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Energy Codes and the Landlord-Tenant Problem

Maya Papineau

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Carleton University

Department of Economics

1125 Colonel By Drive
Ottawa, Ontario, Canada
K1S 5B6

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Maya Papineau[†]
Carleton University

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Abstract

I estimate the energy efficiency premium in unlabeled office buildings by exploiting variation in mandatory building energy standard implementations, as a result of the U.S. 1992 Energy Policy Act. A more stringent energy code leads to rent and price premiums of approximately 4% and 9%, respectively. Significant heterogeneity in the rent premium is observed based on who pays the utility bills, as would be expected absent asymmetric information about energy conservation characteristics among real estate market participants. The rent and price premiums are larger in hotter, more humid climates, and are consistent with full capitalization of the energy savings from a more stringent standard.

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[†] Department of Economics, Carleton University, Ottawa, Canada, K1S 5B6. E-mail: maya.papineau@carleton.ca.

1. Introduction

Commercial buildings consume close to 40% of the electricity and 20% of all energy in the U.S. economy, and mandatory building energy codes affecting the energy efficiency of most new construction in the U.S. have been credited with delivering significant, cost effective energy savings.[1] If these codes deliver valuable energy savings, both prospective owners and tenants should be willing to pay a premium to purchase or locate in buildings constructed under a more stringent energy code, as the energy savings are internalized in these market transactions. However, market premiums from energy efficiency investments may be mitigated due to asymmetric information about a building's energy use characteristics, which has been a long-standing subject of debate among economists and policymakers (Gillingham et al. (2009)).

A frequently cited informational market failure is the landlord-tenant problem in residential and commercial buildings: when a building's energy efficiency is costly to observe, prospective tenants or buyers may not be willing to pay rent or sales premiums for higher efficiency levels because they are unaware, or unconvinced, of a building's efficiency attributes. This weakens the owner's incentive to invest in energy efficiency, even in cases when it is economically efficient to do so. Such foregone net beneficial investments may contribute to an energy efficiency gap between realized levels of energy conservation investment versus the larger set of economically efficient ones. This principal-agent problem has been widely cited as a potential source of investment inefficiency that may merit policy intervention (Jaffe and Stavins (1994); EPA (2003); Murtishaw and Sathaye (2006); Allcott and Greenstone (2012)), yet no work thus far has empirically assessed the prevalence of landlord-tenant informational asymmetries in the commercial building stock.

While Energy Star and LEED buildings have recently been associated with rent and sales price premiums (Eichholtz et al. (2010), Fuerst and McAllister (2011) and Eichholtz et al. (2013)), green-labeling strategies are a policy response explicitly intended to eliminate asymmetric information between buyers and sellers (Milgrom (2008)), and consequently

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[1] See Department of Energy (1993), Cort et al. (2002), CEC (2007), EPA (2009).

observed premiums in labeled buildings cannot settle the question of whether asymmetric information mitigates the return to energy efficiency. In addition, the value of purchasing or locating in green-labeled buildings is at least partly related to the intangible effects of the label, and the voluntary nature of the labeling decision suggests unobservable building characteristics may account for at least a portion of the estimated premium for a green label.

To address the empirical confounders in previous work on the relationship between energy efficiency and price premiums in buildings, in this study I make use of exogenous energy efficiency investment variation to assess whether prospective owners and tenants pay a premium to purchase or locate in energy efficient yet unlabeled buildings. My identification strategy makes use of a unique dataset of geocoded building-level observations that includes information on rental rates, transaction prices, and whether tenants or owners pay for utilities. Each building is assigned to a particular efficiency level by exploiting year-of-adoption variation in the implementation of state-level mandatory energy codes, as directed by passage of the federal Energy Policy Act in 1992. To obtain a credible control sample I match buildings constructed within three years of each other, just before and just after an energy code came into effect, located an average of half a mile apart.

Communicating the efficiency characteristics of a building constructed under a more stringent energy code faces the same challenges as a building in which an owner or developer has independently made the decision to incorporate energy efficient features. For example, energy codes do not require monitoring of the building's energy use attributes, and market participants do not observe an explicit signal of energy performance. These features of energy codes create a unique opportunity to test for evidence of asymmetric information between building owners and prospective tenants or buyers. I utilize these features to develop three testable hypotheses about energy efficiency value premiums when there is asymmetric information about energy use: first, energy efficient buildings will not rent at a premium; second, there will be no observed heterogeneity in rental prices when tenants or owners pay for energy utilities; and third, energy efficient buildings will not sell at a premium. Having assessed whether there is evidence to accept or reject each of these hypotheses, I move on to address whether the estimated premiums are consistent with capitalization of estimated building-level savings.

The results indicate that unlabeled buildings constructed under an energy code are associated with significant rent and selling price premiums of approximately 4% and 9%, respectively. In buildings where tenants pay directly for their own energy utilities, buildings constructed under a more stringent energy code rent for approximately 6.5% more relative to structures built just before a code came into effect. When owners pay utility bills rather than tenants, on the other hand, the rent premium is negative and statistically insignificant. Further calculations suggest that for plausible assumptions on the growth of utility costs, the discount rate and expected ownership or rental contract lengths, the estimated premiums are consistent with full capitalization of estimated building-level savings.

A number of robustness checks confirm the credibility of the identifying assumptions. These include testing whether the utility contract structure is unaffected by treatment status, a test of the plausibility of the stable unit treatment value assumption (SUTVA), a falsification test in which a new building sample is created with a treatment assignment that is uncorrelated with the true assignment, evaluating evidence for tenant sorting, and assessing whether building developers attempted to 'game' new code implementations by concentrating new building construction just before a new energy code came into force.

The observed rent and selling price premiums suggest owners obtain returns to energy conservation investments even in buildings where it is more costly to observe energy efficiency characteristics (relative to green-labeled buildings). These estimates indicate that landlord-tenant principal-agent problems likely do not contribute to an energy efficiency gap in office buildings, particularly when building occupants pay for their own utility bills, though they do not rule out other explanations for the gap, including credit market failures (Palmer et al. (2012)), learning-by-using (Mulder et al. (2003)), or behavioral anomalies (Gillingham and Palmer (2014)).

The remainder of the paper is organized as follows. Section 2 presents information on building energy code adoptions in the U.S., including details of the 1992 Energy Policy Act mandate that induced exogenous state-level variation in code implementation dates. Characteristics of energy codes that may cause potential principal-agent problems in real estate markets are also discussed in this section. Section 3 outlines the identification strategy and empirical model. Section 4 provides a detailed overview of the data set. Section 5 presents the empirical results, and Section 6 briefly concludes.

2. Energy Codes and Asymmetric Information

Background information on energy code development and state-level adoptions is summarized in Section 2.1. Section 2.2 elucidates the characteristics of energy codes that contribute to the perception that informational market failures lead to the under-pricing of energy efficiency in buildings.

2.1. Energy Codes

The first commercial building energy standard in the U.S., Standard 90-75, was spearheaded by a construction industry trade group, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It aimed to provide uniform guidance on energy conservation in buildings that could be implemented by jurisdictions wishing to regulate buildings' energy conservation characteristics. However, local-level stakeholders found Standard 90-75 highly difficult to apply in practice, due to its abstruse language, inflexible options for achieving compliance, and lack of technical support (Shankle et al. (1994)).

Federal involvement in energy standard development began in the late 19070s through the Building Energy Standards Program (BESP), which brought together government and building industry participants with the aim to improve Standard 90-75 (Hattrup (1995)). The BESP collaboration resulted in publication of Standard 90.1-1989 (hereafter ASHRAE 1989), followed by Standards 90.1-1999, 90.1-2004 and 90.1-2007 (heareafter ASHRAE 1999, ASHRAE 2004 and ASHRAE 2007).[2] The requirements in each (increasingly more stringent)

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[2] As an alternative to the ASHRAE standards, some states have adopted the commercial requirements of the International Energy Conservation Code (IECC), published by the International Code Council. Starting with the IECC 2001 and ASRHAE 1999 standards, both IECC and ASHRAE have coordinated the design of their codes so that they would bring about equivalent energy savings. The IECC 2000 code adopted by some states is equivalent to ASHRAE 1989 except for more stringent lighting requirements. The IECC 2000 lighting requirements are equivalent to ASHRAE 1999 (Winiarski et al. (2003)).

standard apply to all newly constructed commercial buildings, with the exception of multi-family residential structures less than four stories in height, which are not under consideration in this study.

The publication of ASHRAE 1989 was followed by passage of the Energy Policy Act (EPAct) of 1992, which required states to adopt the most up-to-date version of the ASHRAE standard. States were given until the end of 1994 to demonstrate both compliance with and adequate enforcement of the EPAct mandate.[3] While, in theory, all states were required to have begun implementing EPAct by late 1994, varied state-level regulatory and legislative adoption structures, building industry lobbying activities and concomitant delays in code enforcement, have led to wide-ranging effective adoption dates for ASHRAE 1989 and subsequent updates. Energy code adoption at the state-level has typically involved some combination of public hearings and commentary, approval by advisory bodies composed of building industry representatives, adoption by state legislatures, and/or signature by a governor, mayor, or other elected officials. Partly in response to building industry pressure, many states commissioned the DOE for state-specific cost-effectiveness studies before beginning formal adoption procedures, and litigation from builders' associations led to substantial adoption delays in some states. For example, in Michigan litigation led to a seven year delay in the passage of a state bill to implement the EPAct mandate for commercial buildings. In Idaho, legal hurdles precipitated a six year delay.[4] The EPAct mandate also requires the DOE to publish a determination regarding whether any newly updated version of the ASHRAE standard achieves positive energy savings compared to its predecessor. The publication of these determinations has typically taken 2-3 years, causing further delays in ASHRAE 1999 and ASHRAE 2004 adoptions.

The post-EPAct federal mandate to adopt an up-to-date building energy standard, the

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[3] State officials were required to submit a certification letter confirming passage of ASHRAE or an equivalent standard. See Department of Energy (2013), for an example.

[4] Other states that faced litigation attempting to prevent energy code adoptions include Illinois, New Mexico, Pennsylvania, and Washington. Such legal delays created uncertainty regarding when a new energy code would come into effect. In Michigan, energy code legislation only came into effect after a judge dismissed a lawsuit following a three-year court case. See the building code assistance project newsletters, BCAP (2013), for further details.

resulting heterogeneity induced by the regulatory process in states attempting to comply with the mandate, and the applicability of the energy standards to the universe of new commercial buildings constructed after the implementation date, leads to a source of variation in energy efficiency that is plausibly orthogonal to building-level characteristics.[5] Post-EPAct state-level implementation dates are illustrated in Figure I. I make use of this state-by-year variation in energy standard implementation dates in my identification strategy, elaborated in Section 3.

2.2. Sources of asymmetric information

Constructing a building in accordance with an energy standard does not require monitoring of the building's energy use characteristics after building completion, and market participants do not observe an explicit signal of energy performance.[6] In this respect, communicating the efficiency characteristics of a building constructed under an energy standard faces the same challenges as a building in which the owner has independently made the decision to incorporate energy efficient features.

