What Do We Know About Urban Sustainability? A Synthesis of Local Government Research and Nonparametric Approach for Moving Forward

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Abstract

The growth in interest regarding urban sustainability has attracted a wide range of empirical and methodological approaches to measuring cities' commitment to environmental, economic, and equity concerns. But just as there is a lack of agreement over the definition of sustainability, there is also no uniform standard for assessing the degree of commitment localities have made to ensure resources, services, and opportunities are available for future generations. This paper advances research into improving methods for assessing urban environmental sustainability by systematically reviewing the literature and then directly testing spatial policy choice and multivariate modeling approaches for measuring environmental sustainability activities. Utilizing nonparametric methods, we compare the precision of factor analysis, Item Response Theory, and more traditional, linear models in predicting the adoption of local government energy efficiency, smart growth, and climate protection policies across two surveys of US cities, and provide a novel diagnostic approach for assessing their validity.

Keywords: Item Response Theory, nonparametric models, survey data, urban sustainability

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Introduction

The last decade witnessed an explosion in empirical research examining sustainability efforts in local governments, as sustainability has increasingly become an organizing focus for public administration (Fiorino, 2010). Urban sustainability refers to local governments' ability and commitment to maintain or enhance the provision of resources, services, and opportunities for current and future residents along economic, environmental, and equity dimensions (Portney, 2013). In response to inaction on climate change at the national and international levels, local governments have emerged as leaders in adopting and implementing policies and programs targeting renewable energy and greenhouse gas (GHG) reduction, sustainable development, and social justice. However, just as there is a lack of agreement over the definition of sustainability (Zeemering, 2009), there is also no uniform standard for assessing the degree of commitment localities have made to achieving a sustainable future and their latent ability to do so.

Much empirical work thus far has been content to use unweighted, additive indices of sustainability-related policies or practices to determine city commitment to and progress toward sustainability. While these analyses have been informative for researchers and practitioners alike, they may also incorrectly label some cities 'more sustainable' than others by assuming a spatially reliable rank order between the policy choices under examination. This is problematic since all sustainability policy goods are not created equal in terms of their long-run impact and benefit-cost distribution within and across local governments (Deslatte and Swann, 2016). The literature widely recognizes this measurement problem but has taken little substantive action toward addressing it.

To move urban sustainability research and practice toward greater uniformity and accuracy in empirically assessing cities' commitment and ability to achieve more sustainable outcomes, we conducted a systematic review of the quantitative research on urban environmental sustainability to gain a more comprehensive understanding of extant work and identify patterns across the literature. Based on this review, we utilized a two-stage methodological strategy using data from two national surveys of US cities to examine the validity of extant statistical approaches. First, we construct three alternative types of dependent variables to measure the latent policy commitment of cities: an additive index of policies adopted; Bartlett scores from a factor analysis; and item response theory (IRT) predicted latent traits for cities. We then fit nonparametric models across three policy areas (community-wide energy efficiency/climate actions; energy efficiency retrofits of government facilities; and green building and GHG reduction efforts) to assess the accuracy of the models in predicting outcomes. Utilizing Multivariate Adaptive Regression Spline (MARS) models, we find evidence that nonparametric statistical techniques which account for unequal weighting of the policy commitment tend to hold more predictive validity and reduce the chances of model overfitting or bias. We conclude with the theoretical implications for such an approach.

Local Government Sustainability Research: A Review and Synthesis

Our literature review focused on quantitative studies of environmental sustainability policymaking in local governments during the period 2003-2016. Although urban planning has studied sustainability since the 1990s (Beatley, 1995; Maclaren, 1996), we used Kent Portney's (2003) seminal book, *Taking Sustainable Cities Seriously*, as a launching point for the systematic and quantitative assessment of the extent to which cities are sustainable based on their policies

and programs adopted or implemented. To identify relevant studies, we performed Boolean searches of the terms 'sustainability' and 'local government' in the publication title or abstract. With some exception[1], we restricted our search parameters further by reviewing studies in which the dependent variable(s) was either an adoption/implementation of environmentally sustainable policy initiative or program (related to areas such as renewable energy, climate protection, smart growth, etc.), or multiple initiatives and programs. While not exhaustive, our search yielded 43 empirical analyses spanning the public administration and policy, urban affairs, and environmental governance literatures. For the purposes of developing more valid measures of sustainability, we chose not to review strictly qualitative or case studies—although some studies we reviewed employed a mixed-methods design—but we acknowledge their immense impact in developing the understanding of urban sustainability processes, such as multi-organizational collaboration (Zeemering, 2014), environmental-economic policy linkages (Fitzgerald, 2010), and the multilevel governance of climate protection (Bulkeley and Betsill, 2003). Also, while not our intention, this literature review consists entirely of US local government-focused studies. Limiting our analysis to one country has both pros and cons. On the one hand, the findings and implications of this study should have greater generalization within the US political and institutional context; on the other hand, we cannot speak to the research on urban sustainability efforts and best practices abroad, especially in European and Asian cities which tend to rank the highest in international sustainability city assessments (see, e.g., Arcadis, 2016).

Data and data sources

Table 1 summarizes the findings from our literature review. For each study, we identify the primary data source, the outcome or dependent variable(s), the analytic techniques, the

predictors or independent variables, and the key research findings. Concerning the data, we find very heavy reliance on survey data to measure local sustainability. About 79% (34 of out 43) of the studies we reviewed used a survey, or multiple surveys, as the primary data source (i.e., used for most of the analysis and/or to construct dependent variables). Of these 34 studies, 26 (76%) employed data from a national survey, such as the International City/County Management Association's (ICMA) 2010 sustainability survey or the Integrated City Sustainability Survey Database (ICSD) (Feiock et al., 2014). Other studies employed survey data from cities within a single state such as Indiana (Krause, 2011c) and California (Bedsworth and Hanak, 2013), or city-level archival data either nationwide or within a state or smaller geographical region such as California's Central Valley (Lubell et al., 2009a). Sources for studies that analyzed archival data included ICLEI-Local Governments for Sustainability (Zahran et al. 2008a, 2008b), the Mayor's Climate Protection Agreement (MCPA) (Krause, 2011a; Wang, 2012b), the US Green Building Council (Cidell and Cope, 2014), among others. Fewer analyses employed data and dependent variables directly from official local government records such as municipal sustainability ordinances in Maine (Levesque et al., 2016) and Florida county comprehensive plans (Lubell et al., 2005). Of the analyses we reviewed that focused on a single state, California received the most empirical attention with four studies, followed by Florida with three analyses. Lubell et al. (2005) was the only study we reviewed that focused exclusively on county governments.

Sample sizes for the studies ranged from the lower end of the 50 (Portney and Berry, 2016) and 55 largest US cities[2] (Portney, 2013) to about 1,500 cities with analyses using ICMA sustainability survey data. Many of the studies we reviewed also used a population threshold above 50,000 or 75,000 for sampling, suggesting prior research focuses mostly on medium- to

large-sized cities and thus research on smaller cities and townships appears to be conspicuously lacking. Interestingly, almost all of the studies in our literature review employed cross-sectional data, as we identified only one study (Lubell et al., 2009a) that examined policy change over time with a panel analysis of land conservation policy choices. A few analyses used multiple surveys across different periods to capture effects associated with policy changes over time. Deslatte et al. (2016) surveyed Florida cities over three time periods to capture exogenous influences on sustainable development choices, and Opp et al. (2016) used two ICMA surveys (2009 and 2010) to test for correlations between local economic development and environmental policy actions. Nonetheless, how cities can better *sustain* sustainability remains uncharted terrain and an open research question for future analyses.

