Greening the Regulatory Landscape: The Spatial and Temporal Diffusion of Green Building Policies in U.S. Cities

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Abstract This paper explores the determinants of green building policy adoption and the spatial and temporal diffusion of such policies. This research builds substantially on previous work by employing an original, robust database of green building policies created by the author for 200 cities in the United States—the Green Building Regulation Database (GBRD)—and a hazard rate model to determine the effect of a range of variables on policy adoption. The results indicate that economic, political, and climate factors, such as the number of patents issued per capita, carbon emissions per capita, and the existing policy landscape, are significant predictors of green building policy adoption. Cities categorized as policy innovators and early adopters of green building policies tend to have lower carbon emissions per capita, are better educated, and have more restrictive land use regulations.

There has been an exponential increase in the number of green buildings constructed in the United States over the past decade. The emergence of various eco-labeling systems, such as the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system and the U.S. Environmental Protection Agency's (EPA's) ENERGY STAR program, have served to heighten awareness of the environmental and social impacts of new construction, both within the real estate industry and among the general public. By 2010, there were more than 2,000 LEED-certified properties in the U.S., with an annual rate of growth of approximately 50% since 2000. Spurred by new regulations and financial incentives, in addition to growing market demand, real estate owners and developers have begun to shift design standards for new buildings to meet a minimum standard of energy and resource efficiency, although obstacles remain to the widespread integration of green practices (Hoffman and Henn, 2008).

Despite the increased awareness and understanding of the benefits of sustainable design, the adoption of green building policies—codes, statutes, or plans that require, incentivize, or otherwise encourage sustainable buildings—has occurred incrementally. To date, there have been relatively few cities that have adopted such policies, resulting in substantial opportunity to enact and improve new green building programs. The policies that have been adopted, such as Local Law 86 in

New York City and Chapter 13C of the San Francisco Building Code, tend to vary significantly with respect to the type and size of buildings affected and, most importantly, the measure of sustainability used (Simons, Choi, and Simons, 2009). While a vast majority of city-level policies utilize the LEED rating system, emerging alternatives and a growing demand for performance-based metrics may shift policy structures in the future.

This paper explores the determinants of green building policy adoption and the spatial and temporal diffusion of such policies. The research builds substantially on previous work by employing an original, robust database of green building policies created by the author for 200 U.S. cities—the Green Building Regulation Database (GBRD)—and a hazard rate model to determine the effect of a range of political, economic, social, climate, and regulatory variables on policy adoption. Supplemental data for the work comes from such sources as the CoStar Group, the U.S. Census, the Bureau of Economic Analysis, the Wharton Land Use Regulation Database, and the U.S. Patent and Trademark Office. The article concludes with a discussion of the implications for public policy and green building market transformation.

Green Building Policies in the United States

For much of the world, the need to reduce carbon emissions to mitigate or reverse climate change is widely accepted and the scale of emissions attributed to the buildings sector is well known (Huovila, Juusela, Melchert, and Pouffary, 2007; Metz et al., 2007). In the U.S., buildings have become the focus of energy efficiency and carbon reduction strategies, particularly because energy efficiency measures in buildings can result in a positive ‘‘double bottom line’’ outcome by reducing carbon and adding value to the underlying real estate asset (Miller, Spivey, and Florance, 2008; Dermisi, 2009; Fuerst and McAllister, 2009, 2011a, 2011b; Eichholtz, Kok, and Quigley, 2010). Buildings are an attractive target for policymakers tasked with climate change mitigation as efficiency measures at the property-level are relatively low-cost, less politically charged, and can have a more immediate impact than comprehensive changes to land use patterns and transportation networks (Gonzalez, 2005; Metz et al., 2007; Wheeler, 2008).

Today, much of the innovation in green building policies is occurring at the city or municipal level, where, in most parts of the U.S., authority over building and zoning codes resides. Green building policies encompass a wide range of interventions through building and zoning codes, tax incentives, and subsidies, among others. These policies can shape the market by (1) leading by example (e.g., through requirements for municipal buildings), (2) raising building and design standards, (3) setting targets and measurable goals, and (4) incentivizing exemplary performance. Critical to the success of any of these policy interventions is ongoing performance data that can be measured, openly distributed, and used as a yardstick to evaluate progress toward established energy or carbon reduction goals. The drive toward greater transparency in energy performance information has the tremendous potential to shift markets and affect the decision-making processes of both tenant and owner. New York City's Greener, Greater Buildings

Plan, for instance, although criticized for dropping the mandatory retrofit component, should play a significant role in changing behavior by providing an additional metric for evaluation of investment alternatives. Similar energy performance disclosure requirements are proliferating in cities across the U.S., such as San Francisco, Seattle, and Washington, D.C., amid growing awareness of the need for transparent energy use data (Burr, Keicher, and Leipziger, 2011).

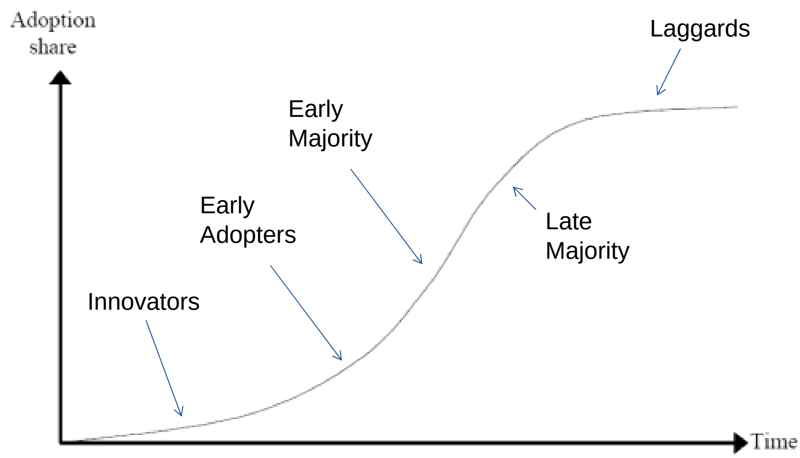
Public policy approaches to green buildings tend to fall into one of two categories: voluntary incentives and mandatory standards (King and King, 2005). Voluntary incentive programs take on a number of forms, including tax abatements, density bonuses, expedited permitting, and technical assistance. Mandatory standards and regulations are, by definition, more binding and can have differing effects depending on policy structure and regulatory context. Certain regulations can limit or delay industry acceptance of sustainable design and construction and the market penetration of energy-efficient buildings. For example, regulatory barriers in the form of outdated zoning, building, and environmental regulations can restrict innovation in Smart Growth planning policies and green building technology, design, and construction (Downs, 2005; Simons, Choi, and Simons, 2009). Furthermore, differing regulations and codes across local municipalities (in New York State, for example, there are more than 932 towns, 62 cities, and 553 incorporated villages, each with its own authority over zoning laws) create friction in the planning, design, and development of green projects, thus adding costs and delays that limit the financial feasibility of such efforts (Choi, 2010).