In order to obtain a new construction building permit by a local jurisdiction, building architects must design structures to satisfy all code requirements and undergo a "plan review" procedure through a local building department. Obtaining a building permit is contingent on the building design satisfying all code requirements in place at the time of review. Once a building permit is obtained, the local building department may perform a random spot-check once construction has begun, though only a subset of buildings undergo such a site inspection (Department of Energy (2010); Department of Energy (2010b)). The steps involved in constructing a building in accordance with an energy standard contrasts significantly with green-labeled buildings, which require third-party verification and monitoring of building performance through all stages of construction and initial commissioning (USGBC (2009a);

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[5] Note also that adoption activity is also unrelated to swings in the business cycle, as code adoptions occurred continuously before, during and after the 2001 and 2008 recessions.

[6] For example, it's not possible to observe, from past building permits in jurisdictional records, which standard a specific building has been constructed under.

USGBC (2009b)).[7] These characteristics of energy standards, and energy efficiency investments in general, contribute to the perception that asymmetric information may lead to the under-pricing of energy efficiency in real estate markets.

The potential effect of asymmetric information between landlords and tenants on energy use decisions in buildings was first noted by Blumstein et al. (1980), citing a number of building industry professionals' belief in the difficulty of recouping efficiency investments as mitigating their interest in energy conservation. While recent evidence suggests this belief persists among real estate equity investors, lenders and developers, the most pessimistic views on the likelihood of obtaining value premiums greater than the incremental cost of energy efficiency investments are held by market participants with no prior experience with energy efficiency projects (Galuppo and Tu (2010)).[8]

On the other hand, the rising popularity of 'green leases', in which tenancy contracts explicitly set out how to allocate energy cost savings between owners and tenants (Oberle and Sloboda (2010)), suggests there is a channel for building owners to benefit from lower utility costs in energy efficient buildings. Commercial space advertising also utilizes energy efficiency as a selling point, as exemplified in Figure II. Reed et al. (2004) conclude that agency issues between landlords and tenants are unlikely to be a major problem affecting energy use. This conclusion is made on the basis of information regarding the prevalence of owner-occupied commercial buildings and the general structure of leasing contracts, though no formal empirical analysis is presented.

The Department of Energy estimates that 50% of office and retail buildings are multi-tenanted (EIA (2003a)), but this statistic is likely to underrepresent the true value since the survey on which it is based counts space which is only partially owner-occupied as being completely owner-occupied.[9] This predominance of multi-tenancy structures in commercial

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[7] A green-labeled building must also be re-certified every one to five years in order to retain its labeled status (USGBC (2012); EPA (2012)).

[8] Close to 70% of survey participants with prior energy efficiency project experience in Galuppo and Tu (2010) believe the benefits of energy efficiency investments outweighed the costs, whereas only 40% of participants without experience do so.

[9] See questions C3 and C5 in EIA (2003b). My data, which only categorize a building as owner-occupied if it is solely occupied by the owner, suggest that out of approximately 91,000 observations with information on whether a building is owner-occupied or multi-tenanted, about 70% of the buildings are multi-tenanted.

buildings led a recent study to suggest that over 40% of commercial space may be subject to agency problems arising from asymmetric information, thereby reducing the incentive to invest in energy efficiency (Prindle et al. (2007)). Given that landlord-tenant informational asymmetries may potentially affect a large proportion of office buildings, the preceding discussion suggests that, thus far, a notable gap in our understanding of the empirical importance of the landlord-tenant problem in commercial buildings is the dearth of reliable empirical studies.

3. Empirical Strategy

Buildings in the sample are assigned to one of two states: unlabeled energy efficient buildings constructed under a newly implemented energy code, or unlabeled buildings with lower energy efficiency attributes (i.e. higher estimated energy use), identified by having been constructed in the implementing jurisdiction before the energy code was implemented. Therefore, treated observations denote buildings constructed under a recently adopted code, and control observations denote buildings that have been constructed under a less stringent code version.[10] The outcome of interest is the sample average treatment effect on the treated (SATT), the average impact of energy codes on rents and selling values in buildings constructed under an energy code regime. An estimate of the SATT can be obtained by evaluating the difference between average values (rents or prices) in buildings constructed after the implementation of a new energy code and buildings constructed under a newly implemented code, *had they been constructed under a less stringent code*. However, the latter element of interest is unobserved. My identification strategy generates a credible estimate of counterfactual building values by exploiting state-level variation induced by mandatory energy standard adoptions in the wake of the 1992 EPAct, and the data's geographic precision to find control observations located within two miles of a treated observation, thereby holding unobservable, small-scale locational characteristics constant.[11]

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[10] Where a 'less stringent code' may include no energy code.

[11] Details of the 1992 EPAct mandate are presented in Section 2.1. The reasoning for selecting a 2-mile radius is discussed in Section 4. Results obtained from steadily decreasing the radius are presented in Appendix Section A.2.

3.1. Testable hypotheses

Asymmetric information between building owners and prospective buyers or tenants impacts value premiums in real estate markets when prospective tenants or buyers are unaware, or unconvinced, of a building's efficiency attributes. Asymmetric information may also lead to adverse selection, whereby rents and selling prices for an energy efficient building are indistinguishable from identical buildings with less stringent energy conservation features. Specifically, three testable hypotheses can be formulated about the impact of adverse selection about energy use in real estate markets.

Hypothesis 1: *Energy efficient buildings are not associated with rent premiums.* Assessing a building's efficiency level is costly and typically requires some combination of observing insulation levels, lighting power densities and HVAC equipment efficiencies, or requesting and analyzing utility bills. Prospective tenants or their representatives might be unable or unwilling to evaluate a building's efficiency level or may not be convinced by claims about a building's energy conservation characteristics.

Hypothesis 2: *Rental premiums are the same regardless of who pays for utilities.* Rental contracts differ in terms of which party is responsible for utility bill payments. In buildings constructed under an energy code where utilities are paid directly by tenants, tenants will benefit from lower utility bills and may therefore be willing to pay a premium to locate in these buildings, relative to buildings where owners are responsible for utility bill payments. However, this will not be observed if tenants or their representatives are unconvinced of a building's efficiency characteristics.

Hypothesis 3: *Energy efficient buildings are not associated with sale price premiums.* Owners of buildings constructed under an energy code can benefit from higher net incomes if they obtain either higher rents (when tenants pay for utilities), or benefit from lower utilities directly (when owners pay for utilities). However, if current owners are unable to convince prospective buyers of a building's energy conservation characteristics, or if prospective buyers believe they will not be able to convince tenants to pay a rent premium, energy efficient buildings will not sell at a premium.[12]

The following sub-section details the empirical framework used to assess whether these hypotheses can be rejected. The question of whether the results are consistent with full capitalization of building-level savings is taken up in Section 5.3.

3.2. Spatial matching and regression

I use spatial matching to create the dataset and regression to estimate the average treatment effect on the treated, as follows:

$$Y_i = \alpha D_i + \beta' X_i + \delta_j + \varepsilon_i, \tag{1}$$

where D_i is a treatment indicator equal to 1 if building i was constructed under a recently adopted building code, X_i denotes the covariate vector, and δ_j denotes a locational fixed effect for group j, i.e. building j and the control buildings located within 2 miles of j; the error term is denoted by ε_i and is assumed independent of the X_i and D_i. Covariates included in the regression include building size, number of stories, and dummy variables for year of construction, class A buildings, and the presence of building-level amenities.[13] In addition to the preceding list of covariates, the sales sample also includes the change in employment in the building's metropolitan statistical area the year prior to sale (to control for changes in the regional demand for office space), and dummy variables for the year of sale.[14] Since energy prices affect the cost of utilities, and therefore building-level operating costs, prevailing retail energy prices around the time a building sold may introduce heterogeneity in the willingness to pay for energy efficiency. To control for this effect I also include the retail price of electricity

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[12] A related informational friction may occur if one considers the possibility that building owner/operators themselves are not accurately informed about a building's efficiency characteristics. This possibility does not alter the empirical hypotheses presented here because the same outcomes would be observed, i.e. no rent or sales price premiums for energy efficient buildings. The same applies if building owners pay for utilities but believe tenants may waste energy as a result, thereby disincentivizing an energy efficiency price premium.

[13] Amenities include: property manager on site, concierge, corner lot, courtyard or atrium, waterfront location, or the availability of nearby public transit, restaurants, day care, retail shops, or a fitness center.

[14] Alternative specifications were also tested that included region by time fixed effects do not change the results.

and natural gas for the year before the building sold. Both heteroskedasticity-robust and clustered standard errors are reported in the results.[15]

3.3. Heterogeneity in the returns to energy efficiency

Equation (1) estimates the average effect of energy codes on office building values. However, absent asymmetric information between landlords and tenants, the premiums accruing to energy efficient buildings are predicted to vary depending on whether tenants or owners pay directly for utilities. In this section I turn to regression on the matched sample to test for evidence of this heterogeneity. The estimating equation is:

$$Y_i = \alpha D_i + \beta' X_i + \theta(\text{Util}_i \times D_i) + \delta_j + \mu_i, \tag{2}$$

where all covariates are the same as those defined in the previous section, with the exception of interaction term $\text{Util}_i \times D_i$. Util_i is a dummy variable equal to one in buildings where tenants pay for utilities, and it is interacted with the treatment indicator. This variable assesses whether the premium to buildings constructed under a code is heterogeneous in buildings where tenants pay directly for utilities. The error term is denoted by μ_i, and is once again assumed independent of X_i and D_i.

3.4. Identifying assumptions

The crucial identifying assumption is unconfoundedness: controlling for observable covariates, the distribution of control outcomes must be the same in buildings with and without energy codes. Second, there must be a sufficiently dense overlap between the covariate distributions of treated and control observations, such that outcomes are observed for each treatment status at all values of the joint covariate distribution. Finally, identification also relies on the assumption of no general equilibrium effects, also referred to as stable unit treatment value (SUTVA): each buildings' potential outcomes are not affected by the treatment

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[15] An alternative identification strategy that might initially seem advantageous is a regression discontinuity design. However, the highly discrete nature of the running variable, year of construction, is not suitable for the application of local linear regression methods.

status of other buildings. These three assumptions define sufficient conditions to interpret the estimated difference in outcomes as the causal effect of energy codes (Barnow et al. (1980); Rosenbaum and Rubin (1983); Rubin (1986)).

As detailed in Section 2.1, the federal EPAct mandate to adopt a more stringent energy standard results from a finding of positive energy savings, based on simulated energy standard impacts in buildings representative of the commercial building stock, and code adoptions apply to all buildings constructed after the implementation date. Heterogeneity in the implementation date is largely due to the speed of state-level regulatory processes and orthogonal to individual building characteristics. However, since buildings constructed under an energy code are one to three years newer than their matched control observations, and newer buildings may rent and sell at a premium, the regression-adjustment might not fully account for this effect in regions where there is poor overlap in the year built distribution. In addition, an implication of the unconfoundedness assumption is that the covariates are predetermined, or unaffected by treatment status. A covariate which may conceivably not be predetermined is the type of rental contract, particularly as it defines who is responsible for paying utilities. My identification strategy also assumes that constructing a building under an energy code does not affect potential outcomes in other buildings (also known as the stable unit treatment value, or SUTVA, assumption). One channel through which SUTVA violations could occur is if building managers in control buildings undertake energy-saving behavioral responses as a reaction to the construction of more energy efficient buildings. In Section 5.2 I present robustness checks to evaluate whether each of these factors might affect the results.

4. Dataset

Data on office building hedonic characteristics, advertised rental rates (in \$/sq.ft./yr.), and transaction data on the most recent sale price and sale date were obtained from the CoStar Group, which maintains a building-level database and multiple listing service that has been tracking the commercial real estate industry since the early 1980s.[16] Each building-level observation is also geocoded with a precise latitude and longitude coordinate.