Outcome variables and analytic techniques

The most common outcome or dependent variables across the studies were counts of environmental sustainability policies often treated as continuous 'sustainability' indices, followed by dichotomous outcomes of whether a policy/program was adopted or implemented, or whether a municipality joined a sustainability network such as ICLEI or MCPA. About 65% (28 out of 43) of the studies we reviewed employed either an index of sustainability-related policies or a smaller count of such policies and programs for a dependent variable. Studies employing ICMA survey data (e.g., Opp and Saunders, 2014; Homsy and Warner, 2015) had the largest possible index scores (typically between 80 and 100 activities). Lubell et al.'s (2009a) environmental sustainability index ranged from 0 to 50 policies adopted, and Portney (2013) included 35 possible policies/programs in his 'Taking Sustainability Seriously Index'. Others such as Deslatte and Swann (2016) used a smaller count of 10 energy efficiency policy tools as

an outcome variable in their analysis. Of the 28 studies using an index or count as a dependent variable, we identified only one study (Homsy and Warner, 2015) that used a weighted dependent variable in which the adoptions of over 100 environmental policies were averaged across 11 environmental policy sub-areas of the ICMA sustainability survey (excluding the 12th social equity sub-area). Some researchers, however, were careful to construct indices to mitigate potential measurement error. For example, when constructing their index, Lubell et al. (2009a) used multiple data sources (i.e., survey and archival data) to verify whether environmental sustainability policies were adopted, and averaged the scores depending on whether the data sources agreed on such policy adoptions. Yet, in rare cases (Turco, 2013)[3], more sophisticated statistical techniques to better gauge cities' environmental sustainability are under-explored. Recent studies (Hawkins et al., 2015; Yi et al., 2017) have attempted to capture commitment to sustainability with binary dependent variables for a dedicated sustainability budget or staff, despite how these outcomes are used as predictors of sustainability policy/program adoption or implementation in earlier work.

Ordinary least squares (OLS) and Poisson (or negative binomial) regression were the most frequently used analytic techniques for estimating sustainability indices (in 12 and 13 studies, respectively), although there is some overlap in how the techniques are employed.[4] Logistic or probit regression were used with about the same frequency (in 13 studies) to model binary outcomes such as ICLEI (Sharp et al., 2011) or MCPA (Krause 2011a) membership, dedicated sustainability staff or budget (Hawkins et al., 2015), adoption of a GHG reduction goal or plan (Bedsworth and Hanak, 2013; Deslatte and Swann, 2016), among others. Of the more advanced statistical techniques, structural equation modeling (SEM) was used in one analysis

(Wang et al., 2012) to model the mediating influence of capacity for sustainability on the relationship between citizen engagement strategies and environmental, economic, and social equity sustainability. Survival analysis was also employed by Wang (2012b) to model California cities' adoption of the MCPA before 2008. Three studies in our literature review employed multilevel modeling to estimate the influences of state-level climate change policymaking and planning (Homsy and Warner, 2015; Krause, 2011a) and county characteristics (Deslatte et al., 2016) on cities' sustainability actions. Interestingly, on the one hand, Krause (2011a) models cities' decision to join a sustainability network (the MCPA) and finds state-level factors (GHG reduction targets, government ideology, manufacturing's contribution to the state economy, and the adoption of a climate action plan) have no influence. On the other hand, Homsy and Warner (2015), using a more sophisticated index of state climate protection activity, find strong support for the multilevel sustainability governance hypothesis in both small (< 45,000 population) and large cities with ICMA sustainability survey data. These inconsistencies present new puzzles and underscore the need for further investigation of the nested nature of sustainability in state and local governments. Finally, considering the likely endogeneity involved in modeling local sustainability policy choices, we identified only a single analysis (Krause, 2012b) that used procedures to control for endogeneity in the form of instrumental variables (IVs) when predicting the influence of sustainability network membership on local activities aimed at reducing GHG emissions. Our findings suggest such procedures are far under-utilized given prevalence of cross-sectional analyses and the endogenous nature of sustainability predictors (e.g., community, interest group, and political support, capacity for sustainability, managerial strategies, ICLEI or MCPA membership etc.) and sustainability policy choices and activities.

Synthesizing the predictors and research findings

Despite growing empirical attention to urban sustainability over the years, our literature review suggests little definitely about the determinants of sustainable cities and even the extent to which they are 'sustainable' relative to other localities. Some consistencies emerge, but the existing literature is filled with mixed and puzzling results. Table 1 identifies the predictors or independent variables tested, along with the main findings, in the 43 analyses we examined. The independent variables fell into five general categories. The first category that emerged was 'political feasibility' (PF), or the extent to which the political ideology of government and/or the electorate affected environmental sustainability actions. Studies analyzing political ideology's influence on local sustainability and climate actions generally anticipate a positive relation between such actions and Democratic or liberal leaning communities. At least one political variable, such as the percentage of Democrat or Republican voters, was included in 18 (or about 42%) of the studies we reviewed. The findings are somewhat mixed. While several studies find greater Democratic (Republican) voter or elected official affiliation correlates to more (fewer) sustainability and climate policy actions (Bedsworth and Hanak, 2013; Krause, 2011a; Krause, 2012a; Wang, 2012b; Zahran et al., 2008b), other analyses find either null (Deslatte and Swann, 2016; Portney and Berry, 2010) or mixed results (Gerber, 2013) for the relationship between political ideology and sustainability actions. Republican affiliation or conservative ideology is typically thought to oppose urban sustainability and climate protection actions, making urban sustainability policymaking and implementation less feasible. But the supply of economic co-benefits from sustainability (Kousky and Schneider, 2003) brings this theory into question, as cities can pursue sustainability actions as a partial means for economic growth and greater

efficiencies. Our literature review suggests the evidence falls slightly more in favor of the political feasibility argument, but these findings may also be an artifact of broad, sweeping binary dependent variables (such as MCPA adoption), and thus we recommend using either a carefully constructed sustainability index or estimating multiple outcome variables separately to model the influence of political ideology or feasibility. Deslatte and Swann (2016) and Gerber (2013) demonstrate the usefulness of dividing dependent variables in terms of the cost/benefit concentration or diffuseness of policies, which could determine the particular sustainability actions necessitate greater political feasibility.

The second category we identified was 'organizational capacity' (OC), or the level of resources, staff, budget/funding, policy expertise, and administrative leadership to support sustainability efforts. Capacity for sustainability comes in different forms, but can be broadly differentiated in terms of 'civic' and 'organizational' capacity. Instead of grouping civic capacity (e.g., population, education level, community support for sustainability, etc.) with organizational capacity indicators (e.g., financial, human, and technical/policy resources), we categorized these predictors separately. The general consensus across the literature is organizational capacity facilities the planning and implementation of sustainable policy, and thus cities with greater organizational capacity should engage in more sustainable actions. About 58% (or 25 out of 43) of the studies estimated the influence of organizational capacity on sustainability actions. Here, the findings are slightly more consistent, but this consistency varies depending on the capacity indicators estimated. With some exception (Hawkins et al., 2015), financial or fiscal capacity generally enhances the ability of local governments to engage in more sustainability and climate actions (Krause 2012a; Homsy, 2015; Homsy and Warner, 2015; Wang et al., 2012). In terms of

dedicated funding for sustainability, however, Cruz (2016) finds no correlation between a city having a sustainability budget and the use of renewable energy residential zoning. Relatedly, the literature suggests mixed effects of local government fiscal health. While some studies find null results for effects of 'fiscal health' or 'stress' (Bae and Feiock, 2013; Deslatte and Swann, 2016), other analyses find evidence of fiscal conditions affecting sustainability actions (Hawkins, 2011; Lubell et al., 2009a; Sharp et al., 2011), although these studies find conflicting results and employ different proxy measures for a likely multidimensional concept.

