code	State-developed code Precedes IECC 1998
Iowa	Effective on 1998	Effective on Jan 1, 2001	Effective on Jan 1, 2004	Effective on Jan 1, 2007	Mandatory statewide code	
Kansas					Voluntary No Statewide code	
Kentucky		Effective on Jul 1, 2005		Effective on Aug 1, 2007	Mandatory statewide code	
Louisiana				Effective on Jun 22, 2007	Mandatory statewide code	
Maine					No Statewide code	
Maryland			Effective on Sep 20, 2004	Effective on Jul 1, 2007	Mandatory statewide code	
Massachusetts					Mandatory statewide code	Seventh edition of Massachusetts Building code for one- and two-family dwellings (equivalent or exceeds IECC 2006)

Table 3.1- Status of Residential Building Energy Code 1998-2008 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	Enforcement Status	Residential Code Notes
Michigan					statewide code	Precedes IECC 1998
Minnesota					statewide code	Precedes IECC 1999
Mississippi					Mandatory No Statewide code	State energy code Precedes IECC 1998
Missouri					No mandatory or voluntary statewide code	Jurisdictions adopted different versions of IECC
Montana			Effective on Sep 3, 2004		Mandatory statewide code	
Nebraska	Effective on 1999		Effective on Jul 1, 2005		Mandatory statewide code	
Nevada					Mandatory	IECC 2003 is mandatory for jurisdictions w/o energy codes. Some southern and northern jurisdictions have adopted IECC 2006.
New Hampshire		Effective on 2002		Effective on 2007	Mandatory statewide code	
New Jersey				Effective on Feb 20, 2007	Mandatory statewide code	
New Mexico			Effective on Jul 1, 2004	Effective on Jan 1, 2008	Mandatory statewide code	
New York	Effective on Jul 29, 1999	Effective on Jul 1, 2002	effective on Jan 1, 2008		Mandatory statewide code	State-developed code Exceeds IECC 2003

Table 3.1 - Status of Residential Building Energy Code 1998-2008 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	Enforcement Status	Residential Code Notes
North Carolina		Effective on Dec 31, 2001	Effective on Jul 1, 2006	Effective on Mar 11, 2008	Mandatory statewide code	
North Dakota					Voluntary No Statewide code	Precedes IECC 1998
Ohio			Effective on Mar 1, 2005		Mandatory statewide code	
Oklahoma			Effective on Jun 1, 2004		Mandatory statewide code	
Oregon		Effective on Apr 1, 2003	Effective on Apr 1, 2005	Effective on Jul 1, 2008	Mandatory statewide code	State-developed code Equivalent or exceeds to IECC2006
Pennsylvania			Effective on Apr 1, 2004	Effective on Dec 31, 2006	Mandatory statewide code	State-developed code Equivalent to IECC
Rhode Island				Effective on 2006	statewide code	
South Carolina		Effective on Jul 1, 2001	Effective on Jan 1, 2005		Mandatory statewide code	
South Dakota					Voluntary	Precedes IECC 1998
Tennessee		Effective on Jul 1, 2003			Mandatory statewide code	
Texas		Effective on Aug 13, 2002			Mandatory statewide code	

Table 3.1 - Status of Residential Building Energy Code 1998-2008 (Continued)

State	IECC 1998	IECC 2000	IECC2003	IECC2006	Enforcement Status	Residential Code Notes
Utah				Effective on Jan 1, 2007	Mandatory statewide code	
Vermont		Effective on Jan 1, 2005			Mandatory statewide code	
Virginia		Effective on Oct 1, 2003		Effective on May 1, 2008	Mandatory statewide code	
Washington			effective on Jul 1, 2002	Effective on Jul 1, 2007	Mandatory statewide code	State-developed code Equivalent to IECC 's
West Virginia			Effective on May 15, 2006		Mandatory statewide code	
Wisconsin					Mandatory statewide code	IECC 2006 is mandatory for one- and two-family dwellings and IECC 2000 for multifamily dwellings
Wyoming					Voluntary	Precedes IECC 1998

Source: Building Codes Assistance Project (BCAP 2008)

Table 3.2 - Summary Statistics

Sample	Complete (n=1232)		No IECC (n=1034)		IECC 1998 (n=19)		IECC 2001 (n=72)		IECC 2003 (n=74)		IECC 2006 (n=33)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Per-Capita Electricity Consumption	14100	4297	13719	4109	14430	5133	16620	4909	16455	4243	15047	4812
Electricity Price	16.66	4.78	16.99	4.87	15.43	4.02	15.26	3.54	14.08	3.78	15.74	4.18
Natural Gas Price	9.13	2.56	8.70	2.29	7.65	2.50	10.99	2.28	11.43	2.23	14.25	1.83
Per-Capita Income	13.33	2.65	12.81	2.37	15.20	0.77	16.46	3.08	15.64	1.90	16.42	1.99
Heating Degree Days	5212	2463	5249	2395	4370	2379	4252	1904	5705	3395	5546	2724
Cooling Degree Days	1140	931	1136	944	1466	1125	1349	829	1017	861	904	635
New Housing Start	28397	39309	25992	36435	62359	61818	54227	57858	30737	42716	22573	20671
IECC 1998	0.015	0.123	0	0	1	0	0	0	0	0	0	0
IECC 2001	0.058	0.235	0	0	0	0	1	0	0	0	0	0
IECC 2003	0.060	0.238	0	0	0	0	0	0	1	0	0	0
IECC 2006	0.027	0.162	0	0	0	0	0	0	0	0	1	0
Appliance Standards	0.175	0.714	0.110	0.583	0.789	1.475	0.306	0.850	0.446	1.112	0.939	1.345

Table 3.3 - PMG Estimates of Household Electricity Demand for Different Versions of IECC

Dependent Variable: Per-Capita Electricity Consumption	(1)	(2)	(3)	(4)
Long-run Coefficients:				
Electricity Price	-0.33***	-0.33***	-0.22***	-0.22***
	(0.024)	(0.020)	(0.020)	(0.020)
Natural Gas Price	0.034***	0.043***	0.020*	0.020*
	(0.012)	(0.010)	(0.010)	(0.010)
Per-Capita Income	0.58***	0.46***	0.52***	0.52***
	(0.031)	(0.039)	(0.041)	(0.041)
Cooling Degree Days	0.23***	0.21***	0.19***	0.19***
	(0.023)	(0.017)	(0.0142)	(0.014)
Heating Degree Days	0.23***	0.19***	0.18***	0.18***
	(0.032)	(0.022)	(0.018)	(0.018)
Accumulated New Unit Starts		0.027**	0.027***	0.026***
		(0.010)	(0.009)	(0.009)
Accumulated New Unit Starts*IECC1998			-0.040	-0.040
			(0.066)	(0.066)
Accumulated New Unit Starts*IECC2000			-0.023**	-0.024**
			(0.011)	(0.012)
Accumulated New Unit Starts*IECC2003			-0.049**	-0.049**
			(0.023)	(0.023)
Accumulated New Unit Starts*IECC2006			-0.003	-0.003
			(0.026)	(0.026)
IECC1998			0.571	0.574
			(0.888)	(0.89)
IECC2000			0.291*	0.301*
			(0.17)	(0.172)
IECC2003			0.641**	0.640**
			(0.325)	(0.325)
IECC2006			-0.037	-0.037
			(0.373)	(0.374)
Appliances Dummy				-0.002
				(0.007)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 3.3 - PMG Estimates of Household Electricity Demand for Different Versions of IECC (Continued)