CoStar's transaction notes were used to discard sales observations that were either made under "distressed" conditions, deferred tax transactions (1031 exchanges), bulk or portfolio transactions (which results in a sale price per square foot representing an average over several disparate properties), or non-arm's-length transactions. Data on the change in employment the year prior to building sale are from the Bureau of Labor Statistics, and retail electricity and natural gas prices are from the Energy Information Administration.

Observations from the rent sample that listed the posted rent as 'negotiable' were discarded, as were observations with no listed utility contract type or no listed leasing company.[17] As opposed to the sale price data, the data on rental rates are from posted listings at the time the data were downloaded, between January and March of 2010, depending on the state.[18] Rental contract types fall into one of three categories: Gross contracts, plus utilities contracts, and net contracts. Gross contracts quote rental rates inclusive of all services for the first year of the contract. Subsequent years are typically subject to 'escalation' clauses based on average building-level increases in expenses (including the impact of energy prices). Plus utilities contracts do not include any utilities in rent, in which case tenants pay for rent plus a separate utilities bill. In net contracts, all services are paid separately, including utilities and other costs such as cleaning, and insurance. Hereafter I will refer to a 'utilities' contract as a contract where tenants pay directly for utilities - either a plus utilities contract

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[16] CoStar defines an office building as a structure in which the primary use is "to house employees of companies that produce a product or service primarily for support services such as administration, accounting, marketing, information processing and dissemination, consulting, human resources management, financial and insurance services, educational and medical services, and other professional services." CoStar also keeps information on retail buildings and 'flex' buildings that combine features of office and retail structures, but they are not included in the analysis.

[17] As discussed in Section 5.2, identifying the leasing company is important as it can be used as a test of the stable unit treatment value assumption (SUTVA).

[18] Data from a given state were all downloaded on the same day. Since 2-mile locational dummies are used in all specifications, including month of download fixed effects do not affect the results.

or a net contract.[19]

Buildings were associated with a particular efficiency level by exploiting state-level and year-of-adoption variation in the implementation of the ASHRAE building energy standard, as described in Section 2 and illustrated in Figure I. Data sources for energy code adoptions and further details of the dataset construction can be found in Appendix Section A.1. Identifying these state-level adoption dates has enabled me to associate buildings in my dataset as being constructed under a specific energy code regime. The code implementation date defines when building permit applications were required to satisfy the new, more stringent energy code criteria in order to be approved by a local building department. Since I observe the year of construction, not the day on which a building developer obtained its building permit, and since a lag occurs between the time a building permit is obtained and the building's construction, the following decision rule was used. In a given state, if the date of a new energy code implementation is in January or February, buildings constructed the year following the code's implementation year are categorized as having been subject to the new energy code; buildings constructed before the new energy code (inclusive of the implementation year) are categorized as controls. If the implementation date of a new energy code is in March or later, buildings constructed two years following the code's implementation year are categorized as having been subject to the new energy code; buildings constructed before the new energy code are categorized as controls.[20] This may lead to some degree of measurement error if a building is mis-categorized, and therefore to attenuation of the

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[19] Given that advertised rental listings are observed at the same time for all buildings, I assume that the other services applying to net contracts are the same across buildings in the treatment and control samples. If the selection on observables and overlap identifying assumptions described in section 3.4 hold, as suggested by Tables II and III and the falsification test presented in 5.2, this is a plausible assumption.

[20] This decision rule is based on data from the U.S. Census Bureau that suggests over 70% of multi-unit buildings are constructed within 13 months of the beginning of construction (see US Census (2010)). This time frame is most relevant since in cases when a significant lag occurs between permit issuance and the beginning of construction, most building departments require permits be re-applied for. In addition, the majority of energy code adoption dates in the data occur after March 1; the following year is used as the effective year for code-subject construction for implementation dates in January or February because these dates are observed mostly in warm southern states where construction activity can occur year-round. A similar decision rule has been used, in a different context, by Jacobsen and Kotchen (2013). I have also obtained estimates by discarding buildings constructed during the effective year, and the results are qualitatively unchanged from those reported in the paper (the point estimates are slightly larger and remain statistically significant).

estimated coefficients. However, estimates obtained by varying this decision rule by a month before and after do not significantly change the results reported below.[21]

Having identified treated buildings as constructed under a specific energy code regime, the geocode associated with each building was used to create the control sample, composed of buildings located within a 2-mile radius of a treated building that were constructed before a given standard came into effect.[22] A 2-mile radius was chosen to balance two competing factors: the desirability of minimizing the distance between treated and control observations versus the impact on the sample size. The importance of controlling for unobservable locational characteristics at a fine geographic scale is well-established in the real estate literature (Bollinger et al. (1998)), and from an econometric standpoint avoiding 'geographic mismatch' is important in order to achieve balance among the unobservables in the treated and control samples (Heckman et al. (1997); Duranton and Overman (2005)).[23] However, the pattern of increasing decentralization and decreasing density in new office space construction implies that the average distance between buildings is greater in newer buildings (Brueckner (2000); Lang (2000)), which constrains how small the radius between buildings can be in order to maintain a reasonable sample size.[24]

The resulting dataset pools together buildings from multiple treatment-control categories, composed of treated buildings that could be identified as being constructed under one of four energy code categories (ASHRAE 1989, IECC 2000, ASHRAE 1999 or ASHRAE 2004), and control buildings located within a 2-miles of a treated building. A list of treated and

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[21] Appendix Section A.4 presents an estimate of the degree of attenuation bias that may be expected. It suggests the magnitude of the bias is modest and lies between 0.02 and 0.03.

[22] Treated buildings and their nearby control buildings must also be located in the same city. This rules out buildings located within two miles of each other on either side of a city boundary.

[23] An alternative to matching buildings on the basis of geographic distance is Mahalanobis matching. The Mahalanobis metric defines two buildings as near each other if they have similar covariates. Matching buildings in my sample using Mahalanobis distance and all observable covariates results in similar overlap in the covariate distributions between treatment statuses compared to matching on the basis of geographic distance. However, since Mahalanobis matching results in considerably larger distances between treated and control buildings, geographic matching is preferable in this case so as to avoid locational mismatch.

[24] Both the sales and rent results are robust to limiting the sample to treated and control buildings to a maximum distance of 0.25 miles apart. Reducing the distance between treated and control buildings below these values results in a 50-70% smaller sample size, for the sales and rent samples, respectively, and larger standard errors. See Appendix Section A.2 for more detail on these results.

control building categories and the share of the rent and sales samples made up of buildings constructed under a given treatment-control category is presented in Table I.[25]

Figure III depicts an example of a treated and control building in Scottsdale, Arizona. They exemplify the low-rise, tilt-up concrete construction practices used in new commercial building structures that tend to be located outside central cities (Lang (2003)). Since each observation is geocoded, it is possible to analyze the extent of spatial dependence of the year built distribution. Many studies have documented the increasing decentralization of new residential and commercial construction that has been occurring since at least mid-century (Anas et al. (1998); Glaeser and Kahn (2004); Irwin and Bockstael (2007)), and the spatial dimension of the data is consistent with this finding. As illustrated in Figure IV, where office building observations are color-coded by the quantiles of the year built distribution in Maryland and Texas, newer commercial construction has a tendency to occur at the urban fringe. This phenomenon is prevalent in all the major urban areas of the dataset.

The dataset obtained from the steps outlined above results in a high degree of overlap between the covariate distributions in the treated and control samples, with the notable exception of the building age distribution: buildings constructed under a code are almost 30 years newer, on average, than buildings in the control sample. This is to be expected, since most of the treated buildings were erected under energy standards that began being implemented by states in the latter half of the 1990s. To improve this discrepancy in the year built distribution (and satisfy the overlap identifying assumption), I discard control observations constructed more than three years before the treated observation it is matched with. Panels (a) and (c) of Figure V show histograms of the year built distribution by treatment status before trimming out the older control buildings, while panels (b) and (d) show the trimmed histograms. The overlap in the year built distribution is much improved after trimming the sample. Figure VI presents maps of the trimmed rent and sales samples, respectively.

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[25] The pooled nature of the sample resulted in a small number of buildings appearing simultaneously as both a treated and control observation; while including these buildings twice in the analysis does not substantively change the results, in the tables reported below I have dropped such multiple matches. For each observation appearing as both treated and control, it is only counted in the treatment regime with the smallest distance to its treated/control observation.

Table II presents summary statistics for the treated and control buildings in the rent sample, and Table III presents summary statistics for the sales sample. The tables indicate the average building is approximately two stories high and measures about 25-30 thousand square feet, a profile that closely resembles the average office building in the U.S. (EIA (2012)). The average treated building was constructed in 2005, whereas the average control building was constructed in 2003. Building sales were observed between 2002 and 2009 for both the treated and control samples. Average rental rates are higher by 0.60 \$/sq.ft./yr. in treated buildings, and average selling prices are higher by 11.78 \$/sq.ft. in treated buildings, relative to their respective control samples.

The normalized difference for each covariate presented in the last column of Tables II and III is a measure of overlap among the covariates in the treated and control samples. A normalized difference less than 0.25 or so is typically considered good overlap (Imbens and Wooldridge (2009)).[26,27] Both tables indicate good overlap for most of the covariates. One exception is the year built distribution, which exhibits a modest lack of overlap. In both trimmed samples the mean disparity in the year built distribution by treatment status is 2 years (and, as noted above, is restricted to be no more than 3 years for a given treated building and its control(s)). This lack of overlap occurs by construction due to the nature of energy code adoptions; in the following section, I present a falsification test to assess whether the modest lack of overlap in the year built distribution might affect the results.

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[26] The normalized difference reports the difference in average covariate values by treatment status, scaled by the square root of the sum of a given covariate's variance. It is preferable to focus on normalized differences rather than t-statistics to assess overlap between covariate distributions, since changes in sample size affect estimated t-statistics but do not affect the plausibility of the overlap assumption. The normalized difference is therefore a more accurate, scale-free measure of overlap.

[27] The normalized differences by contract type (rather than treatment status) also indicate good overlap across all covariates. For example, the normalized difference for building size, stories, and year built are -0.14, -0.14, and 0.18, respectively. The full table of normalized difference by contract type results is not reported here but are available from the author upon request.

5 Results

5.1. Estimated energy efficiency premiums

Table IV shows the results of estimating equations (1) and (2) using the rental sample. Columns (1) - (3) include estimates of equation (1), and indicate that on average a building constructed under a newly adopted energy standard rent at a premium of approximately 4%. Columns (4)-(6) presents estimates of equation (2). The results indicate statistically significant heterogeneity in the rent premium on the basis of which party pays for utilities. The 'Utilities × Code' interaction term identifies buildings constructed under a new energy code in which tenants are responsible for utility bill payments. The estimate in column (4) indicates that in buildings where tenants pay for utilities, a more stringent energy code commands a 6.5% asking rent premium compared to 'utilities' buildings constructed just before a code came into effect.