Other OC variables found to positively relate to local sustainability efforts include a dedicated sustainability office (Cruz, 2016), staff for sustainability (Homsy and Warner, 2015; Pitt, 2010; Wang, 2012b), having a sustainability coordinator (Krause, 2012a), planning office involvement in sustainability (Jepson, 2004), and the presence of a volunteer conservation commission (Levesque et al., 2016). A few recent analyses have also attempted to develop a more comprehensive index of administrative capacity--encompassing financial, human, and policymaking capacity--and model its effect on local sustainability policy choices, generally finding mixed results. Deslatte and Swann (2016) find administrative capacity relates positively to policy tools used to enhance energy efficiency but not to decisions to adopt a GHG reduction goal. Interestingly, Laurian and Crawford (2016) find no correlation between capacity and the implementation of policies for a number of sustainability sub-areas except energy policies. Swann (2015) finds no evidence that capacity matters directly, but rather that it moderates the relationship between inter-departmental collaboration and the implementation of sustainability practices in in-house city government operations.

We also considered ICLEI membership as a component of organizational capacity. For a price, local governments can join ICLEI and gain access to useful information, resources, and networking opportunities that can help them improve environmental sustainability. Multiple studies find ICLEI membership correlates positively to actions for, or commitment to, local sustainability (Daley et al., 2013; Krause, 2012a; Kwon et al., 2014; Hawkins et al., 2015; Swann, 2015). Yet, Yi et al. (2017) find that terminating ICLEI membership has little impact on local commitment to sustainability actions. Homsy (2015) takes a more nuanced approach and finds ICLEI membership relates to more in-house local government energy policies but not to policies targeting the community at large. ICLEI membership has also been analyzed as the dependent variable, with studies showing organized community interests (Sharp et al., 2011) and higher civic capacity (Zahran et al. 2008a) and greater environmental risks (Zahran et al. 2008b) predicting ICLEI membership.

The broadest category of predictors we grouped was 'community characteristics' (CC)[5], or the social (e.g., education level), economic (e.g., median household income), demographic (e.g., population and race), and public interest (e.g., business and environmental support) factors influencing local sustainability actions. All 43 studies we reviewed modeled the influences of various community characteristics. Educational attainment and city population are two of the strongest predictors of sustainability actions across the literature, with positive correlations in the vast majority of the studies. Some studies, however, find more nuanced effects. Deslatte and Swann (2016), for example, show a positive relationship between education and the adoption of a GHG reduction goal but not the adoption of green energy efficiency policy tools. Racial and ethnic composition and homogeneity/diversity are also commonly tested variables, but studies

show mixed evidence of their effects on sustainability actions. While some studies show negative relations between communities with a higher percentage of Black and or Non-White residents and sustainability actions (Kwon et al., 2014; Lubell et al., 2005; Deslatte and Swann, 2016), or more homogeneously White communities have greater sustainability activity (Svara et al., 2013), other studies find higher Hispanic homogeneity and racial/ethnic diversity correlate to more sustainability actions (Opp and Saunders, 2014). Still, many analyses show null results for the effects of race and/or ethnicity. Household income and homeownership are also commonly modeled as independent variables, but with very mixed results. Svara et al. (2013) find negative relations for both income and homeownership; Homsy and Warner (2015) also find a negative relationship for homeownership but a positive correlation for income; and Krause (2011a, 2011b) finds a negative correlation for income. However, others find strong evidence that income leads to more sustainability activity (Bedsworth and Hanak, 2013; Wang, 2012a; Wang, 2012b). Zahran et al. (2008) use a composite measure of 'civic capacity' that includes education and income, finding a positive relation with ICLEI involvement among cities in metropolitan areas. Population density has also been tested widely as a proxy for climate change stress or the urgency of sustainability actions, but most empirical assessments have resulted in null findings, with some exceptions (Krause, 2012a; Svara et al., 2013; Swann, 2015; Zahran et al., 2008a).

We also included support from community, business, and environmental groups within the CC category. Despite such support also capturing the political feasibility of sustainability and climate activity, we decided to investigate their empirical effects separately from the PF category because of the difficulty involved in generalizing these groups' political stances on sustainability policymaking (and to isolate the findings associated with political ideology). We find community

support for sustainability is one of the strongest and most consistent predictors across the literature. Cities with stronger support from the community, civic groups, and residents pursue more sustainability/climate actions and/or make greater commitments to environmental sustainability (Bedsworth and Hanak, 2013; Daley et al., 2013; Krause, 2012a; Laurian and Crawford, 2016; Swann, 2015). More nuanced analyses show homeowner association support correlates to more energy efficiency policy tools, but support from the general public and neighborhood associations do not appear to matter (Deslatte and Swann, 2016); public support relates positively to actions directed at the community at large but not in-house governmental operations (Krause, 2012a); and neighborhood group support predicts the dedication of a staff and budget to sustainability but not one or the other by themselves (Hawkins et al., 2011).

The literature also tends to pit environmental and business/development interests against each other, despite mostly null and mixed empirics. Most analyses obtained null findings for the effects of environmental group support (Daley et al., 2013; Deslatte and Swann, 2016; Hawkins et al., 2015; Krause, 2012a); however, Portney and Berry (2016) find a 'very high' likelihood of inclusion of environmental groups in the policy process relates to more sustainability policies and programs adopted. This could suggest environmental group support may not make a difference in sustainable cities unless it is more meaningfully activated through inclusion in policy planning. Support from business and development interests tends to show slightly more significance, with some studies finding a positive relation with sustainability activity (Deslatte and Swann, 2016; Krause, 2012a). But these findings may relate to developers' orientation to sustainable development and the institutional context. Hawkins (2011) finds less pro-growth support from developer groups correlates to greater smart growth activity, and Hawkins and

Wang (2013) find cities tend to adopt more sustainability policies when business groups are involved in the planning process and when they have a council-manager form of government.

The fourth category that emerged is 'governmental institutions' (GI), or the political institutions of local government, typically council-manager or mayor-council form of local government. Theory suggests council-manager governments will have a greater internal focus and will concentrate on sustainable city operations, whereas mayor-council cities will tend to focus sustainability policies externally to gain greater visibility. We identified some empirical patterns that support this argument, but the evidence is still unclear. On the one hand, Bae and Feiock (2013) show managerial forms of government relate positively to in-house governmental sustainability policies but negatively to community-wide policies. Homsy (2015) also finds a positive relation between the 'presence of a city/town manager' and the adoption of sustainable energy policies in governmental operations using ICMA data. And Deslatte and Swann (2016) find managerial governments correlate negatively to energy efficiency policy tools adopted community-wide. On the other hand, Svara et al. (2013) find a positive relationship between managerial governments and a broader index of sustainability activity, but their dependent variable includes both internally and externally focused activities. Cruz (2016) also finds a positive effect of managerial governments on renewable energy residential zoning decisions. Finally, Levesque et al. (2016) examine Maine municipal sustainability ordinances and find both mayoral and managerial governments, as well a town meeting structures, correlate positively to sustainability ordinances.

