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The Effects of Weather on Massachusetts Municipal Expenditures: Implications of Climate Change for Local Governments in New England

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Table of Contents

Executive Summary 3
I. Introduction 4
II. Weather Patterns 5
III. The Impact of Weather on Municipal Expenditures 9
IV. Implications of Climate Change for Municipal Governments 10
V. Policy Discussion 14
VI. Conclusion 16
References 17
Appendix 18

EXECUTIVE SUMMARY

In New England, municipal governments provide a variety of public services that are vital to residents and businesses, such as public works, police and fire services, and general government administration. However, the region and its local governments face an increasing threat from climate change. As recorded by the National Oceanic and Atmospheric Administration, New England states have become hotter and wetter and have experienced an increased number of extreme precipitation events since 1900. Rising temperatures and more frequent extreme precipitation events are projected for the region through the end of this century. These changes in weather conditions could damage public infrastructure, disrupt the delivery of public services, and increase the costs of snow removal, road maintenance, the heating and cooling of public buildings, and other local services.

Using Massachusetts data from 1990 through 2019, this report examines how weather affects municipal expenditures. It finds that temperature and precipitation have a significant impact on local spending. Based on the estimated historical relationship between temperature and local spending, the report finds that municipal expenditures will increase considerably in the coming decades as a result of projected rising temperatures. These cost increases could create significant fiscal stress on municipalities and force them to raise taxes and fees.

Among the findings highlighted in this report is that during the 1990–2019 period, a 1 degree Fahrenheit increase in average temperature, on average, resulted in a 3.2 percent increase in per capita municipal general-fund expenditures in Massachusetts. During the same period, a 1 percentage point increase in the percentage of days in each year with at least 1 inch of snowfall, on average, led to an increase in per capita municipal expenditures of about 0.4 percent. This report estimates that if global emissions continue to grow at their current rates, resulting in significantly higher temperatures in Massachusetts, per capita annual municipal expenditures will increase 30 percent for the 2090–2099 decade relative to average per capita annual municipal expenditures for the 1990–2019 period. Given the substantial similarities in fiscal structures and weather patterns throughout New England, these findings are likely to apply to other states in the region.

This report recommends that municipalities account for climate change in their long-term municipal financial planning, since early policy actions are often more cost effective than later ones. Investing in improvements to the climate resilience of public infrastructure is important, and it is particularly urgent for New England, given how dated the region's infrastructure systems are.

I. Introduction

The New England region has already begun to experience long-term changes in its weather conditions. It has become hotter and wetter and has seen more frequent extreme precipitation events over the past century (Kunkel et al. 2022). The average temperature in each New England state has risen 3 to 4 degrees Fahrenheit since 1900, and annual precipitation has generally increased since 1895. A record number of extreme precipitation events occurred during the 2005–2014 period. Climate scientists at the National Oceanic and Atmospheric Administration (NOAA) project that temperatures and the frequency and intensity of heat waves and extreme precipitation events in New England will continue to increase in the coming decades.

Municipal expenditures will increase considerably in the coming decades as a result of projected rising temperatures.

Previous research suggests that changes in weather conditions have a significant impact on economic and social activities, especially for low-income areas. Hsiang et al. (2017) show that an increase in the average temperature leads to a reduction in GDP and employment. The negative effect of a higher average temperature on economic growth is stronger for low-income countries and may decrease their political stability (Dell, Jones, and Olken 2012). Extreme high temperatures are also found to increase mortality; therefore, climate change is expected to raise the mortality rate (Deschenes and Greenstone 2011). The largest mortality increases will likely occur in places where temperatures are already high and poverty is prevalent (Carleton et al. 2022). In addition, Ranson (2014) finds that higher temperatures result in more criminal activities.

Using Massachusetts data, this report examines the impact of weather on local government spending, a subject that has not been studied previously. Municipal governments are important economic agents because they provide a wide range of public services, such as snow removal, road maintenance, police and fire services, and general government administration. These services are critical for maintaining residents' quality of life and businesses' smooth operation. It is important to understand how weather affects spending on these local services. Informed by such an understanding, this report makes a projection of the future impact of climate change on local budgets. It then discusses municipal policy actions for mitigating and adapting to climate change.

This report shows that weather has a significant impact on municipal expenditures in Massachusetts. A 1 degree Fahrenheit increase in average temperature, on average, results in a 3.2 percent increase in per capita municipal expenditures from the general fund. A 1 percentage point increase in the percentage of days in each fiscal year with at least 1 inch of snowfall, on average, raises municipal expenditures by 0.4 percent. Public works and general government are shown to be the two most affected government functions, likely because they are directly involved in snow removal, road maintenance, and the heating and cooling of public buildings. Furthermore, municipal expenditures will likely increase considerably by the end of this century as a result of rising temperatures. If global emissions continue growing at their current rates, average per capita municipal expenditures for the 2090–2099 period are projected to be 30 percent, or $924, higher than average per capita municipal expenditures for the 1990–2019 period. It will be difficult for municipalities to absorb these added costs without significantly increasing taxes and fees. This report recommends that municipalities account for climate change in their long-term financial planning and invest in improvements to public infrastructure so that it becomes more adaptative to climate change.

The findings of this report are applicable throughout New England, as all the region's states have similar fiscal structures and weather patterns. Each has either no or an extremely limited county government, and as a result, municipal governments provide almost all local public services. In addition, school districts in New England depend fiscally on municipal governments, which also distinguishes the region from the rest of the United States. School districts in New England have no legal authority to raise taxes; instead, their revenues rely on municipal appropriations and state grants. The New England states have experienced similar increases in temperature and precipitation since the beginning of the 20th century (Kunkel et al. 2022), and they are all projected to see higher temperatures and more extreme precipitation events in future decades. Furthermore, their recent policy responses to climate change have been similar. For example, they have accelerated weatherizing public buildings and improving their energy efficiency. I provide a more comprehensive discussion of regional efforts later in the report.

II. Weather Patterns

Massachusetts municipalities have experienced changes in weather patterns over the last 30 years. Overall, their average temperatures and annual precipitations have trended upward since fiscal year (FY) 1990. Days with extremely hot temperatures or extreme precipitation have become more common. Though municipalities' long-term weather patterns share a similar trend, they are considerably different across regions of the state.