The last two columns of Table IV present results when equation (2) is estimated on subsamples of the dataset with relatively hot, humid climates (column (5)), and cooler, low humidity climates (column (6)).[28] Energy use reductions from building-standard induced conservation investments are predicted to be greater in warm and humid climates relative to climates with relatively mild winters and cooler, low humidty summers (Federal Register (2002), Federal Register (2008), Zhang et al. (2013)). This climate-induced heterogeneity arises because office buildings are highly electricity intensive (Department of Energy (2014)). Air-conditioning load requirements in hotter, more humid climates significantly increase office building energy consumption, but also increase the savings generated from an energy standard. Column (5) in Table IV indicates that heterogeneity in the rent premium is greater in warmer, humid climates, and column (6) suggests there is no heterogeneity observed

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[28] The sample for column (5) estimates was limited to buildings in Florida, Arkansas, Arizona, Georgia, Louisiana, South Carolina, Texas and Kentucky. These states (with the exception of Arizona) have average summer humidity levels above 85% and average summer temperatures above 25 degrees Celsius. Though it is a state with lower humidity levels, Arizona was also added to the analysis due to the high simulated savings estimates from energy standards in that state. Omitting Arizona does not substantively change the reported results. The sample for column (6) estimates was limited to buildings in Utah, Colorado, and Idaho. These states have average summer humidity levels below 60% and average summer temperatures below 21 degrees Celsius.

in cool, low humidity climates. However, the small sample size in column (6) may also contribute to the noisy estimate.

The coefficient for the 'Code' variable in columns (4)-(6) of Table IV is interpreted as the rent premium in buildings constructed under a code relative to buildings constructed just before a code came into effect, in buildings where owners pay for utilities. The coefficient value of -0.039% in column (4) is statistically zero.

Table V presents the sales results. Columns (1) - (3) show estimates of equation (1). In column (3), which includes all the covariates, transacted sale prices in buildings constructed under an energy code are higher by approximately 9%. Results on climate-based heterogeneity are shown in Columns (4) and (5). The estimated premium in hot climates is approximately 10%, whereas the premium is close to zero and statistically insignificant in mild, low humidity climates. Similarly as for the rent results, the small sample size covering the milder climates likely contributes to this imprecise estimate.[29] Nevertheless, these sales results on climate-based heterogeneity are consistent with simulated energy savings estimates that suggest greater savings in hotter, more humid climates.

Taken together, these results provide evidence to reject hypotheses one through three, since more energy efficient buildings are associated with statistically significant rent and selling price premiums, and statistically significant heterogeneity in the rent premium is observed on the basis of whether tenants pay for utilities. The falsification test results in Section 5.2 below also indicate that the findings reported above are not driven by the modest lack of overlap in the year built distribution.[30]

It is also interesting to note that compared to the premium for a green-labeled building (Eichholtz et al. (2010)) the energy standard-induced premium is statistically the same. A Welch t-test cannot reject the hypothesis that both premiums are equal.

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[29] Sales results for the cool, low humidity climates include observations from Washington State, Oregon, Colorado, and Northern California counties. There were no observations from Idaho or Utah, so the sample had to be augmented by observations from these other regions with relatively mild climates.

[30] For the sales samples I also estimated a specification that includes a variable capturing the amount of time between the year of construction and the year of sale. For the rent sample I estimated a specification that includes the amount of time between the year of construction and the year I observed the rent listings (i.e., 2010). Including these variables does not substantively change the point estimates reported here.

5.2. Assessing unconfoundedness

My identification strategy assumes that constructing a building under an energy code does not affect potential outcomes in other buildings (also known as the stable unit treatment value, or SUTVA, assumption). One channel through which SUTVA violations could occur is if building managers in control buildings undertake energy-saving behavioral responses as a reaction to the construction of more energy efficient buildings. While I cannot directly observe such behavioral responses in the control buildings in my sample, in the rental data I observe the company responsible for building-level real estate management services. In recent years, several of the largest integrated property management and leasing companies (as measured by market capitalization) have begun to incorporate energy use management as a core area of expertise.[31] If control building owners in my sample have undertaken behavioral responses to the presence of energy efficient buildings constructed under an energy code, it would be plausible to expect they may hire one of these firms. Columns (1) and (2) of Table VI presents the results of estimating equation (1), but where the dependent variable Y is replaced with a dummy variable for whether or not a major real estate services firm is responsible for property management. The results are highly insignificant, which is consistent with the identifying assumptions.

To assess whether the rental contract is predetermined with respect to treatment status, I estimate equation (1) but replace Y with a dummy variable for a utilities contract. Effectively, this is a test for whether the treatment and control observations in the matched sample exhibit a statistically significant difference in the fraction of rental contracts that stipulate tenants must pay directly for their utility bill ('utilities' contracts). Columns (3) and (4) of Table VI presents these results, which are not suggestive of a systematic relation between the type of rental contract and treatment status, given the statistically insignificant difference in the prevalence of utilities contracts between the treated and control buildings.

Testing for whether the rental contract is exogenous to treatment status is one approach to assess the validity of the identifying assumptions. However, this does not control for unob-

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[31] For example, see CBRE (2014).

servable differences in the assignment of contract types across treated and control buildings. For example, it is possible that heavy energy using tenants differentially sort into buildings based on treatment status or utility contract type. While I do not observe tenant energy use characteristics, I have been able to access additional information from CoStar on the tenants in California office buildings (representing a subset of the data sample). An analysis on the basis of tenant-level SIC codes between treated and control buildings, and between buildings with and without 'utilities' contracts, is not suggestive of a systematic difference. Table VII breaks down California office building SIC codes into 8 different categories, ranging from Agriculture, Chemicals, Oil & Gas, and Transportation, to Financial & Business Services. If certain industries falling within one of these categories tend to be more energy intensive, one might expect differential sorting between more energy efficient (treated) and less energy efficient (control) buildings. For example, it's plausible to expect that more energy intensive tenants may wish to locate in a treated building. In Table VII, both a chi-square goodness of fit test statistic and the normalized difference were calculated for the TREATED, CONTROL, UTILITIES and NO UTILITIES columns. The chi-square test assesses whether the observed share of tenants within each category is statistically different from the unconditional average in the last row of the table.[32] The chi-square test cannot reject the hypothesis that at the SIC code level tenants sort randomly into treatment. The chi-square test for sorting by utility contract type is rejected, but it is primarily 2 SIC code categories that contribute to rejecting the null: Communications and Publishing & Allied Industries. Together these categories make up approximately 2% of the sample. The final columns of Panel A and Panel B of Table VII also present the normalized difference of the SIC codes within each category. Most of the normalized differences lie below 0.25, with the exception of Publishing & Allied Industries and Retail Trade in Panel A (less than 7% of the sample), and Communications and Wholesale Trade in Panel B (less than 5% of the sample). Altogether there is limited evidence to suggest that significant tenant sorting on the basis of treatment assignment or

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[32] The chi-square test statistic is $\chi^2 = \sum \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$, where the observed value is the percent share of observations from a given SIC code in one of the treatment or utility contract categories, and the expected value is the unconditional share in the last row (for example, the unconditional average for tenants in treated buildings is 26%).

contract type.

As previously noted, treated buildings in Tables II and III are two years newer than their matched control observations, on average, and the normalized difference in the means of the year built distribution by treatment status suggests a modest imbalance in overlap. To assess whether this may cause a positive bias, I create a new sample testing for spurious effects of two-year leads of building code changes. The placebo sample is constructed by subtracting three years from the original coding file that assigns a treatment status to each building. The resulting data assignment exhibits a similar discrepancy in the year built distribution as the original file. Placebo 'treated' buildings are two years newer on average: the average 'treated' building in the falsified sample was constructed in 2003, whereas the average 'control' building was constructed in 2001. The normalized difference for the year built distribution is approximately 0.57.[33] Treatment status is also uncorrelated in the original and falsified samples. For example, fewer than 30% of the same buildings appear in the original versus falsified samples, and buildings that appear in both samples have close to a 50/50 chance of having a different treatment status in the falsified sample.[34]

Tables VIII and IX present the results of this falsification test in the rent and sales samples, respectively. The log rent results in Table VIII, columns (1)-(3), indicate a small positive difference between the false treated buildings compared to the false controls, but across all samples it is highly statistically insignificant. There is also no observed heterogeneity in the premium based on whether tenants pay directly for utilities (column (4)), or between hot versus mild climates (columns (5) and (6)). The same picture arises from the sales results in Table IX. The estimates are highly insignificant throughout all specifications in columns (1)-(5).

The results in Appendix Section A.2 indicate the robustness to reducing the maximum allowable distance between buildings. An additional robustness check is presented in the Appendix, namely assessing whether there is evidence that building developers tried to

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[33] While the summary statistics in the falsified samples are not presented here, they are available from the author upon request.

[34] In the rent sample, 21% of buildings in the falsified sample appear in the original sample. In the sales sample, 27% of buildings in the falsified sample appear in the original sample.

'game' energy code implementations by concentrating new building construction just before a new energy code came into force (Section A.3). The evidence suggests the results are unaffected by these checks.

5.3. Evidence for capitalization of the energy savings

Engineering studies have been conducted by the DOE to estimate ex-ante average energy savings attributable to ASHRAE standards 1989, 1999 and 2004, and the IECC 2000 (Hadley and Halverson (1993); Department of Energy (2002); Department of Energy (2008)). These studies estimate the average reduction in site energy use intensity (EUI) per square foot attributable to upgrading to a more stringent ASHRAE code, relative to the preceding code in place, assuming that actual construction practice is conducted in accordance with code requirements.[35],[36] Based on these studies, the average estimated office building site EUI savings from upgrading to a more stringent standard range from 6-12%.[37] These estimated energy savings are obtained from a weighted average of the simulated EUI savings from buildings located in 11 climate regions in the U.S., with weights corresponding to the share of new building construction in each region.

To obtain an estimate of the average EUI savings arising from the matches in my sample, I calculate a weighted average of the Department of Energy's simulated EUI savings for each treated-control match I observe in the data, in each of the 11 climate regions, with weights corresponding to the share of the in-sample buildings in each region, for the treated and control matches constructed under each standard version, as listed in Table I. Performing this weighted average for the rent and sales samples separately results in similar estimated

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[35] Site EUI is defined as the annual BTU value of energy at the point it enters the building, normalized by building area; its unit of measurement is thousands of BTUs per square foot per year (kBTU/sf/yr).

[36] The preceding code in place refers to the code version immediately preceding the code under consideration. For example, the code preceding ASHRAE 1999 is ASHRAE 1989, so DOE simulation studies on the savings from upgrading to ASHRAE 1999 are based on a comparison with baseline savings in an ASHRAE 1989 building.

[37] The average savings range of 6-12% for different standard versions masks a considerable amount of variation in the savings across climate zones in the U.S. For example, in the southern Atlantic region the savings are typically higher by about 2-5%.

EUI savings of approximately 12% in the rent and sales samples.[38]

Assuming reductions in site EUI lead to proportional reductions in utility costs, and given that office building utilities averaged approximately \$3.84/sq.ft./yr. in 2009 (BOMA (2010)), a 12% reduction in annual building energy costs will reduce utility costs by close to \$0.46/sq.ft./yr., or approximately 2.4% of sample average rent in my sample (which totals \$19.20). Obtaining an estimate of the impact of a 12% utility operating cost saving on selling prices is a bit more difficult as it requires an estimate of net operating income (NOI), which I do not observe in the data.[39] Office building NOI estimates over the sample period range from \$20-\$30 per square foot (BOMA (2010)), Jaffee and Wallace (2009)); in that case, a saving of \$0.46/sq.ft. implies a 1.5%-2.4% increase in NOI. Note that reductions in site EUI may lead to larger than proportional reductions in utility costs if tiered or time-of-use pricing is in place, particularly since office building energy consumption is known to be inelastic even when faced with price increases Jessoe and Rapson (2014). In this case, these estimates would underestimate the true operating cost savings and increase the present value of the savings.

