Can municipalities weather the weather?

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Abstract: Abnormal heat reduces municipal revenues, with effects isolated to the current fiscal year. The reduction in municipal revenues concentrates in tax-based revenues, and for those municipalities that rely on fewer revenue sources. Municipalities offset about 32% of this shock with lower current capital spending and the remainder with other current year spending cuts. Temperature shocks have little effect on future spending and raise net debt only when they accumulate over several years. These findings challenge conventional notions of governmental inflexibility and suggest that local governments actively manage spending to offset the financial impact of weather-induced financial risks.

Keywords: Municipal financing; capital expenditures: cash flow shocks; revenue diversification; weather risk

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1. Introduction

Despite mounting evidence on the economic impacts of rising temperatures, we know surprisingly little about how municipal cash flows respond to temperature shocks or how municipalities manage them across spending and financing margins. Understanding these responses is central for the millions of residents who depend on trillions of dollars in local public-good provision (Berry and Marlowe 2024) and for investors who finance these services through the municipal bond market. The net effect of abnormally warm weather on municipal revenues is ambiguous ex ante.[1] Municipal revenues are drawn from multiple bases whose sensitivity to warm weather can differ markedly, and there is limited evidence on how municipalities adjust to revenue shocks, so the pass-through of temperature-induced revenue shocks to expenditures and balance-sheet responses remain unclear. Municipalities can respond to transitory revenue shortfalls through spending adjustments, balance-sheet smoothing (e.g., drawing down cash), or external financing. The extent to which they rely on each margin determines whether warming-induced revenue shocks are absorbed by balance sheets and bondholders or instead translate into reductions in current public-good provision or capital investment.

In this paper, we provide the first empirical evidence on how annual variation in warm weather affects municipal finances. Specifically, we examine: (1) to what extent municipal revenues are affected by heat variation, (2) whether municipal capital investment is insulated from temperature-driven, short-run, non-fundamental revenue shocks, and (3) what other levers (i.e., spending versus debt accumulation) municipalities use to manage warm weather-induced shocks. In addressing these questions, we provide novel evidence that municipalities primarily absorb non-

[1] See Brown, Gustafson, Ivanov (2021), Tran (2023), or Addoum, Gounopoulos, Gustafson, Lewis, and Nguyen (2024) for evidence on how local economies may be disrupted and Addoum, Ng, and Ortiz (2020, 2023) for evidence of how temperature impacts net out across the universe of large firms.

fundamental, heat-induced cash-flow shocks through contemporaneous spending adjustments, including a disproportionate reduction in capital expenditures.

We identify the effect of abnormal warm temperature on municipal financial outcomes using a panel regression with municipality and state-year fixed effects. The key outcomes of interest are measures of municipal revenues and expenditures, which we obtain for 87,501 municipality-years across 47 states from the Census Bureau's Census of Governments (CoG), as compiled by Pierson, Hand, and Thompson (2015).[2] The average (median) municipality in our local government sample (counties, cities, and towns) earns $53 ($3) million in revenues and provides services to 21,000 (1,691) individuals.

The explanatory variable of interest is a standardized measure of cooling degree days (CDDs) in a county-year, where CDDs are the number of degree-days above 65 degrees Fahrenheit. CDDs are a widely used, economically relevant summary statistic for heat and form the basis for temperature-related options contracts traded on the Chicago Mercantile Exchange (Purnanandam and Weagley, 2016). Following Dell, Jones, and Olken (2014), we exploit plausibly random within-municipality variation in annual CDDs, conditioning on state-year fixed effects and local economic controls. Under the identifying assumption that relative temperature shifts within a state over time affect municipal finances only through their impact on local conditions, our estimates capture the causal effect of abnormal heat on municipal revenues and expenditures.

Our first main result is that more abnormally hot temperatures (i.e., more cooling degree days) predict lower municipal revenues. If an already warm month becomes 85 degree-days (or

[2] The Census Bureau's CoG survey consists of a mail canvass, supplemented by direct data feeds, central collection from state sources, and hand collection from municipal financial statements. The COG occurs every five years (ending in '2' and '7') for all state governments and over 90,000 local governments. We exploit the four most recent CoG surveys in 2007, 2012, 2017, and 2022 for our sample. Pierson et al. (2015) standardize this data in The Government Finance Database.

roughly 3 degrees per day) hotter, then our model predicts annual municipal revenues to be approximately 1% lower, or about $19 per resident. The relation between abnormal heat and municipal revenues concentrates in the year of the heat event: municipal revenues are neither affected by previous-year temperatures nor related to future temperature patterns. The revenue response to abnormal CDDs becomes more pronounced at higher CDD levels, and we find little evidence that other annual dimensions of everyday weather (cold weather, precipitation) significantly relate to municipal financial outcomes. These findings suggest that abnormal heat, rather than general weather variation, is the primary driver of the revenue effect.

We next examine whether CDDs affect municipal capital spending, which is an important driver of the future public good they will provide. This question is also interesting because, under plausible assumptions, it allows us to assess whether capital spending serves as an adjustment margin for managing heat-induced revenue shocks. This approach follows the logic in Brown, Gustafson, and Ivanov (2021) whereby routine weather fluctuations affect cash flows, such as revenues, but do not otherwise affect investment opportunities. Interpreted this way, our study provides novel evidence on how contemporaneous shocks cash flows shape municipal spending decisions, mirroring the extensive literature exploring individuals' marginal propensity to consume (e.g., Flavin 1981; Jappelli and Pistaferri 2010; Kaplan and Violante 2014) and the sensitivity of firms' investment and savings to cash flows (e.g., Fazzari, Hubbard, and Petersen 1988; Erickson and Whited 2000; Moyen 2004; Riddick and Whited 2009).

Municipal capital investment is negatively related to CDDs–an 85 CDD increase predicts a 1.7% drop in annual capital spending. Similar to the CDD-revenue relation, capital spending is most sensitive to more extreme CDD values and largely insensitive to non-CDD dimensions of the weather. The comparable dynamics and heterogeneity between CDDs' revenue and capital spending impacts are consistent with CDDs affecting capital spending predominantly via their revenue impact. A small survey of municipal managers further bolsters this idea as managers report current capital spending to be the most common lever that they use to manage revenue shortfalls. Framed by the idea that CDDs affect capital expenditure predominantly through their revenue impact, either indirectly via our interpretation of the OLS estimates or more formally in a two-stage least squares framework, indicates that approximately 32% of the lost revenue dollars show up as reduced capital spending in the same year.

We next study additional channels through which municipalities manage CDD-induced revenue shortfalls, considering the relation between CDDs and non-capital (and total) spending and net debt accumulation. Non-capital spending may be affected by CDDs either directly or via CDDs' revenue impact. For example, abnormal heat in an Alabaman summer could increase emergency service expenses or lower expected public park attendance, leading to fewer employee staffing hours at public parks. However, we end up finding that CDDs affect non-capital and total spending in lockstep with revenues. CDDs' total expenditure impact, which includes capital spending, is extremely similar to its revenue impact in terms of (1) magnitude, (2) dynamics (including the immediate current year effect and little impact of lead or lag CDDs), and (3) heterogeneity. These results are consistent with municipalities managing revenue shocks exclusively in real time via expenditure adjustments, with capital spending being about 2.5 times more sensitive than non-capital spending.