Dependent Variable: Per-Capita Electricity Consumption	(1)	(2)	(3)	(4)
Short-run Coefficients:				
Δ Electricity Price	-0.13***	-0.09***	-0.09***	-0.09***
	(0.019)	(0.023)	(0.026)	(0.026)
Δ Natural Gas Price	-0.005	-0.005	0.0015	0.001
	(0.006)	(0.006)	(0.006)	(0.006)
Δ Per-Capita Income	-0.0387	-0.09**	-0.1***	-0.1***
	(0.042)	(0.044)	(0.045)	(0.045)
Δ Cooling Degree Days	0.08***	0.06**	0.05***	0.05***
	(0.013)	(0.011)	(0.010)	(0.010)
Δ Heating Degree Days	0.13***	0.11***	0.11***	0.11***
	(0.019)	(0.020)	(0.020)	(0.020)
Δ Accumulated New Unit Starts		0.0030	0.0057	0.0056
		(0.011)	(0.012)	(0.012)
Δ Accumulated New Unit Starts*IECC1998			-0.042	-0.042
			(0.028)	(0.028)
Δ Accumulated New Unit Starts*IECC2000			0.014	0.0087
			(0.059)	(0.060)
Δ Accumulated New Unit Starts*IECC2003			0.086	0.088
			(0.067)	(0.066)
Δ Accumulated New Unit Starts*IECC2006			0.39***	0.39***
			(0.14)	-(0.141)
Error-correction Coefficient:	-0.22***	-0.33**	-0.37***	-0.37***
	(0.023)	(0.033)	(0.037)	(0.037)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 3.4 - PMG Estimates of Household Electricity Demand for any Version of IECC

Dependent Variable: Per-Capita Electricity Consumption	(1)	(2)	(3)	(4)
Long-run Coefficients:				
Electricity Price	-0.313***	-0.303***	-0.261***	-0.26***
	(0.024)	(0.0204)	(0.0195)	(0.0195)
Natural Gas Price	0.0354***	0.043***	0.0325***	0.03***
	(0.012)	(0.0104)	(0.0106)	(0.0107)
Per-Capita Income	0.585***	0.461***	0.502***	0.50***
	(0.031)	(0.0398)	(0.0407)	(0.041)
Cooling Degree Days	0.234***	0.210***	0.180***	0.18***
	(0.0234)	(0.017)	(0.0138)	(0.0138)
Heating Degree Days	0.233***	0.199***	0.162***	0.16***
	(0.0323)	(0.0229)	(0.0211)	(0.0211)
Accumulated New Unit Starts		0.0272**	0.0255***	0.02***
		(0.0106)	(0.0096)	(0.0096)
Accumulated New Unit Starts*IECC			-0.022***	-0.02***
			(0.0082)	(0.0082)
IECC			0.275**	0.277**
			(0.115)	(0.115)
Appliances Dummy				-0.0007
				(0.007)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table3.4 – PMG Estimates of Household Electricity Demand for any Version of IECC (Continued)

Dependent Variable: Per-Capita Electricity Consumption	(1)	(2)	(3)	(4)
Short-run Coefficients:				
Δ Electricity Price	-0.134***	-0.094***	-0.091***	-0.09***
	(0.0192)	(0.0238)	(0.0246)	(0.0246)
Δ Natural Gas Price	-0.0059	-0.0055	-0.0009	-0.0009
	(0.0065)	(0.0065)	(0.0069)	(0.0069)
Δ Per -Capita Income	-0.0387	-0.0990**	-0.116***	-0.11***
	(0.0429)	(0.0443)	(0.0444)	(0.0444)
Δ Cooling Degree Days	0.083***	0.061***	0.060***	0.060***
	(0.013)	(0.0113)	(0.0103)	(0.0103)
Δ Heating Degree Days	0.133***	0.113***	0.116***	0.116***
	(0.0194)	(0.0202)	(0.0197)	(0.0197)
Δ Accumulated New Unit Starts		0.00301	0.0005	0.00054
		(0.0118)	(0.0121)	(0.0121)
Δ Accumulated New Unit Starts*IECC			0.111	0.112
			(0.0695)	(0.0696)
Error-correction Coefficient:	-0.222***	-0.336***	-0.367***	-0.36***
	(0.0237)	(0.0332)	(0.0324)	(0.0324)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Figure 3.1 - Residential state energy code status as of October 2008

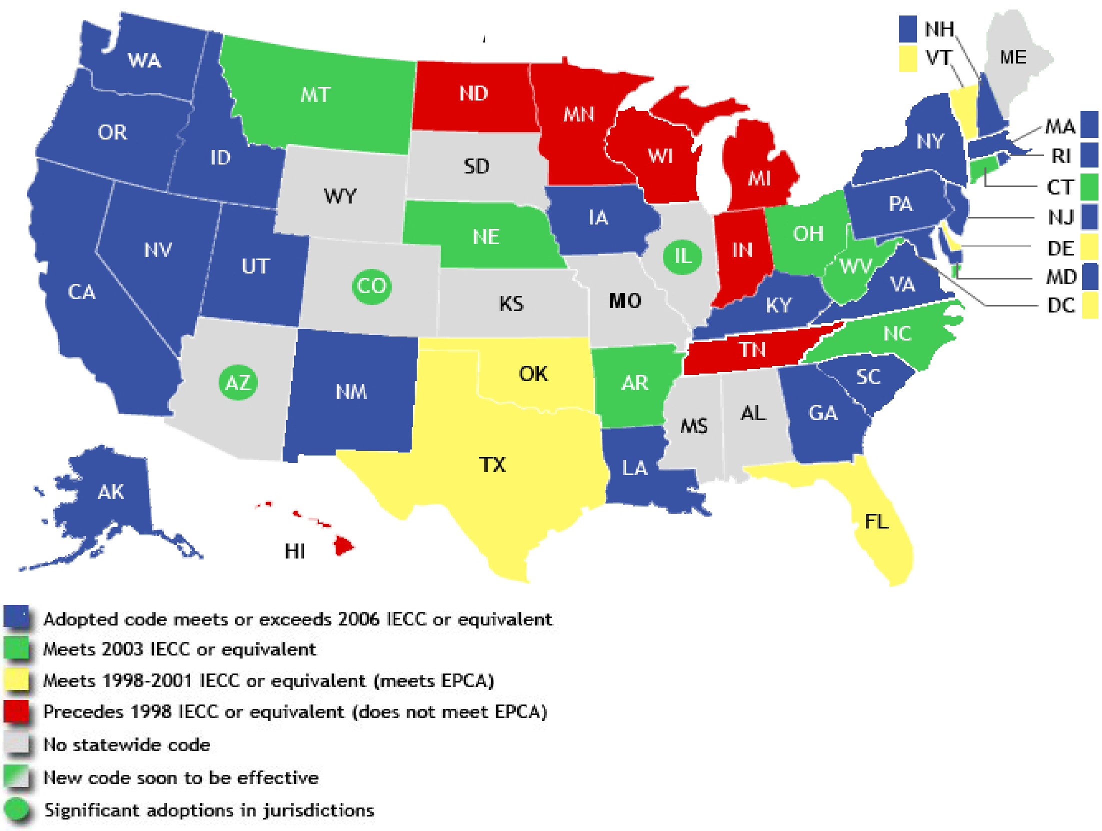


Figure 3.2 – Per-Capita Electricity Consumption (MBtu) for United States 1981-2008