On the other hand, regulations can act as an important mandate for a threshold level of sustainable design and development. For example, New York City requires that all municipal buildings meet certain requirements to achieve LEED Silver ratings and the Town of Babylon (New York) recently adopted legislation requiring all commercial properties greater than 4,000 square feet to achieve LEED certification. Similar examples can be found across the U.S., and government regulations have been widely (and effectively) used in many parts of Europe for decades (the cities of Stuttgart and Freiburg in Germany provide excellent examples). Properly structured green building policies (Porter and van der Linde, 1995) can raise the standard for energy-efficient construction, encourage innovative design and material solutions, and accelerate the market penetration of green buildings (Newell, Jaffe, and Stavins, 1999).

Policy Diffusion Mechanisms

The study of the diffusion of innovations, which includes policy innovations, began in earnest in the 1940s and 1950s. During this time, various disciplines approached the question of how ideas spread from the perspective of an innovation relevant to their specific area of study, with the work of two rural sociologists, Bryce Ryan and Neal Gross (1943), emerging as an influential contribution to the field. In 1962, Everett Rogers wrote what is widely considered the first theoretical synthesis of the process of diffusion, identifying four main elements—innovation, communication, time, and social system—common to all diffusion processes (Rogers, 1962, 2003). Within this framework, Rogers developed five categories of

Exhibit 1 | Adoption S-Curve



Adapted from Rogers (2003).

adopters, based on a normal distribution of adoption as a function of time (shown in Exhibit 1).

Innovators are those who are first to adopt a new innovation and can be viewed as opportunistic, seeking out new ideas that are, by definition, relatively high risk as a result of significant uncertainty surrounding their effectiveness. Policy innovators [also referred to as public entrepreneurs (Schneider and Teske, 1992)] must have strong communication networks, a sophisticated understanding of the problem to be addressed, and the ability to analyze alternative innovative, cutting-edge solutions (Polsby, 1984; Mintrom, 1997; Rogers, 2003). To be successful, policy innovators must have significant political capital and influence in order to convince (or compel) a wide range of actors of the potential opportunity from adopting the policy in question. There is evidence of this process in New York City, where the Bloomberg Administration, supported by relatively high approval ratings,[1] was successful in advancing several greenhouse gas reduction and energy efficiency policies, such as PlaNYC 2030 and, most recently, the Greener, Greater Buildings Plan. Of course, policy innovators take risks, and the failure of a new policy to produce expected outcomes exposes these innovators to political repercussions.

While Rogers (1962, 2003) outlines the critical elements of the process of diffusion, the mechanisms by which new ideas spread can be grouped into four dominant explanatory categories (Simmons, Dobbin, and Garrett, 2008; Shipan and Volden, 2008; Meseguer and Gilardi, 2009). The first mechanism is *coercion*, where policies enacted at the regional, state, or national government level, or through a court-ordered mandate, impose pressure on local governments to follow suit. The second mechanism, *emulation*, occurs when policies are adopted because they represent social or political values that are independent of the primary function of the policy itself. Diffusion by emulation is predicated on one city adopting a certain policy enacted in another city in order to become more like that city in some way (e.g., to achieve similar economic or social characteristics). Third, *competition* encourages the diffusion of policies as governments compete for resources either by adopting similar policies to other municipalities or by attempting to pre-empt other municipalities with more effective and efficient policies. Finally, diffusion through the *learning* process occurs when one city (or, more specifically, decision-makers in that city) seeks a solution to a local problem by adopting a policy that has been successful elsewhere (Berry and Baybeck, 2005). Learning requires that the adopting municipality (1) is aware of other municipalities' policies through communication channels, (2) evaluates policies with respect to some measure of effectiveness, (3) modifies or adapts the policy to local political, economic, social, and cultural conditions, and, finally, (4) adopts the policy.

Often, decision-makers lack the requisite time or expertise to fully evaluate alternative policy options and rely on a variety of heuristics to identify viable policy solutions [Simon, 1985; see also Scott (2008) for more on institutional theory]. These include the *representiveness* heuristic, which bases the evaluation of success on expectations or rhetoric rather than analysis of actual outcomes; the *availability* heuristic, which suggests a higher likelihood of adopting a policy that has a geographically proximate successful example; and the heuristic of *anchoring*, which encourages the adoption of a policy with little adaptation to local context and needs (Weyland, 2007; Meseguer and Gilardi, 2009). It is the heuristic of anchoring that often reinforces the convergence of policy structure across differing jurisdictional frameworks.

Data and Study Area

The Green Building Regulation Database

Green building policy diffusion in the U.S. is explored here by analyzing the adoption of mandatory and incentive-based green building programs. Previous attempts to assemble data on green building policies have been limited by methodology [e.g., cursory web searches as in Simons, Choi, and Simons (2009) and Choi, (2010)] and breadth and depth of information gathered (e.g., Retzlaff, 2009). The GBRD created for this research catalogues the presence, type, structure, and year of adoption of building regulations and codes, incentives, and sustainability plans for 200 U.S. cities covering 44 states. Cities were selected from Core Based Statistical Areas with populations greater than 200,000 and based on the availability of relevant CoStar market data. From the full sample of 200 cities, CoStar data were available for 178 cities. For each city included in this analysis, the following information was gathered:

Green Building Standards: Design standards relating to the attainment of an eco-label certification (such as LEED); the applicability of the standard with respect to building size, type, and ownership (public or private); whether the standard was mandatory; the type and level of certification required; and the year adopted.

Green Building Incentive: Any incentives relating to green building construction, including expedited permitting, fee reductions, etc.; the applicability of the incentive with respect to building size, type, and ownership (public or private); the type and level of certification required to qualify for the incentive; and the year adopted.

Sustainability Plan: Any planning initiative or climate action plan that affects buildings, the type of real estate implicated, and the year adopted.