Massachusetts has become hotter and wetter and experienced more frequent extreme weather events over time. From FY1990 through FY2019, the annual average temperature increased 0.04 degree Fahrenheit per year, on average, across the state's municipalities (Figure 1a).[1] Over the same 30-year span, the share of days in each fiscal year that reached or exceeded 90 degrees Fahrenheit rose 0.015 percentage point per year, on average (Figure 1b). Meanwhile, annual precipitation increased 0.08 inch per year, and the share of days with at least 1 inch of precipitation rose 0.017 percentage point per year, on average, across Massachusetts municipalities (Figures 1c and 1d).

> Massachusetts has become hotter and wetter and experienced more frequent extreme weather events over time.

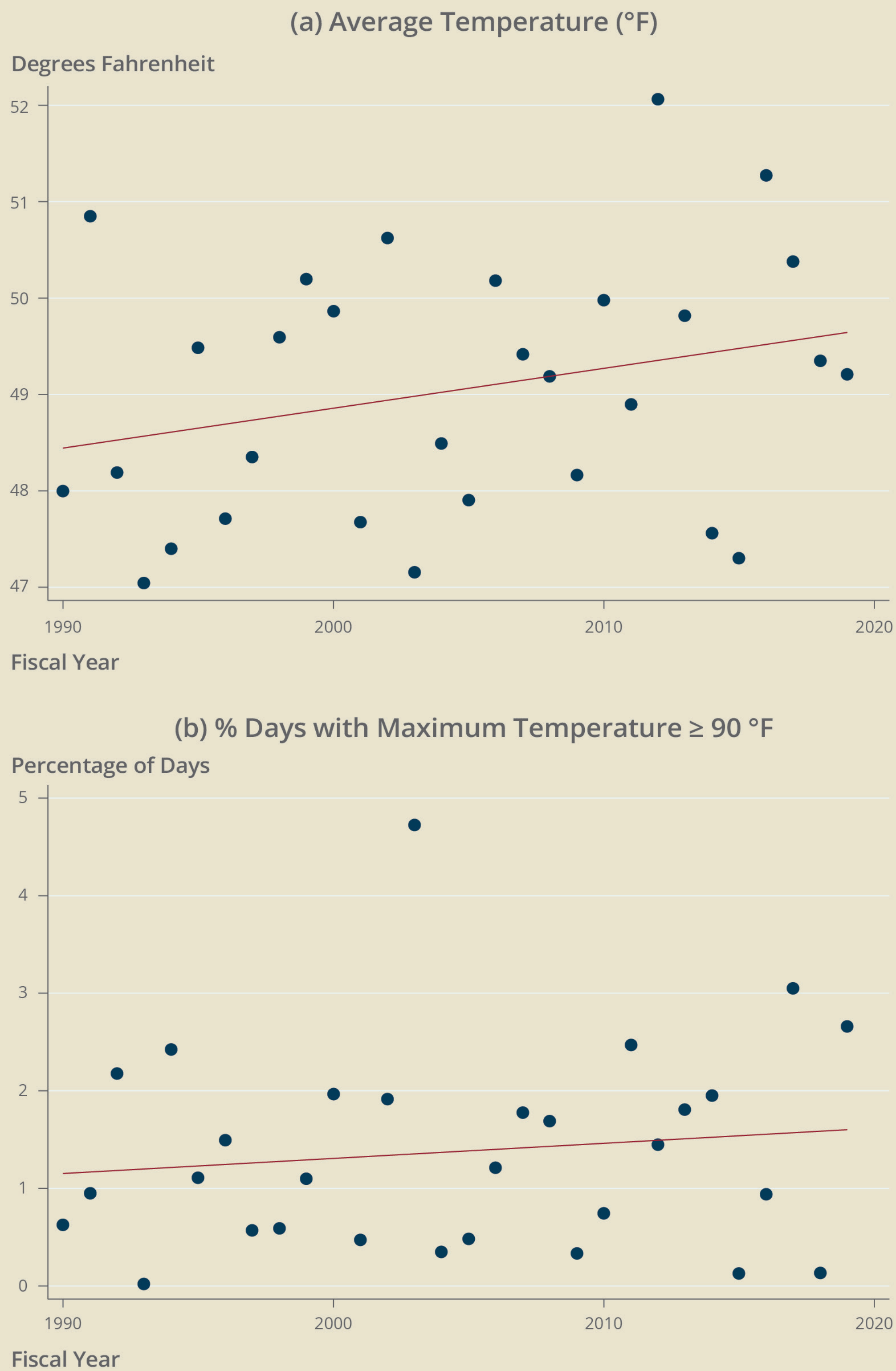
These observations are consistent with a recent assessment of Massachusetts's climate from the NOAA (Kunkel et al. 2022). It finds that the state's average temperature has risen nearly 3.5 degrees Fahrenheit since 1900 and that the average annual precipitation for the 1970–2020 period was greater than that for the 1895–1969 period by about 4.7 inches.

Long-term weather patterns show considerable regional differences in the state. Municipalities in eastern Massachusetts experienced higher average temperatures from FY1990 through FY2019 compared with cities and towns in the western portion of the state (Figure 2a). Municipalities in the southern part of the state tended to have more annual precipitation over that 30-year period compared with cities and towns in the north (Figure 2b).

1 See the Appendix for details on how the weather data for each municipality were constructed.

Figure 1

Massachusetts Weather Trends, 1990–2019



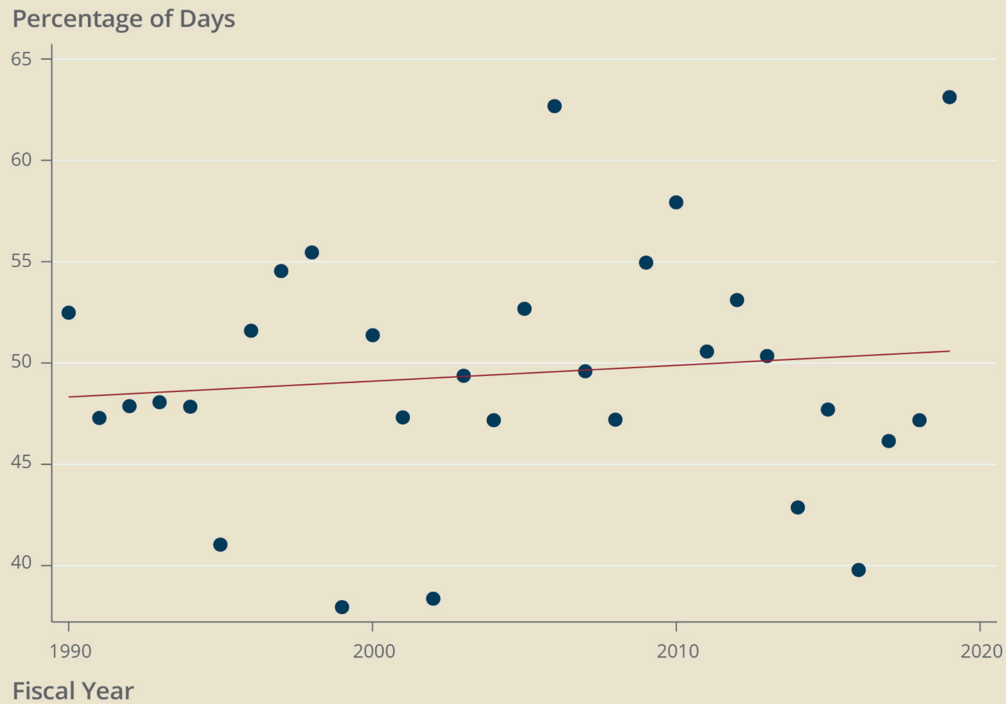
Note(s): Yearly values are calculated as the average of the 350 municipalities in the sample. The red line in each plot represents a univariate regression on fiscal year.