Richard Feiock and his associates employ the political market framework (Feiock et al., 2014) to examine the mediating influence of government institutions on policy choices. Thus far,

research on land use and sustainable development (Deslatte, 2016; Deslatte et al., 2016; Lubell et al., 2009b; Lubell et al., 2005) has demonstrated the most support for the interaction between government institutions and interests groups. However, with some exception (Krause, 2012b), this effect has been under-explored in the urban sustainability and climate policy literature.

The final class of predictors we identified is 'environmental predictors' (EP), or the natural, geographic, and physical environmental conditions (e.g., coastal cities or environmental risks) prompting sustainability and climate protection policy actions. Only about 28% (12 out of 43) of the studies we reviewed modeled the influence of physical environmental and natural predictors. Measures of air quality were some of the most common predictors in this category. While some studies find no evidence that air quality matters in sustainability efforts (Hawkins et al., 2015; Krause, 2011a), other research finds 'air-quality nonattainment' designated by the US Environmental Protection Agency (EPA) relates positively to sustainability activity (Pitt, 2010; Wang, 2102a, 2012b). This suggests cities in metropolitan regions experiencing higher air pollution may be incentivized more by the co-benefits of climate action or have greater urgency to improve health and quality of life outcomes. Climate change risk variables, such as coastal proximity, precipitation, and federally designated disaster areas, were also found across the literature. Coastal cities are at greater risk of sea-level rise, and--although the findings are mixed--there is some evidence such cities have a higher likelihood of sustainability engagement (Pitt, 2010; Zahran et al., 2008b), and they are more likely to engage in climate adaptation (Wang, 2012a). With the exception of Wang (2012a), there is less evidence precipitation matters (Zahran et al., 2008a), and even lesser evidence that disaster areas make a difference in local

sustainability efforts (Krause, 2011b). Cooling degree days have also been operationalized to capture climate status, but the empirics show virtually no relationship to sustainability actions.

In sum, our literature review has systematically identified some clear patterns but many more puzzles and inconsistencies. Perhaps the most telling statistics from our examination of over 40 empirical studies is that nearly 80% of the extant work draws on cross-sectional survey datasets, and over 60% of these studies employ unweighted indices or counts of sustainability actions as outcome variables. Echoing what the literature has long pointed out but has yet to address, better methodological approaches are needed to validate urban sustainability measures and empirical findings.

Shedding Some Assumptions: A Nonparametric Approach To Latent Policy Choices

Our assessment of extant urban sustainability research is that it has advanced theoretical insights into organizational capacity, environmental and institutional effects on sustainability, but may be stretching the limits of cross-sectional survey data and linear modeling methods. Urban policy scholars studying empirical phenomena may have little ability to improve the first limitation; while longitudinal data are being developed slowly within the research community, we use the data we have at hand. In order to continue to advance our understanding of urban sustainability policy, we argue analysts should employ a wider range of methods for exploring the policy space in which city officials make choices. We explore two such options in this paper: latent models which differentially weight policy choices; and a nonparametric method for assessing the predictive validity of models without assuming a linear relationship between predictors and outcomes.

The studies we have previously detailed rely on treating Likert-type responses to survey items as if they are continuous measures. As such, scholars are generally making assumptions that policy actions line up more or less unidimensionally along some latent sustainability trait. Factor analysis is one method for modeling latent characteristics, by exploring how variation in observed variables relates to a potentially lower number of unobserved variables or factors. A similar approach is item response theory (IRT) first used in psychometrics to test the relationship between the 'ability' parameters of individual respondents and the 'item' parameters of the test. Extended to policy choices, IRT models can be used to calibrate the latent willingness or commitment of respondent organizations with the varying difficulty of specific policy actions. These item parameters may vary based on difficulty as well as the item's ability to discriminate between two otherwise similar respondents. A key distinction is that the item information function provided by factor analysis does not vary across the scale of the underlying latent trait or ability, while individual ability does influence the item information function in IRT. Essentially, both methods attempt to model a latent trait. While factor analysis is more appropriate for continuous variables, IRT is used for dichotomous (e.g., 'pass/fail' or 'yes/no') survey items (DeMars, 2010). In this paper, we utilized an exploratory factor analysis to create Bartlett factor scores for the three policy bundles, as well as two-parameter IRT models to generate predicted latent traits for each respondent city based on the city's overall 'ability' or commitment to sustainability, the difficulty of each policy tool, and an item discrimination parameter. These two predicted latent measures are then compared to a simple additive index to assess their predictive validity in nonparametric models which include measures of the categories of predictors identified in the previous section.

Nonparametric statistical approaches are virtually absent from urban policy research, largely because of scholars' reliance on the Null Hypothesis Significance Test (NHST) and assumptions about the normal distribution of their data. Nonparametric methods prevalent in data science, other social sciences and applied predictive modeling do not assume an underlying distribution to the data or that the structure of a model is fixed. In our context, nonparametric regression techniques are useful to compare the predictive validity of our outcome measures. By using a multivariate adaptive regression splines (MARS), we can fit regression models despite the non-normality of the outcome measure, and allow the number of predictors used in the model to be determined by the data. As we explain in more detail below, we can thus 'prune' the model in a way that is theoretically justifiable.

Outcome Measures

We utilize data from a 2010 national survey, *Implementation of Energy Efficiency and Sustainability Programs* (Francis and Feiock, 2011), sent to 1,180 U.S. cities with populations greater than 20,000. The response rate was 57%, or 677 cities, although respondent dropoff reduced our usable sample size to 350 cities. The surveys were sent to either the city manager or the chief administrative officer (CAO), asking whether they had adopted GHG reduction goals as well as 13 energy/climate–related policy tools related to either government facilities or the community at large.

Our EFA identified three latent factors (eigenvalues > 1; factor loadings > .30) we utilized for this study: the first containing the 13 community-based energy/climate policy regulatory or incentive actions, including green buildings, retrofitting existing buildings for energy efficiency, providing alternative transportation systems, green procurement practices,

energy efficient devices and systems, smart grid/net metering, using alternative fuels, and including energy efficiency in land-use decisions; a second factor for government-facility retrofit and energy efficiency measures; and a third factor including the green building, land-use, and climate-related tools. We then predicted Bartlett factor scores, or linear combinations of the observed items, for each factor. Bartlett factor scores rely on shared or common factors to compute metrics while the sum of the squared components for the unique factors is minimized, producing a factor score correlated with the estimated factor.

We then utilized the same groupings of policy tools to create three IRT-generated predicted latent traits for comparison. IRT models rely on Item Characteristic Curves (ICCs) to estimate the probability a given respondent will answer a survey question correctly, accounting for both their own latent ability and the parameters of the question itself (usually its difficulty and discrimination). Extended to policy choices for cities, this allows us to estimate the latent level of sustainability commitment based on their own resources, capacities, and interests, and the differentially weighted policy options. The ICC for our IRT model displayed in Figure 1 for green building/climate-related policies shows a city with an average level of commitment to sustainability has a 70% chance of committing to green building and green procurement policies but still has a less than 20% chance of using smartgrids or incorporating energy use into land use decisions. The ICC allows us to generate a predicted latent trait, called Theta, for each city respondent.

A final outcome measure is an additive index for the same three categories. The indices are right-skewed, with a mean of 2.7 for the 9-point community energy scale, a mean of 3.06 for

the 5-point government-retrofit index, and a mean of 3.5 for the 9-point government green building scale.