Energy Conservation and Renewable Energy: Any incentive or requirement for energy conservation programs and/or renewable energy systems in buildings.

The GBRD was developed using a three-step methodology. First, an online review of municipal planning, building, and sustainability agencies was conducted to determine the presence of the green building policies described above. Second, if a policy was indicated, the applicable building code, zoning code, or local law was reviewed to collect the required policy information. Finally, where sufficient or complete information could not be gathered (such as year of policy adoption, for instance), a survey of the relevant municipal planning, building, or sustainability official was conducted by phone and email. This process was conducted between January 2010 and February 2011.

State-level policies are also included in the database. While a number of studies have examined state adoption of environmental policies (Clark and Allen, 2004), there has been relatively limited discussion of green building regulations enacted at the state level (May and Koski, 2007). However, state green building policies can provide both an impetus to similar action at the local level and a complementary policy environment across different levels of government that may accelerate the adoption of green building practices. The state policies included here represent green building and energy efficiency regulations and incentives (tax incentives, subsidies, grants, municipal loans/bonds). This information was collected from the Database of State Incentives for Renewables and Efficiency, a project of the North Carolina Solar Center and the Interstate Renewable Energy Council.

Additional data were collected from numerous sources, including the U.S. Census, the Bureau of Labor Statistics, the Bureau of Economic Analysis, and the CoStar Group. Carbon dioxide (CO_2) emissions data as of 2002 were extracted from the NASA/DOE funded North American Carbon Program. These data are available at the county level and broken down by building type and per capita measures. For this analysis, county-level emissions data are aggregated by city. Carbon emissions per capita are used as a measure of the environmental impact of a city and the degree to which carbon reduction actions are warranted.

Data on ''utility patents'' by city of issuance were collected from the U.S. Patent and Trademark Office. Utility patents are those *issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof* (U.S. Code Title 35). Although patents have some limitations as a measure of innovation (Acs, Anselin, and Varga, 2002), it is expected that cities with higher numbers of utility patents are more receptive and conducive to technological change and shifts in building practices.

To examine the role of regulatory context in green building policy diffusion, the Wharton Residential Land Use Regulation Index (WRLURI) is included in the model as a measure of the restrictiveness of other land use regulation in the jurisdiction. The WRLURI was created through a survey of over 2,000 municipalities and provides a snapshot of the extent of land use regulations affecting residential development in a particular jurisdiction (Gyourko, Saiz, and Summers, 2008). It is expected that municipal governments with more restrictive land use regulations may be more willing to intervene in real estate markets to promote green building. Similarly, municipalities with more restrictive regulations may also be more likely to adopt mandatory green building polices rather than voluntary, incentive-based structures. A complete summary of variable data sources is provided in Exhibit 2.

The Current Landscape of Green Building Policies: Evidence from the GBRD

The GBRD database reveals a burgeoning landscape of green building policies across the U.S., with approximately one-quarter of all cities surveyed adopting some form of green building standard for either privately- or publicly-owned buildings (Exhibit 3). The most common metric used is the LEED rating system, and over three-quarters of cities with a green building policy make LEED certification, typically at the Silver level, a requirement for publicly and/or privately-owned buildings. More than half of the green building policies apply to buildings of 5,000 square feet or more.

There is, however, a wide variation in the stringency of these requirements. For example, Chapter 13C of the San Francisco Building Code, adopted in 2008, requires that all commercial buildings over 25,000 square feet and all residential buildings greater than 5 units and 75 feet in height must achieve LEED Silver certification.[2] This policy represents one of the most ambitious code mandates affecting privately-owned buildings. In the city of Pittsburgh, an amendment to the Pittsburgh Code approved in 2006 allows for a 20% floor-area ratio (FAR) bonus for commercial projects that achieve LEED New Construction or Core & Shell certification.[3] This policy represents an example of a robust incentive-based policy. Of course, such bonus and incentive schemes are not without their challenges in implementation.[4]

In general, cities that adopt green building policies tend to be larger, both in terms of population and office market size, and have a population that is healthier, more active, better educated, and younger (Exhibits 4 and 5).[5] These cities are more dense, have lower carbon footprints, and lower average temperatures. There also appears to be a vertical relationship between policies enacted at the state level and those adopted by cities. Data from the GBRD reveal that almost all cities with green building standards are in states with at least some incentives for energy efficient buildings or renewable energy systems, typically in the form of tax incentives or grant programs. This lends support to coercion and learning as mechanisms of diffusion, as cities are influenced, and supported, by state policies. Competition also appears to play an important role in the spread of green building policies, particularly as cities are increasingly framing competition in terms of