Source(s): Global Historical Climatology Network daily

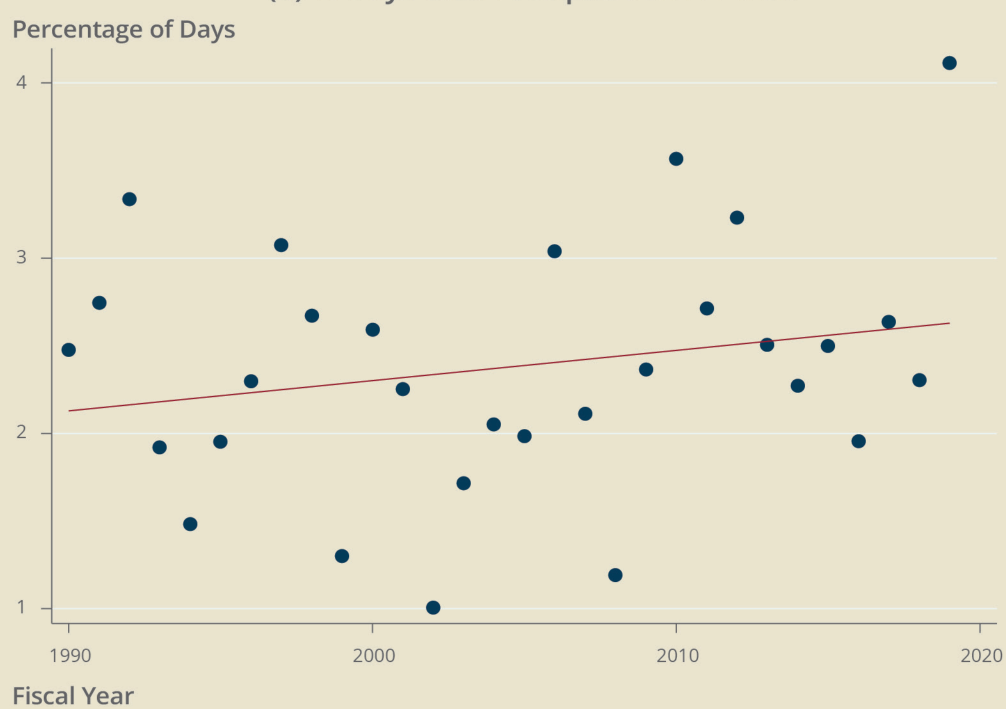
Figure 1
Continued

Massachusetts Weather Trends, 1990–2019

(c) Total Precipitation (Inches)



(d) % Days with Precipitation ≥ 1 Inch

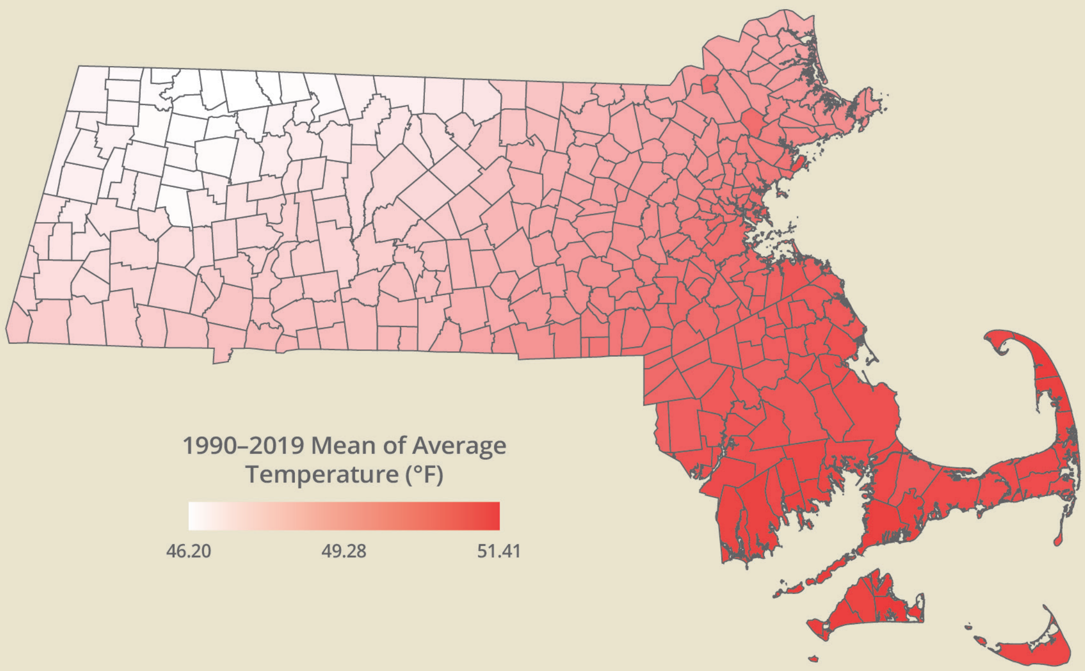


Note(s): Yearly values are calculated as the average of the 350 municipalities in the sample. The red line in each plot represents a univariate regression on fiscal year.