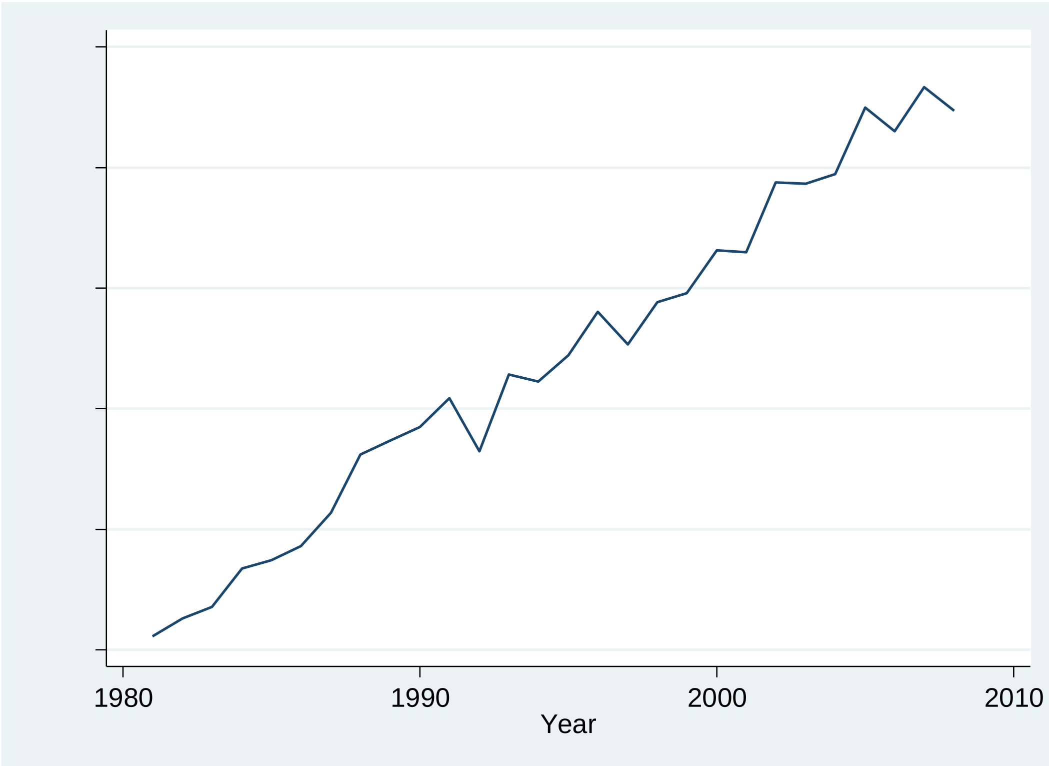
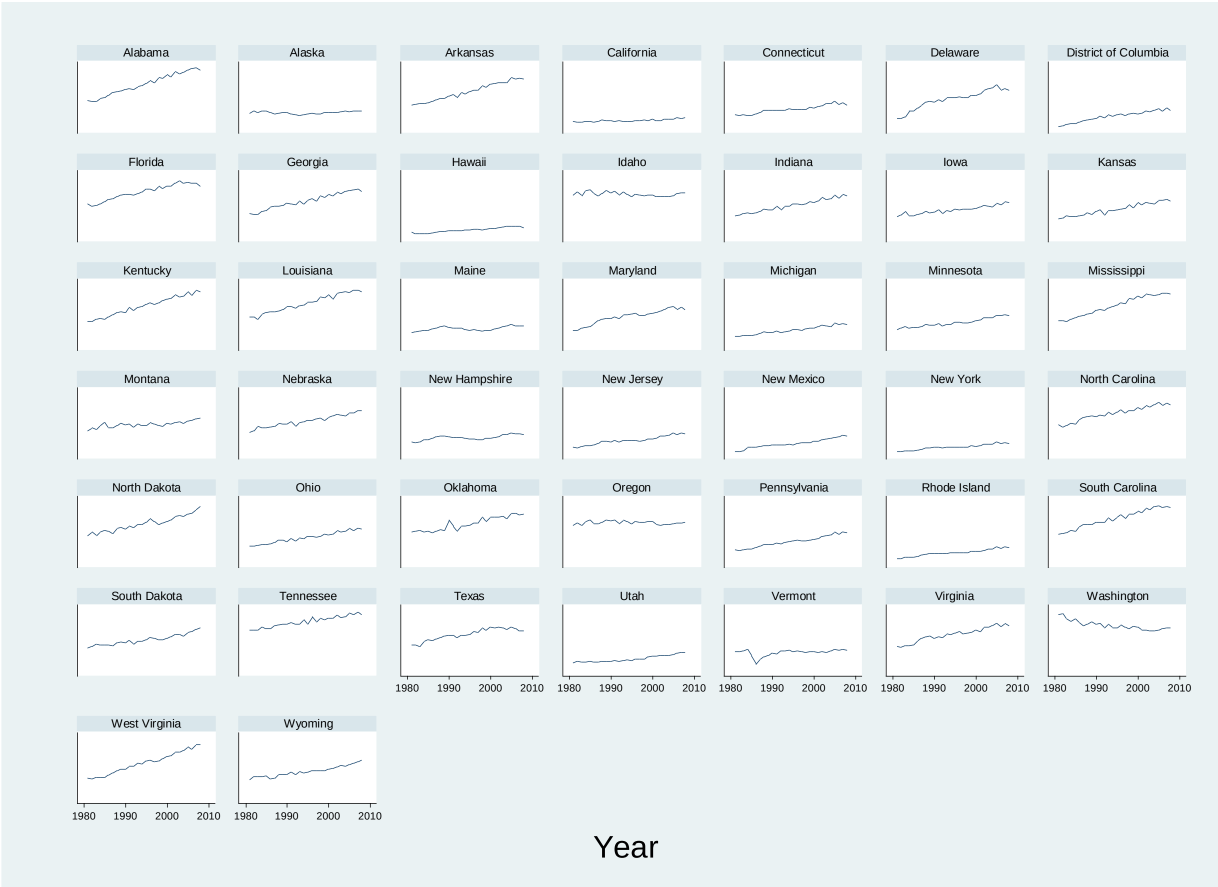


Figure 3.3 – Per-Capita Electricity Consumption (MBtu) By States 1981-2008



Appendix A – MG and DFE Estimates of Household Electricity Demand for Different Versions of IECC