Exhibit 2 | Variable Data Sources

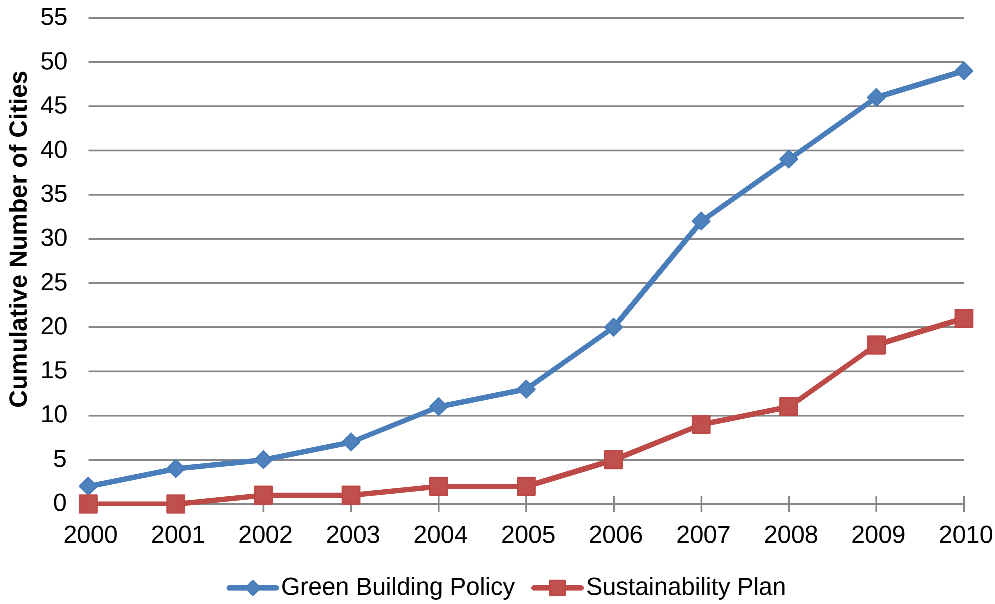
Variable	Source
Real Estate Market	
Age of Structures, Median	U.S. Census
% LEED Certified, sq. ft., 2004	USGBC / CoStar
% Urbanized	U.S. Census
Socioeconomic	
% Population between 22 and 34 Years of Age	U.S. Census
Population, 1995 (per 1,000,000 persons)	U.S. Census
Population, % Growth 1995–2005	U.S. Census
Education, % Bachelors Degree or Higher, 2000	U.S. Census
Per Capita Income, 1995, (000s)	Bureau of Economic Analysis
Per Capita Income, % Growth 1995–2005	Bureau of Economic Analysis
Economic	
GMP per Capita, 2000, per 100,000	Bureau of Economic Analysis
GMP per Capita, % Growth 2000–2008	Bureau of Economic Analysis
Government Employment, % of Total, 2000	Bureau of Labor Statistics
Total # of Patents, 1999 (00s)	U.S. Patent and Trademark Office
Political / Regulatory	
Non-profit Organizations, per 10,000 pop., 2000	Urban Institute National Center for Charitable Statistics
Sustainability Plan Previously Adopted	GBRD
Green Building Policy, State	DSIRE
Land Use Regulation Index	Wharton Residential Land Use Regulation Database
Democratic Mayor	U.S. Census and U.S. Conference of Mayors
Climate	
CO_2 Emission per Capita, metric tons	NASA / Department of Energy
Climate Zone 2	ASHRAE
Climate Zone 3	ASHRAE
Climate Zone 4	ASHRAE
Climate Zone 5	ASHRAE
Climate Zone 6	ASHRAE
Climate Zone 7	ASHRAE
Temporal-Spatial Control	
# of Previous Adopters in State	GBRD

carbon reduction targets and climate change mitigation in an effort to improve quality of life and attract firms and residents (Rogerson, 1999). Energy efficiency in buildings has emerged as a new economic development strategy that is predicated on fostering innovation and creating new investment, employment, and R&D opportunities.

Empirical Strategy

Using data from the GBRD, this paper examines the political/regulatory, environmental, economic, and social determinants of green building policy

Exhibit 3 | Green Building Policies by Year of Adoption



Source: GBRD.

adoption and diffusion across U.S. cities. In particular, the focus of this empirical analysis is to better understand the mechanisms by which green building policies have spread—both temporally and spatially—across the country over the past decade.

Determinants of policy adoption and diffusion are analyzed here using a Cox proportional hazards model with a binary dependent variable for the adoption of a green building standard (Cox, 1972; Berry and Berry, 1990; Rincke, 2007; Shipan and Volden, 2008). The hazards model allows for both time invariant and time-varying covariates, which accounts for changes in municipal-level characteristics over the study timeframe. Therefore, the likelihood of adopting a green building policy is given as a function of a range of factors using annual data for the year preceding the year of adoption. It also allows for the analysis of censored data, when the event in question (in this case the adoption of a green building policy) occurs before or after the study period. In the Cox proportional hazards model, the hazard is assumed to be:

$$h(t) = h_0(t)\exp\{\beta_1 x_1 + \cdots + \beta_k x_k + g(t)(\gamma_1 z_1 + \cdots + \gamma_m z_m)\},$$

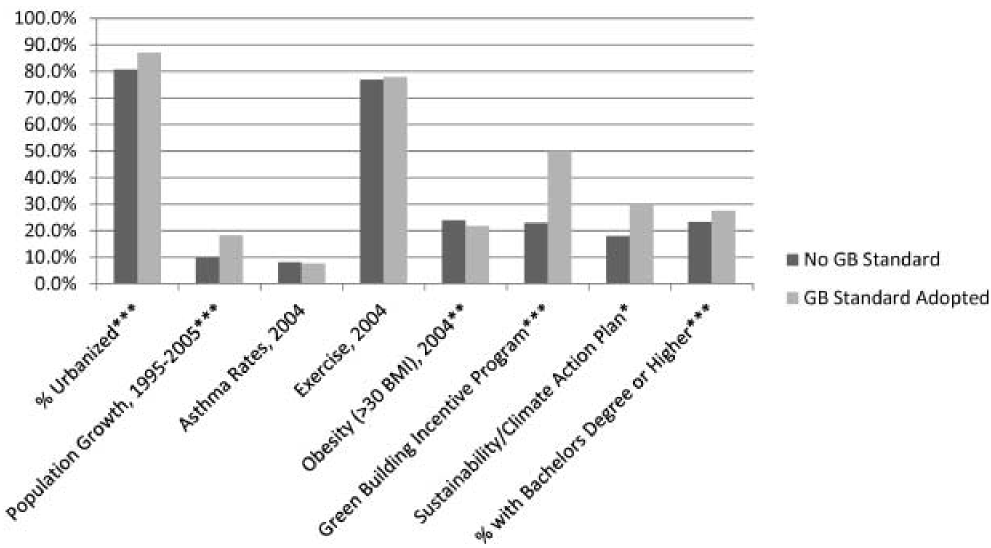
where $(z_1,\ldots, z_m)$ are the time-varying covariates. The hazard function is the conditional probability of a municipality adopting a green building regulation

