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Vulnerability and capacity: explaining local commitment to climate-change policy

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Abstract. We examine the reasons why a US locality would voluntarily commit to the Cities for Climate Protection (CCP) campaign. Using geographic information systems analytic techniques, we map and measure a locality's vulnerability to climate-change impacts at the county level of spatial precision. We analyze multiple measures of climate-change vulnerability, including expected temperature change, extreme weather events, and coastal proximity, as well as economic variables, demographic variables, and civic-participation variables that constitute a locality's socioeconomic capacity to commit to costly climate-change policy initiatives. Bivariate and logistic regression results indicate that CCP-committed localities are quantitatively different to noncommitted localities on both climate-change risk and socioeconomic-capacity dimensions. On vulnerability measures, the odds of CCP-campaign participation increase significantly with the number of people killed and injured by extreme weather events, projected temperature change, and coastal proximity. On socioeconomic-capacity measures, the odds of CCP-campaign involvement increase with the percentage of citizens that vote Democrat and recycle, as well as the number of nonprofit organizations with an environment focus. The odds decrease in a county area as the percentage of the labor force employed in carbon-intensive industries increases.

Introduction

Climate change is an environmental problem with considerable social, economic, and ecological risks (Scheraga and Grambsch, 1998). The thermometric instrumental record indicates that the global average surface temperature is increasing, and is up by about 0.6 °C in the last one hundred years. Proxy data from ice cores and tree rings suggest that the 'abrupt' warming trend of the 20th century is 'unique' by historical standards (North, 2003). The impacts of temperature change are many, and include coastal flooding and beach erosion, extreme weather events, continental drying and drought, loss of habitat and species, decreased revenue for commercial fisheries, fluctuations in crop yields, and increased spread of vector-borne diseases

like malaria and encephalitis (Hurd et al, 2004; Parry et al, 2001; Scheraga and Grambsch, 1998; Smith et al, 2003; White, 2004).

Researchers note that these ecological, social, and economic impacts are distributed unevenly by geography (Mendelsohn et al, 1994; 2000). For example, warming trends are selectively harmful to coastal, maritime, and low-lying island societies, where the risks of inundation could render coastal settlements uninhabitable (Titus, 1986). Likewise, there are potential beneficiaries to climate change (De Leo et al, 2001). Because climate models show increased warming at the poles, Northern Canada may benefit economically from warming trends, with increased shipping activity due to deeper ports and longer navigational seasons (Watson et al, 1997). Insofar as national governments are rational, *their willingness to participate in policy solutions to mitigate and to adapt to the risks of climate change may be partially determined by these spatially distributed impacts* (Goulder, 2003; Victor, 2003).

Most climate-policy initiatives focus on stabilizing the concentration of carbon dioxide (CO_2) in the atmosphere, but also include restricting development on floodplains and at elevations below sea level, preventing the buildup of fuel loads in forests, and insulating vulnerable coastal communities with dykes and sea walls (Titus, 1986; 1998). These policy instruments are designed to increase the resilience of human and natural systems to climate change and variability. However, policy instruments can create as many distributional problems as they solve.[(1)] For example, efforts to curb greenhouse gas (GHG) emissions, known to scientists to be a key predictor of climate variability in the last century (Watson, 2001), can impose a greater absolute burden on carbon-intensive societies where the abatement/compliance costs are significantly higher (Edmonds and Sands, 2003; Zahran et al, 2006). Likewise, low-altitude, underdeveloped areas stand to benefit disproportionately from the enactment of policies to attenuate the risks of climate change. *Therefore, the willingness of a government to support a climate-policy solution is also partially determined by the relative distribution of costs and benefits that accompany policy action.*

Because the costs and benefits of climate-policy action and climate-policy inaction are spatially nonrandomly distributed, climate change constitutes a potential 'tragedy of the commons'. Hardin (1968) used the concept of 'tragedy' to symbolize the expected degradation of environmental resources when they are owned commonly. Climate is such a 'common' resource because it cannot be readily fenced or be allocated according to need or willingness to pay. In common ownership, without a coercive authority to coordinate behavior, it is rational for an individual party to withdraw from and negatively add to common pool resources until failure (Dietz et al, 2003). The degradation of a common resource is a tragedy that harms everybody. In Hardin's words: "ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (1968, page 162).

The destination of collective ruin is hard to avoid because the collective benefits of climate-protection efforts are nonexcludable. Insofar as climate stability is desired by all, individual parties benefit from the reduction of CO_2 emissions/concentrations in

[(1)] Distributional dilemmas occur not only across nations but within nations. In the United States climate-change-impact studies forecast regional differences in economic growth, loss of habitat and species, costly changes in water supply and weather-related mortality, and even region-specific disruptions to recreational activities (Scheraga and Grambsch, 1998; Watson et al, 1997). Assuming uniform change across climate divisions, Mendelsohn (2003) finds the highest costs of climate change to market sectors in agriculture, forestry, energy, and water in the Southeast, South Plains, and Southwest, whereas the Midwest and Northeast regions of the country have had relative gains to such market sectors.

the atmosphere whether or not they participate in reduction efforts (Edmonds and Sands, 2003). For example, if signatories to the Kyoto Protocol meet targets and timetables specified by the agreement and manage to reduce anthropogenic sources of climate change, nonratification countries like Australia and the United States benefit from these costly efforts. In fact, significant competitive benefits will be accrued to Australia and the United States by an avoidance of costly reforms to production modalities, which cooperators willingly absorb (Zahran et al, 2006). The same pattern of uneven costs and benefits exists at the local scale.

With costs and benefits of action and inaction being distributed unevenly by place, and with there being strong incentives to free-ride the costly mitigation efforts of others, why would a political entity voluntarily participate in a collective enterprise to reduce the risks of climate change? In the United States (and in the absence of a federal mandate to do so), over one hundred localities have joined the Cities for Climate Protection (CCP) campaign which is sponsored by the International Council for Local Environmental Initiatives (ICLEI). The CCP campaign coordinates the climate-change risk-mitigation efforts of about 675 municipalities globally (ICLEI, 2005). Officials in these localities have publicly recognized (by council resolution) that climate change is a significant local concern, and have committed themselves and the residents that they represent to policies intended to reduce local GHG emissions (Betsill, 2001; Betsill and Bulkeley, 2004). CCP localities account for an estimated 19.63% of all CO_2 emissions that are generated annually in the United States.[2]

Participation in the CCP campaign is therefore an intriguing empirical question (Betsill, 2000). From a strictly rational-choice perspective it seems unwise for a local government to voluntarily assume the costs of climate-change protection, because: (1) reducing local emissions will not fully insulate a locality from the adverse transboundary effects of global climate change; (2) the costs of climate-change mitigation are significantly higher than the expected benefits when participation is voluntary; (3) the collective benefits of climate protection are nonexcludable and nonrival; and (4) there is no federate mandate or significant assistance for the implementation of climate-change protection programs—in fact, US Congress prohibits use of federal monies for programs that are defined as implementing the Kyoto Protocol before ratification (Betsill, 2000). Our study empirically examines the reasons why a US locality would voluntarily commit to the CCP campaign, when there are powerful incentives to do otherwise.