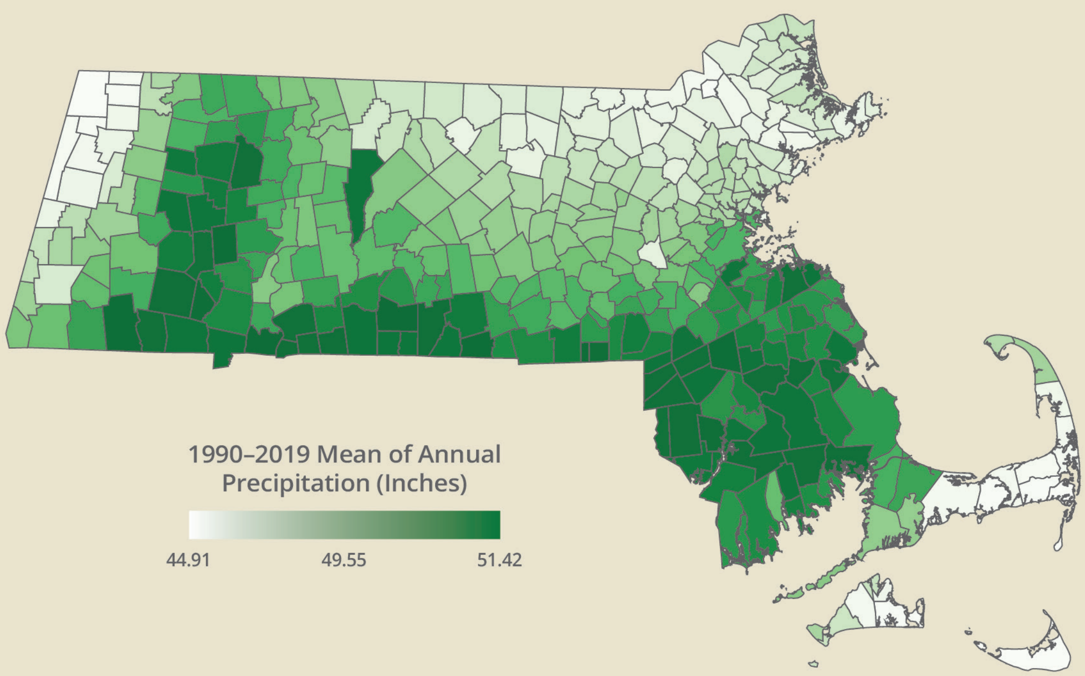
Source(s): Global Historical Climatology Network daily

Figure 2 Regional Differences in Long-term Weather Patterns

(a) Average Temperature



(b) Annual Precipitation



Source(s): Global Historical Climatology Network daily

III. The Impact of Weather on Municipal Expenditures

I use a statistical method to systematically analyze the relationship between weather and government spending among Massachusetts municipalities over the last three decades. The analysis shows that temperature and precipitation have a significant impact on municipal expenditures, with this impact varying by government function and by community type.

I use regression analysis to examine the effects of weather on municipal general-fund expenditures during the FY1990–FY2019 period.[2] This approach controls for per capita property tax base, per capita state grants, and other confounding factors that may be corrected with weather variables.[3] This enables me to interpret the regression results as causal effects of weather on local government spending.

The regressions show that weather has a statistically significant and economically meaningful impact on municipal expenditures (Table 1). A 1 degree Fahrenheit increase in annual average temperature, on average, results in a 3.2 percent increase in inflation-adjusted per capita total general-fund expenditures. The average Massachusetts municipality spent $3,108 per capita per year (in 2019 dollars) in total general-fund expenditures over the FY1990–FY2019 period. For this level of yearly spending, a 3.2 percent increase represents an additional $100 of per capita expenditures. Total expenditures also appear to be affected by the frequency of extremely cold days and heavy snowfalls. A 1 percentage point increase in the percentage of days with a maximum temperature of 32 degrees Fahrenheit or colder or in the percentage of days with at least 1 inch of snowfall, on average, leads to an increase in per capita total expenditures of about 0.4 percent. This amounts to an increase of about $12 per capita in 2019 dollars for the average Massachusetts municipality.

Among the government functions supported by the general fund, public works, general government, and human services are more affected by weather than others (Table 2). For example, spending on public works increases with annual average temperature and total snowfall. The latter result conforms to the common understanding that more snowfall generates higher costs for snow removal and road maintenance.

In addition, weather affects different types of communities to differing extents. Massachusetts coastal communities are highly vulnerable to damage from nor'easters, tropical storms, and hurricanes (Kunkel et al. 2022). Indeed, Zhao (2022) suggests that an increase in the percentage of days with at least 1 inch of precipitation results in larger municipal expenditures for coastal municipalities than for inland municipalities. Climate experts warn that densely populated urban areas are more vulnerable to the effects of heat waves, storms, and flooding (Kunkel et al. 2022). However, the results in Zhao (2022) paint a mixed picture of the effects of weather on the spending of densely populated urban areas relative to the spending of sparsely populated rural areas. On the one hand, an increase in the percentage of days with at least 1 inch of precipitation results in more government spending in high-density areas than in low-density areas. On the other hand, government spending in high-density areas appears to be less affected by increases in average temperature, annual precipitation, and the frequency of extremely cold days. This is likely because these high-density communities enjoy greater economies of scale, and their economic structures depend less on weather compared with the economic structures of low-density rural areas where agriculture still plays an important role.

2 The general fund accounts for most financial activities that are governed by normal municipal appropriations and that support daily government operations. It is outside the scope of this paper to study other government funds, such as enterprise funds and capital projects funds.

3 I include municipality fixed effects to control for unobserved municipal characteristics that were constant over time. I also include fiscal-year fixed effects to control for shocks shared by all Massachusetts municipalities in each fiscal year, such as business cycles and state policy changes. In addition, I include a time trend that is specific to each municipality to account for the possibility that municipalities' spendings were on different time paths.

Table 1 The Impact of Weather on Total General Fund Expenditures

	Total Expenditures
Temperature	
Average Temperature (°F)	0.0323*** (0.00827)
% Days with Maximum Temperature ≥ 90 °F	0.00131 (0.00179)
% Days with Maximum Temperature ≤ 32 °F	0.00406*** (0.000936)
Precipitation	
Total Precipitation (Inches)	0.0000105 (0.000496)
% Days with Precipitation ≥ 1 Inch	−0.00323 (0.00228)
Total Snowfall (Inches)	−0.000106 (0.000117)
% Days with Snowfall ≥ 1 Inch	0.00420*** (0.00162)
N	10,500

Note(s): Dependent variables are in log real per capita dollars. Regressions control for fiscal-year fixed effects, municipality fixed effects, municipality-specific linear time trends, log real per capita equalized valuations, and log real per capita state grants. Standard errors are in parentheses and are clustered by municipality.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Author's calculations

IV. Implications of Climate Change for Municipal Governments

With climate change, average temperatures are expected to rise in the coming decades. Based on the historical relationship between temperatures and local spending, rising temperatures will likely increase Massachusetts's average per capita municipal expenditures by as much as 30 percent by the end of the century relative to average expenditures for the 1990–2019 period. These cost increases could create significant fiscal stress for local governments.