Despite the virtual offsetting of revenue shocks with expenditure cuts, we nevertheless examine whether municipalities adjust their balance sheet in response to CDDs. We find little evidence that a single year's worth of CDDs meaningfully affects municipal debt levels or issuance activity, either in the year of or the four years following the CDD shock. We do, however, find that prolonged CDD exposure leads to an accumulation of net debt. Specifically, the cumulative CDD exposure over the previous five years positively predicts a municipality's net debt per capita. Thus, municipalities manage transient CDD-induced revenue shocks by adjusting immediate cash flows but turn to their balance sheet to address longer-term exposures.

In our final set of analyses, we explore the heterogeneity in municipal responses to abnormal heat. We find that the composition of a municipality's revenue is a primary predictor of its sensitivity to temperature. This idea manifests across two dimensions. First, the sensitivity of revenue to temperature attenuates as a municipality's revenue becomes more diversified. This result is insensitive to the simultaneous inclusion of interactions between temperature shocks and an area's size or economic conditions. Second, the types of revenues that a municipality relies on generate heterogeneity in CDDs' revenue impact. The adverse effect of temperature on revenues is mitigated in areas that rely more on property taxes, intergovernmental transfers, and utilities revenue. We further assess the role of the institutional environments in which municipalities operate and find that they have little influence on our results. For instance, the sensitivity of an area's revenues or spending to CDDs is unrelated to balanced budget rules or statewide tax and spending limitations. In sum, it appears that municipal managers prioritize their financial austerity and balance sheet over current investment when faced with non-fundamental short-term CDD-induced revenue shocks. This idea is corroborated by our small survey in which all managers report that they scale spending to revenues because that is what they believe their constituents want.

Our study makes several important contributions to the literature. Our analysis provides the first empirical evidence that abnormal warm-weather shocks affect municipal cash flows. Using plausibly exogenous within-municipality variation in cooling degree days, we show that abnormal heat systematically depresses municipal revenues—especially tax revenues—with effects that are concentrated in the contemporaneous fiscal year and are strongest in very hot years. This extends the existing evidence on the economic effects of weather on private firms and industries (e.g., Jin, Li, Lin, and Zhang 2025; Addoum, Ng, and Ortiz-Bobea 2023; Hong, Li, and Xu 2019) or broad economic outcomes (e.g., Dell et al. 2009, 2012, 2014; Burke, Hsiang, and Miguel 2015) to municipal governments. Importantly, our findings highlight that routine variation in temperature—not only extreme events—can generate meaningful fiscal shocks. In doing so, our setting provides a clean measure of non-fundamental cash-flow risk for an economically important class of debt issuers whose securities are widely held by households and institutions.

Our main contributions relate to how municipal spending responds to these CDD-induced revenue shocks. Thus, our study contributes to the broader finance literature on how organizations respond to, and can insulate themselves from, non-fundamental cash-flow shocks (Almeida and Campello 2007; Dambra 2018; Brown et al. 2021). Our study parallels the large literature in corporate finance on the relation between cash flows on investment and cash savings (e.g., Fazzari, Hubbard, and Petersen 1988; Erickson and Whited 2000; Moyen 2004; Riddick and Whited 2009) as well as the extensive literature on individuals' propensity to consume out of income (e.g., Flavin 1981; Jappelli and Pistaferri 2010; Kaplan and Violante 2014). Weather-induced revenue shocks in our setting are short-run and plausibly exogenous to municipal fundamentals. We show that municipalities adjust expenditures in real time to offset these shocks, in contrast to work documenting multi-year adjustment paths following fundamental revenue changes (Holtz-Eakin, Newey, and Rosen 1989; Buettner and Wildasin 2006; Helm and Stuhler 2024). Capital expenditures are approximately three times as sensitive to CDD-induced revenue shocks as operating expenditures, and municipalities do not meaningfully change their net debt issuances in response to one-year heat shocks. Together with our survey evidence that managers view current capital projects as their primary adjustment margin, these patterns provide novel public-sector evidence on investment–cash flow sensitivity. In contrast to commonly held notions of governmental inflexibility (Niskanen 1971) and bureaucratic incentives to maintain current expenditures (Hayes, Razzolini, and Ross 1998; Wu et al. 2020), our findings suggest that municipalities use capital spending and modest cuts to operating services as the main buffer to protect their balance sheets and debt-service capacity from transitory heat shocks.

These findings have implications for the $4 trillion municipal bond market. A large literature estimates a variety of reduced-form pricing responses to credit risks, some of which stem from underlying environmental or climate risks (see e.g. Painter, 2020, Acharya, Johnson, Sundaresan, and Tomunen, 2024, Lopez, Murphy, Tzur-Ilan, and Wilkoff, 2025, Jeon, Barrage, and Walsh, 2025). These market-based estimates combine the impact of climate exposure on current cash flows with the expected impacts on future cash flows and their volatility. For instance, Goldsmith-Pinkham, Gustafson, Lewis, and Schwert (2023) find that sea level rise exposure affects municipal bond prices primarily via an uncertainty channel, while Acharya, Johnson, Sundaresan, and Tomunen, (2024) and Jeon, Barrage, and Walsh (2025) explicitly use forward looking measures of climate risk exposure. By contrast, our design isolates the short-run cash-flow channel, indicating that routine variation in annual CDDs generates modest, transitory revenue shortfalls that municipalities almost entirely absorb through contemporaneous expenditure cuts, with little immediate adjustment in net debt. In other words, municipalities treat CDD-induced shocks as cash-flow fluctuations to be managed on the spending side of the budget rather than as events that relax or tighten borrowing constraints in the current year. Taken together with evidence that municipal bond yields are sensitive to long-run climate risk measures, our results imply that if CDDs matter for municipal investors, it is primarily through how they shift expectations about the long-run path of climate and fiscal capacity, rather than through large immediate changes in the cash flows backing outstanding debt.

Our study further highlights the value of diversified revenues in mitigating a municipality's exposure to fiscal shocks. Copeland and Ingram (1982) and Gore (2009) argue that undiversified revenue sources increase credit risk and make governments more susceptible to adverse revenue shocks, but the existing policy literature offers mixed evidence and is often limited by identification challenges (e.g., Hendrick 2002; Carroll 2009; Jiminez and Afonso 2022). By exploiting plausibly exogenous weather variation, we identify how revenue diversification attenuates the sensitivity of revenues to heat and dampens the pass-through of these shocks to total spending. Our findings reinforce the notion that diversified revenue structures enhance fiscal resilience and demonstrate that such diversification allows municipalities to manage cash-flow volatility without relying on intergovernmental transfers or running deficits.

Finally, our study adds to the literature on how local governments respond to climate change and contributes to emerging work in climate finance. We complement existing evidence on the role of forward-looking climate risks or the impacts of large natural disasters (Jerch, Kahn, and Lin 2023) by showing that routine heat risk—unaccompanied by disaster declarations or offsetting intergovernmental aid—generates fiscal stress. In the short run, municipalities treat heat-induced revenue shortfalls as cash-flow shocks and neutralize them through spending cuts, thereby preserving debt-service capacity and insulating bondholders. Over longer horizons, however, repeated exposure to abnormal heat gradually appears on the balance sheet in the form of higher net debt, indicating that climate risk that is initially absorbed through cuts to public investment ultimately manifests as elevated leverage for municipal issuers. This perspective underscores the importance of integrating climate-related risks into public-sector fiscal management and informs debates on the long-run resilience of municipal finances and municipal bond markets in a warming climate.