To address this research question, we investigate incentives for CCP participation that correspond with a locality's physical location and structural makeup. We use geographic information systems analytic techniques to map and measure a locality's vulnerability to climate-change impacts at the county level of spatial precision. We analyze multiple measures of climate-change vulnerability (ie temperature change; extreme weather events; and coastal proximity) along with economic variables, demographic variables, and civic-participation variables that constitute a locality's socioeconomic capacity to commit to costly climate-change-policy initiatives. This approach allows us to: (1) empirically test theoretical propositions by environmental social scientists on the determinants of climate-policy participation; (2) statistically unpack the risk vulnerability and socioeconomic-capacity factors that predict variation in CCP-campaign participation; and (3) provide direction to planners and policy makers on how to

[2] No comprehensive county-level CO_2-emissions data are available. We use Hazardous Air Pollutant (HAP) data at the county level as a proxy. For 1999, at the state level, there is a Pearson's correlation 0.811 between the total estimated annual HAP emissions (a sum of the major, area, and other on-road mobile-source emissions, and nonroad mobile-source emissions), in pounds, and the state CO_2-emission inventories from fossil fuel combustion (in million metric tonnes of CO_2).

widen local involvement in initiatives that are meant to reduce the adverse impacts associated with global warming and climate change.

Our investigation of climate-change risk and socioeconomic-capacity variables predicting CCP commitment is organized into four sections. First, we provide a brief background on the CCP campaign, we review relevant literature, and we delineate testable hypotheses derived from theories of collective action. Second, we detail our research design— we discuss secondary data collection, variable operations, and data-analysis procedures. Third, we present and discuss descriptive, bivariate, and binary logistic regression results. In the final section we discuss implications of results and provide suggestions for future research in order to enhance understanding of how risk vulnerability and social-structural measures influence local public-policy outcomes on global climate change.

Literature review and theory

Cities for climate-change protection

In 2000, about 47% of the world's population lived in urbanized areas. There are 411 urban agglomerations with 1 million or more inhabitants (Population Reference Bureau, 2005). A significant percentage of human activities that aggravate climate change are concentrated in cities. By some estimates, 78% of global CO_2 emissions emanate from cities (Betsill, 2000). In 1991 the ICLEI launched the Urban CO_2 Reduction Project to counter such trends. The program coordinated the CO_2-reduction efforts of fourteen municipalities in Canada, the United States, and Europe. The program proved remarkably successful, with municipalities achieving significant reductions both in CO_2 emissions and in operating expenditures (Betsill, 2000; Betsill and Bulkeley, 2005). For example, through energy efficiency, urban reforestation, diversification of transportation, and recycling and waste prevention initiatives, officials in St Paul, Minnesota, reduced CO_2 emissions by 940 000 tons (exceeding Kyoto Protocol objectives), and saved the local economy an estimated US \$59 million annually (St Paul Energy Conservation Project, 2005).

In 1993 the ICLEI officials rolled the CO_2 project into the more ambitious CCP campaign. The stated mission of the campaign is to enlist "cities to adopt policies and implement measures to achieve quantifiable reductions in local greenhouse gas emissions, improve local air quality, and enhance urban livability and sustainability" (ICLEI, 2005). The CO_2-reduction target that is set for cities is a 20% reduction from 1990 levels (Betsill, 2000; Collier and Lofstedt, 1997). This 'Toronto Target' is significantly more stringent than the standards set by the Kyoto Protocol (Betsill, 2000; Van Kooten, 2003). With 675 municipalities globally working toward this reduction target and a reported 10% annual increase in the number of localities joining (ICLEI, 2005), the collective benefits of the CCP campaign are potentially large.

To join, a locality must pass a resolution or must issue an executive decree that binds it to the CCP campaign's master objective—reduction of GHG emissions. The CCP campaign uses a performance-based approach, structured on five milestones that localities commit to undertake (Strengers, 2004). The milestones move localities from a baseline inventory of emissions, to the adoption of reduction targets, to the elaboration and implementation of action plans and standardized progress reports (ICLEI, 2005). The administrative costs vary according to the size and the complexity of the local government, the nature and pace of plan enactment, and whether officials can galvanize community and private support for plan initiatives.

Incentives: risk and capacity

Because participation in the CCP campaign is voluntary, and the ICLEI has no coercive authority to reward or to punish the behavior of participants and nonparticipants, coordinated action across localities to mitigate the risks of climate change can be considered to be a collective action dilemma. CCP campaign initiatives, like all collective policy actions on climate change, produce collective and selective costs and benefits that are market and/or nonmarket in nature (Griffin, 2003). A major collective benefit of participation in the CCP campaign is the reduction of aggregate GHG emissions—a major cause of climate variability in the last century (Oreskes, 2004). With greater climate stability the expected impacts of climate change on terrestrial and marine ecosystems, infrastructure, and patterns of mortality are reduced.

The problem with such collective benefits, as with all collective action dilemmas, is that they cannot be withheld from nonparticipants in the CCP (Lubell et al, 2006). The nonexcludability of collective benefits significantly undermines incentives to participate, leading to suboptimal provision of policy goods (Olson, 1971). Without a coercive authority to monitor and sanction behavior, collective endeavors like the CCP campaign are more likely to succeed if localities accrue selective (excludable) benefits from participation. In Olson's words: "Only a *separate and 'selective' incentive* will stimulate a rational individual in a latent group to act in group-oriented ways" (1971, page 51).