These percent savings estimates represent one year of energy savings (as a share of estimated average rent and NOI, respectively), and would therefore accrue to tenants over the length of a tenancy contract and to owners over the length of ownership. The annual percent

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[38] These estimates are on the high end of the DOE simulation estimates for two reasons. First, the sample of buildings I observed are disproportionately located in southern regions with larger than average savings. For example, in the rent and sales samples, 48% and 59% of buildings, respectively, are located in southern states with the highest estimated savings due to energy standards: Arkansas, Arizona, Florida, Georgia, Louisiana, North Carolina, New Mexico, Nevada, South Carolina, Texas, and Virginia. Second, some states have adopted a standard that skips one standard version and goes directly to a more stringent one if it was already published at the time of adoption (e.g., in New Mexico and Nevada, ASHRAE 1999 was adopted when no standard was in place). Note that while the weighted average estimated savings described above account for regional variation in the energy savings by using 11 representative climate zones, the realized savings may be higher if average temperatures are more volatile and/or humidity levels are higher among in-sample buildings, and lower if average temperatures are milder and/or humidity levels are lower.

[39] The market price of commercial property can be expressed as $P_0 = \sum_{t=1}^{L} \frac{NOI_t}{(1+i_t)^t}$, where P_0 is the price at the purchase date, L is the expected length of ownership, NOI_t is net operating income (operating income - operating costs) in period t, and i_t is the discount rate at t. Therefore, changes in net operating income affect the selling price. Assuming a flat term structure and that current net operating income is a sufficient statistic for future net income, the market price can be expressed as $P_0 = \frac{NOI}{(i-g)}$, where g is the growth rate of NOI. Therefore, for a given i and g, a 2% higher NOI for an energy efficient building is associated with a 2% increase in the price.

savings can be compared to the estimated rent and price premiums to assess whether the energy savings are reflected in observed office market pricing outcomes. The point estimates for selling prices suggests buyers pay a 9% premium for a more energy efficient building, and the rent premium for locating in an energy code building where tenants pay for utilities is estimated as approximately 6.5%. Since the savings accrue over the length of a tenancy contract or over the expected length of ownership, a simple present value calculation, given plausible assumptions for the growth of utility bill savings, the discount rate, and expected ownership or rental contract length, suggests it is plausible that the estimated rent and sales price premiums correspond to complete capitalization of the estimated energy savings.[40]

The market for purchasing commercial property is increasingly composed of real-estate investment trusts and mutual funds, which are known to have high annual portfolio turnover rates (for example, Carhart (1997) finds annual turnover rates of 60-90%). Therefore, while buildings are long-lived assets the ownership length of commercial building assets is likely to be considerably lower, particularly for buildings sold in the time period under consideration, 2002-2009. Given the nature of the commercial property market, the discount rate for NOI savings is best approximated by the return from a plausible alternative investment, such as the stock market. The S&P 500 averaged a short-term return of approximately 10%-15% over the period under consideration. Assuming average NOI of $20, the estimated sales price premium is consistent with complete capitalization of the energy savings for an expected ownership length of five years, a discount rate corresponding to 12%, and a 2% growth rate in utility cost savings.[41] If an average NOI of $30 is assumed instead, complete capitalization is consistent with an expected ownership length of 10 years and a 15% discount

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[40] The capitalization calculations below are completed separately for the sales and rent premium because market pricing decisions are completed by separate parties. Following the real estate literature, purchase price decisions are assumed to be completed by assessing how lower operating costs will improve net operating income, whereas rental market prices are assumed to be determined by the expected rent savings accruing to a tenant over the length of a contract.

[41] Average annual commercial sector electricity prices in the U.S. increased at a rate of about 3%-4% per year on average between 2002 and 2009. A 2% increase in the savings over time is assumed in the calculations since energy efficient buildings are likely to benefit from smaller increases in utility costs.

rate.[42]

In the rental market, the discount rate for energy savings can be approximated by the capitalization rate for commercial buildings, since the volatility of rental income is highly correlated with the volatility of energy prices (Eichholtz et al. (2010)). Capitalization rates in the U.S. fluctuated between 4% and 7% between 2005 and 2009 (Chervachidze and Wheaton (2013)). With a discount rate of 5.5%, the present value of the utility cost savings totals approximately 2.5% of average sample rent, which is lower than the point estimate but falls within the confidence interval of the estimated rent premium.[43,44]

Two additional points are important to note in estimating the plausibility of full capitalization. First, as noted above the rent premium is on the higher end of the estimated present value of the savings. This could be attributed to the fact that the estimated rent premium is an asking, or advertised rent premium.[45] This means that the estimate may include a built-in bargaining cushion if brokers expect the transacted rent to be lower, thereby bringing the actual rent premium more in line with the estimated savings. In addition, if prospective tenants are risk averse with respect to utility bill volatility, owners have an incentive to increase the advertised rent premium (McAfee and McMillan (1987)). Second, since building level net operating income and utility bills are not observable, other combinations of the variables assumed above may also produce less than full capitalization. However, the purpose of this exercise was to show that plausible combinations of these unobserved variables can represent

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[42] Since selling prices are in \$ per square foot, the present value of the estimated savings S is
$PV = S\sum_{n=0}^{L}[(1+gr)/(1+r)]^n$.

[43] Commercial tenancy contracts typically span over multiple years, typically between 3-15 years. The average length is approximately 5 years. Service sector lease lengths are on average even longer, compared to the manufacturing sector (Fisher and Ciochetti (2007)). Taking into consideration the previously cited factors that may increase energy expenditure savings (tiered pricing or more humid climates), a \$0.60/sq.ft./yr. operating cost saving leads to a present value cost saving representing 3% of average sample rent, whereas a \$0.90/sq.ft./yr. operating cost saving represents 5% of average sample rent.

[44] Since rents are quoted in \$/sq.ft./yr., the present value of the expected savings is
$PV = S\sum_{n=0}^{L}[gr/(1+r)]^n$, where S is estimated savings, gr represents the annualized growth of utility costs and L is the tenancy contract length.

[45] Databases with transacted rent data are not available; this is why all papers in the literature have utilized asking rents (for example, Eichholtz et al. (2010) and Eichholtz et al. (2013)).

full capitalization, which is certainly possible.

6. Conclusion

The question of whether energy efficient yet unlabeled office buildings command premiums that reflect the value of energy savings has, thus far, remained undetermined. This is an important question because it can shed light on whether asymmetric information between current owners and prospective buyers or tenants mitigates the returns to energy conservation investments in commercial buildings. Assessing the prevalence and impact of asymmetric information about energy use characteristics, through its impact on pricing in commercial buildings, is an important step in the determination of the optimal mix of policies to best address the climate change externality. As noted by Stavins (2011), the realized cost-effectiveness of carbon pricing strategies is impacted by the pervasiveness of landlord-tenant agency problems in the building stock. In addition, policies targeted towards addressing such principal-agent problems need to be crafted to differentiate among heterogeneous end-uses and contractual structures affecting energy use, as all of these features may affect the magnitude of the inefficiency.

Since communicating the energy conservation attributes of energy codes faces the same challenges as when an owner or developer has independently made the decision to incorporate energy conservation characteristics, energy code adoptions create a unique opportunity to test for evidence of asymmetric information between building owners and prospective tenants or buyers. This paper estimates value premiums in buildings constructed under a more stringent energy code by using exogenous variation in state-level energy code adoptions over the past fifteen years. I find that on average, unlabeled buildings constructed under a more stringent energy code are associated with statistically significant rent and selling price premiums of approximately 4% and 9%, respectively. Significant heterogeneity is also observed in the rent premium depending on which party (owners or tenants) is responsible for utility bill payments, and the heterogeneity is greater in hot, humid climates, as would be expected absent asymmetric information. The premiums plausibly represent complete capitalization of estimated energy savings in rents and prices. Finally, it should be noted that a Welch t-test indicates that both the estimated purchase price premium and the rent premium are statistically the same as the premium for a green-labeled building. It's also interesting to note that green-labeled buildings in are significantly larger and taller than the average commercial building, whereas buildings constructed under an energy standard are of similar size and height as the average office building in the U.S., as noted in Section 4. This is suggestive of a considerable amount of segmentation in the energy efficiency market (Dickson and Ginter (1987)).

The results suggest that in commercial buildings we likely need not be overly concerned about the frequently cited suggestion that asymmetric information between landlords and tenants mitigates the returns to energy efficiency and contributes to an energy efficiency gap. However, it should be noted that other market failures contributing to an energy efficiency gap are not ruled out by the results of this study (Palmer et al. (2012), Mulder et al. (2003), Gillingham and Palmer (2014)). Evidence from a number of settings suggests behavioral anomalies may lead decision-makers (such as property developers) to undervalue energy savings when making investment decisions (DellaVigna (2009); Allcott and Greenstone (2012); Newell and Siikamaki (2014)), though much of the research on the impact of behavioral failures that affect energy use has, thus far, focused on the transportation sector (Helfand and Wolverton (2011); Allcott (2011), Allcott and Wozny (2013); Allcott (2013)). Similar studies applied to the commercial building sector would prove beneficial at improving the cost-effectiveness of policies aimed at addressing particular market or behavioral failures.