2. Identification Strategy

Our research objective is to explore if and how municipal finance outcomes respond to everyday changes in warm temperatures. Our identification strategy exploits plausibly random variation in an area's weather in a panel regression over four distinct Census Bureau surveys, spanning 2007 through 2022.[3] Our methods mirror those discussed in Dell, Jones, and Olken (2014), which are increasingly popular in studies that seek to draw causal inference regarding the effects of weather. Our main empirical specifications take the following form:

$$Y_{mt} = \alpha_{st} + \delta_m + \beta_1 CDD_{mt} + \ Controls + \varepsilon_{mt} \quad (1)$$

where Y_{mt} equals the revenues or expenditures of municipality m in year t, scaled by the population that it serves. Our baseline analyses employ an ordinary least squares (OLS) estimator. We find qualitatively similar results using winsorized measures of unscaled revenues and expenditures and the Poisson maximum likelihood estimator recommended by Cohn, Liu, and Wardlaw (2022). Our main explanatory variables of interest are standardized measures of cooling degree days (CDDs), which we obtain from the National Oceanic and Atmospheric Administration (NOAA), supplemented with PRISM Weather Data for years after 2022. CDDs capture the extent of uncomfortably warm weather over a given period. Specifically, CDDs count the number of degree-days above 65 degrees Fahrenheit in municipality m during year t. For example, a single 75-degree day adds ten units to the CDD measure, which are then aggregated over the 365 days in year t. Because our municipal finance outcomes are observed at the annual level, we intentionally

[3] The Census survey occurs every five years, with smaller incomplete random samples in other years. As we explain below, data quality improves after 2003. Nevertheless, we replicate our results using a 7-year sample spanning the 1992-2022 editions of the survey.

employ an aggregate annual measure of temperature, rather than measures based on short stints of extreme weather. As Akyapı, Bellon, and Massetti (2025) discuss, this approach aligns closely with studies on the macroeconomic impacts of weather, which either link global temperature to total output or use approaches such as ours that identify off random changes in temperature (see, e.g., Dell, Jones, and Olken 2012; Deryugina and Hsiang 2014; Burke, Hsiang, and Miguel 2015; Kalkuhl and Wenz 2020; Newell, Prest, and Sexton 2021).

CDDs, our temperature measure of choice, are widely regarded as one of the most economically relevant summary statistics for heat. CDDs are the foundation for the main temperature-related options contracts traded on the Chicago Mercantile Exchange and are commonly used in academic studies (see, e.g., Purnanandam and Weagley 2016; Bae, Jeon, Szaura, and Zurita 2023). They have also been shown to have substantial economic impacts on outcomes such as migration (Baylis, Bharadwaj, Mullins, and Obradovich 2025).

We also include lagged county-level controls for the unemployment rate, per capita income, and the natural log of the number of business establishments (Dambra, Even-Tov, and Naughton 2023). In addition, we control for municipality-level population to capture size-related differences across municipalities. In our baseline specification, all independent variables, including CDDs, are winsorized at the top and bottom percentile and then standardized. The inclusion of municipality fixed effects (δ_m) ensures that we identify off within-municipality variation in CDDs. State–year fixed effects (α_{st}) control for time-varying climate, policy, and local economic conditions.[4] We cluster our standard errors by county.

[4] Although the ability to control for local policies is important, we acknowledge that states vary widely in size and therefore within-state variation in weather. To ensure that this does not drive our results, we replicate our analysis after combining our smallest contiguous states into a single fixed effect block. Specifically, we combine VT, NH, MA, RI, and CT into a single block that is roughly the size of Maine and NJ, DE, and MD into a block the size of West Virginia, which itself is the smallest remaining state in our sample of the continuous U.S. Results are virtually unchanged with this adjustment to the fixed effects structure.

As Dell, Jones, and Olken (2014) discuss, this framework requires few explicit identifying assumptions when estimating the causal effects of abnormal weather. The key identifying assumption is that shifts in relative temperatures of different areas within the same state over time are unrelated to municipal financial outcomes, except through the effect of warm weather on these outcomes. To descriptively test this assumption, we supplement our main empirical tests with regressions that augment Eq. (1) with lead and lagged CDD measures. The lagged temperature outcomes shed light on the longevity of warm weather's effect on municipal financial outcomes, while the future temperature shocks act as placebo tests that help validate our identifying assumptions.

3. Data and Descriptive Statistics

3.1 Data Overview

Our data are derived from several sources. For our municipal outcomes and populations, we exploit the Census Bureau's Census of Governments (CoG) as compiled by Pierson, Hand, and Thompson (2015) in The Government Finance Database.[5] The CoG is a comprehensive survey of state and local government financial data for all governments in the United States for fiscal years ending in "2" and "7." The Census Bureau utilizes a combination of (most prominently) direct data feeds from municipalities' accounting systems, survey questionnaires, data collection from annual financial reports, and other federal agency data to compile the CoG.[6]

We restrict our analysis to post-2003 fiscal years (i.e., 2007, 2012, 2017, and 2022) to ensure a consistent reporting approach for CoG revenues and expenses for all municipalities

[5] https://my.willamette.edu/site/mba/public-datasets.

[6] While the Census Bureau provides annual municipal financial data on local government operations via the Annual Survey of Local Government Finances, the sample is smaller, inconsistent over time due to sampling, and often requires imputation (Census Bureau estimates) of financial data. The CoG undergoes a more thorough data validation and covers every government in each period, which is critical given our reliance on municipality fixed effects.

following the full adoption of GASB 34, which significantly altered and standardized municipal financial statements (Baber, Beck, and Koester 2024). In robustness tests, we document qualitatively similar results after extending this panel back three more five years increments to being in 1992. The CoG allows for a large cross-sectional panel, covering 22,046 different municipalities across 47 states. Within the CoG data, we analyze county-level governments (Unit Type Code = 1) and municipalities (Unit Type Code = 2). Our revenue and expense variables are derived from The Government Finance Database in Pierson et al. (2015) and are detailed in Appendix A.

We collect county-level unemployment data from the Bureau of Labor Statistics, county-level personal income per capita from the Bureau of Economic Analysis, and the number of establishments from the Census Bureau's County Business Patterns. We inflation-adjust all dollar-denominated variables to 2022 dollars using the Consumer Price Index (CPI). Finally, we obtain county-month measures of cooling degree days from the NOAA Monthly U.S. Climate Divisional Database, and supplement with PRISM Weather Data for years after 2022, assigning county-year weather metrics to all municipalities in that county. Our final sample includes 87,501 municipal-year observations.