The ICLEI offers excludable benefits to CCP participants, such as software and analytic services, access to case studies and fact sheets, and strategic plans to enable localities to inventory, track, and reduce GHG emissions (ICLEI, 2005). ICLEI officials claim that participation in the CCP campaign provides secondary benefits such as reduced utility and fuel costs, improved local air quality, and increased job growth in energy goods and services. As incentives for participation, these selective benefits are problematic. First, logistical supports offered by the ICLEI are not fully excludable. Localities routinely advertise GHG policies and technical solutions. For example, officials in Seattle proudly share information with journalists, academics, and localities on how they reduced GHG emissions to 59% of 1990 totals (Office of Sustainability and Environment, 2002). With such information openly available, the ICLEI is not a monopoly broker of technical advice. Second, the ancillary benefits of increased energy efficiency and sector-specific job growth are achievable without participation in the CCP campaign. And, third, the benefits of participation in the CCP are offset by selective costs of policy enactment.

As stated above, selective costs and benefits of policy action and inaction have a geographic dimension. In our view, the uneven geographic distribution of expected costs and benefits is the critical factor for understanding variation in CCP-campaign involvement. Selective incentives to participate in the CCP campaign spring from two major sources: (1) the extent to which a locality is *vulnerable to the risks* of climate change and variability; and (2) the *socioeconomic capacity* of a locality to commit to GHG emission reduction targets.

First, incentives for CCP participation on the basis of climate-change-risk vulnerability are measurable by examination of a locality's coastal proximity, expected temperature change, and history of extreme weather events. These 'fingerprints' of vulnerability broadly influence the willingness of a locality to take on the problem of GHG emissions. Climate scientists note that the climate-change-induced risk of sea-level rise/inundation is selectively harmful to coastal localities (Watson, 2001). Insofar as local officials are rational, landlocked localities have no apparent reason to fear the specific risk of a rise in sea level. Coastal counties, on the other hand, have a greater incentive to participate in the CCP campaign to hedge the risk of sea-level

rise and the associated inundation. In fact, the majority of localities participating in the CCP campaign are coastal (see figure 1).

High-resolution global models, nested global–regional models, and statistical downscaling approaches indicate that disruptive and relatively abrupt warming trends are unevenly distributed spatially (Watson, 2001). We assume that localities with higher expected temperature changes are selectively incentivized to assume the costs of climate-policy reform. A much-talked-about expected consequence of temperature change is an increase in the frequency and the intensity of extreme weather events (Watson, 2001). Insofar as the past is a reasonable basis for future projection, localities with documented histories of natural calamity (ie floods and hurricanes) that cause human injury and death are more likely to commit to the CCP campaign. Together, coastal proximity, expected temperature change, and susceptibility to extreme weather events constitute a locality's selective vulnerability to climate change and variability. Stated as a testable proposition: *if all things are held equal, localities with a higher expected vulnerability to the risks of climate change are significantly more likely to commit to the CCP campaign*.

Socioeconomic capacity is a second factor that motivates localities to enact CCP policy prescriptions. These costs and benefits are related to a locality's political, civic, and economic design or composition (Betsill, 2001; Pickvance, 2002; Rydin, 1999; Rydin and Pennington, 2000). Local composition characteristics approximate a locality's selective capacity to respond politically to the threats of climate change and variability. Some characteristics enable capacity, increasing the probability of CCP enactment, whereas other characteristics encumber capacity, thereby decreasing the odds of CCP participation.

An obvious obstacle to participation in the CCP campaign is the extent to which a local economy is dependent on carbon-intensive activities and industries (Betsill, 2000; Collier and Lofstedt, 1997; Saporito, 1992). High dependence of carbon-intensive activities makes commitment to the CCP campaign selectively costly. Insofar as local officials are rationally constrained by the economic interests of constituents, localities with a high percentage of residents employed in industries that are sensitive to carbon reduction efforts, for example, are significantly less likely to commit to the

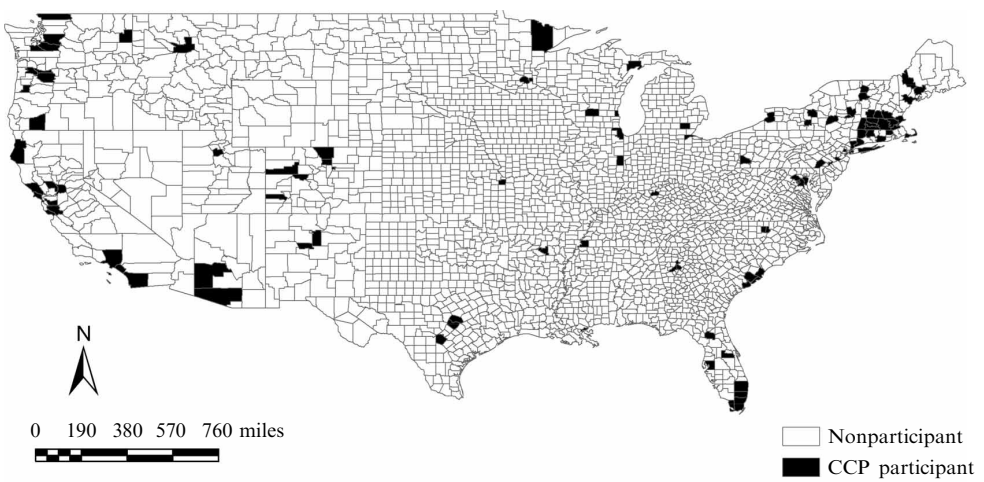


Figure 1. Spatial distribution of Cities for Climate Protection (CCP) participating localities at the county scale. Note: Counties are placed in their true location on Earth using longitude and latitude coordinates.

CCP campaign. Australia and the United States advance this 'economic harm' argument for refusal to ratify the Kyoto Protocol (Rollings-Magnusson and Magnusson, 2000). At the county scale, officials in Wayne County, Michigan, (or Detroit) are significantly less likely to commit residents and local businesses to CO_2 reduction targets, because of the selective costs imposed by such policy action, relative to other localities where fewer residents and businesses are involved in CO_2-intensive industries.

A locality's socioeconomic capacity to commit to the CCP campaign is also influenced by selective benefits that are related to its political and civic composition. In the summer of 2004 our research team conducted a representative national survey of adult residents in the United States on global warming and climate change. Respondents were asked whether they support ratification of the Kyoto Protocol—a national policy that is equivalent to the local CCP campaign. Three variables stood out as being highly correlated with respondent willingness to support the Kyoto protocol (see table 1): how often respondents recycle ($t = 4.124$; $p = 0.000$); the extent to which respondents participate in forms of environmental citizenship, such as by joining environmental groups and by donating monies to environmental causes ($t = 8.819$; $p = 0.000$); and whether a respondent self-identified as politically Democrat ($t = 10.097$; $p = 0.000$). From a collective-action perspective, such individuals derive selective benefits from enactment of activist climate policies in the form of preference satisfaction (Lubell et al, 2007). That is, ratification of the Kyoto Protocol increases the subjective utility for environmentally concerned citizens in comparison with citizens who are less concerned about the environment.