[Insert Figure 1 here]

Predictors

We utilize 13 predictors in our models which represent commonly used proxies for the categories identified in our synthesis, including measures of political feasibility (percentage of population voting *Democrat* in the 2008 presidential election), organizational capacity (per capita *property tax* revenues), community characteristics (measures of *education* levels, Herfindahl–Hirschman Indices for *age* and *race* diversity, *business* and *environmental* group support for sustainability, *population* and population *density*), and governmental institutions (*council-manager* form of government). Serving as a proxy for environmental predictors, we include measures of governmental priority given to *economic development* and *environmental protection*, making the assumption that local governments prioritizing environmental protection will be highly correlated with those with environmental amenities to protect. For an additional indicator of organizational capacity, we also include a dichotomous measure for whether cities are *ICLEI* members.

Data pre-processing revealed that that none of our outcome measures approximate a normal distribution. Moreover, few of the predictors appear to have a linear relationship with the outcome measures, despite their frequent use in linear models in the extant research. Typical transformation steps (natural log, including squared terms) did not satisfactorily address this nonlinearity. All predictors were standardized. Two measures of capacity (own-source revenue) and community characteristics (median household income) were omitted from the models due to

high correlation (> .8) with other variables in the models (per capita property taxes and education levels).

MARS Model

Multivariate adaptive regression splines are a nonparametric method for fitting predictive models when predictors have nonlinear or interactive effects on outcomes (Friedman, 1991). The benefit of MARS models for our study is that it makes no assumptions about the relationship between the outcomes and predictor models and relies on cross-validation to assess the generalizability of the model to predictions with new data. Typically, predictive models have relied upon partitioning datasets into training and test sets for model tuning, although small sample sizes make this approach problematic. Resampling procedures such as cross-validation and bootstrapping are widely utilized way to overcome this problem. MARS models create surrogate measures instead of the original predictors to allow for fitting 'ridge' functions (which look like bent ridge lines rather than a linear regression line) in piecewise linear models over different intervals of the data (Friedman, 1991). MARS splits predictors into two 'mirroring' groups by identifying cut-points (knots) for the predictors which minimize residual errors. For each hinge, values are zeroed out on the opposite side of the cut-point, and then both contrasting components are included as independent variables in the model, producing 'hockey stick' functions (Kuhn and Johnson, 2013). The MARS algorithm creates a full set of surrogate measures. Then, in a second step, it systematically deletes those which do not significantly contribute to the model equation. The two model-tuning parameters -- the 'forward pass' of systematically identifying cut-points for each predictor and adding them to the model subsets, then the 'backward pass' of pruning those which do not improve explanatory power--provide a

uniform process for evaluating different measures of our latent sustainability commitment trait using the 'industry standard' of theoretically informed predictor variables. In other words, the nonparametric approach allows us to minimize the potential of overfitting our models and biasing our evaluation of which outcome measure is superior. In describing the results, we evaluate each outcome measure across the three policy groups by three criteria: the number of predictors retained in the model; the generalized cross-validation (GCV) statistic; and the coefficient of determination, or R-squared, for each model.

Results

MARS models for all nine of our outcome measures were estimated using the 'earth' package in R. All nine of the MARS models display nonlinear relationships between our outcomes and varying subsets of retained predictors. Generally, the IRT models with latent outcomes displayed superior generalizability. A lower GCV value is better for model-fitting. For our community energy/climate measure, the IRT model produced the lowest generalized cross-validation (GCV) statistic (.05), which estimates how the model would perform on new data. Figure 2 displays the ridge functions fit for each of the retained predictors. The IRT model also retained the most variables--eight of the 13 predictors--which are shown in Figure 2. The 'earth' package allows us to determine which are deemed the most important to explaining the systemic structure of the data. The relative importances of variables is defined as the measure of the effect that a change in an observed predictor has on the observed value of the outcome, and it is calculated based on the number of subsets of the model which contained the variable (more influential variables are kept in more subsets during estimation); a measure of the largest net decrease in the residual sum of squares (RSS); and a measure of the largest net reduction in the

GCV criterion. The 'evimp' function in the 'earth' package scales these last two decreases from 0 to 100, so the higher the score, the greater the decrease in RSS or GCV. We see from the results in Table 2 that chamber of commerce/business association support for community-wide energy conservation and climate protection efforts has the most influence over the latent level of governmental policy commitment, followed by environmental group support, prioritization of environmental protection, population growth and density, age diversity, liberal ideology and population change. We can also see from the hinge functions plotted in Figure 2 that most of these predictors have nonlinear effects, and have components or 'mirror' halves of their values omitted. This suggests that the marginal influence of these variables matters for predictive purposes, but only between specific ranges of the predictors. For instance, population and population density have more predictive use to the model at low levels, suggesting there may be a population threshold for smaller cities to engage in energy and climate protection activities. Environmental support matters more at lower levels, and then has a negative influence over community-wide activities at higher levels.

[Insert Table 3 and Figure 2 here]

Our outcome measure for government-facility retrofit and energy efficiency actions is largely consistent, with the IRT model outperforming both the additive index and Bartlett factor score method, although the number of predictors retained was lower (6 of 13). This outcome had a range of 0-5 prior to its IRT transformation, and is thus the least likely to resemble a continuous distribution. Again, chamber/business support is the deemed the most relative important measure (retained in 11 subsets of the estimating process, with the highest decrease in GCV and RSS), followed by population and density, ideology, prioritization of environmental

preservation by the local government, and per capita property taxes collected. Unlike in the community model, with government-facility retrofitting and energy efficiency we see higher levels of population density negatively associated with the latent level of governmental policy commitment. Ideology also has a positive influence at high levels--the opposite of our community model.

[Insert Table 4 and Figure 3 here]

For our third outcome measure including the green building, land-use, and climate-related tools, we have essentially a split decision. Our IRT model has the lowest GCV criterion, while the Bartlett factor score model has a higher R-squared (.43 compared to .29 for IRT) and retains the most predictors (5 of 13 retained compared to 4 for IRT). A way to interpret this result is that the Bartlett model explains more of the variance in our data while the IRT model may make more accurate predictions when applied to new data. Both models agree that ICLEI membership is the most important predictor of latent government commitment to green building/climate change policies. They both also list population and environmental prioritization as the next two important predictors (although in inverse order), and they differ over chamber support (included in the IRT) and property taxes and education (included in the Bartlett model).

[Insert Table 5 and Figure 4 here]

Conclusion

A normative goal for sustainability research is to develop theoretical frameworks and models which can predict the level of human development an urban area can manage without reducing the quality of life for future generations. As a predictively valid quantitative endeavor, the field has much room for development. While progress has been made in the theoretical

development of urban sustainability, clearly researchers have a need for richer data sources and more robust statistical approaches. Across our nine models, the highest R-squared (.43) still explains less than half the variance in our observed policy responses. This study has demonstrated the heavy reliance of extant local government research on data which prevents causal claims and research designs which can often violate the assumptions of linear regression. It is little wonder we find conflicting evidence overall for most theoretical explanations, or that our multivariate adaptive regression spline models can safely discard a majority of our theoretically informed explanatory variables without losing predictive power.

Through a thorough synthesis of the extant empirical literature and a demonstration of nonparametric methods, we have contributed to this research endeavor by demonstrating a need for more precise measurement of latent policy commitments of cities as well as demonstrating one more robust methodological approach for overcoming the data limitations all too familiar to urban scholars. To be sure, there are many more. Gill and Meier (2000) have long lamented data limits and a lack of methodological sophistication in public administration research. We have seen some advancement in the use of longitudinal data, surveys with broader coverage such as Feiock et al.'s (2014) ICSD, and the use of Bayesian methods which do not rely on the flawed Null Hypothesis Significance Test (Deslatte et al., 2016).