3.2 Descriptive Statistics

Table 1 presents descriptive statistics for our sample. The average total inflation-adjusted revenue for a municipality in our sample is approximately $1,880 per capita, with a standard deviation of $1,770 per capita, underscoring the heterogeneity of our municipal government sample. On a per capita basis, the average municipality in our sample incurs expenses of $1,910 per individual.[7]

[INSERT TABLE 1 HERE]

As a point of reference, the median population in our sample is the City of Weston in Missouri, outside of Kansas City. The City of Weston had revenues of $4.2 million and 13 full-time employees, including its own mayor, Board of Aldermen, judicial court, public works department, and police department.[8]

In Figure 1, we decompose municipal revenues and expenses into subcomponents. Panel A decomposes revenues into taxes, fees, utilities, intergovernmental transfers. Together, these revenue sources comprise over 90% of municipal revenues in our sample. The largest component of municipal revenues is tax revenues, which comprise about 37% of the average municipality's revenue. The next largest source is intergovernmental revenues, which account for about 22% of municipal revenues, while fees and utility revenues each constitute approximately 15%.

[INSERT FIGURE 1 HERE]

On the expense side, approximately 12% of spending is in the form of capital investment and more than 25% of spending is in the form of salary. Utilities expenses make up the second largest portion of total costs. Together, the statistics in Figure 1 are qualitatively similar to those discussed in Ross and Peng (2023).

In terms of temperature outcomes, the average municipality in the full sample experiences 1,333 cooling degree days annually, with considerable variation across the sample. These represent degree-days above 65 degrees for the average municipality's fiscal year. Much of this variation is

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[7] Expenses according to the Census Bureau format do not follow the traditional accounting expenses as defined by the Governmental Accounting Standards Board (GASB). For instance, capital expenditures are included in the Census Bureau's definition of total expenditures. See Appendix A for more details.

[8] See the City of Weston's website.

across areas; most municipalities exhibit a within-muni standard deviation of CDDs of between 78 (the 25th percentile) and 155 (the 75th percentile). In our regression analyses we standardize our CDD measure across the full sample. Thus, dividing the coefficient by ten generates the predicted impact of approximately 85 CDDs (i.e., 10% of the full sample standard deviation), which is roughly equal to a one standard deviation CDD shock for a municipality.

4. CDD Revenue Impact

Our study first investigates the impact of warm weather shocks on municipal finances. *Ex-ante*, it is unclear whether and how abnormally warm weather will impact municipal revenues. The existing literature studying the private sector offers mixed evidence on the effect of temperature or other adverse weather variation on retail sales and productivity (Addoum et al. 2020; Addoum et al. 2025; Dell et al. 2012; Tran 2023). Although this literature weakly suggests that municipal tax income may decline, due for example to a drop in local sales or income, Figure 1 shows that taxes comprise less than 40% of municipal revenues, and abnormal weather shocks may have different effects on similarly important revenue streams derived from fees or utilities.

We begin to address the empirical question of how CDDs affect municipal revenues by regressing per capita municipal revenues on CDDs, which, given our fixed-effect structure, captures abnormal heat exposure during the fiscal year. Table 2 presents our baseline estimates of the relation between CDDs and total municipal revenues per capita. In column 1, we estimate an OLS panel regression with municipality and state–year fixed effects and our standard set of county-level controls. The coefficient on CDDs is negative and statistically significant, indicating that higher-than-usual heat reduces municipal revenues. In economic terms, our results suggest that if an already warm month becomes roughly 85 degree-days hotter (just under 3 degrees

Fahrenheit per day), annual municipal revenues fall by approximately 1%, or about $19 per resident.[9]

[INSERT TABLE 2 HERE]

Column 2 of Table 2 shows that this result is robust to estimating a Poisson Pseudo-Maximum Likelihood (PPML) model with unscaled revenues, which accounts for skewness in municipal revenues. The PPML estimates yield a very similar semi-elasticity of revenues with respect to CDDs, suggesting that our conclusions are not driven by functional-form assumptions. Appendix Table A1 indicates similar results after adjusting the state-year fixed effects by combining small states into larger blocks, which enhances the within fixed-effect-bin CDD variation for small states.

In Appendix Table A2 and Appendix Figure A1 we mitigate concerns relating to the relatively short, four-year, panel that we employ in two ways. First, Appendix Table A2 presents qualitatively similar results using a seven-period panel spanning five-year increments from 1992 through 2022. Second, Appendix Figure A1 shows that within our main sample the estimated CDD–revenue relation is relatively stable across years in our sample. Together, these robustness analyses mitigate the likelihood that our relatively short four-year panel impacts our inferences.

Figure 2 decomposes municipal revenues into their components and confirms our expectation of a strong negative relation between CDDs and tax revenues, which is the single

[9] As we state at the end of Section 3, throughout our analyses we benchmark magnitudes to an 85-CDD shift. This is similar to the within municipality standard deviation in most areas and is one-tenth of the full sample standard deviation of CDDs, which we use to standard the explanatory variable of interest (meaning that the economic magnitudes discussed reflect the impact of a 0.1-unit shift in the standardized CDDs measure used throughout our analyses).

biggest municipal revenue category.[10] In general terms, we interpret the tax-based responses as being consistent with the argument that consumers and producers transact less in the local economy when they are subject to uncomfortable heat over a variety of transactions (i.e., business activities, retail and luxury purchases, license acquisitions, etc.). Other major revenue categories also tend to load negatively on CDDs, but these estimates are generally statistically insignificant when viewed in isolation. Notably, we find little systematic relation between CDDs and intergovernmental transfers, which are the second-largest source of municipal revenues. The insensitivity of intergovernmental revenues to CDDs underscores that our effects are not simply capturing disaster-related transfers or broader macroeconomic shocks that would mechanically flow through higher-level governments (e.g., Jerch, Kahn, and Lin 2023).

[INSERT FIGURE 2 HERE]

In column 3, we examine whether other dimensions of everyday weather exhibit similar impacts or affect the estimated relation between CDDs and revenues. We augment our baseline specification with controls for heating degree days (HDDs), total precipitation, and cold-season precipitation. The coefficient on CDDs remains virtually unchanged and statistically significant, while the additional weather variables are jointly and individually insignificant. Appendix Figure A3 examines the relation between an even broader set of weather characteristics in the absence of CDD controls and confirms the takeaway from column 3 of Table 2 that non-CDD dimensions of weather have little impact on municipal revenues. This evidence supporting the economic

[10] Appendix Figure A2 further decompose tax revenues into their major subcomponents. Each tax subcomponent is negative, but only the coefficients for sales taxes and licensing taxes are statistically significant at conventional levels. The largest level effect (i.e., OLS coefficient) is on property taxes, which is the largest tax category accounting for 57% of tax revenue. Property taxes, which include both real estate taxes and taxes applied to other tangible or intangible assets for individuals and businesses, including financial assets, luxury assets, and business inventory and equipment, is less sensitive on a percentage basis, but still exhibits a negative coefficient.

consequences of abnormal heat, rather than generic weather variation, is consistent with the motivation for Dell, Jones, and Olken (2014)'s survey on the economic consequences of weather as well as evidence on adverse effect of forward-looking heat stress metrics on asset prices documented in Acharya, Johnson, Sundaresan, and Tomunen (2024).

In columns 4 and 5 of Table 2, we explore whether more extreme realizations of heat disproportionately drive the CDD–revenue relation. We do so in column 4 by removing CDD variation in the bottom tercile of CDDs with our *CDD Extreme* measure and in column 5 by allowing for a non-linear (quadratic) effect of CDDs. Both specifications indicate that the marginal revenue impact of CDDs becomes more negative at higher levels of CDDs: moderate increases in CDDs have economically modest effects, while years in the upper part of the CDD distribution are associated with substantially larger revenue declines. This pattern suggests that extreme heat is particularly disruptive for local economic activity.