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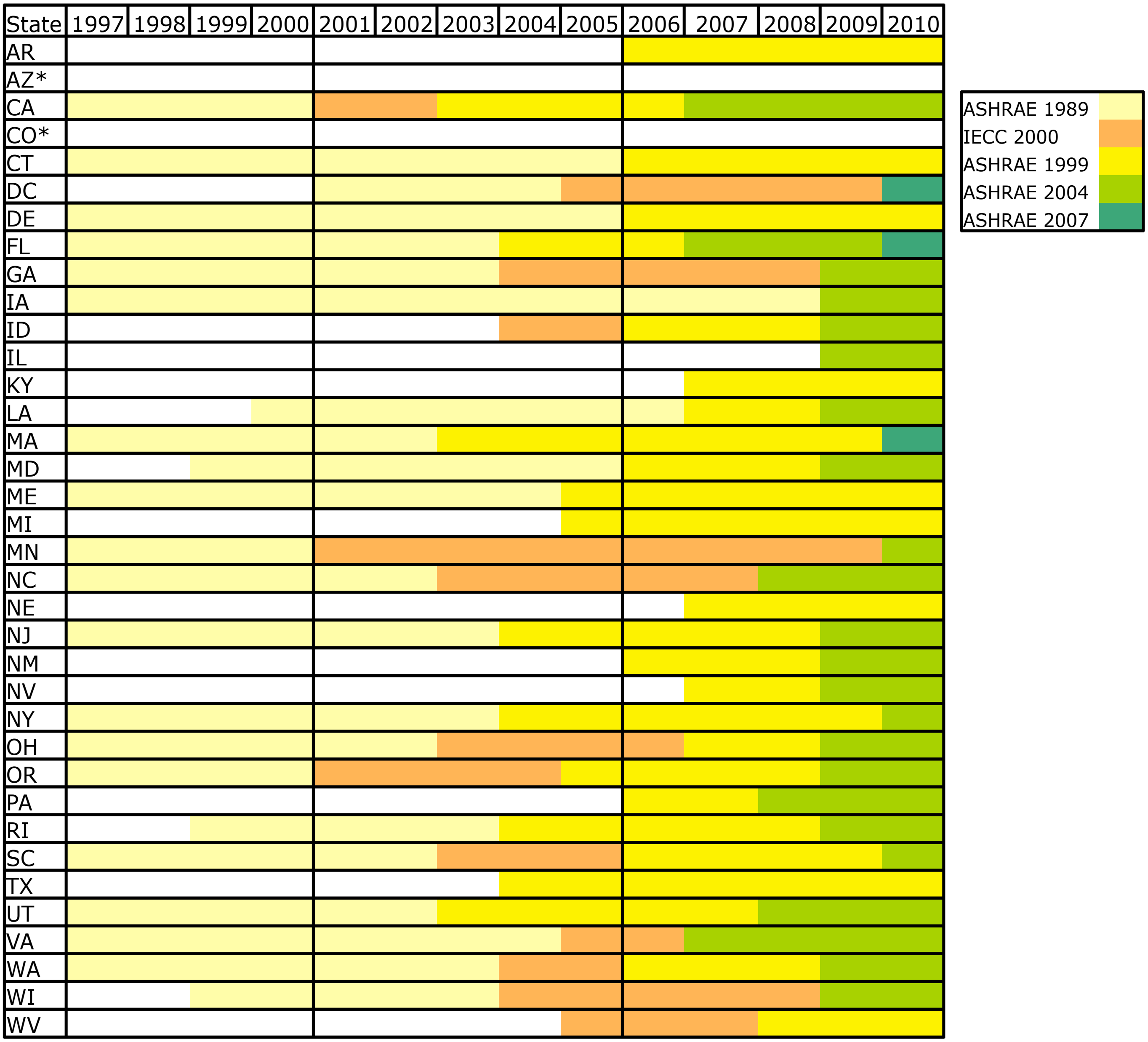
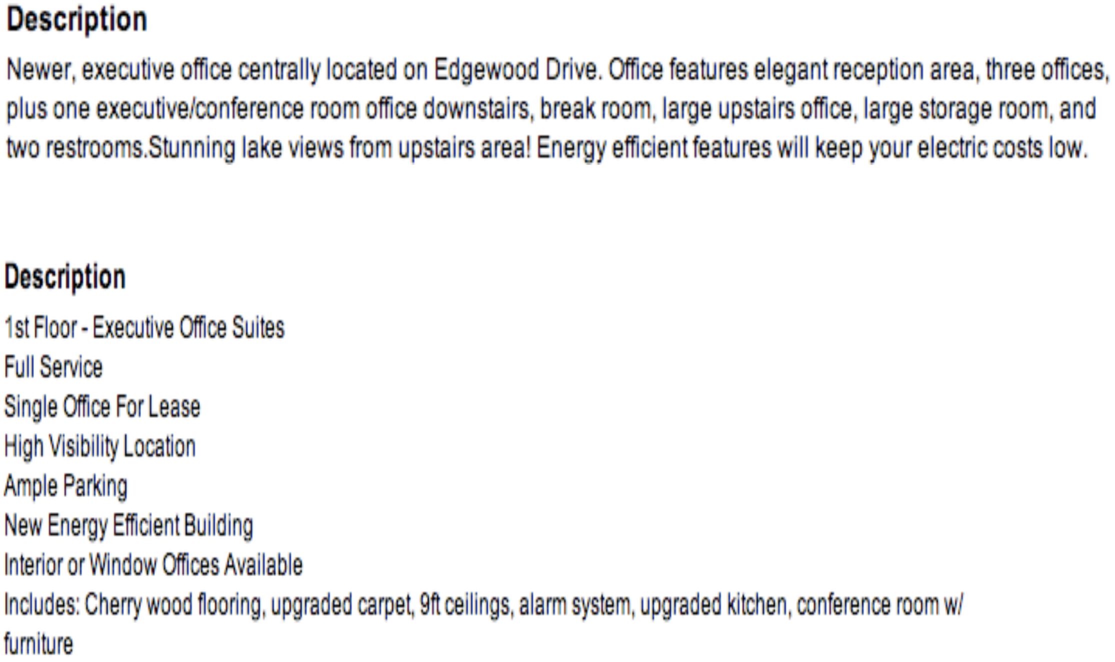
Figure I: State Adoptions



* denotes home-rule states

Notes: The figure identifies state-level implementation dates for increasingly stringent versions of a mandatory energy efficiency standard. Record-keeping for state adoptions began improving in the mid-1990s as a result of the 1992 Energy Policy Act, consequently it is not possible to identify precise ASHRAE 1989 adoption dates in states that adopted the standard before 1996. Because of this, ASHRAE 1989 adoptions are only included in the dataset if they went into effect after January 1, 1997 (as is the case in District of Columbia, Louisiana, Maryland, Rhode Island, and Wisconsin). In Home-Rule states (Arizona and Colorado), state-level energy standard legislation cannot be legally enforced in individual municipalities. However, many jurisdictions in these states have independently adopted energy codes, in which case I have tracked jurisdictional-level adoptions. Details of the dataset creation are described in Section 4 and Appendix Section A.1.

Figure II: Signaling Energy Efficiency



Description

Newer, executive office centrally located on Edgewood Drive. Office features elegant reception area, three offices, plus one executive/conference room office downstairs, break room, large upstairs office, large storage room, and two restrooms.Stunning lake views from upstairs area! Energy efficient features will keep your electric costs low.

Description

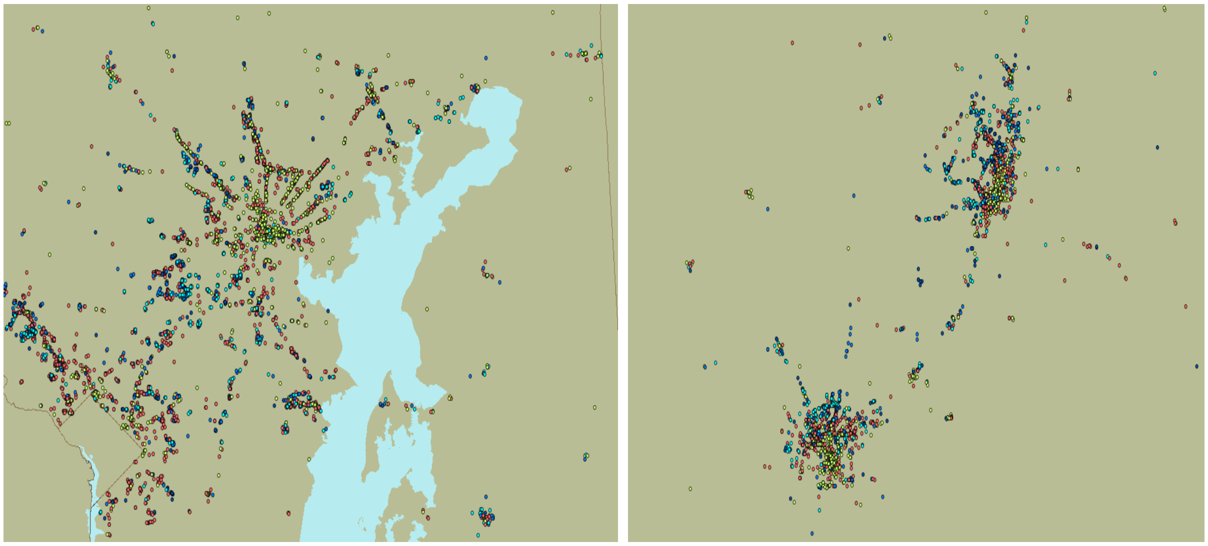
1st Floor - Executive Office Suites
Full Service
Single Office For Lease
High Visibility Location
Ample Parking
New Energy Efficient Building
Interior or Window Offices Available
Includes: Cherry wood flooring, upgraded carpet, 9ft ceilings, alarm system, upgraded kitchen, conference room w/ furniture

Notes: These two ads were found by entering search terms “energy efficient” in a multiple listing service for commercial space (www.loopnet.com).

Figure III: Building Match Example

Notes: Treated and control matches located in Scottsdale, AZ. The building on the left was constructed in 2006. The building on the right was constructed in 2003. ASHRAE 1999 came into effect in September 2003.

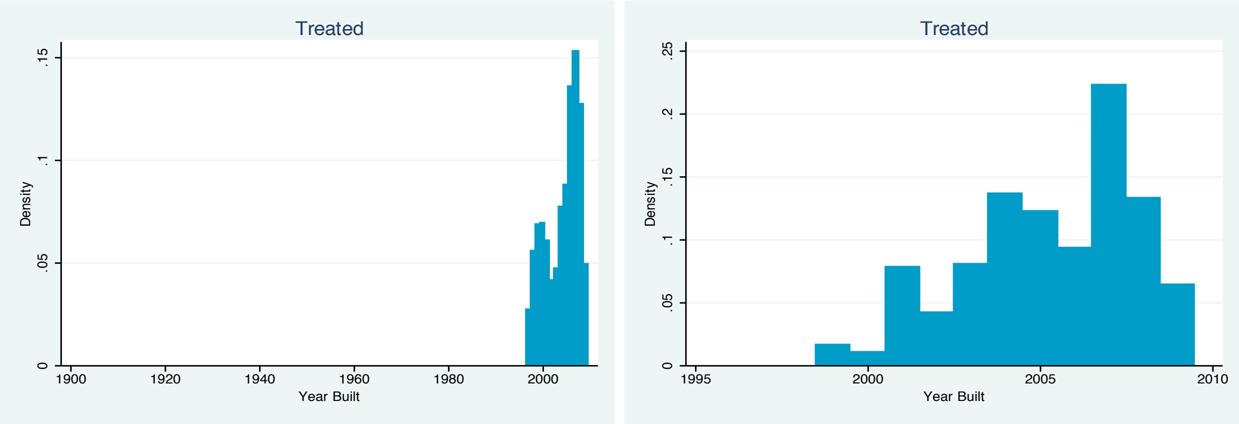
Figure IV: Quantiles of the Year Built Distribution



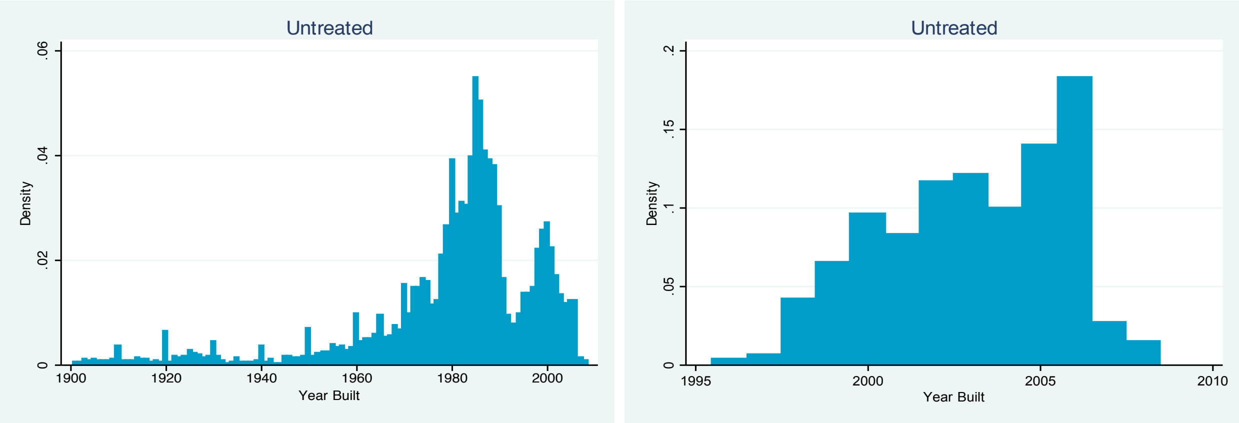
(a) Maryland (b) Austin and San Antonio, Texas

Notes: Each dot represents a building. The lowest tertiles of the year built distribution (the oldest buildings) are represented by yellow dots, the middle quartiles are represented by red dots, and the upper tertiles (newest buildings) are represented by blue dots.