Any method which has the potential to improve measurement accuracy for phenomena under investigation should be widely tested across additional studies and empirically validated or invalidated. This study could also benefit from a comparison of its empirical findings across multiple datasets with greater coverage. While utilizing spatial models of choice such as IRT may not be a cure-all for the data limitations we face with observational research, we offer some

evidence they are more predictively valid within the policy area of energy and climate-related policies. This approach could be fruitfully expanded into other areas of sustainability such as development and land use and social equity policies. Additionally, researchers should shed their fears of using nonparametric methods for exploring data. While stepwise regression or 'data mining' without clear theoretical justification is unquestionably a poor practice for social scientists, we attempt to avoid this epistemological minefield by relying on the most rigorous literature survey so far conducted of urban sustainability research to inform our model-fitting. Our results suggest many of the proxy measures employed in hypothesis testing may be over-extended when they are enlisted to 'stand in' as approximations for many unobservable socio-environmental influences which do not have linear effects on policy outcomes. Model over-fitting is a primary culprit for research findings which do not generalize across studies. While the corpus of sustainability scholarship has blossomed into an agenda with much potential promise, the field is ripe for analysis which attempts to replicate results, re-examines assumptions about data distributions, and capitalizes on widely accepted statistical methods employed fruitfully in other fields.

Notes

1. Some of the studies reviewed were descriptive (e.g., Saha and Paterson, 2008) or performed tests such as means comparisons and bivariate correlations (e.g., Opp and Saunders, 2014) and thus did not have a dependent variable.

2. The four largest US cities (New York, Los Angeles, Chicago, and Houston) were excluded from these analyses.

3. Turco (2013) was not included in the 42 studies we reviewed because the study did not meet our search parameters.

4. The category 'community characteristics' was the broadest class of predictors, including socioeconomic, demographic, population, and interest group variables used to predict local environmental sustainability policy choices. Although these predictors also capture the 'political feasibility' of sustainability policy choices, we separated out interest group variables (such as support from business, environmental, civic, and homeowner groups) to more clearly identify studies finding support for political ideological explanations.

Tables and Figures

Table 1. Summary of literature review findings

				Predictors tested					
Author/date	**Primary data source**	**Outcome variable(s)**	**Analytic technique(s)**	**PF**	**OC**	**CC**	**GI**	**EP**	**Key finding(s)**
Bae and Feiock 2013	US national survey	Count of sustainability policy tools (city govt. operations and community-wide)	Poisson regression		x	x	x		Council-manager government positively correlates to sustainability policy tools for in-house city government operations, but negatively to community-wide tools

Bedsworth and Hanak 2013	California-based surveys	Binary outcomes: adoption of comprehensive climate policies; planned/ongoing GHG reduction actions	Descriptive; logistic regression; qualitative analysis	x	x	x			Adoption rates of comprehensive climate policies (emission inventories and climate action plans) were fairly high and growing; programs for action areas (transportation, energy, land use, etc.) were more common for municipalities than for residents and businesses; population size, household income, support from local leaders and stakeholders, and partisanship predict climate plan/action adoptions
Cidell and Cope 2014	Archival	Binary adoption of a LEED-based green building policy; number of green buildings (continuous)	Logistic and linear regression	x		x			Greater population, neighboring LEED cities, LEED professionals per capita, and MCPA-signed cities predict local LEED policies; presence of LEED policies lead to more green buildings
Cruz 2016	ICMA sustainability survey	Binary adoption of residential zoning codes for renewable energy	Logistic regression		x	x	x		Number of green firms, sustainability network membership, dedicated staff for sustainability, council-manager government, and educated population increase likelihood of residential zoning for renewable energy
Daley, Sharp, and Bae 2013	US national survey (analysis of cities with pop. > 75,000)	Continuous: community-wide sustainability initiative index score	OLS regression		x	x	x		ICLEI membership associated with more community-wide sustainability initiatives irrespective of government form; interlocal cooperation associated with more initiatives but only for mayor-council cities; general interest group

									support (e.g., civic groups) associated with more initiatives
Deslatte and Swann 2016	US national survey	Binary outcomes: energy efficiency index; GHG reduction goal adoption	Zero-inflated negative binomial; logistic regression	x	x	x	x		Determinants of energy efficiency policy tools and GHG reduction goal adoption differ; administrative capacity, community characteristics, and council-manager form of government predict energy-saving tools, but not GHG reduction goals
Deslatte, Swann, and Feiock 2016	Florida land use surveys	Sustainable land use tool indices; binary policy tool adoptions	Bayesian multilevel Poisson and logistic regression	x		x	x		Council-manager cities more likely to strategically and comprehensively employ sustainable land use policy tools following economic upheaval, and more likely to use incentive zoning for social inclusion than mayor-council cities
Gerber 2013	Michigan Public Policy Survey	Binary outcomes: climate policy adopted; Climate Protection Agreement member; Cool Cities member	Logistic regression	x		x			Partisanship of jurisdictions' electorate matters when climate policy targets residents or businesses; partisanship of elected officials matters when policy targets public employees; regional partisanship affects local climate policy decisions
Hawkins 2011	Massachusetts survey and Common-wealth Capital Scorecard (CCS)	Continuous: CCS local smart growth policy score	Heckman selection OLS regression		x	x	x		Mayor-council governments, greater fiscal capacity and fewer constraints, less pro-environmental support from neighborhood groups, and less pro-growth support from developer groups correlate to

									higher CCS smart growth score
Hawkins and Wang 2013	US national survey	Count of sustainable development policies aimed at reducing costs for businesses	Zero-inflated Poisson regression			x	x		Cities are integrating environmentalism into sustainable development policies; political institutions mediate influence of business interests on policies adopted; cities tend to adopt more policies when business groups are involved in planning and when cities have a managerial form of government
Hawkins et al. 2015	Integrated City Sustainability Database (see Feiock et al., 2014)	Binary outcomes: dedicated sustainability staff; budget; both	Logistic regression	x	x	x	x	x	Local environmental and social priorities, regional collaboration, and climate protection network membership predict commitment of resources to sustainability
Homsy 2015	ICMA sustainability and service delivery choices surveys	Count of energy sustainability policies (city govt. operations and community-wide)	Negative binomial regression; qualitative analysis		x	x	x		Municipal utilities correlate to more energy sustainability policies community-wide, but not in-house; more climate change/energy sustainability policies in states encourages in-house and community-wide sustainability policymaking
Homsy and Warner 2015	ICMA sustainability survey	Continuous (weighted) environmental policy adoption score	Multilevel regression		x	x	x		Local factors do fully account for local environmental policymaking; state-level climate change and renewable energy planning also influence local environmental policy action
Jepson 2004	US national survey (pop. > 50,000)	Continuous sustainable development policy actions	Descriptive; chi-square; regression		x	x			Moderately high sustainable development across communities of all sizes

									and in all regions; planning office leadership role correlates to more actions taken
Krause 2011a	Archival	Binary signed Mayor's Climate Protection Agreement (MCPA)	Multilevel regression	x		x	x	x	Local-level factors drive cities' commitment to climate protection more than state-level factors
Krause 2011b	US national survey (pop. > 50,000)	Municipal climate protection index	OLS regression	x	x	x	x	x	Local government capacity has largest impact on climate activity; risks generally did not have an impact; manufacturing and political leaning predict climate activity
Krause 2011c	Indiana survey	Municipal climate protection index	OLS regression	x	x	x		x	GHG-mitigation activities present in all respondent cities; policy entrepreneurs drive climate activity, while climate network membership does not
Krause 2012	US national survey (pop. > 50,000)	Count of GHG emissions-reducing activities	OLS regression (procedures to control for selection effects and endogeneity)	x	x	x		x	ICLEI CCP membership has small to moderate impact on GHG-reducing activity; MCPA membership has no effect
Kwon, Jang, and Feiock 2014	ICMA sustainability survey	Sustainability; environmental conservation; energy reduction indices	T-tests; Poisson; negative binomial	x	x	x	x	x	California cities are more advanced than other US cities in sustainability policy; different influences across sustainability, environmental conservation, and energy use reduction policy actions
Laurian and Crawford 2016	US national survey of small- to mid-size cities and counties	Sustainability implementation indices	Linear regression		x	x			Local public support, innovation-supportive organizational culture, and framing support in localities strongly predict sustainability implementation;