Figure 3 further examines the timing of the revenue response using a distributed-lag specification of CDDs estimated via OLS. The figure plots coefficients on leads and lags of CDDs from an OLS model that mirrors our baseline specification, except that we augment the model with previous and future years' CDD realizations. We find that the revenue impact of CDDs is immediate and confined to the contemporaneous period: coefficients on lagged CDDs (years –1 through –4) and future CDDs (years +1 and +2) are economically small and statistically indistinguishable from zero. This pattern, particularly with respect to the future CDD realizations that act as placebos, helps rule out concerns that our results are driven by pre-trends in local economic conditions or by slow-moving regional climate trends. Instead, the estimates are consistent with abnormal annual heat generating a transitory, short-run revenue shock.

[INSERT FIGURE 3 HERE]

The findings in Table 2 and Figure 3 offer the first evidence that municipal revenues, especially those that are tax-related, are negatively related to abnormal heat within a year. These effects are most pronounced for areas experiencing extreme heat, the revenue impact is short-lived, and other dimensions of weather play little role. This evidence positions CDDs as a non-fundamental shock to public-sector revenues that is plausibly exogenous to municipal investment.

5. CDD Investment Impact

We next examine whether CDDs influence municipal investment. This analysis brings data to bear on a core economic question—posed here in the municipal context for the first time—as to how shocks to current-period cash flows shape spending decisions. The question is inherently empirical. For instance, there is a large literature on individuals' marginal propensity to consume, including Parker, Souleles, Johnson, and McClelland (2013) and Kaplan and Violante (2014), who estimate that individuals spend about 25% of an income shock on non-durable consumption. On the corporate side, studies such as Riddick and Whited (2009) estimate firms' propensity to save out of cash flows, while a large literature debates the extent and meaning of the sensitivity of firms' investment to same-period cash flows. Among this literature, Brown, Gustafson, and Ivanov (2021) examines how bank borrowing firms respond to exogenous cash flow shocks, finding that their investment is largely shielded due to their ability to manage the shock via adjustments to their bank borrowing.

Our study is both the first to examine this idea in the context of municipalities and especially well-suited to do so. CDDs affect revenues, but are unlikely to impact the underlying stock of infrastructure or investment opportunities. Thus, under similar identifying assumptions as papers such as Brown, Gustafson, and Ivanov (2021), who exploit abnormal but non-disastrous weather as a shock to cash flows that is assumed exogenous to investment opportunities, we ask whether municipalities shield their investment from CDDs' revenue impact.[11] Because we view the CDD-investment relation as interesting in its own right, we defer a formal two-stage least squares (2SLS) until Section 5.1, initially emphasizing our reduced form estimates that directly link CDDs to municipal investment.

Table 3 examines the CDD-capital investment relation using capital expenditures per capita as the dependent variable, with an otherwise identical structure to our analysis of municipal revenues in Table 2. Column 1 presents OLS estimates in which the coefficient on CDDs is negative and statistically significant, indicating that municipalities cut capital investment in years with abnormally high CDDs. The point estimate of –0.057 implies that a one-standard-deviation increase in CDDs leads to a meaningful reduction in capital outlays per resident. Comparing this coefficient to the -0.177 estimate in column 1 of Table 2 suggests that about 32% of the lost revenue dollars show up as reduced capital spending in the same year.

[INSERT TABLE 3 HERE]

In column 2, we conduct a similar comparison using the PPML specification. Here, the coefficient on CDDs in the capital expenditure model is -0.188, indicating an approximate 1.7% capital spending decline in response to 85 more CDDs, which as we discuss above corresponds to just over a one standard deviation shock to *within-municipality* CDDs. Thus, current capital outlays serve as a primary "dial" that managers turn when cash flows unexpectedly drop.

[11] For instance, our setting bypasses many endogenous channels through which the investment-cash flow sensitivity may emerge, such as those discussed in Erikson and Whited (2000), Gomes (2001), and Alti (2003), which build on the idea that there are some uncontrolled for underlying shocks or that cash flows contain information regarding future investments not included in controls for Tobin's Q.

In column 3, we add the same additional weather controls used in the revenue specifications—heating degree days, total precipitation, and cold-season precipitation—to test whether other aspects of municipal weather affect the CDD–capital spending relation. The coefficient on CDDs is essentially unchanged and remains statistically significant, while the coefficients on the additional weather variables are small and insignificant. This mirrors the revenue results and reinforces the interpretation that it is abnormal heat, rather than generic weather variation, that drives the capital spending response.

In columns 4 and 5, we respectively isolate upper tail variation in CDDs and allow for a non-linear effect of CDDs by introducing a quadratic term. In both cases, as in our analysis of revenues, we find that the marginal impact of CDDs on capital expenditures becomes more negative at higher levels of CDDs. Modest deviations from typical temperatures are associated with relatively small changes in capital spending, while very hot years are associated with disproportionately large cuts in capital outlays.

Figure 4 provides additional detail by plotting dynamic estimates of the response of capital spending to CDDs. The solid line shows the effect of current, lagged, and future CDDs on capital expenditures. The series exhibits roughly the same dynamics we documented for revenues: the largest and most statistically significant effect occurs contemporaneously, with little evidence of meaningful pre-trends or long-run persistence.

[INSERT FIGURE 4 HERE]

Appendix Figure A4 decomposes the dynamic effect of CDDs on capital spending into its effect on utilities capital spending and non-utilities spending, each of which represents about half of municipalities' capital spending in our sample. The negative relation between same year CDDs and capital spending is similar for utilities and non-utilities spending. However, we find a significant reversal of utilities spending after about two years (i.e., the coefficient CDD_{t-2}), suggesting that utilities projects are more likely to be delayed for a few years rather than cancelled. We find that other forms of capital spending (transportation, health, parks, etc.) do not reverse in future periods, suggesting a more permanent reduction in these outlays.

Taken together, Table 3 and Figure 4 show that capital outlays are sensitive to heat-induced revenue shocks. Both the dynamics and the concentration in extremely hot years mirror variation in the CDD–revenue relation, reinforcing the idea that extreme heat affects capital spending primarily through its revenue impact. These findings offer public-sector evidence of investment–cash flow sensitivity.[12]

5.1. A Corresponding 2SLS Estimate

Given our general interest in the impact of CDDs on municipal financing, we have thus far regressed these outcomes directly on CDDs using reduced form OLS specifications. Yet, we informally interpret the OLS estimates as if CDDs primarily affect municipal capital spending through their impact on contemporaneous revenues, rather than by altering underlying investment opportunities. This logic mirrors the identifying assumptions in Brown, Gustafson, and Ivanov (2021), who exploit abnormal snow cover as an exogenous cash-flow shock that influences firms' financing decisions without directly shifting investment opportunities. Motivated by the arguments

[12] Although there is ongoing debate regarding the extent to which investment cash flow sensitivity reflect financial constraints (see e.g., Fazzari, Hubbard, Petersen, 1988; Kaplan and Zingales, 1997; Erikson and Whited, 2000; Moyen, 2004), the arguably exogenous nature of our cash flow shocks make it likely that any observed sensitivity reflects municipal managers acting as if they are financially constrained (i.e., not raising capital in real time or tapping available liquidity sources).

in Brown et al. (2021), we next conduct a 2SLS analysis where we use column 1 of Table 2 as the first stage and then plug the predicted value (i.e., $\widehat{Total\ Revenue}$) into column 1 of Tables 3.