Figure V: Year Built Distribution (Combined Rent and Sales Samples)



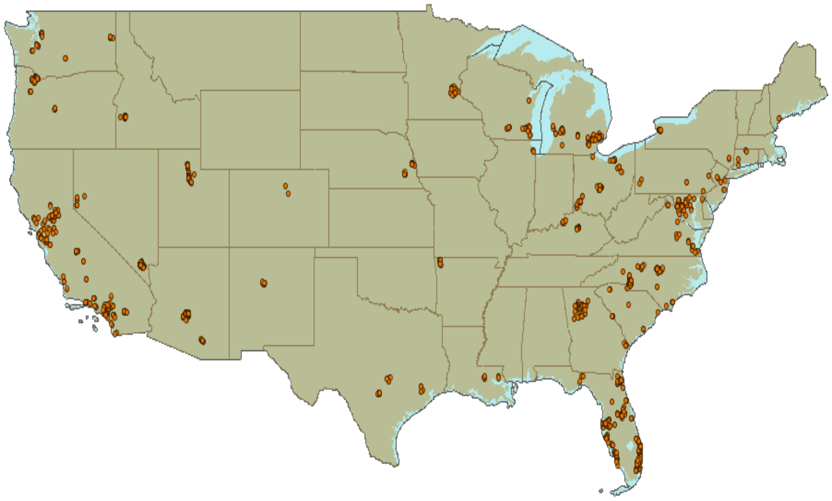
(a) Full sample (n=12,740; mean=2003) (b) Trimmed sample (n=1,254; mean=2005)



(c) Full sample (n=42,731; mean=1982) (d) Trimmed sample (n=2,393; mean=2003)

Notes: Panels (a) and (c) show histograms of the year built distribution by treatment status before trimming out the older control buildings, while panels (b) and (d) show the trimmed histograms.

Figure VI: Buildings Data



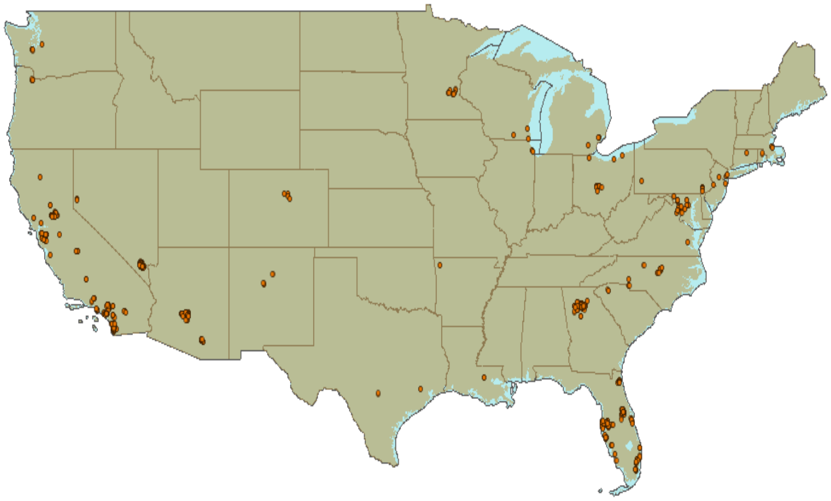


Table I: Treated and Control Categories

Treated	**Control**	**Rent**	**Sales**
ASHRAE 1989	pre-ASHRAE 1989	1.7%	1.9%
IECC 2000	pre-ASHRAE 1989	0.9%	0.2%
IECC 2000	ASHRAE 1989	22.0%	19.1%
ASHRAE 1999	pre-ASHRAE 1989	18.2%	27.3%
ASHRAE 1999	ASHRAE 1989	21.8%	22.9%
ASHRAE 2004	ASHRAE 1989	5.4%	1.5%
ASHRAE 2004	ASHRAE 1999	30.0%	27.1%
Total:		100%	100%

Notes: The data pool together building matches from multiple treated and control categories, listed above. The last two columns show the share of the rent and sales samples taken up by buildings paired on the basis of having been constructed under a given treated-control category.

Table II: Summary Statistics, Rent

	Treated				Untreated				Norm. Diff.
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Rent ($/sq.ft./yr.)	19.57	6.04	4.88	50.70	18.97	6.18	1.16	56.92	0.07
Stories	2.29	2.04	1.00	32.00	2.16	2.93	1.00	70.00	0.04
Size (000s)	34.13	39.09	2.29	312.18	36.70	66.91	1.20	1504	-0.03
Built	2005	2.44	1999	2009	2003	2.65	1996	2008	0.55
Class A (%)	19.32	39.51	0.00	100	18.35	38.72	0.00	100	0.02
Utilities (%)	48.81	50.17	0.00	100	42.77	49.49	0.00	100	0.09
Occupancy (%)	70.91	19.70	0.30	100	75.33	18.87	30.25	100	-0.16
Amenities (%)	29.23	45.51	0.00	100	35.58	47.89	0.00	100	-0.10
SIC Code	6952	1650	191	9711	6935	1651	762	9651	0.02
Observations	797				1,335				
Avg. Distance:	0.56 miles								

The normalized difference measures the degree of overlap for each covariate across the treated and control samples. A normalized difference lower than 0.3 is typically considered good overlap.

Table III: Summary Statistics, Sales

	Treated				Untreated				Norm. Diff.
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Sale Price ($/sq.ft.)	221.21	89.45	35.62	588.85	209.43	79.28	24.07	538.46	0.10
Stories	1.75	1.38	1.00	15.00	1.56	1.01	1.00	13.00	0.11
Size (000s)	25.67	45.01	0.89	350.00	21.42	36.17	1.28	325	0.07
Year Sold	2007	1.69	2002	2009	2006	1.81	2002	2009	0.31
Built	2005	2.29	1999	2009	2003	2.40	1996	2008	0.52
Class A (%)	10.23	30.35	0.00	100	7.20	25.87	0.00	100	0.08
Amenities (%)	21.64	41.24	0.00	100	34.63	47.61	0.00	100	-0.21
High Vacancy	0.009	0.09	0.00	1.00	0.004	0.06	0.00	1.00	0.05
Employment △ (%)	1.91	1.97	-7.70	6.35	2.32	2.25	-7.70	6.35	-0.14
Elec. Price (c/kWh)	9.71	2.22	5.67	15.51	9.56	2.13	5.67	15.92	0.05
Nat. Gas Price ($/kcuf.)	11.47	1.99	5.99	15.94	10.57	2.09	5.99	15.53	0.31
Observations	342				722				
Avg. Distance:	0.50 miles								

The normalized difference measures the degree of overlap for each covariate across the treated and control samples.
A normalized difference lower than 0.3 is typically considered good overlap.

Table IV: Rent results

	(1)	(2)	(3)	(4)	(5)	(6)
	Full Sample				Hot, Humid	Cool, Low Humidity
Code	0.0499***	0.0499***	0.0407***	-0.0386	-0.0495	0.0756
	(0.0111)	(0.0152)	(0.0168)	(0.0446)	(0.0442)	(0.0707)
Utilities x Code				0.0653**	0.0844*	0.0705
				(0.0320)	(0.0482)	(0.0428)
Utilities				-0.171***	-0.111**	-0.103**
				(0.0283)	(0.0422)	(0.0371)
Fixed Effects	YES	YES	YES	YES	YES	YES
Covariates	NO	NO	YES	YES	YES	YES
Robust s.e.	YES	NO	NO	NO	NO	NO
Clustered s.e.	NO	YES	YES	YES	YES	YES
Observations	2,132	2,132	2,132	2,132	657	90
R-squared	0.65	0.65	0.68	0.70	0.72	0.92

Standard errors in parentheses. Clustered errors denotes clustering at the market level. *** p<0.01, ** p<0.05, * p<0.1. Heterogeneity in the rent premium based on climate is reported in columns (5) and (6).

Table V: Sales results

	(1)	(2)	(3)	(4)	(5)
	Full Sample			Hot, Humid	Cool, Low Humidity
Code	0.0987***	0.0987***	0.0882**	0.1060*	0.0047
	(0.0211)	(0.0268)	(0.0380)	(0.0632)	(0.1279)
Fixed Effects	YES	YES	YES	YES	YES
Covariates	NO	NO	YES	YES	YES
Robust s.e.	YES	NO	NO	NO	NO
Clustered s.e.	NO	YES	YES	YES	YES
Observations	1,064	1,064	1,064	401	67
R-squared	0.65	0.65	0.68	0.65	0.91

Standard errors in parentheses. Clustered errors denotes clustering at the market level. *** p<0.01, ** p<0.05, * p<0.1. Heterogeneity in the sales premium based on climate is reported in columns (5) and (6).

Table VI: Robustness

	(1)	(2)	(3)	(4)
	Leasing Company		Utility Contract	
Code	-0.027	-0.024	0.034	0.036
	(0.021)	(0.027)	(0.024)	(0.028)
Fixed Effects	YES	YES	YES	YES
Covariates	NO	YES	NO	YES
Clustered s.e.	YES	YES	YES	YES
Observations	2,132	2,132	2,132	2,132
R-squared	0.53	0.53	0.56	0.57

Standard errors in parentheses. Clustered errors denotes clustering at the market level.
*** p<0.01, ** p<0.05, * p<0.1

Table VII: Assessing the Evidence for Tenant Sorting

	PANEL A					PANEL B				
	TREATED		CONTROL		NORM. DIFF	UTILITIES		NO UTILITIES		NORM. DIFF
	N	%	N	%		N	%	N	%	
Ag., Chem., Oil & Gas, Transport	8	27	22	73	0.21	11	35	20	65	-0.18
Communications	6	25	18	75	0.21	6	25	18	75	-1.04*
Financial & Business Services	274	24	871	76	0.10	442	39	703	61	0.05
General Contractors, Construction	26	33	53	67	0.25	45	58	33	42	0.41
Government & Nonprofits	106	28	271	72	-0.18	145	38	232	62	-0.21
Publishing, & Allied Industries	4	29	10	71	-0.53	9	64	5	36	0.15*
Retail Trade	38	35	72	65	0.43	52	47	59	53	0.01
Wholesale Trade	13	22	47	78	0.06	30	51	29	49	0.54
Total	475	26	1364	74	-0.07	740	40	1,099	60	0.01

Notes: The table reports the number (N) and percent share (%) of observations in each industry category. The industry categories represent similar standard industrial classification (SIC) codes. Panel A reports values for tenants located in treated versus control buildings and panel B reports values for tenants who pay for their utility bills directly (denoted 'UTILITIES')versus tenants who do not (denoted 'NO UTILITIES'). The normalized difference, calculated using the mean and standard deviation of SIC codes in each category, is reported in the last column of each panel. Categories that contribute to rejecting the χ^2 test in Panel B are denoted with a *.