Exhibit 4 | Descriptive Statistics

	With Green Building Policy		No Green Building Policy		
	Mean	Std. Dev.	Mean	Std. Dev.	Diff. (Mean)
Total RBA	488,000,000	621,000,000	130,000,000	183,000,000	358,000,000
LEED Bldgs. (as of 2010)	39.9	45.7	6.4	10.0	33.5
Population Density (per sq. mi.)	2,619	1,144	1,904	622	715
Carbon Footprint (metric tons per capita)	2.27	0.57	2.6	0.4	−0.3
% Urban	86.5%	10.0%	80.7%	9.4%	5.8%
% 25–34 Years Old	19.1%	1.7%	17.8%	2.1%	1.3%
GDP per capita, % Growth 2001–2008	9.4%	6.8%	8.3%	7.8%	1.1%
Population, 1995	2,136,532	3,108,072	633,126	823,938	1,503,406
Population, % Growth 1995–2005	16.3%	12.8%	10.7%	10.7%	5.6%
Per Capita Income, 1995	24,289	3,783	21,666	3,354	2,623
Per Capita Income, % Growth 1995–2005	53.2%	8.9%	49.7%	9.0%	3.5%
% with Asthma	7.8%	1.3%	8.3%	1.5%	−0.5%
% Exercise Regularly	78.0%	3.6%	77.3%	4.4%	0.7%
% Obese Population (BMI >30)	22.0%	2.7%	23.6%	3.4%	−1.6%
% in State with Green Building Tax Incentive	44.0%	50.1%	45.3%	50.0%	−1.3%
Employment, Construction, % of Total 2001	6.3%	1.3%	6.1%	1.5%	0.2%
Employment, Government, % of Total 2001	14.4%	4.9%	15.1%	5.6%	−0.7%
% with Bachelors Degree or Higher	28.2%	6.0%	23.1%	5.3%	5.1%
Average Electricity Price	11.5	3.4	11.0	2.7	0.5
Average Annual Temperature (Fahrenheit)	54.3	7.8	56.6	9.0	−2.3
% with Republican Mayor	16.3%	37.3%	20.3%	40.6%	−4.0%

Note: The values in the table are year 2000 values unless otherwise indicated.

Exhibit 5 | Comparison of Cities with and without a Green Building Policy, Selected Characteristics



Independent sample *t*-test performed to analyze difference in means.
* Significant at the 90% confidence level.
** Significant at the 95% confidence level.
*** Significant at the 99% confidence level.

within the study period. Robust standard errors are estimated to account for heteroscedasticity and uncorrected serial correlation over time or space. The explanatory variables are categorized into real estate market factors, socioeconomic characteristics, political/regulatory, and climate variables. Spatial controls are also included to test for spatial correlation.

The equation estimated here is given by:

$$h_i(t) = h_0(t)\exp\{RE + SE + ECON + POL + CLIMATE + SPATIAL\},$$

where h_0 is the baseline hazard function; *RE* is a set of real estate market variables, including percentage of urban area, median age of structures, and the proportion of LEED certified space prior to policy adoption; *SE* is a vector of socioeconomic characteristics of city *i* including population, education, and income variables; *ECON* represents economic conditions described through gross municipal product, employment, and patent variables; *POL* is a set of political and regulatory measures, including the number of environmental non-profit organizations, the presence of a municipal sustainability plan, state-level green building policies, the political party affiliation of the mayor, and a measure of the restrictiveness of local land use regulations; *CLIMATE* includes a variable for the carbon emissions per capita and a series of dummy variables for the climate zone of city *i*; and *SPATIAL* is temporal-spatial control variable for the number of cities in the same state that adopted a green building policy prior to city *i*.

Results

Hazard Rate Model

The results of the hazard rate model (Exhibit 6) reveal that regulatory, economic, and climate variables are clear predictors of green building policy adoption. The results are robust to different model specifications, including stratifying the model by climate zone to account for the varying significance of adoption drivers in different climate contexts. The first column of Exhibit 6 reports the coefficients for each variable, followed by the robust standard error. The third column displays the hazard rate.

A city that previously adopted a sustainability or climate action plan is more likely to adopt a green building policy. This is a logical progression: a city analyzes its current environmental impact and energy consumption, identifies targets for carbon and energy use reduction, and outlines strategies to achieve those goals. The green building policy, then, is the implementation of part of the sustainability plan for the city. This process has been reflected in the path of adoption in cities like San Francisco and New York. While the adoption of a sustainability plan may share certain predicators with the adoption a green building policy, there is substantial difference in scope, legislative process, and relevant stakeholders. Of course, city sustainability plans are often criticized for their lack of specific implementation strategies and evaluation metrics (Wheeler, 2008), but despite this they often represent an important first step in taking action against climate change.

The finding above is supported by the positive, statistically significant coefficient for carbon emissions per capita. Cities with higher per capita emissions are more likely to adopt a green building policy, reflecting what may be a rational public policy response to an actual or perceived problem. It follows that cities that have developed a sustainability plan know and understand the source of their carbon emissions and, consequently, take action to curb emissions in buildings. This finding also supports pre-emption as a motivation by city officials, who recognize that carbon emissions may become regulated by higher levels of government in the future and thus decide to act to avoid regulations being imposed on them (e.g., the narrow defeat of the proposed American Clean Energy and Security Act of 2009). In other words, cities may see that action will need to be taken to reduce emissions and decide to proactively address the issue by creating their own green building policy. For instance, San Francisco’s green building policy is more restrictive than the recently adopted CalGreen green building code in California, which gives city officials greater control over green building design requirements.

The measure of innovation included in the model—patents per capita—is significant, indicating that cities with a greater number of patents issued are more

Exhibit 6 | Hazards Model Regression Results

Variable	Coeff.	Robust Std. Error	Hazard Rate
Real Estate Market			
Age of Structures, Median	−0.026	0.069	0.974
% LEED Certified sq. ft., 2004	0.000	0.000	1.000
% Urbanized	0.679	2.751	1.971
Socioeconomic			
% Population between 22 and 34 Years of Age	2.089	16.891	8.074
Population, 1995 (per 1,000,000 persons)	−0.003	0.156	0.999
Population, % Growth 1995–2005	3.644	2.982	38.250
Education, % Bachelors Degree or Higher, 2000	3.988	5.376	53.969
Per Capita Income, 1995 (000s)	−0.008	0.151	0.999
Per Capita Income, % growth 1995–2005	−3.221	2.836	0.040
Economic			
GMP per Capita, 2000, per 100,000	4.530	6.420	1.045
GMP per Capita, % growth 2000–2008	0.143	3.627	1.154
Government Employment, % of Total, 2000	4.229	5.281	68.665
Total # of Patents per capita, 1999	0.001	0.000	1.001***
Political / Regulatory			
Non-profit organizations, per 10,000 pop., 2000	0.116	0.167	1.123
Sustainability Plan previously adopted	1.953	0.896	7.046**
Green Building Policy, State	−0.621	1.067	0.538
Land Use Regulation Index	0.186	0.295	1.204
Democratic Mayor	0.240	0.483	1.271
Climate			
CO_2 Emission per Capita, Metric Tons	0.052	0.019	1.054***
Climate Zone 2	−1.201	1.217	0.301
Climate Zone 3	−2.014	1.184	0.133*
Climate Zone 4	−1.205	1.598	0.300
Climate Zone 5	−1.970	1.377	0.139
Climate Zone 6	−1.579	1.496	0.206
Climate Zone 7	−1.204	1.378	0.300
Spatial			
# of Previous Adopters in State	0.191	0.199	1.211

Notes: The number of observations is 120. The log likelihood is −154.693 and the Wald χ^2 is 155.36.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

likely to adopt a green building policy. On average, cities with a green building policy had approximately 33% more patents per capita than cities without such a policy. Innovative cities may be more receptive to incentives for resource-efficient design, and may be more likely to link innovation in green building technologies, systems, and design to economic competitiveness. Although cities have historically been loci of innovation (Glaeser, 2011), what is notable in the case of climate change is that a relatively small number of citizens are willing to bear the costs of carbon reductions that will, by definition, have a global impact (Engel and Orbach, 2008).