Our 2SLS analysis offers a more formal examination of the dollar impact of CDD-induced revenue shocks on investment. Importantly, the estimated magnitude is disciplined by a natural benchmark. If the CDD spending effects are due to causal impacts of shifts in revenues, as opposed to correlations with other omitted factors, then the coefficients representing the total effect of CDD-induced revenues shocks on spending (along with any impact on the balance sheet) should sum to one since every dollar of the revenue impact needs to go somewhere. Thus, the coefficient representing the effect of CDD-induced revenues on capital spending should be between zero and one, with larger coefficients representing capital spending being a more economically relevant lever that municipalities pull to manage CDD-induced revenue shocks.

This benchmark is especially important because standard diagnostics indicate that the CDD shock only marginally satisfies tests for IV strength. Our baseline 2SLS framework uses column 1 of Table 2 as the first stage, where the CDD instrument has a t-statistic of 2.37. We use the specification in column 4 that uses *CDD Extreme* to predict revenues, which has a larger t-statistic of 3.34 (i.e., first stage F-statistic of approximately 11.15). Stock and Yogo (2002) show that the implied F-statistic of approximately 11 indicates that the 2SLS estimate may retain roughly 10% of the bias of the OLS coefficient.

Table 4 presents OLS and 2SLS estimates for the effect of revenue on capital spending, respectively. The OLS estimates in column 1 indicate a strong positive correlation between revenues and capital spending. This is likely driven by both (1) a causal effect of revenue dollars impacting spending and (2) the fact that local economic growth, measured in a variety of forms, drives both revenues and investment. The 2SLS estimates in column 2 isolate the effect of a non-fundamental revenue shock on municipal capital spending.

[INSERT TABLE 4 HERE]

The second stage 2SLS coefficients are 0.320 and 0.355, respectively, meaning that 32 to 36 cents of every dollar of CDD-induced revenue shock flows into (or out of) capital spending.[13] Notably, the magnitude is of similar order of magnitude to the OLS coefficient, rising by just over 50%. Thus, our setting is unlikely to be plagued with the common problem whereby second stage estimates are over inflated that can accompany weak IVs that do not fully satisfy the exclusion restriction (see e.g., Jiang, 2017).

6. Where do the dollars go? Current Spending or Municipal Debt

We next study additional channels through which municipalities manage CDD-induced revenue shortfalls. We consider two primary channels: non-capital spending and accumulation of net debt.

6.1 Non-capital and Total expenditures

Table 5 examines the relation between CDDs and non-capital and total municipal expenditures per capita. The specifications in Table 5 mirror those used to examine CDDs' revenue impact in columns 1 and 3 of Table 2. Columns 1 and 2 show that, whether or not we control for other dimensions of the annual weather, CDDs significantly predict a decline in non-capital spending. The coefficients of approximately -0.14 are about 2.3 times the size of the capital

[13] The estimate in column 2(3) of Table 4 must be the ratio of the coefficients in columns 1 (4) of Tables 3 and 2.

spending coefficients, meaning that non-operating expenses account for about two-thirds of the sending reduction in response to CDDs. However, capital spending comprises only about 17% of total spending. Relative to the average amount of capital and non-capital spending, these coefficients indicate that capital investments are about 2.5 times as sensitive as non-capital spending to CDDs.

[INSERT TABLE 5 HERE]

In columns 3 and 4, we sum capital and non-capital spending to study the relation between CDDs and total spending, providing a more holistic view of how CDDs affect municipal spending. Column 3 shows a statistically significant negative relation between CDDs and total spending. The magnitude of the coefficient (–0.193) implies that an increase of 85 CDDs, or about 2.9 degrees warmer per day in an already warm month, reduces total expenditures just over $18 per resident, or roughly 1% relative to average spending levels. This estimate is strikingly close in magnitude to the revenue effect in Table 2, suggesting that municipalities offset heat-induced revenue shocks with nearly dollar-for-dollar contemporaneous spending adjustments. Finally, column 4 shows similar relations between other dimensions of the weather and expenditures as we find in our analyses of revenues in Table 2.[14]

Appendix Figure A7 decomposes the total spending response across major non-capital expenditure categories. Municipalities also trim a range of other expenditures when faced with CDD-driven revenue shortfalls. Salary expenses decline modestly and are only marginally

[14] Appendix Figures A5 and A6 provide similar robustness analyses to those shown with respect to revenues: the CDD impact is similar across the four years in our sample and non-CDD weather dimensions exhibit little predictive power on municipal spending. Columns 3 and 4 of Appendix Table A2 further shows that our spending results are robust to the expanded 7-edition CoG panel spanning 1992-2022.

statistically significant. Across the other categories on the x-axis, we observe negative point estimates for health and welfare, parks and highways, police and safety, utilities, and administrative non-capital expenses, but only police-related and administrative-related expenses are reliably statistically significant (with t-statistics above 2). Thus, in addition to the disproportionate decline in capital spending, CDDs lead municipalities to cut back modestly across a variety of operating categories, with the aggregate effect across these categories filling in the gap between the revenue shock and the capital adjustment alone.

Figure 5 further examines the dynamics of total spending by plotting the lead–lag coefficients from an OLS model of total expenditures on CDDs. The pattern closely resembles that for revenues and for capital expenditures: a sizable and statistically significant contemporaneous decline in total spending, but little evidence of pre-trends or persistent effects in subsequent years.

[INSERT FIGURE 5 HERE]

Taken together, our findings thus far tell a cohesive story. Abnormally hot years generate transitory, tax-based revenue shortfalls. Municipalities respond in real time by pulling back on discretionary spending, with capital outlays absorbing a disproportionately large share of the adjustment. In aggregate, these adjustments nearly fully offset the revenue loss, implying that municipalities rarely smooth these shocks through multi-year deviations from a balanced budget or via capital-market transactions and instead manage them primarily through contemporaneous expenditure cuts. In sum, our findings suggest that the immediate fiscal stress of abnormal heat is borne almost entirely on the spending side of the budget. In the short run, bondholders likely experience little direct impact from these shocks, while residents and future taxpayers bear the cost through reduced capital formation and modest cuts to operating services.

6.2 Debt Adjustments

Finally, we examine whether and when exposure to abnormal heat shows up on municipalities' balance sheets. If municipalities treat CDDs as temporary cash-flow shocks and adjust spending one-for-one in the year of the shock, there is no reason to expect net debt to change in response to a single hot year. However, persistent or repeated shocks may erode fiscal buffers or force municipalities to rely more heavily on borrowing over time.

Table 6 analyzes this question using net debt issuance and net debt levels per capita as outcome variables. Column 1 regresses net debt issuance (new debt issued minus debt retired) on current CDDs and controls. The coefficient on CDDs is economically and statistically insignificant, indicating that municipalities do not meaningfully increase or decrease their net borrowing in response to a one-year heat shock.