Table VIII: Falsification Test - Rent

	(1)	(2)	(3)	(4)	(5)	(6)
	Full Sample				Hot, Humid	Cool, Low Humidity
Code	0.0160	0.0160	0.0268	0.0192	0.0453	-0.133
	(0.0127)	(0.0133)	(0.0241)	(0.0287)	(0.0649)	(0.146)
Utilities x Code				0.00804	-0.00699	0.183
				(0.0323)	(0.0484)	(0.171)
Utilities				-0.196***	-0.164***	-0.302***
				-0.033	-0.0408	-0.0705
Fixed Effects	YES	YES	YES	YES	YES	YES
Covariates	NO	NO	YES	YES	YES	YES
Robust s.e.	YES	NO	NO	NO	NO	NO
Clustered s.e.	NO	YES	YES	YES	YES	YES
Observations	1,883	1,883	1,883	1,883	681	92
R-squared	0.65	0.65	0.71	0.71	0.74	0.85

Standard errors in parentheses. Clustered errors denotes clustering at the market level. *** p<0.01, ** p<0.05, * p<0.1.
Heterogeneity in the rent premium based on climate is reported in columns (5) and (6).

Table IX: Falsification Test - Sales

	(1)	(2)	(3)	(4)	(5)
	Full Sample			Hot, Humid	Cool, Low Humidity
Code	-0.0470	-0.0470	-0.118	0.0342	0.243
	(0.0424)	(0.0489)	(0.0975)	(0.141)	(0.975)
Fixed Effects	YES	YES	YES	YES	YES
Covariates	NO	NO	YES	YES	YES
Robust s.e.	YES	NO	NO	NO	NO
Clustered s.e.	NO	YES	YES	YES	YES
Observations	818	818	818	545	13
R-squared	0.68	0.68	0.7	0.68	0.92

Standard errors in parentheses. Clustered errors denotes clustering at the market level. *** p<0.01, ** p<0.05, * p<0.1.
Heterogeneity in the sales premium based on climate is reported in columns (5) and (6).

Appendix: For Online Publication

A.1 Further details of the dataset creation

In order to obtain code implementation information going back far enough in time to track adoption dates for ASHRAE-1989, data from a variety of sources were utilized, including an online database maintained by the Building Codes Assistance Project (hereafter BCAP) (BCAP (2010)); archives of BCAP's bi-monthly newsletters going back to 1997, obtained by e-mail from BCAP staff; the Department of Energy's online energy codes database (Department of Energy (2010)); and one report from the Department of Housing and Urban Development (HUD (1997)).[46]

Renovated buildings were dropped from the analysis: although certain types of building renovations are subject to an energy code, and CoStar identifies buildings that have been renovated, it is not possible to identify whether the renovation undertaken in a particular building triggered energy code requirements.[47] Buildings in either treatment category with occupancy rates below 30% were also discarded so as to avoid effects caused by vacancy rates due to buildings undergoing renovation or other idiosyncratic (and unobservable) reasons.

Arizona and Colorado are unique states with respect to energy code adoptions. Because these are 'Home-Rule' states, state-level energy standard legislation cannot be legally enforced in individual municipalities and/or counties. However, many jurisdictions in these states have independently adopted energy codes; I have tracked jurisdictional-level adoptions in these states by going through municipal registers (many of which are available online at

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[46] ASHRAE 1989 standard adoptions were more difficult to pinpoint, as in some cases different sources cited inconsistent dates. More accurate record-keeping for states' adoptions began improving in the mid-1990s. As a result, I only include ASHRAE 1989 adoptions if all the data sources had matching implementation dates. I was not able to find adoption dates for standards prior to ASHRAE 1989. However, as noted in Section 2.2.1, states only began adopting increasingly stringent energy standards in the mid-1990s as a result of the 1992 Energy Policy Act mandate, and it is this variation I seek to exploit.

[47] For example, the most recently adopted ASHRAE standard is applicable to renovations if more than 50% of the lighting fixtures are replaced, but not if the roof and floor are altered where no new cavities are created, if storm windows are installed, or if existing windows are replaced over an area less than 25% of the total fenestration area.

Municipal Code Corporation (2014)), and emailing jurisdictional building officials.[48]

Some states have adopted their own codes, though in several of these cases the state-developed code has adopted one of the ASHRAE standards by reference and made only minor modifications to the original standard. In these states I have relied on estimates of the energy use intensity (in kBTU/s.f./yr.) of each code update and matched them to the ASHRAE or IECC standard version with similar energy saving estimates.

A.2 Varying the Distance Between Buildings

Table A1 presents results where the maximum allowable distance between buildings steadily decreases in 0.25 mile increments, starting with 1.75 miles and ending with 1.0 miles. The results closely resemble those in the main paper, where the maximum distance is 2 miles. Table A2 presents the same for the sales sample. Again, the results parrallel those in the main paper, though some attenuation can be observed as the sample size decreases.

A.3 Manipulating Year of Construction

One concern is that since adoption and implementation dates for energy codes are publicly known, building developers may try to "game" their building's construction date by rushing to obtain their building permits before the new energy code comes into effect, which would result in a discontinuity in the year built distribution whereby fewer buildings may end up being constructed in the year or two following a code implementation date.

Figure A1 depicts the distribution of building construction dates in the full sample of sales and rent observations, two years before and two years after a code came into effect. Close to 25% of buildings were constructed in each of the four years, slightly more buildings were constructed after a new energy code implementations, and there is less than a one percent difference between the share of buildings constructed just before and just after a code came into effect, all of which are not suggestive of strategic energy code avoidance behavior.

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[48] One issue that may arise with respect to home rule states is the possibility that treatment status may be correlated with changes in unobserved local regulations, which may bias the estimates. To address any concerns from this possibility, I have also conducted estimation without buildings from home-rule states, with no substantive change in the results.

A.4 Estimate of the Extent of Attenuation Bias

Though it's not possible to test for attenuation bias directly, a back-of-the-envelope estimate of the attenuation bias can be obtained from a basic errors-in-variables model (Hausman (2001)), with the following formula:

$$-\frac{\sigma_u^2}{\sigma_x^2+\sigma_u^2}, \tag{1}$$

where σ_x^2 is the variance of the energy code treatment variable of interest (x), assuming it is measured without error, and σ_u^2 is the variance of random (mean zero) unobserved shocks to x. The observed treatment variable is $\tilde{x} = x + u$. To approximate the variance of shocks to x, I use data from the US Census on the average number of months it takes to construct buildings with 10-19 units from authorization to completion, normalized by 24 months to obtain a variable that ranges between 0 and 1.[49,50] To approximate the variance of the treatment variable, σ_x^2, I use data on the treatment assignment in the rent and sales samples, both of which lead to similar observed variance. An alternative data source was also used to estimate σ_x^2, namely the share of the post-1992, state-level value of commercial construction erected under a code, using the treatment assignment arising from the decision rule used in the main paper. Data on the value of new commercial construction was obtained from the U.S. Census Bureau. Alternating between the rent sample, sales sample, and value-of-construction approaches to calculating the variance suggests the magnitude of the bias ranges from 0.020 to 0.033. This suggests the largest attenuation bias that may be observed is under 3.3%. This would increase the value of the rent premium (in levels) from 57 cents per square foot to 59 cents per square foot, and the sale premium from \$26.91 per square foot to \$27.79 per square foot.

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[49] I use the 10-19 units measure as it most closely corresponds to the mean building size in my sample. The observed bias range is unchanged if the average time to build is estimated with buildings larger than 20 units instead.

[50] It takes 15 months, on average, to construct a commercial building. I normalize the variable to lie between 0 and 1 because the treatment variable is a dummy.

Appendix References

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Figure A1: Buildings constructed pre- and post- code

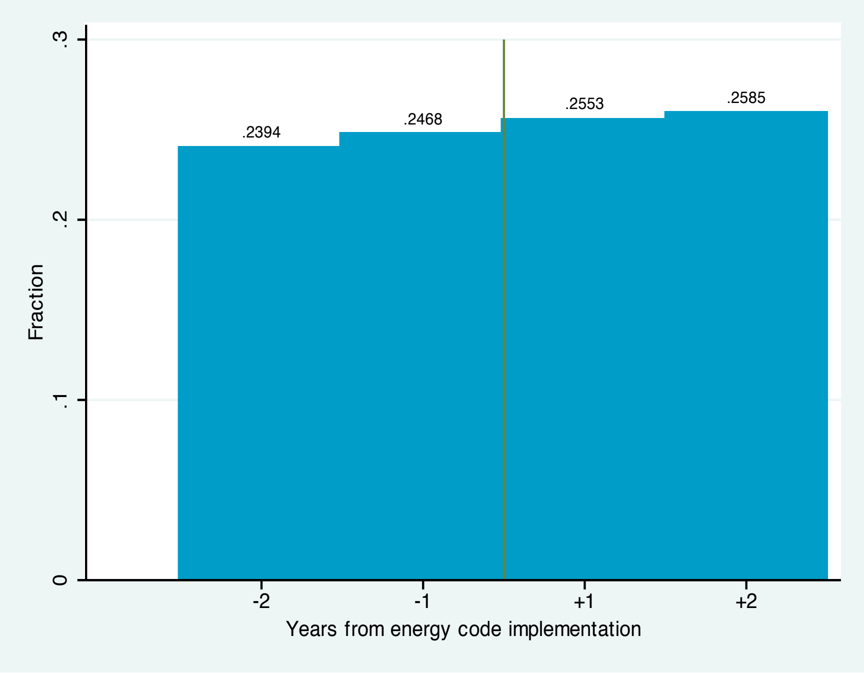

Table A1: Rent results varying the distance between buildings

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1.75 mi		1.5 mi		1.25 mi		1.0 mi	
Code	0.018	0.018	0.017	0.017	0.013	0.013	0.005	0.005
	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.0237)
Utilities x Code	0.072**	0.072*	0.054*	0.054*	0.065**	0.065*	0.063*	0.063*
	(0.032)	(0.039)	(0.032)	(0.033)	(0.033)	(0.037)	(0.033)	(0.038)
Utilities	-0.1554***	-0.1554***	-0.135***	-0.135***	-0.136***	-0.136***	-0.123***	-0.123***
	(0.026)	(0.029)	(0.025)	(0.026)	(0.027)	(0.031)	(0.029)	(0.032)
Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Covariates	YES	YES	YES	YES	YES	YES	YES	YES
Robust s.e.	YES	NO	YES	NO	YES	NO	YES	NO
Clustered s.e.	NO	YES	NO	YES	NO	YES	NO	YES
Observations	1,861	1,861	1,763	1,763	1,641	1,641	1,469	1,469
R-squared	0.71	0.71	0.72	0.72	0.73	0.73	0.76	0.76

Standard errors in parentheses. Clustered errors denotes clustering at the market level.
*** p<0.01, ** p<0.05, * p<0.1

Table A2: Sales results varying the distance between buildings

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1.75 mi		1.5 mi		1.25 mi		1.0 mi	
Code	0.086**	0.086**	0.079**	0.079**	0.072**	0.072*	0.078**	0.078*
	(0.034)	(0.040)	(0.034)	(0.039)	(0.035)	(0.039)	(0.036)	(0.040)
Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Covariates	YES	YES	YES	YES	YES	YES	YES	YES
Robust s.e.	YES	NO	YES	NO	YES	NO	YES	NO
Clustered s.e.	NO	YES	NO	YES	NO	YES	NO	YES
Observations	1,028	1,028	1,003	1,003	971	971	932	932
R-squared	0.68	0.68	0.69	0.69	0.69	0.69	0.68	0.68

Standard errors in parentheses. Clustered errors denotes clustering at the market level.
*** p<0.01, ** p<0.05, * p<0.1