Officials in localities that are characterized by high percentages of environmentally concerned and ideologically center-left residents benefit selectively from involvement in the CCP campaign by satisfying the political preferences of the citizens that they represent. Officials in environmentally concerned localities stand to benefit disproportionately (in terms of political capital) from involvement in the CCP campaign to, say, elected officials in counties where residents manifest considerably lower interest in environmental protection as compared with job growth. Localities with a political and civic makeup that is environmentally oriented and politically Democratic are more structurally capable of participating in the CCP campaign because of the higher political rewards that follow from participation. Together, industrial, political, and civic

Table 1. Descriptive statistics and mean comparisons of US residents by Kyoto Protocol support.

	Kyoto support	*N*	Mean	Standard deviation	Standard mean error	Mean difference	*t*
Vote Democrat	1	767	0.395	0.489	0.018	0.295	10.097
	0	169	0.101	0.302	0.023		
Recycle	1	804	3.313	0.952	0.036	0.336	4.124
	0	174	2.977	1.080	0.082		
Environmental citizenship	1	783	1.407	1.457	0.052	0.793	8.819
	0	171	0.614	0.960	0.073		

Notes: All *t*-test results are statistically significant where $p = 0.000$. Based on *F*-test results, unequal variances are assumed for all variables. *Environmental citizenship* ($\alpha = 0.701$) contains four dichotomously measured items (1 = yes; 0 = no). Survey respondents were asked whether they engaged in the following citizenship activities in the last twelve months: contacting a public official about an environmental issue, signing an environmental petition or appeal, donating money to an environmental organization, or belonging to any environmental groups or organizations. 'Recycle' is an ordinal measure. Respondents were asked to indicate how frequently they engage in this behavior (four-point scale: 1 = never; 4 = always).

Table 2. Variable operations, data sources, and expected sign.

Variable name	Variable operation	Sign	Data source
Climate risk variables			
natural hazard casualty	Factor score of the number of weather-related fatalities and injuries in a county area that occurred between 1960 and 2004.	+	Spatial hazard events and losses database for the United States, 2004
temperature change	Hadley Center monthly time-series climate data for the United States are plotted at the 0.5×0.5 degree of spatial resolution. Average minimum temperature projections for 2099 are subtracted from 2004 data to estimate projected unit change in average minimum temperature for a county.	+	National Center for Atmospheric Research, 2000
coastal proximity	Measured dichotomously. A county receives a score of 1 if it is a National Oceanic and Atmospheric Administration (NOAA) designated coastal county (at least 15% of its area is in coastal watershed) and a score of 0 if it is not.	+	NOAA
Socioeconomic variables			
percent net Democrat	Total percentage of votes cast for John Kerry in a county minus the total percentage of votes cast for George Bush in a county.	+	Atlas of US Presidential Elections, 2004, http://www.uselectionatlas.org/
percent recycle	Respondents in the Mediamark Research Incorporated survey were asked to indicate whether they had recycled products in the last twelve months. Percent recycled is the total number of adults in a county that recycled products in the last twelve months, divided by the total number of adults who are eighteen or older in the county.		Application Geographic Solutions Inc. and Media Mark Inc., 2003
nonprofit environmental organization	Total number of nonprofit organizations of tax-exempt status with US$25 000 in gross receipts required to file Form 990 with the Internal Revenue Service with an environmental focus [as defined in the National Center for Charitable Statistics (NCCS) taxonomy] in a county.	+	National Center for Charitable Statistics, Core Files, 2001
HAP emissions per capita	The Environmental Protection Agency (EPA) tracks emissions (in pounds) of 188 hazardous air pollutants (HAP) known or suspected to cause serious health problems. Total HAP emissions at the county scale are divided by total population to derive the measure.	−	EPA Air Data County Emissions Report, 1999
percent carbon employment	Total civilian population of sixteen years or older in a county who are employed in agriculture, forestry, mining, construction, manufacturing, transportation, warehousing, and utilities, divided by the total employed population of sixteen years or older in a county.	−	US Census Bureau, Population and Housing Files, 2000
Control variables			
percent college educated	Total number of persons in a county of twenty-five years older with a bachelor's degree master's degree, professional degree, or doctorate degree, divided by the total number of persons of twenty-five years or older in a county.	+	US Census Bureau, Population and Housing Files, 2000
percent urban population	Total number of persons residing in 'urban'-defined areas divided by the total number of persons in a county. Urban consists of territory, persons, and housing units in: places of 2500 or more persons incorporated as cities, villages, boroughs (except in Alaska and New York), and towns (except in the six New England States, New York, and Wisconsin), but excluding the rural portions of 'extended cities'.	+	US Census Bureau, Population and Housing Files, 2000

compositional qualities constitute a locality's selective capability to act on climate change and variability. Stated as a testable proposition: *if all things are held equal, localities with a higher socioeconomic capacity are significantly more likely to commit to the CCP campaign.* In the next section, we delineate variable measurements that approximate incentives stemming from a locality's climate change risk and socioeconomic capacity. All operations are summarized in table 2.

Variable operations and data sources

Dependent variable

The dependent variable, CCP campaign status, is measured dichotomously. A county receives a score of 1 if it (or any city or town nested within it) has officially committed to the CCP campaign by council resolution. A county receives a score of 0 if it (or a city or town nested within it) has not officially committed to the CCP campaign. Officials at the Local Governments for Sustainability World Secretariat in Toronto, Canada were contacted to derive a valid list of participating localities. Overall, 112 of the 3107 valid counties examined are party to the CCP campaign as of November 2005. Committed localities are urbanized and densely populated, representing approximately eighty million US residents. Geographically, CCP-committed counties are predominately coastal or are located near to inland water bodies, and are concentrated in the Atlantic Northeast, the Pacific Northwest, the Bay area of California, with a few localities peppering the Great Lakes and Gulf Coast regions of the country (see figure 1).