[INSERT TABLE 6 HERE]

In Figure 6, we study whether there is any dynamic relation between CDDs and debt issuance. We find little evidence of such a relation as every coefficient, ranging from four years after the CDD shock to two years before, is statistically insignificant. Moreover, the point estimates are small. For example, every point estimate in Figure 6 is less than 0.05 in magnitude, with the year of, and subsequent two years' effects being all less than 0.02 in magnitude. In contrast, the year "0" total revenue and spending effects are approximately -0.18, indicating that debt market engagement is not a primary tool that municipal managers use to manage the CDD-induced revenue shocks that we study.

[INSERT FIGURE 6 HERE]

Column 2 of Table 6 uses net debt levels as the dependent variable and similarly finds no significant relation with contemporaneous CDDs. These results are consistent with the near one-for-one matching of revenue and spending declines documented above: in a typical hot year, municipalities absorb the shock on the flow side of the budget rather than through debt issuance.

Columns 3 and 4 shift focus to longer-run exposure by replacing the one-year CDD measure with a five-year cumulative CDD measure. In column 3, the coefficient on standardized five-year CDDs is positive and statistically significant, indicating that municipalities exposed to persistently hotter conditions over several years tend to accumulate higher net debt levels per resident. Column 4 allows for a non-linear relation using raw five-year CDD counts and their square, and the estimates point to a convex pattern: net debt levels rise more strongly once cumulative heat exposure reaches higher levels.

Overall, the debt results dovetail with our revenue and spending evidence. In the short run, municipalities treat abnormal heat-induced revenue shortfalls as cash-flow shocks, largely balancing their budgets via contemporaneous spending cuts and leaving net debt issuance unchanged. However, when abnormal heat becomes a more persistent feature of the local climate, the cumulative strain appears on the balance sheet in the form of higher net debt. This pattern is consistent with municipalities having limited ability or willingness to make indefinitely large expenditure cuts in response to repeated revenue shocks, eventually turning to debt financing as a margin of adjustment.

7. Heterogeneity: Revenue Composition and Linking CDDs' Revenue and Spending Impacts

Thus far, we find that abnormally warm weather constrains the average municipality's cash flow generation. In response, governments cut back on capital investment and expenses in lockstep with revenues, with longer-term heat exposure leading to increased leverage. In this section, we explore how these reactions to abnormal heat vary across municipalities. Beyond describing cross-sectional differences, we use these heterogeneity patterns as stress tests of our identification strategy. If CDDs capture quasi-random cash-flow shocks, their effects should be strongest in municipalities whose revenues are most exposed to local economic activity and weakest where revenues are insulated from local conditions.

We first consider the effect of a government's revenue composition. We predict that areas with more diversified revenue sources will be better insulated from temperature shocks, on average, for two reasons. First, these areas are better diversified in terms of their cash-generation activities, some of which will be less sensitive or even immune to weather variation. Second, having more diversified revenue categories indicates that these municipalities have flexibility in managing revenues toward their projections. These predictions are consistent with arguments from the prior municipal accounting literature that having undiversified revenue sources increases municipalities' credit risk and their susceptibility to adverse revenue shocks (Copeland and Ingram 1982; Gore 2009).

Column 1 of Table 7 investigates how the CDD–revenue relation varies with revenue diversification, computed as the inverse of a Herfindahl index (Copeland and Ingram 1982).[15] We find a highly negative and significant baseline effect of CDDs and a positive offsetting coefficient on the interaction with a municipality's revenue diversification. Since our revenue dispersion measure is standardized, the baseline negative coefficient on CDDs confirms our full sample estimate whereby a municipality with average revenue dispersion exhibits a negative relation

[15] Our results are qualitatively similar in columns 1 and 2 of Table 6 when we deploy a categorical count measure of revenue sources rather than our revenue diversity measure.

between CDDs and revenue. The positive interaction between CDDs and revenue dispersion suggests that municipalities whose revenues are highly concentrated in a small set of categories exhibit much larger revenue declines when CDDs are high, while those with more dispersed revenue bases display much weaker sensitivity.

[INSERT TABLE 7 HERE]

Motivated by our conjecture that CDDs affect spending through their role as a revenue shock, we next study whether revenue dispersion moderates the CDD-*spending* relationship in the same manner observed for CDDs and revenues in column 1. If municipalities with more diverse revenue bases offset the effects of CDD-type shocks, then we would also expect municipalities expenditures to be less affected by abnormally warm weather. We explore this in column 2 of Table 7. The positive and statistically significant coefficient on *CDDs* × *Rev. Dispersion* in column 2 suggests that expenditures of municipalities with more diverse revenue streams are indeed less sensitive to abnormal heat. These patterns reinforce the interpretation of CDDs as a revenue-driven cash-flow shock rather than as a direct shock to underlying spending needs. The fact that revenue dispersion predicts both the revenue decline and the magnitude of the spending response suggests that expenditure adjustments are primarily a reaction to the revenue shortfall, not through independent channels through which heat might influence costs.

In columns 3 and 4 of Table 7, we introduce additional heterogeneity into our tests both to understand the role of other moderators of the CDD-revenue relation, and to continue our descriptive examination of how similar these moderators manifest in the revenues versus spending analyses. We construct an additional measure for how insulated the area's revenue composition is from CDD shocks, defined as the percentage of revenues coming from property taxes, intergovernmental transfers, utilities, and other (non-tax, non-fee sources). To the extent that a government's revenues are comprised from these sources, we expect them to be less adversely exposed to abnormally warm weather. Conversely, if their revenue bases constitute largely tax- or fee-based revenues, which better encapsulate economic transactions in local economies, we expect municipalities cash inflows to be more exposed to CDDs.[16]

In addition, we incorporate a host of interactions between CDDs and other features of both the local economy and statewide institutional regulations. For instance, we interact CDDs with all our local economic control variables, including the area's population, as well as measures of the area's urbanity and political leaning. We further examine whether state-level institutional frictions meaningfully shape the revenue and spending responses to CDDs. We focus on three commonly studied dimensions: balanced-budget requirements (Costello et al. 2017), tax and expenditure limitations (TELs) (Wen, Xu, Kim, and Warner (2020), and access to Chapter 9 bankruptcy (Basu, Beck, Gore, and Rich 2025; Gao, Lee, and Murphy 2019). Using state-level data on balanced-budget rules and their restrictiveness, TEL indices, and Chapter 9 access, we augment our baseline models with interactions between CDDs and each of these institutional variables.[17]

Column 3 of Table 7 shows that the attenuating effects of revenue diversification on the CDD-revenue relation remain robust to including a rich set of interactions between CDDs and local economic conditions, including population, unemployment, income per capita, the number of establishments and indicators for metro and more Democratic areas. Additionally, areas with revenues that we expect to be less exposed to CDDs (e.g., intergovernmental revenue dependent

[16] These partitions are based on our ex-ante expectations regarding the most CDD sensitive revenue streams. None of the categories that we label as insulated exhibit a significant relation with CDDs in either Figure 2 or Appendix Figure A2. The closest to significant is property taxes, but that is largely due to the magnitude of property taxes as a revenue category –on a percentage basis property taxes are about 60% as sensitive as the typical tax dollar. In fact, a comparably strong measure of revenue insulation is the fraction of tax revenue derived from property taxes.
[17] We provide detailed variable definitions for our modifying variables in Appendix A.

municipalities) exhibit an attenuated CDD-revenue relation (as evidenced by the positive *CDDs × % Rev. Insulated* coefficient). In contrast, with the exception of urbanity, we find little evidence that local economic conditions such as political leaning or statewide institutional features meaningfully affect governmental responses to abnormal heat.