Dependent Variable:	(1)		(2)		(3)		(4)	
Per-Capita Electricity Consumption	MG	DFE	MG	DFE	MG	DFE	MG	DFE
Long-run Coefficients:								
Electricity Price	-0.272***	-0.409***	-0.28***	-0.43***	1.096	-0.431***	1.095	-0.431***
	(0.0453)	(0.0399)	(0.0391)	(0.0404)	(1.410)	(0.0408)	(1.410)	(0.0410)
Natural Gas Price	0.0344	0.0741***	0.0317*	0.0678**	-0.444	0.0835***	-0.443	0.0835***
	(0.0229)	(0.0232)	(0.0168)	(0.0263)	(0.448)	(0.0294)	(0.448)	(0.0295)
Per-Capita Income	0.532***	0.369***	0.361***	0.505***	1.881	0.523***	1.890	0.522***
	(0.0524)	(0.0474)	(0.0621)	(0.0803)	(1.476)	(0.0842)	(1.476)	(0.0845)
Cooling Degree Days	0.154***	0.0527**	0.159***	0.0526**	0.342*	0.0546**	0.343*	0.0545**
	(0.0276)	(0.0260)	(0.0224)	(0.0255)	(0.187)	(0.0257)	(0.187)	(0.0258)
Heating Degree Days	0.220***	0.0925	0.204***	0.103	-0.0995	0.108	-0.0971	0.108
	(0.0369)	(0.0678)	(0.0276)	(0.0663)	(0.283)	(0.0663)	(0.283)	(0.0665)
Accumulated New Unit			0.0394**	-0.04***	0.447	-0.046***	0.445	-0.046***
Starts			(0.0177)	(0.0175)	(0.433)	(0.0179)	(0.433)	(0.0180)
Accumulated New Unit					0.136	-0.00239	0.136	-0.00240
Starts*IECC1998					(0.144)	(0.0329)	(0.144)	(0.0329)
Accumulated New Unit					-0.122	-0.00362	-0.158	-0.00360
Starts*IECC2000					(0.145)	(0.0117)	(0.143)	(0.0117)
Accumulated New Unit					0.372	-0.0248*	0.585	-0.0248*
Starts*IECC2003					(2.017)	(0.0129)	(1.781)	(0.0130)
Accumulated New Unit					-21.21	-0.00771	-21.24	-0.00751
Starts*IECC2006					(21.03)	(0.0206)	(21.02)	(0.0208)
IECC1998					-1.722	0.0762	-1.722	0.0765
					(1.892)	(0.600)	(1.892)	(0.600)
IECC2000					1.611	0.0389	1.977	0.0385
					(1.729)	(0.145)	(1.692)	(0.145)
IECC2003					-4.294	0.332*	-6.626	0.331*
					(24.34)	(0.189)	(21.40)	(0.189)
IECC2006					230.7	-0.0262	2.836	-0.0284
					(228.2)	(0.284)	(1.814)	(0.287)
Appliances Dummy							76.08	0.000780
							(76.08)	(0.0118)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Appendix A – MG and DFE Estimates of Household Electricity Demand for Different Versions of IECC (Continued)

Dependent Variable:	(1)		(2)		(3)		(4)	
Per-Capita Electricity Consumption	MG	DFE	MG	DFE	MG	DFE	MG	DFE
Error-correction Coefficient:	-0.553***	-0.256***	-0.693***	-0.261***	-0.76***	-0.264***	-0.7***	-0.264***
	(0.0397)	(0.0170)	(0.0415)	(0.0175)	(0.0654)	(0.0179)	(0.0655)	(0.0179)
Short-run Coefficients:								
Δ Electricity Price	-0.0803**	-0.061***	-0.0246	-0.033***	-0.0183	-0.0622**	-0.0144	-0.0624**
	(0.0318)	(0.0236)	(0.0282)	(0.0240)	(0.0597)	(0.0242)	(0.0598)	(0.0243)
Δ Natural Gas Price	-0.00960	-0.0147*	-0.0112	-0.0144*	-0.00160	-0.0162*	-0.0017	-0.0162*
	(0.00923)	(0.00806)	(0.00881)	(0.00816)	(0.0114)	(0.00833)	(0.0115)	(0.00833)
Δ Per-Capita Income	-0.160***	-0.0838*	-0.171***	-0.0969**	-0.25***	-0.109**	-0.23**	-0.109**
	(0.0473)	(0.0444)	(0.0550)	(0.0466)	(0.0759)	(0.0473)	(0.0760)	(0.0474)
Δ Cooling Degree Days	0.0438***	0.0363***	0.0212**	0.0365***	0.00585	0.0365***	0.00549	0.0365***
	(0.0120)	(0.00466)	(0.00886)	(0.00468)	(0.0171)	(0.00472)	(0.0171)	(0.00473)
Δ Heating Degree Days	0.0727***	0.0810***	0.0463***	0.0804***	0.0617**	0.0797***	0.0589*	0.0797***
	(0.0153)	(0.0122)	(0.0137)	(0.0122)	(0.0302)	(0.0123)	(0.0302)	(0.0123)
Δ Accumulated New Unit Starts			0.00360	-0.0279**	0.0356	-0.0284**	0.0375	-0.0284**
			(0.0282)	(0.0132)	(0.0427)	(0.0135)	(0.0429)	(0.0135)
Δ Accumulated New Unit					1.770	-0.301	1.770	-0.301
Starts*IECC1998					(2.209)	(0.908)	(2.209)	(0.908)
Δ Accumulated New Unit					-2.034**	-0.0370	-1.8**	-0.0363
Starts*IECC2000					(0.898)	(0.297)	(0.926)	(0.297)
Δ Accumulated New Unit					13.38	-0.133	11.49	-0.130
Starts*IECC2003					(10.49)	(0.445)	(10.28)	(0.448)
Δ Accumulated New Unit					3.576	0.758	3.576	0.751
Starts*IECC2006					(3.605)	(0.560)	(3.605)	(0.570)
Hausman Test	10.45 (0.0334)		3.82 (0.7013)		3.30(0.914)		5.92 (0.92)	

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
For the Hausman test, the *p*-values are reported in brackets.
Hausman test comparing PMG and MG results.

Appendix B – MG and DFE Estimates of Household Electricity Demand for any Version of IECC

Dependent Variable:	(1)		(2)		(3)		(4)	
Per-Capita Electricity Consumption	MG	DFE	MG	DFE	MG	DFE	MG	DFE
Long-run Coefficients:								
Electricity Price	-0.272***	-0.409***	-0.28***	-0.438***	1.074	-0.433***	1.072	-0.433***
	(0.0453)	(0.0399)	(0.0391)	(0.0404)	(1.410)	(0.0404)	(1.411)	(0.0406)
Natural Gas Price	0.0344	0.0741***	0.0317*	0.0678**	-0.455	0.0853***	-0.454	0.0852***
	(0.0229)	(0.0232)	(0.0168)	(0.0263)	(0.448)	(0.0283)	(0.448)	(0.0284)
Per-Capita Income	0.532***	0.369***	0.361***	0.505***	1.858	0.515***	1.865	0.515***
	(0.0524)	(0.0474)	(0.0621)	(0.0803)	(1.476)	(0.0816)	(1.476)	(0.0817)
Cooling Degree Days	0.154***	0.0527**	0.159***	0.0526**	0.339*	0.0511**	0.341*	0.0510**
	(0.0276)	(0.0260)	(0.0224)	(0.0255)	(0.186)	(0.0255)	(0.186)	(0.0255)
Heating Degree Days	0.220***	0.0925	0.204***	0.103	-0.071	0.102	-0.069	0.102
	(0.0369)	(0.0678)	(0.0276)	(0.0663)	(0.282)	(0.0657)	(0.282)	(0.0659)
Accumulated New Unit Starts			0.0394**	-0.047***	0.444	-0.046***	0.442	-0.046***
			(0.0177)	(0.0175)	(0.433)	(0.0176)	(0.434)	(0.0176)
Accumulated New Unit					-20.94	-0.0115	-20.65	-0.0115
Starts*IECC					(21.13)	(0.00779)	(21.11)	(0.00781)
IECC					227.6	0.115	-4.142	0.113
					(229.5)	(0.103)	(21.37)	(0.104)
Appliances Dummy							76.08	0.00135
							(76.08)	(0.0112)