Climate-change-vulnerability variables

With reference to climate-change-impact literature, we measured and analyzed three types of risk: risk due to temperature change, risk due to coastal proximity, and risk due to extreme weather patterns. All measures of climate-change vulnerability were georeferenced at the county scale. Our temperature change variable was measured as the projected unit change in average minimum temperature (in $^{\circ}$C) for a county from 2004 to 2099. We used regionally downscaled temperature-projection data. Hadley Center monthly time-series data on average minimum temperature for the United States were plotted at the 0.5×0.5 degree of spatial resolution. In cases where climate divisions intersect county boundaries, temperature data were averaged across intersecting climate divisions. Temperature data were derived from the National Center for Atmospheric Research.

Our natural hazard casualty variable was measured as a factor score of the number of reported injuries and fatalities from natural-hazard events at the county level from 1 January 1960 to 31 July 2004. Higher values on our natural-hazard casualty variable reflect more pronounced histories of injury and death from extreme weather events. Casualty data were collected from the Spatial Hazard Events and Losses Database for the United States. Finally, our coastal proximity variable was measured dichotomously. A county received a score of 1 if it was designated by the National Oceanic and Atmospheric Administration (NOAA) as an 'at-risk coastal' county, and a score of 0 if it was not. NOAA defines a county as being at-risk coastal if at least 15% of its total area is located in a coastal watershed.

Socioeconomic-capacity variables

As with climate-change-risk variables, all measures of socioeconomic capacity were georeferenced at the county scale. Two measures of environmental concern were used: 'percent recycle' and 'nonprofit environmental-organization' activity. Our percent recycle measure was derived from the MRI Consumer Behavior database, 2003. Researchers at Applied Geographic Solutions Incorporated have configured MRI

household records to various levels of political, administrative, and statistical scales. A Mosaic coding technology based on a cluster algorithm (ie iterative relocation) was used to derive geodemographic profiles of areas. percent recycle was measured as being the total number of adult respondents answering 'yes' to a question on whether they recycled products in the last twelve months, divided by the total number of adults of 18 years of age or older residing in the county. Our nonprofit environmental organization variable was measured as the total number of nonprofit environmental organizations located in a county. Nonprofits are defined as organizations of tax-exempt status with US \$25 000 in gross receipts required to file Form 990 with the Internal Revenue Service. Data were derived from the National Center for Charitable Statistics, Core Files 2001. In addition to environmental-concern measures, we estimated the political ideological orientation of a locality with 2004 presidential election voting data. Our percent net Democrat variable was measured as the total percentage of votes cast for John Kerry minus the percentage of total votes cast for George W Bush.

Two variables were used to estimate the industrial commitments of a locality that may circumscribe its capacity to sign the CCP initiative: 'HAP emissions per capita' and the percentage of residents employed in carbon-reduction-sensitive industries. Because no comprehensive county-level CO_2-emissions data were available, we used HAP emissions data as a proxy. The Environmental Protection Agency (EPA) is mandated to monitor and regulate 188 HAPs. For 1999, at the state level, there is a Pearson's correlation of 0.811 between the total estimated annual HAP emissions and the state CO_2 emission inventories from fossil-fuel combustion. HAP emissions per capita was measured as the total HAP emissions at the county scale divided by the total population in the county. HAP emissions data were derived from the EPA's AirData County Emissions Report (EPA, 1999). percent carbon employment was measured as the total civilian population of 16 years or older in a county employed in agriculture, forestry, mining, construction, manufacturing, transportation, warehousing, or utilities, divided by the total employed population of 16 years or older in a county.

Control variables

Two control variables were included in logistic regressions models: percent urban population and percent college educated. Both measures are derived from the US Census Bureau's (2000) population and housing files. Because of the strong correlation between level of education and willingness to support climate-policy solutions (Jaeger et al, 1993; O'Connor et al, 1999; 2002; Zahran et al, 2006), we estimated the percentage of adults in a county with a college degree. percent college educated was measured as the total number of persons in a county of 25 years or older with a bachelor degree, a master's degree, a professional degree, or a doctorate degree, divided by the total number of persons who are 25 years or older in a county. Because the CCP campaign grew out of the ICLEI's Urban CO_2 Reduction Project from 1991 to 1993, participation in the CCP campaign is biased toward urban localities. To control this effect we estimated local urbanization. percent urban population[(3)] was measured as the total number of persons residing in urban places divided by the total number of persons residing in a county area.

[(3)] According to the US Census Bureau, 'urban' consists of territory, persons, and housing units in: places of 2500 or more persons incorporated as cities, villages, boroughs (except in Alaska and New York), and towns (except in the six New England states, New York, and Wisconsin), but excluding the rural portions of 'extended cities'; census-designated places of 2500 or more persons; other territory, incorporated or unincorporated, included in urbanized areas.

Statistical results

Descriptive and independent samples *t*-test results are presented in table 3. Results indicate that CCP-committed localities are quantitatively different to noncommitted localities on both climate-change-risk and socioeconomic-capacity dimensions. On socioeconomic-capacity variables, CCP-committed localities are significantly more likely to vote Democrat where the mean difference on percent net Democrat is 41.75%. On environmental-concern estimates, CCP localities are significantly more likely to host a nonprofit environmental organization ($t = 5.604$; $p = 0.000$), and have a significantly higher percentage of residents that recycle (39.44% versus 34.84%). As a whole, results on these three measures suggest that localities are more likely to commit to the CCP campaign if residents manifest proenvironmental sentiments and behaviors.

Our structural encumbrance measures of HAP emissions per capita and percentage of residents employed in carbon-reduction-sensitive sectors of the economy behave as expected. Again, the logic behind inclusion of such measures is based on the rationality assumption that localities facing greater expected policy-enactment costs are less likely to commit to the CCP campaign. Noncommitted localities have a significantly higher percentage of residents employed in carbon-intensive industries (36.75% versus 23.19%; $t = -24.498$; $p = 0.000$) and emit significantly more HAPs per capita (88.95 versus 23.19; $t = -10.028$; $p = 0.000$). It appears that such economic characteristics do, in fact, limit the capacity of a locality to commit to the CCP initiative.

Table 3. Descriptive statistics and mean comparisons for counties by Cities for Climate Protection (CCP) status.