The Climate Explorer, created by the NOAA Climate Program Office, provides annual projections for county-level temperatures, precipitation, and other climate conditions out to the year 2100.[4] The projections were made under two scenarios of global emissions of heat-trapping gases. Under the "high-emissions" scenario, global emissions will continue growing at current rates.[5] This is sometimes known as the "business-as-usual" path. Under the "low-emissions" scenario, global

4 The Climate Explorer website, Frequently Asked Questions, accessed September 21, 2022, https://crt-climate-explorer.nemac.org/faq/.

5 This scenario is also known as the Representative Concentration Pathway 8.5 (RCP 8.5), in which the atmosphere's radiative forcing level in 2100 is at least 8.5 watts per square meter greater than pre-industrial-era values.

Table 2 The Impact of Weather on Expenditure Subcategories

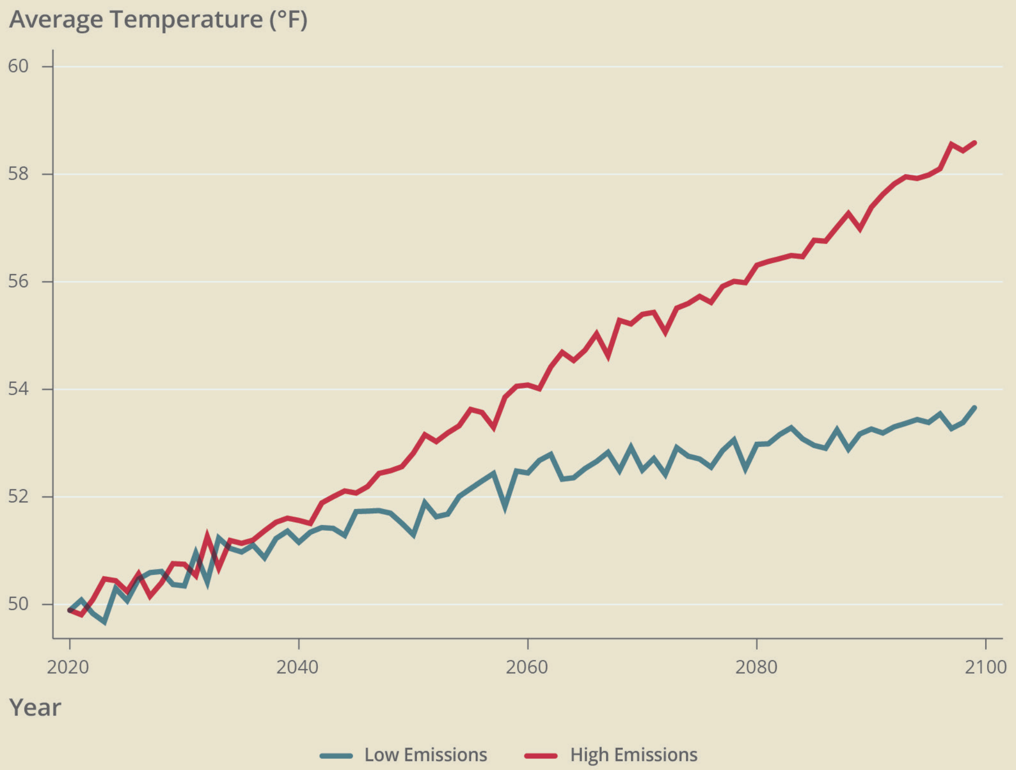
	Public Works	General Government	Education	Police	Fire	Human Services	Culture and Recreation
Temperature							
Average Temperature (°F)	0.0840*** (0.0188)	0.0577*** (0.0138)	0.0136 (0.0103)	0.0231 (0.0176)	0.0400* (0.0222)	−0.0617** (0.0274)	0.0268 (0.0231)
% Days with Maximum Temperature ≥ 90 °F	−0.000683 (0.00420)	0.00650 (0.00413)	0.00366 (0.00242)	0.00530 (0.00411)	−0.00568 (0.00622)	0.00157 (0.00737)	−0.00673 (0.00526)
% Days with Maximum Temperature ≤ 32 °F	−0.00101 (0.00265)	0.00399* (0.00205)	0.00229* (0.00121)	−0.00275 (0.00244)	0.000710 (0.00460)	0.0120*** (0.00416)	0.00720** (0.00312)
Precipitation							
Total Precipitation (Inches)	−0.000230 (0.00105)	0.000174 (0.000867)	0.0000128 (0.000628)	0.00203** (0.000959)	0.00115 (0.00141)	−0.00187 (0.00269)	−0.000611 (0.00138)
% Days with Precipitation ≥ 1 Inch	0.00108 (0.00467)	−0.00375 (0.00419)	−0.00477 (0.00407)	−0.000899 (0.00402)	−0.000260 (0.00604)	0.0246** (0.0105)	−0.00146 (0.00685)
Total Snowfall (Inches)	0.00168*** (0.000305)	0.000123 (0.000264)	−0.000471 (0.000341)	−0.000317 (0.000257)	−0.000322 (0.000579)	−0.000554 (0.000657)	0.000141 (0.000434)
% Days with Snowfall ≥ 1 Inch	0.00527 (0.00420)	0.00828** (0.00342)	0.00225 (0.00221)	0.00438 (0.00360)	−0.00299 (0.00709)	0.000560 (0.00920)	−0.00204 (0.00579)
N	10,500	10,500	10,500	10,410	10,080	10,470	10,410

Note(s): Dependent variables are in log real per capita dollars. Regressions control for fiscal-year fixed effects, municipality fixed effects, municipality-specific linear time trends, log real per capita equalized valuations, and log real per capita state grants. Standard errors are in parentheses and are clustered by municipality.

*p < 0.10, **p < 0.05, ***p < 0.01

Source(s): Author's calculations

Figure 3 Projections for Massachusetts Average Temperature



Note(s): Annual projections for Massachusetts are calculated by aggregating county-level projections to the state level using county areas as weights. The high-emissions projection (also known as RCP 8.5) reflects growth in emissions at current rates, whereas the low-emissions projection (RCP 4.5) reflects a serious reduction in emissions through the end of the 21st century.

Source(s): National Oceanic and Atmospheric Administration Climate Program Office

emissions will peak around 2040 and afterward remain relatively stable.[6] This would require a substantial reduction in emissions through the end of the 21st century.