Equally interesting from the perspective of better understanding the diffusion of green building policies are the variables that are not significant. Most notable are the variables for the mayor's political party affiliation, the density of environmental non-profit organizations, and the climate zone of the city. Although it might be assumed that a democratic mayor (and the electorate that would vote for them) would be more likely to consider climate change an important issue, the results show no significant variation across political parties (Dunlap, Xiao, and McCright, 2001; Shipan and Lowry, 2001). This suggests that either there is some convergence on the issue of building energy efficiency across parties or the motivations differ among democrats, republicans, and independents, but the resultant approach is still to enact green building policies. Along these lines, the number of environmental organizations does not appear to play a role in green building policy diffusion. It is possible that it is not the number of non-profit organizations, but their capabilities and political capital that is important. For instance, the USGBC has been a primary change agent in the market transition to more energy efficient buildings. It is conceivable that the power of the USGBC and its national reach have been more influential in framing public policy around green buildings than local advocacy groups.

Finally, the climate zone of the city is not a significant factor in policy adoption and diffusion, except for climate zone 3, which is negative and marginally significant at the 90% level. There are eight climate zones in the U.S.,[6] categorized according to the number of heating degree days (hdd) or cooling degree days (cdd) per year, as well the average humidity in the region. Climate zones 1 and 7 represent extremes in terms of cooling and heating requirements, respectively, with zone 1 averaging more than 9,000 cdd and zone 7 averaging between 9,000 and 12,600 hdd. The results of the analysis presented here show that the climate zone of the city does not influence the likelihood of adopting a green building policy, although cities in climate zone 3, one of the most temperate climate environments where heating and cooling demands are relatively low, are somewhat less likely to adopt. In some ways, the insignificance of the climate zones is counterintuitive. One would expect that cities with extreme temperatures (and thus greater cooling or heating loads and energy demands) would be more likely to prioritize and regulate building energy efficiency. On the other hand, it is conceivable that cities in the extreme climate zones (or, more specifically, building owners in these climate zones) have greater economic incentive to design and construct energy-efficient buildings and therefore do not require a green building policy to shift design standards (as building codes may already be more stringent). However, the data reveal no significant differences in the mean number of ENERGY STAR or LEED certified properties in the extreme climate zones.

The coefficient for *percent LEED certified square footage in 2004* is also not significant. This suggests that the amount of LEED certified buildings in a city does not affect the likelihood of adopting a green building policy. In cities with more LEED certified space, it would be expected that the local real estate community, including contractors and design professionals, is more familiar with green building practices and thus less opposed to green building regulation. This might occur because as awareness and understanding of green building design increases, additional costs associated with green building should decrease. In the same vein, elected officials may have the opportunity to see the benefits of sustainable design and thus better understand the potential for public policy to shift construction standards and achieve energy efficiencies and carbon reductions in buildings. However, the results indicate that this variable is not a predictor of policy adoption, suggesting that policymakers are influenced by other factors, such as policies in other cities.

Mandatory vs. Voluntary Policies: Empirical Evidence

A second model specification was estimated to determine the factors that influence whether a city adopts a mandatory policy. For the sample of 49 cities that adopted some form of policy (full data are available for 41 of these cities), the results indicate significant positive coefficients for carbon emissions, democratic and independent mayors, and land use regulations. Cities with higher carbon emissions per capita were more likely to adopt a mandatory policy. This may be a response to a greater perceived need to address carbon reductions through efficiencies in the buildings sector. Cities with democratic or independent mayors were more likely to institute a mandatory green building program. This is expected, as there is a historical tendency for democrats and independents (albeit less so) to favor policy solutions that involve government intervention.

Most interestingly, cities with more restrictive land use regulations (as measured by the WRLURI) are significantly more likely to adopt a mandatory green building policy. This finding suggests that cities that favor regulatory responses to control development and possible negative externalities also favor regulatory strategies to address climate change and energy efficiency in buildings. One concern here is if existing land use regulations raise the cost of construction (Mayer and Somerville, 2000; Quigley and Rosenthal, 2005), an additional green building requirement may further increase costs (Kats, 2003; Langdon 2007, 2010) and create a disincentive for more efficient buildings and innovative technological and design approaches.

Diffusion over Time

The number of municipal green building policies has expanded dramatically over the past ten years. Through the end of the year 2000, only Seattle, Washington and Austin, Texas had adopted a green building policy. Both cities enacted regulations that required municipal buildings to achieve certain prescribed sustainable design standards. Since 2000, the growth in municipal green building policies has been exponential, with a sharp increase beginning in 2006, coinciding with high-profile policy adoptions in New York and Washington, DC. Exhibit 7 shows the cumulative hazard estimate of the expected number of policy adoptions in the GBRD sample beginning in the year 2000.