	CCP status	*N*	Mean	Standard deviation	Standard mean error	Mean difference	*t*
Climate-change-risk variables							
natural hazard casualty	1	112	1.31	3.56	0.34	1.35	4.023
	0	3027	−0.05	0.71	0.01		
temperature change	1	111	2.95	1.26	0.12	0.54	4.402
	0	2989	2.41	1.40	0.03		
coastal proximity	1	112	0.63	0.48	0.05	0.44	9.397
	0	3027	0.20	0.40	0.01		
Socioeconomic variables							
percent net Democrat	1	112	18.76	22.99	2.17	41.75	18.195
	0	2999	−22.99	23.88	0.44		
percent recycle	1	112	39.44	3.98	0.38	4.61	11.815
	0	3028	34.84	5.61	0.10		
nonprofit environmental organization	1	112	0.55	0.98	0.09	0.52	5.604
	0	3028	0.03	0.19	0.003		
HAP emissions per capita	1	112	32.18	21.92	2.07	−56.77	−10.028
	0	2994	88.95	288.28	5.27		
percent carbon employment	1	111	23.19	5.58	0.53	−13.56	−24.498
	0	3024	36.75	8.76	0.16		
Control variables							
percent urban population	1	112	83.56	20.74	1.96	45.63	22.439
	0	2994	37.93	29.72	0.54		
percent college educated	1	111	31.65	9.80	0.93	15.68	16.701
	0	3024	15.97	7.12	0.13		

Notes: All *t*-test results are statistically significant, where $p = 0.000$. Based on *F*-test results, unequal variances are assumed for all variables except percent net Democrat. HAP = hazardous air pollutant.

Comparison of CCP-committed localities and noncommitted localities on climate-change-risk variables also demonstrates significant differences. Results show that almost two thirds (0.63%) of CCP committed counties are defined by NOAA as at-risk coastal, compared to only 20% of noncommitted localities. This difference is statistically significant, where $p = 0.000$. When examining extreme-weather-event history, it is evident that CCP-comitted localities have experienced significantly more death and injury from natural hazards than noncommitted localities ($t = 4.023$; $p = 0.000$). Both committed and noncommitted counties are projected to experience sizable change in average minimum temperature over the next one hundred years, but temperature changes are expected to be significantly higher in CCP-committed counties (2.95°C versus 2.41°C $t = 4.402$; $p = 0.000$). Overall, it seems that CCP-committed localities are marked by greater vulnerability to the risks of climate change. Greater objective risk may explain their willingness to absorb the costs of climate-change protection. Finally, control variables of both percent college educated and percent urban population are positively associated with CCP-enactment-committed localities, are significantly more urban, and contain significantly more educated residents as compared with noncommitted jurisdictions.

In the second phase of analysis we examined a logistic regression model. Table 4 reports binary logistic regression coefficients estimating the odds of CCP commitment. Because there is no direct equivalent to R^2 in logistic regression, variance inflation factors (VIF) cannot be accurately computed. To screen independent variables for multicollinearity, we analyzed zero-order correlations and VIF tests in ordinary least squares regression. No two variables appearing in the model have a correlation of more than 0.585, and all VIF scores are well below acceptable standards (the highest being 2.506). As shown in table 4, coefficient estimates are stable across models—not one variable coefficient reverses direction or shifts considerably in size. We focus our interpretation on the fully saturated model.

Overall, almost 60% of variation in CCP commitment is explained by our suite of variables. Beginning with socioeconomic-capacity measures that reflect local environmental concern, a unit increase in percent net Democrat increases the odds of CCP enactment by a factor of 1.054 ($p = 0.000$). Similarly, a percentage increase in recycling activity boosts the odds of CCP commitment by a factor of 1.093% ($p = 0.046$). A unit increase in the number of nonprofit organizations with an environmental focus (as defined and inventoried by the NCCS) significantly increases the odds of CCP enactment ($p = 0.001$). Taken together, these results suggest that localities with a higher percentage of environmentally concerned and left-leaning residents are significantly more likely to commit to the CCP campaign. When considering variables that undermine a locality's socioeconomic capacity to absorb the costs of climate-change mitigation, results show that a unit increase in the percentage of persons working in carbon-intensive industries decreases the odds of CCP enactment, where $p = 0.092$. In contrast, the estimate for HAP emissions per capita is statistically insignificant in terms of predicting CCP involvement.

Climate-change-vulnerability measures of projected temperature change, record of natural calamity, and coastal proximity are all statistically significant, where $p < 0.05$. For example, a county that has at least 15% of its land area encased in a coastal watershed is 1.817 times more likely to commit to the CCP campaign than a noncoastal county. For every projected °C increase in average minimum temperature from 2004 to 2099 there is a 1.261 increase in the odds of CCP commitment. Results also show a significant positive relationship between a locality's history of natural calamity and CCP-campaign involvement. A unit increase in the hazards casualty factor score,

Table 4. Binary logistic regression coefficients estimating odds of Cities for Climate Protection (CCP) commitment.

	B	exp(B)	B	exp(B)	B	exp(B)
Climate-change-risk variable						
natural hazard casualty	0.526**	1.692	0.472**	1.604	0.363**	1.437
	(0.323)		(0.095)		(0.103)	
temperature change	0.482**	1.620	0.183*	1.201	0.232**	1.261
	(0.081)		(0.110)		(0.111)	
coastal proximity	2.10**	8.163	0.661**	1.936	0.597**	1.817
	(0.226)		(0.267)		(0.289)	
Socioeconomic variables						
percent net Democrat			0.058**	1.060	0.053**	1.054
			(0.007)		(0.007)	
percent recycle			0.162**	1.175	0.089**	1.093
			(0.032)		(0.044)	
nonprofit environmental organization			0.745**	2.106	0.743**	2.102
			(0.231)		(0.230)	
HAP emissions per capita			−0.004	0.996	−0.002	0.998
			(0.004)		(0.003)	
percent carbon employment			−0.095**	0.910	−0.045*	0.956
			(0.021)		(0.027)	
Control variables						
percent urban population					0.018**	1.019
					(0.007)	
percent college educated					0.043**	1.044
					(0.021)	
Constant	−5.570**	0.004	−7.318**	0.001	−8.401**	0.000
	(0.323)		(1.468)		(1.660)	
Nagelkerke R^2	0.231		0.571		0.585	
Model χ^2	195.818		446.802		521.928	
−2 log likelihood	759.211		508.228		433.101	
N	3071		3071		3071	

Notes: Standard errors are shown in parentheses. Null hypothesis test of coefficient equal to zero; HAP = hazardous air pollutant. ** $p < 0.05$; * $p < 0.10$.