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Appendix B – MG and DFE Estimates of Household Electricity Demand for any Version of IECC (Continued)

Dependent Variable:	(1)		(2)		(3)		(4)	
Per-Capita Electricity Consumption	MG	DFE	MG	DFE	MG	DFE	MG	DFE
Error-correction Coefficient:	-0.553***	-0.256***	-0.693***	-0.261***	-0.73***	-0.263***	-0.73***	-0.263***
	(0.0397)	(0.0170)	(0.0415)	(0.0175)	(0.0551)	(0.0177)	(0.0547)	(0.0177)
Short-run Coefficients:								
Δ Electricity Price	-0.0803**	-0.069***	-0.0246	-0.063***	-0.0368	-0.062***	-0.0332	-0.063***
	(0.0318)	(0.0236)	(0.0282)	(0.0240)	(0.0344)	(0.0241)	(0.0346)	(0.0242)
Δ Natural Gas Price	-0.00960	-0.0147*	-0.0112	-0.0144*	-0.0006	-0.0164**	-0.0003	-0.0163**
	(0.00923)	(0.00806)	(0.00881)	(0.00816)	(0.0106)	(0.00824)	(0.0108)	(0.00825)
Δ Per -Capita Income	-0.160***	-0.0838*	-0.171***	-0.0969**	-0.20***	-0.103**	-0.21***	-0.103**
	(0.0473)	(0.0444)	(0.0550)	(0.0466)	(0.0623)	(0.0468)	(0.0610)	(0.0468)
Δ Cooling Degree Days	0.0438***	0.0363***	0.0212**	0.0365***	0.0134	0.0367***	0.0131	0.0367***
	(0.0120)	(0.00466)	(0.00886)	(0.00468)	(0.0114)	(0.00469)	(0.0114)	(0.00470)
Δ Heating Degree Days	0.0727***	0.0810***	0.0463***	0.0804***	0.0396**	0.0807***	0.0382**	0.0808***
	(0.0153)	(0.0122)	(0.0137)	(0.0122)	(0.0167)	(0.0122)	(0.0167)	(0.0122)
Δ Accumulated New Unit Starts			0.00360	-0.0279**	0.0335	-0.0291**	0.0354	-0.0291**
			(0.0282)	(0.0132)	(0.0382)	(0.0135)	(0.0384)	(0.0135)
Δ Accumulated New Unit Starts*IECC					13.86	0.122	13.75	0.125
					(10.45)	(0.187)	(10.36)	(0.188)
Hausman Test	10.45 (0.0334)		3.82 (0.7013)		1.14 (0.9796)		5.41 (0.7972)	

Notes: Standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
For the Hausman test, the *p*-values are reported in brackets.
Hausman test comparing PMG and MG results.

Chapter 4

Impact of Building Energy Codes on the Households Electricity Consumption: A Pseudo Panel Approach

4.1 Introductions

As of May 2013, one of several editions of International Energy Conservation Code (IECC) is adopted in 45 states in residential building sector in U.S. (BCAP 2013). IECC is a modern, up-to-date building energy conservation code which was introduced to the nation first on 1998. It focuses on energy efficient building envelopes and insulation of energy efficient mechanical, and power system requirements. The main goal of IECC is to reach an optimal utilization of fossil fuel and nondepletable resources trough controlling the heat flow into and out of the building. The Residential Energy Conservation Survey (RECS 2009) reported that space conditioning (cooling and heating) accounts for more than half of the residential energy consumption. Houses used about 48% of their energy consumption for heating and cooling in 2009, down from 58% in 1993. The factors which support such downward trend in energy consumption are adoption of more efficient equipment; better insulation; efficient doors and windows; and population migration to warmer places.

This paper examines the effect of energy efficient building code IECC 2006 on electricity consumption of residential sector in Idaho, New Mexico, and Ohio using household level data. The empirical analysis employs pseudo panel approach on two strategies to evaluate how building energy code change (from IECC 2003 to IECC 2006) impact electricity consumption. The first approach is a pre- and post-code-change comparisons in electricity consumption between buildings subject to the before and after IECC 2006 implementation. The second comparison approach captures the sensitivity of energy consumption with respect to weather fluctuation. Generally, these approaches are similar to study by Jacobson *et al.* (2013), which evaluate the impact of energy consumption for residences constructed within three years before and three years after Florida's 2002 residential building code change. They use monthly observations for repeated years (1999-2005) for households live in the northern climate region of Florida.

The household level data for this paper is taken from the American Community Survey (ACS) for the years 2005 to 2010. Because ACS data do not observe households over time, a pseudo panel data is created which observes groups of relatively homogenous households over time (Deaton, 1985). The pseudo panel approach controls for unobserved household specific effects that may otherwise bias the effect of energy building code on electricity consumption in individual cross-sectional regressions. I find that the impact of code change on electricity consumption by the pseudo panel is considerably higher than these obtained from OLS estimation with individual data and pseudo panel approach without controlling the cohorts fixed effects. The results show that after controlling for unobserved effects, IECC 2006 appears to have caused a 19% decrease in annual electricity consumption for Idaho, New Mexico, and Ohio. It is also shown that the consumption of electricity decreased for air-conditioning by controlling the year and weather fluctuation.

There is a growing literature on the impact of building energy code on energy consumption, using individual micro data. Jacobson *et al.* (2013) found a reduction of 4-6% in electricity and natural gas consumption for residences built just before and after Florida's building energy code 2002.[17] Koirala *et al.* (2013) conducted a cross-sectional analysis for ACS 2007 to estimate the impact of IECC 2003 and IECC 2006 in residential energy consumption. They showed that household can reduce electricity, natural gas, and heating oil consumption by 1.8%, 1.3%, and 2.8% respectively. Horowitz *et al* (1990) estimated the effect of Model Conservation Standards on annual electricity consumption for residences built before and after the code implemented in Tacoma, Washington. They found a 13.7% reduction in electricity consumption.

All previous studies on this literature use either panel data or cross- sectional data. There is a lack of information on panel data, even if exists, those are expensive and suffer from attrition problem. The attrition and nonresponse get bigger as the number of time periods increase. On contrary, there exists a large set of repeated cross-sectional surveys drawn anew each year. These data are not subject to attrition bias and can extended for long time periods. But since a random sample is taken from the population each time therefore individual households cannot be traced over time. The main contribution of this study is that instead of using one cross- sectional survey data, I construct a pseudo panel data using several survey data which facilitates to track the cohorts over time and making possible to identify the effect of building energy code on electricity consumption before and after adoption.

The paper proceeds as follow: in section 2 describe the energy code IECC 2006. Section 3 describes the data set and pseudo panel construction. Section 4 describes the empirical setting. Regression results are presented and discussed in section 5. Section 6 concludes.

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[17] In 2002, there were three major changes on the 2001 Florida Building Code which brings it parallel with the IECC.

4.2 The Building Code: IECC 2006

The IECC 2006 is the fourth edition of International Energy Conservation Code which presents the code as originally issued with some changes reflected in the 2003 edition. The residential section of IECC was considerably revised in 2004, therefore IECC is summarized in two main eras: 2003 and before, and 2004 and after. The climate zones were decreased from 17 zones to 8 primary zones, and the code became more simple and clear to follow for the building categories.