I focus on projections for the average temperature, since the regressions suggest that it has the most significant impact on local spending.[7] Figure 3 indicates that the annual average temperature in Massachusetts is projected to rise in future decades under either scenario.[8] It will likely rise from about 50 degrees Fahrenheit in 2020 to nearly 54 degrees Fahrenheit under the low-emissions scenario and almost 59 degrees Fahrenheit under the high-emissions scenario by the end of this century.

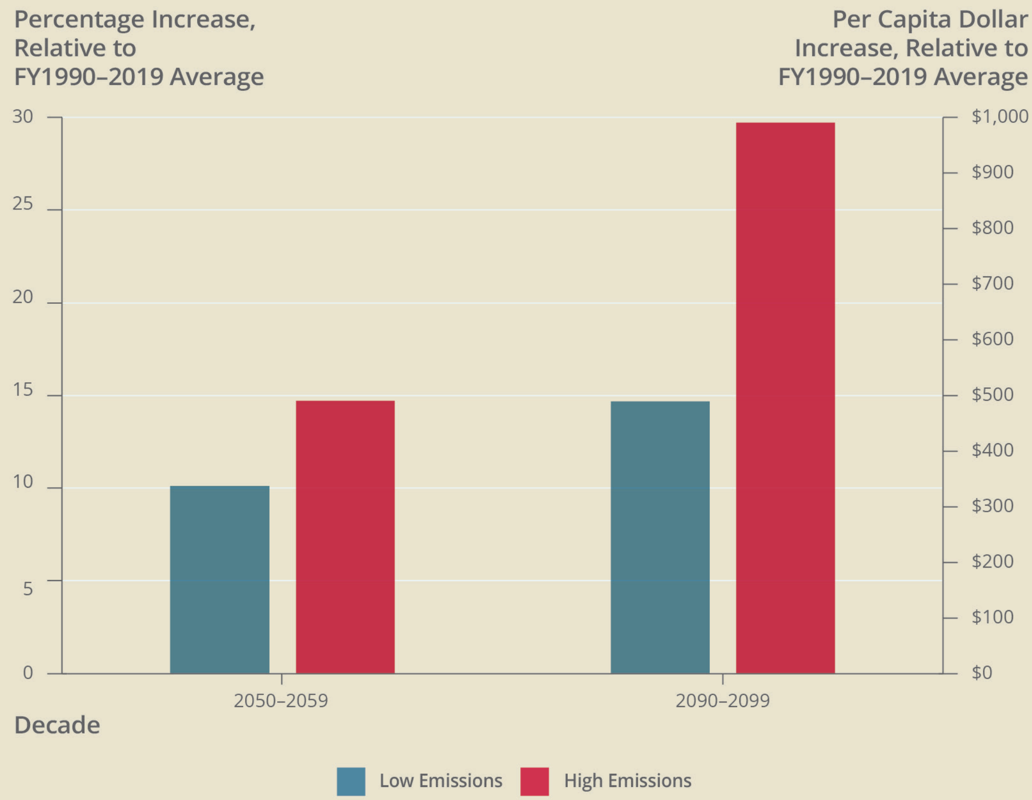
A couple of caveats should be noted when using the regression model to project the fiscal impact of climate change. First, the regression coefficients in Tables 1 and 2 are identified based on year-over-year changes in weather conditions. These short-term weather changes may affect government costs differently compared with the long-term changes associated with climate change. If that is true, the regression results will not be entirely applicable to projecting the impact of climate change. Second, because the regression model was estimated based

6 This scenario is also known as the Representative Concentration Pathway 4.5 (RCP 4.5), in which the atmosphere's radiative forcing level in 2100 is 4.5 watts per square meter greater than pre-industrial-era values.

7 The projections for the annual average temperature are derived by taking an average of the projected annual average maximum and minimum daily temperatures.

8 I use county area as the weight to calculate the weighted mean as the average temperature for the state.

Figure 4 Projected Impact of Temperature Increases on Massachusetts Municipal Expenditures in Future Decades



Source(s): See Appendix Table 1

on historical data, using it to make projections assumes implicitly that the relationship between weather and local spending in the future will be the same as it was in the past. However, that may not be the case. In fact, Zhao (2022) finds some evidence that Massachusetts municipal governments have adapted and become less sensitive to temperature over the past 30 years. Thus, the fiscal projections based on the regression results should be treated as directional guidance rather than as precise forecasts.

Figure 4 illustrates the impact of projected temperature increases on Massachusetts municipal expenditures for future decades.[9] The figure depicts two future decades: a mid-century decade (2050 through 2059) and the last decade of the century (2090 through 2099). The Climate Explorer creators recommend using decadal averages as a more reliable alternative to annual projections, since annual projections could have large margins of error. With the projected rise in temperatures, municipal expenditures are estimated to increase 10 to 15 percent for the 2050–2059 period and 15 to 30 percent for the 2090–2099 period relative to the 1990–2019 period. In terms of dollar changes from average per capita annual expenditures for the 1990–2019 period, projected temperature increases are estimated to raise municipal expenditures by $314 to $457 per capita (in 2019 dollars) for the 2050–2059 period and by $456 to $924 per capita (in 2019 dollars) for the 2090–2099 period. These large increases could have a significant impact on the fiscal health of local governments and may be difficult or impossible to accommodate without significant increases in taxes and fees.

9 Appendix Table 1 shows how the impact of projected temperature increases on Massachusetts municipal expenditures is calculated.

V. Policy Discussion

A robust policy response is necessary to address the impact of climate change on municipalities. Some research suggests that early actions are important and often more efficient than later ones in alleviating future impact (Catalano, Forni, and Pezzolla 2020). It is more cost effective to reduce emissions and adapt proactively, but such policy may not have received sufficient emphasis in current municipal budgets. Thus, municipalities should take into account climate change in their long-term financial planning. It is important to make efforts to "climate-proof" public infrastructure, such as roads, public buildings, and water and sewer systems.