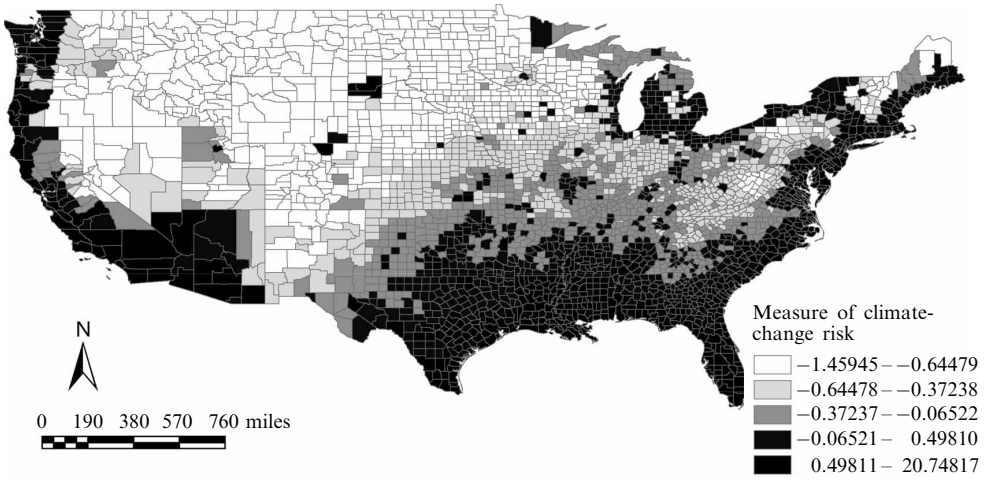
derived from the number of deaths and injuries from extreme weather events, increases the odds of CCP involvement by a factor of 1.437.

Control variables in the model are also significant predictors of CCP involvement. Increasing urban composition and the percentage of college-educated residents are positively and significantly related to CCP enactment. As previously mentioned, the ICLEI launched the CCP campaign as an extension of the Urban CO_2 Reduction Project. As a result, recruitment efforts for the CCP campaign have concentrated (though not exclusively) in urban localities. Results show that a percentage increase in urban composition increases the odds of CCP enactment. Similarly, a percentage increase in the number of residents (aged over twenty five) with at least a bachelor's degree, increases the odds of CCP enactment by a multiplicative factor of 1.044.

Next, to visualize and theoretically simplify the analysis of variation in CCP-campaign involvement, we plotted all localities on the two dimensions of socioeconomic capacity and climate-change vulnerability. All measures of socioeconomic capacity were factor analyzed to derive a principal component. This required the reverse of the scoring measures of HAP emissions per capita and of the percentage employed in carbon-sensitive industries. To derive a principal component of climate-change vulnerability we

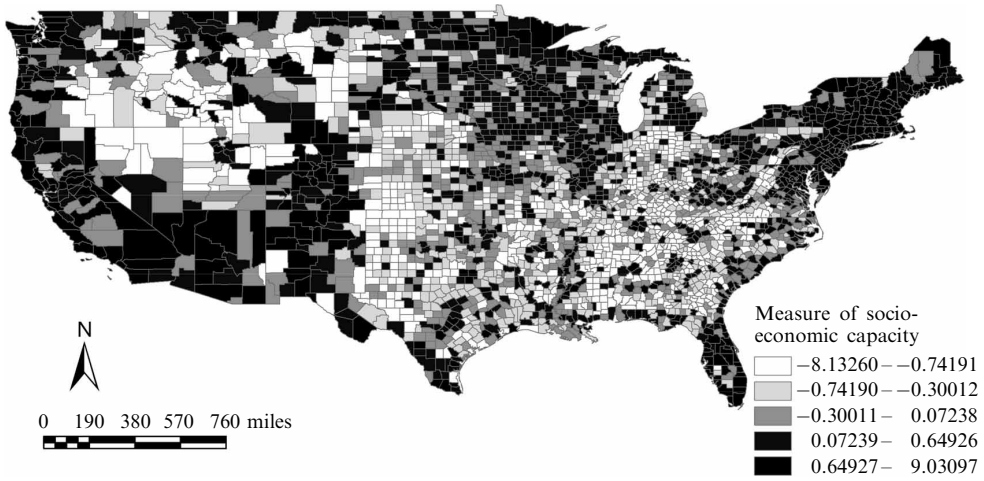
unpacked our natural hazard casualty variable, loading the number of injuries and the number of fatalities as separate variables alongside coastal proximity and expected change in average minimum temperature. Figures 2 and 3 visually display the distribution of climate-change vulnerability and socioeconomic-capacity factors at the county scale. Darker colors reflect higher values and lighter colors reflect lower values. On the geographic relationship between the two dimensions of vulnerability and capacity, the Gulf Coast region of the country is particularly notable—climate-change risks are high and capacities to enact the CCP campaign are relatively low.

The results of scatter plotting socioeconomic-capacity factors and climate-change-vulnerability factors are presented in figure 4. Light-shaded dots represent



Note: Measures of climate-change risk were factor analyzed to derive a principal component, and the distribution of component scores was divided into quintiles; counties are placed in their true location on Earth using longitude and latitude coordinates.

Figure 2. Spatial distribution of climate-change risk at the county scale.



Note: Measures of socioeconomic capacity were factor analyzed to derive a principal component, and the distribution of component scores was divided into quintiles; counties are placed in their true location on Earth using longitude and latitude coordinates.

Figure 3. Spatial distribution of socioeconomic capacity at the county scale.

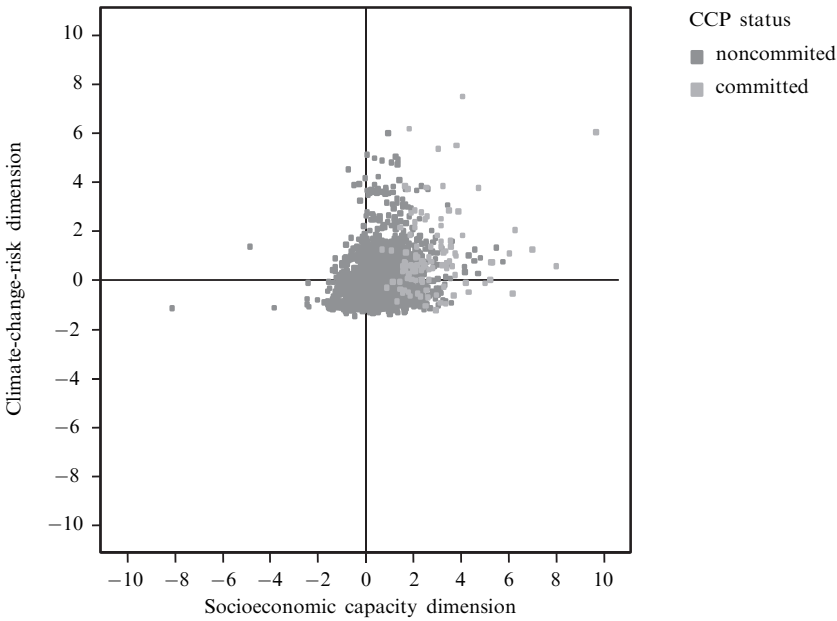


Figure 4. Scatter plot of climate-change risk and socioeconomic capacity by Cities for Climate Protection (CCP) status.