The trajectory of municipal green building policy adoption mirrors the overall pace of market transformation, evidenced by the expansion in the number of

Exhibit 7 | Cumulative Hazard Estimate

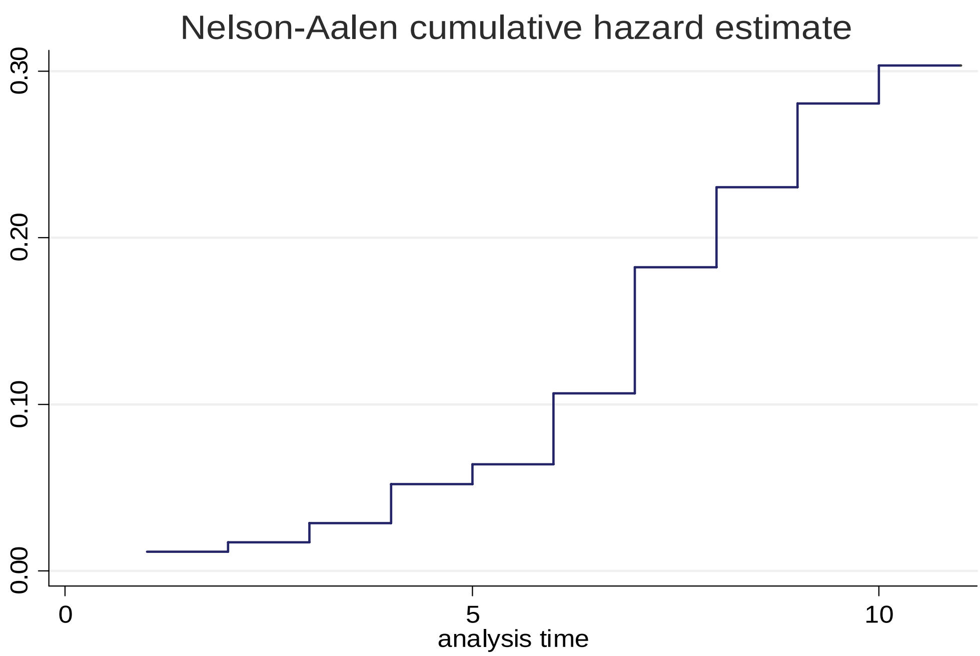


Exhibit 8 | Selected City Characteristics by Adopter Category

	Innovator[a]	Early Adopter	Early Majority	Late Majority
Year Policy Adopted	2000–2003	2004–2006	2007–2008	2009–2010
Population, 1995	2,031,710	3,265,302	2,055,806	1,140,351
Education, % Bachelors	31%	31%	27%	25%
Patents, 1999	1,762	1,097	712	364
*LEED sq. ft., 2004**	586,343	105,166	226,878	81,500
CO_2 per capita, metric tons	2.88	4.21	8.38	4.51
N	7	13	19	10

Notes: The sources are GBRD, U.S. Census, U.S. Patent and Trademark Office, USGBC, and NASA/DOE.
[a]The Innovator category includes cities that adopted a policy between 2000 and 2003; therefore, the LEED certified space data is post-adoption.

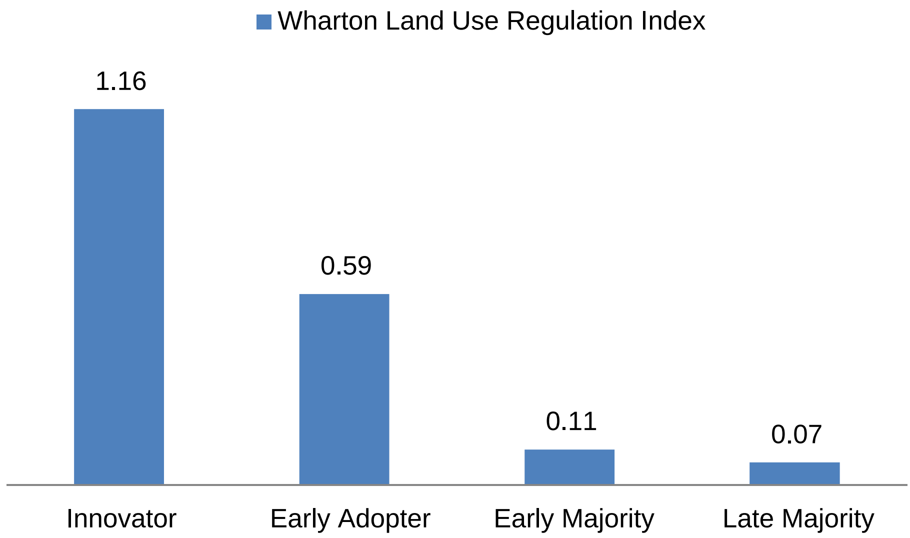
LEED certified buildings across the U.S., which has grown from 667,600 square feet certified in the year 2000 to approximately 500 million square feet certified in 2010 (USGBC).

Looking at descriptive statistics by time of adoption reveals interesting texture across adopter categories within the sample. Exhibit 8 shows the pre-adoption data for population, education, patents, LEED certified space, and carbon emissions per capita, broken down by Roger's (2003) categories of innovation adopters. Policy ''innovators'' and ''early adopters'' (i.e., those earliest to adopt a new innovation) are better educated, have a higher number of patents per capita, have more LEED certified space as of 2004, and lower carbon emissions per capita. This suggests that policy innovators are, in fact, innovative in other capacities and share different motivations for green building policy adoption. These innovator cities are better educated, which is consistent with previous research on diffusion (Rogers, 2003). In addition, these cities do not appear to be responding to a crisis in terms of their own carbon emissions; instead, it is possible that these cities view building energy efficiency as an opportunity to stimulate economic activity and increase competitiveness, key factors in the competition mechanism of diffusion (Porter and van der Linde, 1995). These cities, which include Portland, San Francisco, and Seattle, also tend to have a greater concern for environmental quality and protection, suggesting that green building policies are viewed as an additional tool to protect the natural environment. The ''early majority'' cities, on the other hand, may be motivated by a fear that carbon reduction requirements may be imposed on them by higher levels of government, and are therefore acting to pre-empt the intervention (the coercion mechanism). Based on interviews with various city building officials, cities that adopt policies later are also looking to the innovators and early adopters and either learning from their policy decisions or trying to emulate those cities to replicate some desirable city characteristics. It should be noted, of course, that when looking at the entire set of U.S. cities, the 41 presented here may all be considered innovators should the pace of green building policy diffusion continue.

When looking at policy structure, innovators and early adopters were more likely to introduce policies that applied only to municipal or publicly-owned buildings and that have both mandatory standards and incentives. Innovators and early adopters were also much more likely to have more restrictive land use regulations (Exhibit 9). The WRLURI is normalized at 0, with positive values indicating higher levels of regulation and negative values representing a less restrictive regulatory environment (Gyourko, Saiz, and Summers, 2008).