There are major differences between the 2003 and 2006 editions. The IECC 2006 defines climate zones completely based on geopolitical boundaries such as state and county lines, therefore eliminates the need for local climate data which were used on the old versions. The IECC 2006 increases the stringency in multifamily buildings as much as the single family, while in IECC 2003 the multifamily requirements are remarkably less stringent than the single family buildings. The IECC 2006 has fixed envelope efficiency requirements for either low or high window-wall ratios. The IECC 2003, in contrast, has different envelope requirements for homes with high and low window-wall ratios. IECC 2003 also requires R-19 insulation for the ceiling, while IECC 2006 requires R-30 cavity insulation.[18]

Since ACS is conducted annually, this paper focuses only on the states with the effective date of IECC 2006 starting at the beginning of calendar year. Therefore, I can capture all residences were constructed at the same year and were subject to the code change, and avoid biases coming from including the residences constructed before code implementation for the sates which effective date of code is other than the beginning of the year.

[18] R-value is a measure of heat flow resistance through a given thickness of material. The higher the R-value, the larger the insulation power and more effective at energy savings.

Idaho approved its first statewide residential and commercial energy standards through House Bill 586 on March 27, 2002. The IECC 2000 went into effect by January 1st, 2003. Then Idaho Legislatures adopted the building energy code every three years as they were revised by the International Code Council. The IECC 2003 became effective on January 1, 2005. The next updates were IECC 2006 on January 1st, 2008; and IECC 2009 on January 1st, 2011.

The Construction Industries Division of New Mexico updates or amends the residential building code every three years. The most recent version, the New Mexico Energy Conservation Code 2009, based on IECC 2009 became effective on January 1st, 2012. New Mexico adopted IECC 2003 with an effective date of July 1st, 2004, and IECC 2006 with effective date of January 1st, 2008.

The Ohio Board of Building Standards adopted the IECC for first time on March 1st, 2005. The IECC were updated from 2003 to 2006 version on January 1st, 2008. Then, the Board of Building Standards re-adopted the IECC 2006 by including more prescriptive options for one-, two-, and three- family residence. Ohio does not have a formal schedule set for adoption of IECC.

4.3 Data

The data for this paper were collected by U.S. Census Bureau, as a part of U.S. Department of Commerce, Economics and Statistics Administration. The Census Bureau conducts the American Community Survey (ACS) every year. The ACS is a nationwide survey of housing unit addresses and group quarters, collecting detail information on social, economic, housing, and demographic characteristics since 1996. Since 2007, the ACS just has started to report the exact year when the construction first built which determines if the residence was subject to the building energy code change or not. Because of this lack of information, I only focus on IECC 2006 which was mostly adopted by states after 2007. This study uses ACS data for Idaho, New Mexico, and Ohio from 2005 through 2010, three years before and three years after IECC 2006 went into effect on January 1st, 2008 in these states. This study also includes housing units, one-family house detached structures, with no business or medical office in property. Therefore we have a more homogenous household sample since apartments, mobile homes and trailers are excluded. Single family houses consume more residential energy and have higher average amount spent per household member on energy than the other types of houses. Single family houses (attached/detached) used about 80% of residential energy in 2005, while the multi-family units used 15% and mobile homes and trailers consumed only 5%.[19]

The IECC 2006 measures, state level residential building energy code, are obtained from Building Codes Assistance Project (BCAP 2013). The heating degree days (HDD) and cooling degree days (CDD) information were obtained from the National Climate Data Center (NOAA).

The basic idea in creating a pseudo panel data set is to divide the population into cohorts so that each cohort shares a set of characteristics which stay constant over time such as age, gender, race, place of residence and so on. The within average of cohorts are treated as unit of observation. Since the survey sizes are finite we should be thoughtful in the choice of cohorts and number of observation in each cohort. On one hand, we want to have homogenize cohorts, therefore choose large numbers of cohorts with small observation in each one; on the other hand, we are looking for small measurement error and therefore decrease the number of cohorts with

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[19] U.S. Energy Information Administration, Residential Energy Consumption Survey, 2005

large number of individuals in each cohort. Verbeek and Nijman (1992, 1993) showed that at least 100 observations per cohort are sufficient to have consistent estimation results.

There are 184,355 household observations for three states from which to build the pseudo panel. In the base case, a pseudo panel was defined by 9 birth cohorts (born between year 1935-1939, and subsequent five year intervals, until 1975-1979), 3 levels of education (from no schooling completed to high school graduate, some college but less than 1 year to associate's degree, and bachelor's degree to doctorate degree), 2 regions (Midwest, and West) and 6 survey years (2005 to 2010) of 324 cohort-year observations. Number of observations is more than 100 in each cell, and the average number of individuals per cell is 521. The birth cohort construction assumes that everyone who is X years old in year t will be in the same cohort as everyone who is $X + 1$ years old in year $t + 1$. It ensures that if an individual is sampled in a later yare, it will be in the same cohort.

Table 4.1 summarizes the descriptive statistics for all explanatory variables for pseudo panel data. It shows that annual mean electricity consumption is 15,498 (kWh). The average household's income is $85,000 and on average 3 persons lives in each household whom 88% are white. The average residence has 3.2 bedrooms and about 15% use electricity for heating in their houses. The mean value of HDD and CDD are 5,664 and 813 respectively. Table 4.2 compares the energy consumption and other household characteristics before and after the building energy code change. Houses built after the building energy code consume 133 kWh less electricity than the houses built before code change. Households in new houses have higher income and experience more HDD and less CDD than the households in the old residences. The other socioeconomics and house characteristics are quite similar for both groups of old and new houses.

4.4 Empirical Model

This study uses two empirical strategies to investigate the impact of building energy code change on household electricity consumption (Jacobson *et al.* 2013). The first strategy is a before-and-after comparisons liner regression model of the form:

$$y_{it} = \alpha CodeChange_{it} + x_{it}\beta + v_t + f_{it} + \varepsilon_{it} \qquad i = 1, \dots, N, \;\; t = 1, \dots, T \qquad (1)$$

where y_{it} is annual electricity consumption (kWh) of household i at period t; $CodeChange_{it}$ is a dummy variable for whether the building was constructed after the building energy code change; α is its associated coefficient; x_{it} is a vector of socioeconomics and house characteristics including the natural log of the household income, race, number of persons in the household, number of bedrooms, and an electric heat indicators; β is its associated coefficient vectors; v_t is a survey year specific intercept which controls for year to year common effects to all households, such as changes in the electricity price or weather fluctuation; f_{it} captures unobserved individual heterogeneity; ε_{it} is an error term with scalar covariance matrix, i is the number of households in the survey at period t, and T is the number of periods.