									organizational capacity, public participation, and policy innovation diffusion across localities do not predict implementation
Levesque, Bell, and Calhoun 2016	Maine municipal sustainability ordinances	Sustainability index	Poisson regression	x	x	x	x	x	Stronger environmental interests, higher growth, more formal governing institutions, and greater municipal capacity correlate to more sustainability policy adoption
Lubell, Feiock, and Handy 2009	Archival and California Central Valley survey	Environmental sustainability index	Cluster analysis; regression	x	x	x			More sustainable cities are likely fiscally healthier and higher in socioeconomic status
Lubell, Feiock, and Ramirez 2005	FL county comprehensive plans), archival	Count of conservation amendments	Zero-inflated Poisson regression			x	x	x	Strength of development interests inhibit professional managers' ability to pursue more environmentally sustainable land use
Lubell, Feiock, and Ramirez de la Cruz 2009	FL municipal comprehensive plans, ICMA survey, archival	Land conservation index	Heckman selection panel analysis			x	x	x	Higher socioeconomic interests encourage preservation of environmental amenities but also, and paradoxically, single-family home construction
Opp & Saunders, 2014	ICMA sustainability survey	Sustainability practices index	Correlations; means comparison	x		x	x		Community characteristics (population size, political leaning, diversity, etc.) correlate to engagement in sustainability practices; "best case" cities identified
Opp, Osgood, and Rugeley 2014	ICMA sustainability survey	Environmental policy index	Means comparison; OLS regression			x	x		Higher educated, more populated, and Western cities more likely to engage in environmental policy actions; differences

									across environmental policy subareas
Osgood, Opp, and DeMasters 2016	ICMA local economic development survey; ICMA sustainability survey	Environmental policy indices*	Means comparison; correlations	n/a	n/a	n/a	n/a	n/a	Local context determines whether cities use sustainability for economic development; cities using sustainability as an economic tool are more likely to adopt regulatory tools over incentive-based environmental strategies; cities facing greater competition employ environmental tools with greater revenue-saving potential
Pitt 2010	US national survey	Count of climate mitigation policies adopted and pursued	OLS, Poisson, negative binomial regression		x	x		x	Internal characteristics (staff working on energy/climate planning; environmental activism; local government environmental awareness) determine climate policy actions more than external forces (exception: influence of neighboring jurisdictions)
Portney 2013	55 largest US cities	Index of Taking Sustainability Seriously	Case studies; regression		x	x			Reliance on manufacturing discourages willingness to engage in sustainability actions; greater commitment, Creative Class, and government-environmental group interaction increases sustainability efforts
Portney and Berry 2010	Social Capital Benchmark Survey	Binary outcomes: cities with sustainability practices	OLS regression	x		x			Cities more committed to sustainability tend to have more citizen participation generally

Portney and Berry 2016	Surveys of local advocate groups and sustainability activities in 50 largest US cities	Sustainability policies and programs index	OLS regression; case analysis			x			"Very likely" inclusion of environmental groups in policymaking process correlates to more sustainability policies and programs
Ramirez 2009	Florida land use surveys	Count of growth boundaries; density bonuses; smart growth zoning	Poisson regression			x	x		Urban sprawl increases use of density bonuses and smart growth zoning; increased developer (environmental group) support negatively (positively) correlates to density bonuses; mayoral cities mediate influence of homeowner group support on adopting smart growth policies
Saha and Paterson 2008	US national survey (pop. > 75,000)	n/a	Descriptive	n/a	n/a	n/a	n/a	n/a	Cities adopt sustainability practices in piece-meal fashion; more substantive commitment to sustainability is rare; little connection to social justice/equity
Sharp, Daley, and Lynch 2011	50% random sample US cities (pop. > 100,000)	Binary ICLEI membership; censored ICLEI milestones count	Logistic and tobit regression			x	x		Organized interests influence adoption and implementation of local climate mitigation strategies, but effect is larger in mayor-council cities
Svara, Watt, and Jang 2013	ICMA sustainability survey	Sustainability activity rating	Descriptive; regression			x	x		Cities undertake traditional activities (e.g., recycling) and those delivering short-term benefits, but not innovative activities (e.g., GHG reduction); form of government, community characteristics, and priorities explain actions but not in ways

									consistent with race, class, or wealth division
Swann 2015	US national survey	Count of sustainability policy tools (city govt. operations and community-wide)	Zero-inflated negative binomial		x	x			Relationships between local sustainability engagement and collaboration mechanisms depend on policy targets (in-house city govt. operations or community-wide), capacity, and stakeholder support
Wang 2012	California local government annual planning surveys	Binary outcomes: adopt climate mitigation action; adopt climate adaptation action	Probit regression	x	x	x		x	California cities engage in climate action incrementally and adopt individual, "win-win" actions more often; city size, income, and political preferences predict mitigation actions, while coastal cities engage in more adaptation strategies
Wang et al. 2012	US national survey (pop. > 50,000)	Sustainability index	Structural equation modeling	x	x	x	x		Sustainability efforts positively correlate to capacity building; stakeholder involvement furthers capacity for sustainability efforts
Wang, Hawkins, and Berman 2014	US national survey (pop. > 50,000)	Financial capacity; sustainability strategies indices	OLS regression	x	x	x	x		Stakeholder engagement strategies positively correlate to financial capacity for sustainability efforts
Yi, Krause, and Feiock 2017	Archival, ICSD, US national survey	Binary dedicated sustainability staff; budget; sustainability policy commitment index	Difference-in-differences; logistic, OLS regression		x	x	x		Terminating ICLEI membership does not significantly impact local commitment to sustainability actions
Zahran et al. 2008a	Archival	ICLEI Cities for Climate Protection (CCP) involvement (ratio of cities in metro area)	Spatial analysis; OLS regression			x		x	Climate change stressors predict less local involvement in CCP campaign; high civic capacity predicts more involvement at metro area level

Zahran et al. 2008b	Archival	Binary ICLEI CCP campaign status	Spatial analysis; means comparison; logistic regression	x		x		x	Physical/environmental risks and socioeconomic factors predict CCP involvement at local level

Note: PF = political feasibility/ideology; OC = organizational capacity; CC = community characteristics/capacity/support/economy; GI = government institutions; EP = environmental predictors; n/a = not applicable.
* Osgood, Opp, and DeMasters (2016) test correlations between economic development characteristics and environmental indices, and thus have no dependent variable.