Green building policies adopted recently have tended to focus more on privately-owned buildings, in addition to municipal facilities. This transition is consistent with market transformation over the past ten years in green building design and construction. In the infancy of the green building movement in the U.S., cities were reluctant to impose green building mandates on the private sector due to cost premiums associated with more efficient systems, sustainable materials, and greater design integration [for historical cost impacts, see Kats (2003)]. However, as costs have decreased over time due to increased knowledge and demand for green buildings, combined with a greater appreciation of the urgency of climate change mitigation, cities have looked to shape markets by influencing design and investment decisions through policy requirements. This transition can be seen in individual cities through policy amendments over time. For example, the city of Portland, Oregon has revised its green building policies twice since initially adopting a standard for publicly-owned buildings in 2001. In 2005, Portland

Exhibit 9 | Restrictiveness of Land Use Regulations by Adopter Category



instituted a series of incentives for privately-owned buildings that achieved LEED Silver certification. Most recently, in 2009, Portland adopted a "feebate" program for commercial and multi-family residential buildings, and instituted an energy disclosure requirement for existing buildings. These amendments and revisions reflect the policy trajectory of several U.S. cities with respect to green building over the past decade.

Policy Implications and Conclusions

Government policies are critical to the expeditious and large-scale deployment of innovative energy-efficient building technologies, materials, and design and construction practices. Green building policies can be used both to create a baseline standard for building energy performance and to encourage new innovations in product and process that can result in greater efficiencies over time. While the potential exists for policies to shift markets toward more sustainable building practices, only a small percentage of cities have adopted robust green building policies. As has been shown here, the cities that have tend to have higher carbon emissions per capita, an environment that encourages innovation, and a sustainability plan in place. Policies of "early adopter" cities focused initially on municipal and city-owned buildings, which allowed the public sector to lead the private markets by increasing awareness and lowering the costs associated with green building practices.

Discerning the mechanism of green building policy diffusion is in many ways more challenging than establishing the determinants of policy adoption. Often, a combination of the four mechanisms presented here—coercion, emulation, competition, and learning—are at work simultaneously. There does not appear to be evidence to suggest that the coercion mechanism is driving green building policy diffusion, since the presence of a state green building policy did not affect local policy adoption. However, it is possible that cities are anticipating changes to federal regulations that may impact their policies in the future, and therefore pre-empting possible future mandates.[7]

With respect to the learning mechanism, while cities may be learning about policy options from one another, their managers are not making rational decisions based on policy evaluation studies, since there has been only limited work in this area until recently (Simons, Choi, and Simons, 2009; Choi, 2010; Fuerst, Kontokosta, and McAllister, 2011). Interviews conducted with officials in Chicago and Portland revealed that cities are exchanging ideas on policy structure and development, but there are still information limitations on actual policy impact.

Competition and emulation mechanisms may be more useful in explaining the early stages of green building policy development over the past decade. Those cities earliest to adopt green building policies recognized the importance of environmental responsibility in the built environment and had the means through a higher-income, well-educated, and innovative population to enact policies to encourage and require greater efficiency in buildings. Those cities that followed the earliest adopters (2000 to 2006) may have been driven by a desire to remain competitive, in terms of job creation, infrastructure investment, and environmental impact, with the early adopters (e.g., Boston, Chicago, and Los Angeles following New York City and San Francisco). Likewise, many cities also may have been driven to enact policies to follow the lead of larger cities without necessarily competing with them (e.g., Cleveland, Ohio, Madison, Wisconsin, and Dallas, Texas).

The findings presented here suggest a number of ways to encourage and accelerate the adoption and diffusion of green building policies. First, cities need to understand their carbon footprint. A city that quantifies its carbon emissions can establish baselines that can be used to measure changes over time. A city's carbon emissions can also be used to benchmark performance against other cities and to create a mechanism for higher levels of government to incentivize or penalize cities based on their relative impact.

Second, cities should develop a sustainability or climate action plan to guide green building policy decision-making. All but five of the cities with a sustainability plan adopted before 2007 currently have a green building policy in place. While most sustainability plans are not enacted into law, they provide an important foundation for understanding the city's current environmental impact and opportunities and strategies to reduce it. The findings presented here indicate that a sustainability plan is a significant predicator of green building policy adoption.

Third, cities that provide a platform for innovation, measured as the number of patents issued per capita, are more likely to adopt green building policies. This suggests that these cities recognize the potential of sustainable buildings to catalyze innovation in building technology, construction processes, and real estate capital markets. Therefore, creating an urban environment where innovation can occur and thrive is an important component of policy adoption.

Finally, while not discussed in the empirical findings, there is a need for continued communication between cities regarding green building policies. Interviews conducted as part of the development of the GBRD revealed numerous cities, including Portland, Chicago, and Washington DC, learned about and shaped their green building policies based on actions in other cities. Open communication channels between cities and stakeholders can facilitate learning, which will serve to refine green building policy interventions over time.

Several questions remain to be explored. First, it is necessary to determine the optimal mix of incentives and regulations—''carrots and sticks''—that balance efficiency goals with constrained municipal budgets. While regulations raise the baseline level of construction and design standards, they can also raise costs and, in the aggregate, limit new development and constrain innovation. Incentives may encourage developers to pursue more sustainable projects, but they are typically only effective when designed to offset the costs associated with sustainable design and to respond to non-capital costs, such as administrative hurdles and knowledge exchange. Second, the potential exists for regulations to create a market mindset of ''teaching to the test,'' where developers build to the required standard (e.g., LEED Silver), but have little incentive to exceed the mandate. Regulations may also focus the market too closely on one rating system or set of design criteria, thus incentivizing the attainment of a particular certificate at the cost of encouraging innovative solutions to achieve performance goals. Therefore, the effect of various policy interventions and structures on green building market penetration must be explored.

Endnotes

1 The NY1-Marist Poll reported that approximately two-thirds of registered New York City voters rated Mayor Bloomberg as doing an ''excellent'' or ''good'' job in office, from October 2005 to October 2008.

2 San Francisco Building Code 2007, Chapter 13C ''Green Building Requirements.''

3 Pittsburgh Code, Title Nine, Zoning Chapter 915.04.F ''Sustainable Development Bonuses.''

4 Density bonuses, for example, can be limited due to infrastructure constraints, local community opposition to larger buildings, and a concern for architectural character.

5 For example, cities with any green building standard had lower rates of asthma and adult obesity and residents were more likely to regularly exercise (data provided by the Department of Health and Human Services, Centers for Disease Control and Prevention).

6 No cities in the database are located in Climate Zone 8.

7 Pre-emption of state or federal policies by local regulations typically will only hold when the local policy is more restrictive (Diller, 2007). Of course, cities may pre-empt state and federal policies in an effort to stimulate local market transformation and build regional competitive advantage.

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