In recent years, New England states and many municipalities in the region have actively pursued ways to address the challenges presented by climate change. For example, they have endeavored to reduce emissions of heat-trapping gases. Transportation is one of the largest sources of emissions in the region (Massachusetts Executive Office of Energy and Environmental Affairs 2022). To reduce emissions from transportation, states and municipalities have expanded and upgraded or plan to expand and upgrade bicycle and pedestrian infrastructure and public transit. The Massachusetts Department of Transportation committed $240 million in 2018 to fund additional sidewalks and bike lanes (Massachusetts Executive Office of Energy and Environmental Affairs, Massachusetts Executive Office of Public Safety and Security, and Massachusetts Emergency Management Agency 2018). Vermont runs a program called VTrans that awards money to bicycle and pedestrian infrastructure programs.[10] Connecticut aims to deploy a fleet of municipal vehicles that is 100 percent electric by 2030 and operate a bus fleet that is entirely electric by 2035.[11] On the local level, Worcester, Massachusetts, recently partnered with a nonprofit and a state agency to run a pilot program providing 100 free e-bikes to residents,[12] and Burlington, Vermont, offers a $200 rebate to any resident purchasing an e-bike.[13] Many states offer subsidies for the purchase of electric vehicles. These policies are designed to encourage alternative transit modes that use cleaner energy and less energy than gas-fueled cars.

> New England states and many municipalities have actively pursued ways to address the challenges presented by climate change.

Heating and cooling buildings is another major source of emissions in the region (Massachusetts Executive Office of Energy and Environmental Affairs 2022). States and many municipalities have accelerated weatherizing public buildings and improving their energy efficiency. For example, in June 2022, Maine launched a $15 million initiative to fund improvements to heating and cooling systems in public schools, municipal buildings, and nonprofit residential facilities.[14] Through its Lead by Example program, Connecticut has provided more than $117 million to fund energy improvements to state agency buildings since 2012, including retrofitting heating and cooling systems, installing LED lighting, and improving insulation.[15]

10 State of Vermont Agency of Transportation website, Bicycle and Pedestrian Program, accessed September 21, 2022, https://vtrans.vermont.gov/highway/local-projects/bike-ped/.

11 The Office of Governor Ted Lamont press release, "Governor Lamont Signs Executive Order Directing Connecticut State Agencies To Implement Actions That Reduce Carbon Emissions and Adapt to Climate Crisis," December 16, 2021, https://portal.ct.gov/Office-of-the-Governor/News/Press-Releases/2021/12-2021/Governor-Lamont-Signs-Executive-Order-Directing-Connecticut-State-Agencies-To-Implement-Actions.

12 MassBike website, Worcester E-Bike Program, accessed September 21, 2022, https://www.massbike.org/ebikeworcester.

13 Burlington Electric Department website, E-Bikes, accessed September 21, 2022, https://www.burlingtonelectric.com/ebike.

14 State of Maine Office of Governor Janet T. Mills press release, "Governor Mills and Efficiency Maine Announce $15 Million Maine Jobs and Recovery Plan Initiative to Cut Energy Costs in Schools and Public Buildings," June 17, 2022, https://www.maine.gov/governor/mills/news/governor-mills-efficiency-maine-announce-15-million-maine-jobs-recovery-plan-initiative-cut.

15 Connecticut Department of Energy and Environmental Protection website, Lead by Example: Improving Energy Management at State Facilities, accessed September 21, 2022, https://portal.ct.gov/DEEP/Energy/Lead-By-Example/Lead-By-Example.

Another popular strategy for emission reduction is to increase the use of cleaner and renewable energy to replace fossil fuels. For example, Maine[16] and Rhode Island[17] have committed to purchasing 80 percent and 100 percent, respectively, of their electricity demand from providers of renewable energy by 2030. West Warwick, Rhode Island, recently became the first municipality in the state to source 100 percent of its electricity from local providers of solar and wind power.[18]

Municipalities across the region have also been actively adapting to climate change. In addition to improving the heating and cooling systems of public buildings, many have updated their zoning codes to move housing away from areas with an increasing flood risk. Meanwhile, states have played an important role in providing technical and financial support and helping municipalities better prepare for climate change. For example, the state of Rhode Island requires members of local planning commissions to complete training modules through a program called Prep-RI, which educates them about the risks of development in areas prone to flooding.[19] Massachusetts runs a Municipal Vulnerability Preparedness (MVP) grant program to help cities and towns evaluate their risk level and prepare for climate change. At least 335 municipalities, accounting for 99 percent of the state's population, have received such grants.[20] Furthermore, the MVP grant program in Massachusetts, the Climate Resilience Fund in Rhode Island, and the Infrastructure Adaptation Fund in Maine have funded many local projects to protect against climate change. For example, Falmouth, Massachusetts,[21] and Warren, Rhode Island,[22] received grants from their respective states to remove dams and restore the flood plains around rivers in their jurisdictions. In 2022, Maine granted a total of $20 million to 13 municipalities to make improvements to stormwater and wastewater facilities.[23] These projects will increase natural water-storage capacity and help prepare for extreme precipitation and rising sea levels. In addition, many municipalities have received state grants to plant more trees to provide shade and help reduce the number of "heat islands" in densely populated areas.[24]

16 State of Maine Office of Governor Janet T. Mills press release, "Governor Mills and Efficiency Maine Announce $15 Million Maine Jobs and Recovery Plan Initiative to Cut Energy Costs in Schools and Public Buildings," June 17, 2022, https://www.maine.gov/governor/mills/news/governor-mills-efficiency-maine-announce-15-million-maine-jobs-recovery-plan-initiative-cut.

17 State of Rhode Island Governor Gina M. Raimondo Executive Order 20-01, Advancing a 100% Renewable Energy Future for Rhode Island by 2030, January 17, 2020, https://governor.ri.gov/sites/g/files/xkgbur236/files/2021-06/Executive-Order-20-01.pdf.

18 State of Rhode Island Climate Change website, Cities and Towns, Success Stories, accessed September 21, 2022, https://climatechange.ri.gov/cities-and-towns.

19 State of Rhode Island Climate Change website, Toolkits and Guidance, New Mandatory Education for Planning Boards/Commissions, accessed September 21, 2022, https://climatechange.ri.gov/cities-and-towns/toolkits-and-guidance.

20 Massachusetts Executive Office of Energy and Environmental Affairs press release, "Baker-Polito Administration Awards Municipal Vulnerability Preparedness Planning Grants to Seven Municipalities," February 15, 2022, https://www.mass.gov/news/baker-polito-administration-awards-municipal-vulnerability-preparedness-planning-grants-to-seven-municipalities.

21 Massachusetts Executive Office of Energy and Environmental Affairs, Municipal Vulnerability Preparedness, Coonamessett River Restoration: Phase 2 Construction, accessed September 21, 2022, https://www.mass.gov/doc/falmouth-fy19-featured-project-case-study/download.

22 State of Rhode Island Department of Environmental Management press release, "DEM Awards $4,360,600 to Help RI Communities Confront the Effects of Climate Change," July 29, 2020, https://www.ri.gov/press/view/38968.