CCP-committed localities and dark-shaded dots represent noncommitted localities. By dividing the scatter plot into quadrants of high – high, low – low, low – high, and high – low, the recruitment dilemma for the CCP campaign becomes clear. No jurisdiction with comparatively low socioeconomic capacity and low climate-change risk is party to the CCP campaign. In fact, not one locality on the negative side of socioeconomic capacity (low – high quadrant) is among the list of committed areas. In contrast, almost all committed localities are comparatively high on dimensions of socioeconomic capacity and vulnerability to the risks of climate change. Based on our visual results, it appears that localities falling into the high – high quadrant are most likely to commit to the CCP campaign and that socioeconomic capacity, in particular, may be a necessary precondition for CCP involvement.

Conclusion

The results of our study indicate that specific geographic and socioeconomic characteristics motivate local jurisdictions to participate in the CCP campaign. Understanding these motivators and the general profile of jurisdictions committed to climate-change policy provides important insights for policy makers who are interested in reducing greenhouse gas emissions at the local level. First, public decision makers appear to be aware of the physical threat and geographic vulnerabilities associated with climate change. Proximity to the coast and previous casualties from natural hazards such as floods and hurricanes are powerful triggers for CCP involvement. Because global climate change is most often associated with sea-level rise/inundation and increased storm frequency, we expect policy makers to be most receptive to these types of vulnerabilities. The fact that expected warming trends correlate with CCP involvement is a positive indicator that local jurisdictions are cognizant of climate-change threats, to the degree that they are willing to take action. Overall, our results indicate that the effects of place and proximity selectively motivate participation in the CCP campaign, and that, from a pure risk-aversion standpoint, it appears that CCP-committed

localities are responding to the threats of climate change and variability. Highlighting coastal communities that are most vulnerable to sea-level rise and storm surge and also making them aware of potential threats may help increase the level of participation in the CCP campaign.

Second, the socioeconomic makeup of a local jurisdiction appears to be a primary motivator of local participation in the CCP program. Specifically, we observe that well-educated, politically liberal, urban communities, with a strong record of environmental activities, appear more supportive of policies to mitigate the adverse consequences of climate change. Organized environmental activities facilitate a public sensitivity to climate-change issues, which may better enable public decision makers to gain support for participation in the CCP. Further, linking environmental activities to the issue of climate change may thus provide an effective strategy for policy makers interested in their locality becoming involved in CO_2 reduction programs. From a collective-action perspective, the logic behind inclusion of environmental-action variables in prediction models is that officials and functionaries in localities with environmentally concerned residents selectively benefit from joining the CCP campaign in terms of satisfaction of citizen preferences. Officials in such localities are more likely to receive political rewards for enacting environmentally friendly policies.

Third, our results suggest that localities with a combination of high geographic risk and socioeconomic capacity associated with climate change are the most willing participants in the CCP campaign. As shown in figure 4, communities falling into the high – high quadrant are the most likely candidates to embrace the idea of taking action to mitigate the adverse impacts of climate change. Thus, if participation remains voluntary, recruitment should focus on localities that appear in the high – high quadrant of the plot. Such localities have greater incentive to enact reforms. Since committed localities represent only 14.7% (85 of 577) of all the jurisdictions with this high – high profile, there is an opportunity for CCP officials to target these likely recruits to increase the number of participants in the program. These high – high-quadrant communities thus represent the 'low-hanging fruit' in a strategy to broaden the level of participation in the CCP or similar programs. Another policy implication stemming from the results shown in figure 4 is the fact that several localities involved in the CCP are on the lower side of the physical risk dimension (high – low quadrant). This finding is a signal to policy makers in the US, as it shows that inland communities that are less exposed to the threats of climate change can also be recruited into the CCP campaign. Decision makers who are interested in climate-change policy could, conceivably, target less vulnerable localities with a high degree of socioeconomic capacity. In general, recruiting jurisdictions outside of the high – high quadrant will require greater incentives for participation. These incentives could include clarifying the collateral risks that all localities face when vulnerable communities are hit.

Advanced economies like the United States are spatially integrated and coastal. According to Rappaport and Sachs (2003, page 5) the United States is, increasingly, a coastal nation. Coastal counties account for over 50% of the US population and hold a disproportionate share of total civilian income and productive enterprise. Natural disasters such as Hurricane Katrina, that strike coastal localities, produce effects that reverberate across the country. These effects are most apparent in the disruption of supply chains that produce price spikes for desirable commodities. These effects harm all. The vulnerability of localities to supply-chain failures that are related to climate-change-induced natural calamities may be a good device to persuade involvement in the CCP campaign.

While this study provides several insights into why a local jurisdiction in the US might participate in the CCP to mitigate the adverse impacts of climate change,

it should be considered as being only a first step in examining the topic of policy enactment. First, we analyzed only a few geographic indicators of vulnerability associated with climate change. Future research should include additional measures and should map them at various levels of spatial specificity, from higher aggregations like metropolitan areas to lower levels such as census tracts and block groups. A detailed map showing the degree of vulnerability for every local community in the US, based on a range of indicators (in addition to the summary maps we render), would help to inform communities about the possible consequences of climate change and would possibly motivate them to take corrective actions. Second, we analyzed a limited number of socioeconomic characteristics that may enable a locality to adopt climate-change policies. Future studies should expand this number and should explore other socioeconomic and demographic factors that may be important motivators for jurisdictions to engage in programs such as the CCP. Third, our analysis of every county in the US provides important information at the broad statistical level, but is limited when it comes to understanding local contextual factors. Future research should select communities falling in the high – high quadrant in figure 4 for case-study analysis. This research approach will provide a detailed level of contextual understanding of the factors motivating local CCP participation that broad statistical analysis cannot accomplish. Finally, our study examined only whether a locality is involved in the CCP campaign. Additional study should be done on the specific policies that these jurisdictions have adopted and the degree to which they are being implemented throughout the community.

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