The unobserved individual heterogeneity cannot be controlled by adding individual fixed effect to the model with household survey data. Therefore the least square estimations of Eq. (1) will be biased and inconsistent. Deaton (1985) introduced pseudo panel estimation technique to the literature to deal with this issue. The basic idea is to divide the population into cohorts so that each cohort shares a set of characteristics which stay constant over time such as age, gender, place of residence and so on. The within average of cohorts are treated as unit of observations in pseudo panel. Averaging Eq. (1) over the cohort observations purges all individual heterogeneities, the resulting model can be written as:

$$\bar{y}_{ct} = \alpha\overline{CodeChange}_{ct} + \bar{x}_{ct}\beta + v_t + \bar{f}_c + \bar{\varepsilon}_{ct} \qquad c = 1, \dots, C, \;\; t = 1, \dots, T \qquad (2)$$

where $\bar{y}_{ct} = (\frac{1}{i_c})\sum_{i \in n_c} y_{it}$, $\overline{CodeChange}_{ct} = (\frac{1}{i_c})\sum_{i \in n_c} CodeChange_{it}$, $\bar{x}_{ct} = (\frac{1}{i_c})\sum_{i \in n_c} x_{it}$, $\bar{f}_c = (\frac{1}{i_c})\sum_{i \in n_c} f_{it}$, $\bar{\varepsilon}_{ct} = (\frac{1}{i_c})\sum_{i \in n_c} \varepsilon_{it}$, i_c is the number of observation in cohort c, n_c is the set of observation in cohort c, and C is the total number of cohorts. In Eq. (2), $\bar{f}_c$ is the average of the fixed effects for those households in cohort c in the survey year t. It is obvious that $\bar{f}_c$ is not constant over time because the surveys are collected separately at different time. Hence, unobserved $\bar{f}_c$ is correlated with the explanatory variables and resulting in inconsistent estimation results. The bias can be eliminated if the sample size in each cohort is sufficiently large, then $\bar{f}_c$ can be treated as the true cohort effect (f_c) or the unobserved cohort fixed effect. In this case, Eq. (2) can be estimated by using cohort dummy variables (one for each cohort) as follow:

$$\bar{y}_{ct} = \alpha\overline{CodeChange}_{ct} + \bar{x}_{ct}\beta + v_t + f_c + \bar{\varepsilon}_{ct} \qquad c = 1, \dots, C, \;\; t = 1, \dots, T \qquad (3)$$

All error components in Eq. (1) which are correlated with the explanatory variables have been eliminated from the error term, therefore fixed effect estimation of Eq. (3) based on cohort means is consistent. We also assume that the error terms are normally distributed and uncorrelated either within or across cohorts, but since the data are aggregated across cohorts and the size of cohorts are used to calculate the mean values, it is possible to have aggregate heteroskedasticity.[20] Following Dargay (2007) we can use weighted least-square method by

[20] The size of cohorts used to calculate the means varies; therefore there is variation on the mean values. Hence the larger cohorts have a smaller standard error of the mean and the smaller have a larger one. Therefore the measurement errors of each variable will be correlated with the sample size of the cohort used.

weighting each cell with square root of the number of households in each cell to correct the heteroskedasticity. The parameter of interest is α which captures the average difference in electricity consumption between households was built before and after energy code change. We would expect α to be negative which means that the building energy code causes a reduction in electricity consumption.

The second strategy is also a before-and-after comparisons liner regression model which focuses how weather fluctuation may differently impact pre and post code change electricity consumption.

$$\bar{y}_{ct} = \alpha\overline{CodeChange}_{ct} \times [\overline{CDD}_{ct}, \overline{HDD}_{ct}] + \delta[\overline{CDD}_{ct}, \overline{HDD}_{ct}] + v_t + f_c + \bar{\varepsilon}_{ct} \qquad (4)$$

where the policy variable code change is interacted with CDD and HDD. The estimate of α is our primary interest, and indicates that how house differ in electricity consumption responses to weather changes before and after code change. The sign of interacted coefficients of code change with CDD and HDD are expected to be negative, which means that houses built after the building energy code change is less sensitive to increase in CDD and HDD, and the cooling and heating devices are more efficient during cooling and heating days in the houses with IECC 2006.

4.5 Results

The change in three states building energy code from IECC 2003 to 2006 combined with the ACS data from 2005 to 2010 provides an opportunity to test the effect of energy code on electricity consumption. The estimates from the regression with individual data, and pseudo panel for first specification are presented in Table 4.3. Column (1) shows the OLS regression results from cross-sectional data, and next two columns show the results from the pseudo panel model with and without controlling for cohort fixed effects. The results show that the estimated effect of code change on electricity consumption from the pseudo panel with controlling cohort fixed effects is remarkably larger than those from the pseudo panel without cohort fixed effects and from the regression with individual data. The downward can be explained by housing market condition. The construction of new houses decreases due to the housing crash and there will be fewer household residences built with new building energy code in the market, and therefore the decline in electricity consumption in efficient buildings will decrease. This would imply a negative correlation between housing crash and decline in electricity consumption in new buildings, and with a negative correlation between new housing stock and housing crash, the cross section data regression would show an upward endogeneity bias due to neglected factor of housing crash.

Based on the pseudo panel estimation on column (3), houses built after the IECC 2006 consume 3,085 kWh per year less than houses built before IECC 2006 implementation. The results suggest that the IECC 2006 results in a 19% decrease in residential electricity consumption. I also find that household with higher level of income, more bedrooms and persons in house consume more electricity. A 10% increase in household income or bedroom is associated with an increase of 327 kWh and 364 kWh respectively, or an increase of 2 percent, in electricity consumption.

It is possible that the results for Eq. (3) depend on the way in which the cohorts are defined and constructed. Therefore, two alternatives cohort constructions are used to test the effect of cohort construction on the results. The first one is defined by 6 birth cohorts (born between year 1926-1935, and subsequent 10 year intervals, until 1976-1985), 3 levels of education, 2 regions and 6 survey years of 216 cohort-year observations, and the second one is defined by 5 birth cohorts (born between year 1926-1935, and subsequent 10 year intervals, until 1966-1975), 2 gender, 2 regions and 6 survey years of 120 cohort-year observations. Columns (4) and (5) in Table 4.2 shows that the results are relatively robust across alternative cohort specifications.

The first column of Table 4.4 reports the electricity estimates of Eq. (4). The results show that electricity consumption is increasing in CDD and HDD, and confirms that household uses electricity for cooling and heating systems. The interaction term of CDD with code change indicates that the electricity consumption of post-code-change building is less sensitive to a rise in CDD. The marginal effect of one unit increase in CDD is 48.3 kWh/year smaller for post-code-change building. This marginal effect is equivalent to 2.04% decrease in responsiveness to CDD relative to the response of pre-code-change buildings, which is 2,343 kWh/year. The results for HDD suggest that the post-code-change buildings are less efficient respect to electric heating. The positive response to HDD is less important because as it shown on the summary statistics only about 15% of household use electricity for heating their houses. Columns (2) and (3) confirm the same results for CDD and HDD with alternative cohort constructions.

Next, I calculate the benefits and cots of the IECC 2006 for three states for a single residence. The benefit includes the decreased cost on utility bills and the avoided social costs of greenhouse gas emissions, while the cost includes the higher compliance cost of the IECC 2006. The houses built after the code implementations consume about 3,085 kWh per year less than houses built before IECC 2006. With the average marginal price of 11.06 ¢/kWh for three states, the average houses built under the IECC 2006 saves $341.2 per year in electricity bill. The equivalences for emission reduction from IECC 2006 for each residence is about 2.17 metric tons of CO_2. To obtain the associated benefits of carbon reduction, I use the low and high social cost of carbon for 2010 from EPA.[21] The results for avoided damages from the decreased electricity consumption of IECC 2006 range between $10.23 and $76.17 per residence each year.