23 State of Maine Office of Governor Janet T. Mills press release, "Mills Administration Awards Nearly $20 Million from Maine Jobs & Recovery Plan to 13 Maine Communities to Protect Infrastructure from the Effects of Climate Change," July 19, 2022, https://www.maine.gov/governor/mills/news/mills-administration-awards-nearly-20-million-maine-jobs-recovery-plan-13-maine-communities.

24 Massachusetts Executive Office of Energy and Environmental Affairs website, Municipal Vulnerability Preparedness Program Action Grant Projects, accessed September 21, 2022, https://www.mass.gov/info-details/municipal-vulnerability-preparedness-program-action-grant-projects.

Examples of local projects that received Climate Action Grants through the Massachusetts Municipal Vulnerability Preparedness (MVP) program in recent years[a]

- Boston received $280,000 to conduct a Heat Resilience Planning Study. The final report, released in July 2022, includes an assessment of urban "heat islands" in the city and outlines mitigation and resilience strategies for expected higher temperatures (City of Boston 2022).
- Easthampton received more than $2 million to design and fund "green infrastructure" improvements to a street in the city. The improvements include rebuilding an eroded stream bank, rebuilding sidewalks, and adding tree and plant cover to provide shade and increase the soil's water-storage capacity.
- Mattapoisett received $960,000 to purchase 120 acres of coastal wetlands for conservation and to provide natural protection against sea-level rise and coastal storms.
- Newburyport received $1 million to fund reconstruction of a stone revetment wall that will help protect the city's wastewater treatment plant from storm surges in the Merrimack River. The project brought the wall up to Federal Emergency Management Agency (FEMA) standards and included the construction of a recreational multi-use path along the river.
- Uxbridge received $257,000 to develop a mosquito-control plan in anticipation of an increased insect population due to warming winter temperatures. The town used the funding to conduct assessments, design upgrades to water-storage systems, and host a regional conference on mosquito control.

a Massachusetts Executive Office of Energy and Environmental Affairs website, Municipal Vulnerability Preparedness Program Action Grant Projects, accessed September 21, 2022, https://www.mass.gov/info-details/municipal-vulnerability-preparedness-program-action-grant-projects.

VI. Conclusion

This report examines the role of weather in the provision of local public services. It uses Massachusetts data from a 30-year period to quantify the impact of temperature and precipitation on municipal expenditures. It finds that a 1 degree Fahrenheit increase in average temperature, on average, results in a 3.2 percent increase in per capita local expenditures.

This finding can help policymakers better understand what climate change in the region will mean for local budgets in the future. If global emissions continue to grow at their current rates, the average temperature in Massachusetts is expected to rise from under 49 degrees Fahrenheit for the 1990–2019 period to over 53 degrees Fahrenheit for the 2050–2059 decade and 58 degrees Fahrenheit for the 2090–2099 decade. Assuming that the relationship between average temperature and municipal expenditures in the future is the same as it was from 1990 through 2019, per capita local spending is projected to increase 15 percent for the 2050–2059 decade and 30 percent for the 2090–2099 decade relative to the level of the past three decades. These spending increases will create significant fiscal stress for municipalities. Given the substantial similarities in fiscal structures and weather patterns throughout New England, these findings are likely to apply to other states in the region.

It is important for policymakers to take actions now to address and be prepared for the projected climate change. They should account for climate change in their long-term municipal financial planning. It is prudent and sound to invest in improving the climate resilience of public infrastructure, which will benefit municipalities for many years to come.

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Appendix: Constructing Municipality-level Weather Data

Since municipality-level weather data are not publicly available, I construct them using data from the Global Historical Climatology Network daily (GHCNd). This network includes numerous weather stations from all over the United States and the rest of the world. It applies a common set of quality-control procedures to each station's climate records to ensure the quality and comparability of the data. Therefore, the GHCNd data are generally considered high quality and have been widely used in weather-related research (Dell, Jones, and Olken 2014).

For this project, I use data reported by weather stations in and near Massachusetts. From 1990 through 2019, more than 1,100 weather stations located within 50 miles of the centroid of at least one Massachusetts municipality were reporting data in the Global Historical Climatology Network.[25] To align the weather data with the local spending data, I aggregate daily weather records at the station level to annual weather statistics at the municipality level in two steps. First, I calculate the weighted average of each daily weather variable among weather stations within 50 miles of a municipality's centroid. I assign a higher weight to a weather station closer to the centroid.[26] Second, I aggregate the daily weather data to the fiscal-year level for each municipality.[27]

25 I tried reducing the cutoff to 40 miles, but doing so leaves no relevant weather stations for a few municipalities for part of the sample period.

26 I use the inverse of the distance between the centroid of a municipality and each weather station that is within 50 miles of that centroid as the weight.

27 In Massachusetts, Fiscal Year (FY) *t* starts on July 1 in calendar year *t*–1 and ends on June 30 in calendar year *t*.

Appendix Table 1

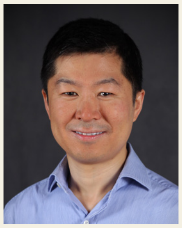
Projected Impact of Increased Average Temperature on Municipal Expenditures for Massachusetts

Future Decade	2050–2059		2090–2099	
Emissions Scenario	Low	High	Low	High
Inputs for Projection				
1. Projected Average Temperature (°F)	51.97	53.39	53.38	58.04
2. Observed Average Temperature for FY1990–FY2019 (°F)	48.84	48.84	48.84	48.84
3. Estimated Impact on Total Expenditures Per Degree Change in Average Temperature	0.0323	0.0323	0.0323	0.0323
4. Average Per Capita Total Expenditures for FY1990–FY2019 (In 2019 Dollars)	$3,108	$3,108	$3,108	$3,108
Outputs of Projection				
5. Percentage Change in Per Capita Total Expenditures Relative to FY1990–FY2019 (%)	10.11	14.70	14.66	29.72
6. Dollar Change in Per Capita Total Expenditures Relative to FY1990–FY2019 (In 2019 Dollars)	$314	$457	$456	$924

Note(s): Average per capita total expenditures for FY1990–2019 are calculated as the weighted average across 350 municipalities in the sample, weighted by population. Projected and observed temperatures for Massachusetts are calculated as a weighted average of temperature for each county or municipality, using their respective areas as weights. The value in Row 3 is the estimated coefficient on average temperature in Table 1. The values in Row 5 are the differences between Rows 1 and 2 multiplied by the value in Row 3. The values in Row 6 are the products of the values in Rows 4 and 5.

Source(s): National Oceanic and Atmospheric Administration Climate Program Office, author's calculations

About the Author



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