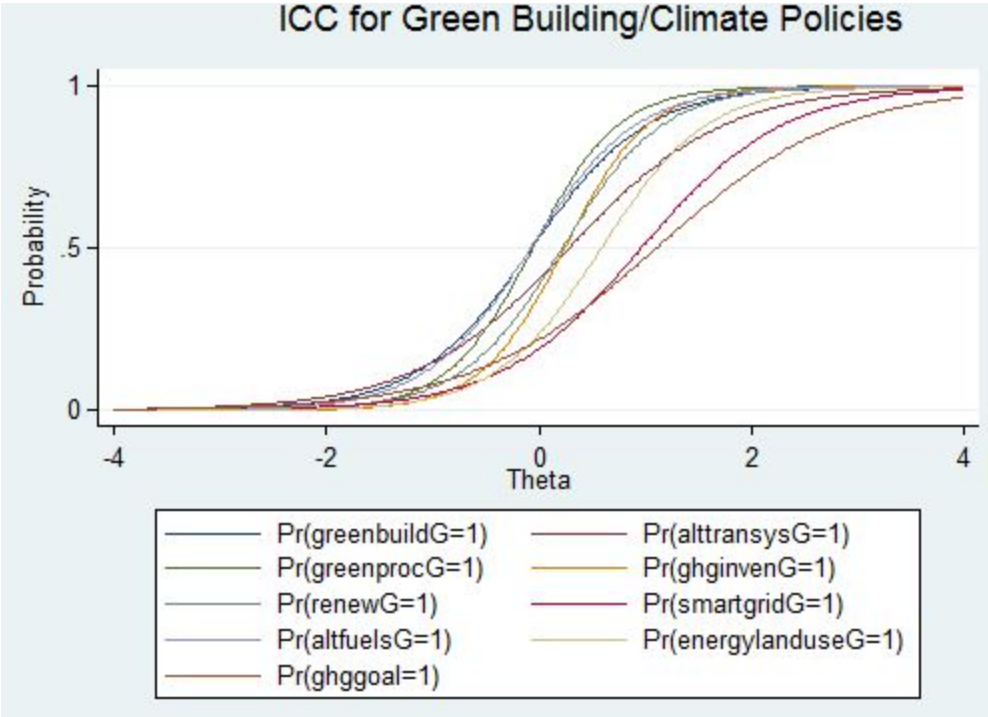

Figure 1. The ICC for our IRT model for green building/climate-related policies shows a city with an average level of commitment to sustainability has a 70% chance of committing to green building and green procurement policies but still has a less than 20% chance of using smartgrids or incorporating energy use into land use decisions. The ICC allows us to generate a predicted latent trait, called Theta, for each city respondent.

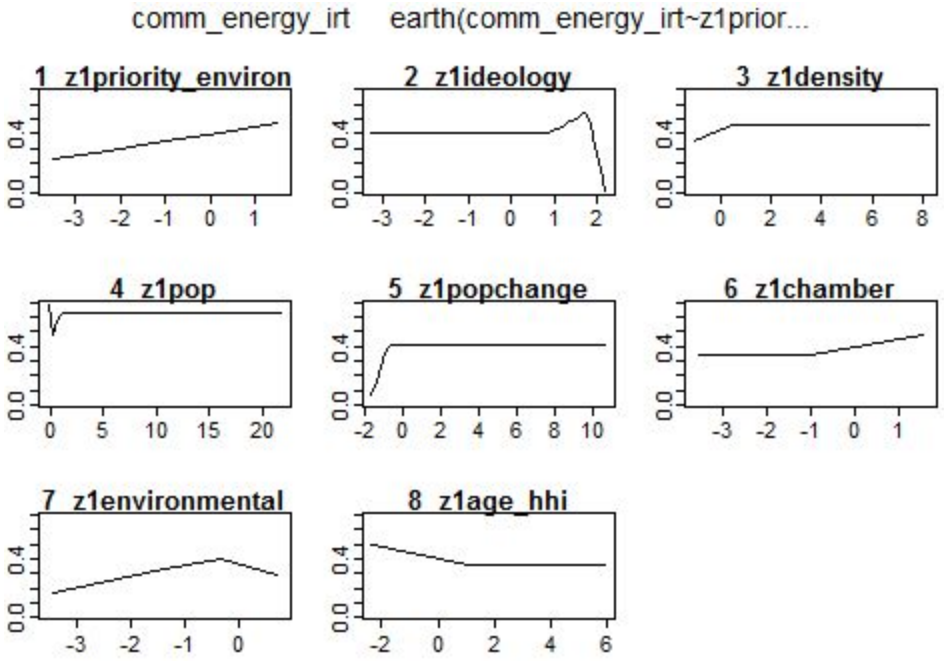

Figure 2. After finding cut points for green building predictors, the MARS model estimates two new 'hockey stick' features which are used in a linear regression model. The splines allow for piecemeal linear model fitting. The above IRT model selected 14 of 23 terms, and 8 of 13 predictors, showing nonlinear relationships for all the predictors except prioritization of the environment.

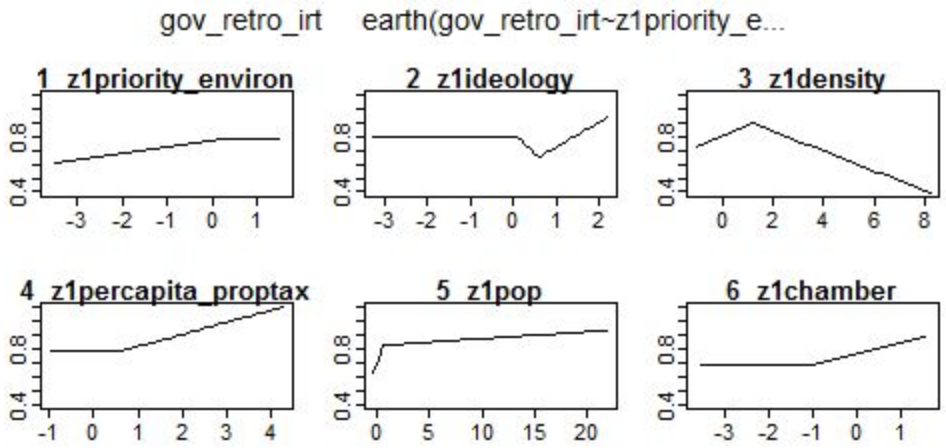

Figure 3: The IRT model for government-facility retrofits and energy efficiency measures shows the strongest predictive validity, with chamber/business association support being the most important predictor.

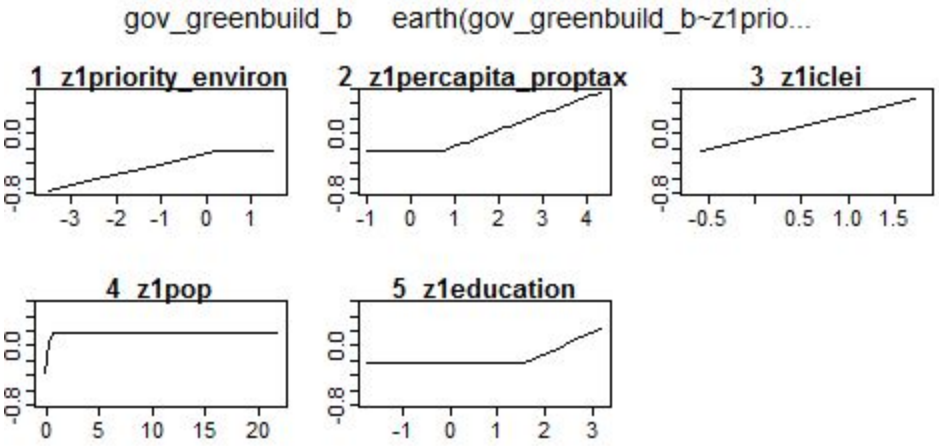

Figure 4: The Bartlett factor score model for government-facility green building and climate policies retained the most predictors and has the highest R-squared. Both the Bartlett and IRT models identified ICLEI membership as the most important predictor for explaining observed outcomes.