Since the building energy code is applied on whole building therefore it is not easy to calculate the compliance cost of IECC 2006. But using a performance-based approach requires the overall efficiency of a building compare to the baseline design, instead of a specific features of new building. As explained in section 4.2, one of the major changes to the baseline house in IECC 2006 is increasing the ceiling insulation requirements from R-19 to R-30. Following the assumption of Lucas (2011), I assume a two-story, single-family house with a conditional floor area of 2,400 ft^2 with a slab-on-grade foundation. The house has 9-ft ceiling , and ceiling area is 1,200 ft^2. Assuming one feet squares costs $0.38, the building with an R-30 ceiling insulation would add $456 for entire ceiling to overall construction costs.[22] Under the best-case scenario – a zero discount rate – the private payback period is 1.3 years and low and high social payback period by including CO_2 benefits are 1.29 and 1.09 years.

4.6 Conclusion

This study uses a pseudo panel method to examine the impact of IECC 2006 on electricity consumption in Idaho, New Mexico, and Ohio. The pseudo panel approach controls for

[21] United States Environmental Protection Agency, "Technical Support Document: -Social Cost of Carbon for Regulatory Impact analysis – Under Executive Order 12866- http://www.epa.gov/OMS/climate/regulations/scc-tsd.pdf

[22] The cost is based on the 2011 RS Means published cost data. www.rsmeans.com

unobservable household characteristics, which may bias the effect of building energy code on electricity consumption. This paper find a positive endogeneity bias in the effect of building energy code on electricity consumption based on individual data and pseudo panel data without controlling for cohort fixed effects. Based on pseudo panel method, the electricity consumption decreased by 19% for the residences built after IECC 2006 implementation, which is higher than those found in my second paper for the IECC 2000 and 2003. It is shown that new residential buildings electricity consumption has decreased by about 2.5% and 5% in the states with IECC 2000 and IECC 2003 respectively. The results make important contribution to the policy and decision makers. The U.S. Department of Energy (DOE) analyzes each new version of IECC to determine whether it is expected to save energy compare to its predecessors. This study shows that IECC 2006 clearly appears to be successful in decreasing the electricity consumption in new residential buildings relative to the previous editions such as IECC 2000 and 2003.

Table 4.1 - Descriptive Statistics for Pseudo Panel Data

Variable	Observation	Mean	Std. Dev.	Min	Max
Electricity (kWh)	324	15498	1279	11863	18225
Household Income	324	84931	27906	42104	154183
Bedroom	324	3.278	0.192	2.884	3.704
Number of Persons	324	3.060	0.660	2.094	4.265
Electric Heat	324	0.156	0.034	0.080	0.280
Race	324	0.882	0.057	0.710	0.976
HDD	324	5664	284	5026	6221
CDD	324	813	121	625	1040

Table 4.2 - Descriptive Statistics for Houses Built Before and After the Building Code Change

	Before Code (n=162)	After Code (n=162)	
Variable	Mean	Mean	Difference
Electricity (kWh)	15564	15432	-133
	(1294)	(1263)	
Household Income	83469	86392	2923
	(27368)	(28443)	
Bedroom	3.270	3.286	0.016
	(0.184)	(0.199)	
Number of Persons	3.079	3.040	-0.039
	(0.644)	(0.677)	
Electric Heat	0.150	0.162	0.012
	(0.031)	(0.036)	
Race	0.877	0.886	0.009
	(0.064)	(0.049)	
HDD	5468	5861	393
	(238)	(167)	
CDD	861	765	-96
	(83)	(134)	

Standard deviations are reported in parentheses.

Table 4.3 - Pre- and post-code-change Comparisons for Electricity Consumption for Individual Data, and Three Alternatives Cohort Means

	Individual data (cross-sectional regression) OLS (1)	Pseudo panel (9 years birth- 3 education- 2 regions cohort means) WLS (2)	Pseudo panel (9 years birth- 3 education -2 regions cohort means) WLS (3)	Pseudo panel (6 years birth- 3 education- 2 regions cohort means) WLS (4)	Pseudo panel (5 years birth- 2 gender –2 region cohort means) WLS (5)
Code change	-166.7	-622.2	-3,085*	-2,840**	-3,069
	(137.6)	(1,444)	(1,765)	(1,093)	(2,062)
Income	1,250***	-337.0	3,266***	2,275***	4,505***
	(25.71)	(544.2)	(974.8)	(861.8)	(814.5)
Number of Bedrooms	1,370***	4,627***	3,640***	4,117***	3,223*
	(26.95)	(971.5)	(826.3)	(1,477)	(1,657)
Electric Heat	7,785***	8,473***	2,507	-1,586	-6,349
	(55.36)	(2,160)	(1,677)	(2,556)	(3,077)
Number of Persons	1,186***	110.9	914.4**	1,898***	-139.57
	(16.06)	(168.4)	(452.7)	(424.8)	(814.5)
Race	117.1*	-5,476***	1,794	6,847**	4,667
	(62.87)	(1,685)	(1,795)	(2,805)	(4,335)
Constant	-7,998***	6,880*	-36,140***	-35,257***	-48,411***
	(272.4)	(3,905)	(10,346)	(8,719)	(8,071)
Cohort Effect	No	No	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes
Observations	184,355	324	324	216	120
R-squared	0.165	0.285	0.783	0.833	0.75

Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Table 4.4 - Pre- and post-code-change Comparisons for Electricity Consumption due to Weather Fluctuation for Three Alternatives Cohort Means

	Pseudo panel (9 years birth- 3 education- 2 regions cohort means) WLS (1)	Pseudo panel (6 years birth- 3 education- 2 regions cohort means) WLS (2)	Pseudo panel (5 years birth- 2 gender- 2 regions cohort means) WLS (3)
Code Change × CDD	-48.30***	-59.55***	-49.45***
	(13.27)	(10.46)	(16.53)
Code Change × HDD	6.23***	7.91***	6.53***
	(1.71)	(1.34)	(2.04)
CDD	2,343***	1,989 ***	1,911***
	(766.9)	(409)	(626)
HDD	9,293***	2,031*	3,921**
	(1,814)	(1,108)	(1,744)
Constant	-81,287***	-14,302	-32,754**
	(18,292)	(10,124)	(16,158)
Observations	324	216	120
R-squared	0.64	0.8	0.64

Notes: Standard errors in parenthesis. (*** p<0.01, ** p<0.05, * p<0.1)

Chapter 5

Conclusion

The three essays in this dissertation present an analysis of selected aspects of residential building energy code adoption and its impact on energy consumption, which give rise to several important policy recommendations.

While the IECC has introduced less than two decades to the nation, as of May 2013 about 45 /+6ive states have adopted any version of IECC at the state level. But there is no uniform and clear rule for adoption of the building energy code by the states. The adoption depends on some socio-economics, political, spatial, and environmental factors. In particular, the states with higher level of degree days, relative political extraction, population growth and pollution level are more likely to adopt the IECC. Furthermore, the odd of adoption is negative for the states which have Republican Governor in place. Per-capita disposable income and gross state product do not contribute to the adoption of IECC by states. In the first essay, it is also concluded that the neighbor states with any version of IECC have a great impact on adoption of codes.

Each time a new version of IECC is published, the DOE investigate whether the new version save more energy compare to old versions. The last two essays investigate the impact of different versions of IECC on household per-capita electricity consumption in two different ways: using micro and macro level data. The results show that residential per-capita electricity consumption in new houses has decreased for the states which adopted any version of IECC.

One of the key implications of this analysis for policy makers is that electricity consumption has decreases more in the states which adopted IECC 2006 than the states adopted IECC 2000 or 2003. If the policymakers want decrease the electricity consumption in residential sector, it is better to focus more on the states which have lower energy price, degree days, relative political extraction, and pollution level.

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