In column 4 of Table 7, we once again find a similar interactive relations between a variety of factors and CDDs using municipal spending, as opposed to municipal revenues, as the dependent variable. Municipal expenditures are most affected by CDDs when municipalities have less dispersed revenue streams and are more dependent on transaction-based revenue sources. The CDD spending relation is generally not related to political leaning or statewide institutional municipal financing frictions, again with the exception that the relation is more pronounced in rural areas.

7.1. Key Empirical Takeaways

There are three important takeaways from our cross-sectional analyses. First, revenue diversification aids municipalities in insulating them from temperature-induced variation in revenues, which in turn shields their spending. Although the evidence supporting this takeaway is descriptive in that we do not have exogenous variation in revenue composition, it is robust and largely insensitive to the inclusion of many additional control variables and their interactions with CDDs. This evidence is consistent with the idea that revenue diversification insulates municipalities from quasi-random cash-flow shocks induced by abnormal heat. This interpretation also aligns with arguments in the public finance literature that undiversified revenue structures increase credit risk and make governments more susceptible to adverse shocks (Copeland and Ingram 1982; Gore 2009). Our setting extends this work by showing that, even after conditioning on detailed local economic controls, municipalities with more numerous and more evenly distributed revenue sources are substantially less exposed to temperature-driven revenue declines.

Second, formal state-level mandates relating to municipal finances play little role in the relation between CDDs and municipal revenues or spending. This takeaway is especially interesting given the lock-step nature in which both revenues and spending respond to variation in CDDs. While balanced-budget requirements and TELs may shape longer-run fiscal dynamics (e.g., Costello, Petacchi, and Weber 2017), our evidence indicates that they do not materially alter the short-run way in which municipalities manage CDD-induced cash-flow shocks. Instead, municipalities appear to rely primarily on contemporaneous spending adjustments, regardless of the formal institutional environment in their state.

Third, the way in which CDDs impact revenue and spending are remarkably similar. This set of results is consistent with CDDs affecting municipal spending predominantly because they first affect municipal revenue, meaning that CDDs represent a non-fundamental shock to municipal revenues. Taken together, these heterogeneity results function as quasi-experimental validation checks: CDDs matter most where municipal cash flows are *ex-ante* most vulnerable to local economic disruptions and least where revenue is insulated, which is hard to reconcile with spurious correlation driven by slow-moving fundamentals.

8. Disciplining Our Estimates with Survey Evidence

In our final set of analyses, we discipline our estimates by conducting a survey of municipal managers to see the extent to which our findings align with their perceptions. Our empirical evidence above provides several new insights to the municipal finance literature. We find that abnormally warm weather reduces municipal revenues, municipalities appear to adjust their expenses downward in real time to offset adverse revenue shocks, and that capital outlays are the most likely type of spending to be adjusted.

Given the novelty of these findings in relation to the existing academic literature, we supplement this empirical evidence by conducting a field survey of municipal finance managers. Utilizing our sample, we searched the websites for contact information for the head of the municipalities finance department.[18] From our sample, we randomly ordered our municipalities sample and collected contact information from municipal websites for 200 managers (of which 184 had legitimate email addresses). We then emailed a Google survey to these managers through Google forms regarding the operational responses to cash windfalls.[19] Thirteen managers responded to our survey, resulted in a participation rate of 7.1%. Appendix B shows the survey questions and responses, with Panel A indicating that respondents included managers from varied municipal sizes ranging from small municipalities (populations < 1,000) to large municipalities (populations > 100,000). Table 8 presents select answers that summarize the most important ways that the survey enhances the interpretation of our findings.

[INSERT TABLE 8 HERE]

Panel A of Table 8 presents the most important takeaway from our survey, which is that municipal managers report current period capital spending to be the main lever they use to offset revenue shortfalls –69.2% of respondents note that this is very important and 23.2% of respondents note that this is the most important. Interestingly, less than half of respondents noted that future capital expenditures are useful mechanism to respond to a cash shortfall. These findings

[18] The title of such positions varied across municipalities (e.g., Treasurer, Finance Director, Town Clerk, Finance Officer, Town Administrator). If a finance-related role was not found, we collected contract information from the City Administrator, City Manager, or Mayor.
[19] We sent initially sent our survey on 4/28/2025, with a follow up request on 5/8/2025.

corroborate our empirical evidence in Figure 4 and Table 3 that current capital expenditures are highly sensitive to the unexpected revenue declines due to abnormally warm weather. Interestingly, this evidence contrasts with prior literature's findings that municipal managers respond to cash shortfalls in subsequent budgeting periods (Costello, Petacchi, and Weber 2017; Helm and Stuhler, 2024). The second most common response to mitigating revenue shortfalls was to draw on cash reserves, credit lines, or issue debt (61.5% of respondents noted that this was very important). This municipal manager response is consistent with prior empirical evidence that municipalities with higher revenue uncertainty retain more cash (Gore 2009) as well as our longer-run evidence that persistent CDD shocks can lead to more net debt (i.e., debt minus cash) on the balance sheet as documented in Table 5.

Panel B of Table 8 summarizes responses to the question of how frequently weather contributes to revenue shortfalls. The responses are very consistent with our empirical findings indicating that CDDs have a marginal effect on revenues (up to a few percentage points in extreme cases), but that generally there is little relation between aspects of the weather and municipal revenues. They are also broadly consistent with our identifying assumption that weather variation is not a fundamental shock to municipal finances. Only 7.7% of managers perceive weather as regularly driving weather shortfalls, while 38.5% acknowledge there have been years when weather has affected revenue. This lack of impact is not driven by a lack of variation in revenue as Appendix B, Panel B, shows that approximately one-quarter (23.1%) of our municipal managers experienced significant deviations in their revenue receipts versus their budgeted revenues in at least one of the past four years, with another 30.8% experienced significant deviation from budgeting revenues in 10% to 25% of reporting years. Our evidence of a statistically significant revenue impact of CDDs highlights the value of our large sample to provide novel statistical evidence on the CDD-revenue relation.

Appendix B also presents a few other takeaways from our survey. Panel C shows that taxes and fees comprised the most common deviation from revenue expectations, which intergovernmental transfers having the least variation from revenue expectations. These initial readings are broadly consistent with how we define the percentage of insulated revenue.

Panel E presents responses to the question of what drives their fiscal austerity. Managers noted that the fiscal discipline in response to cash shortfalls is in line with what they believe their constituents want (100% believe this is very important), along with requirements to maintain a balanced budget (83.3% believe that is very important), and concerns regarding financial constraints (75% believe that is very important). We also were interested in further understanding what constitutes a balanced budget for municipal managers. In Panel F, we document significant variation in responses as to municipal governments' definitions of a balanced budget. The majority of respondents noted that a balanced budget implies that their municipality will not project spending above projected receipts (58.3%), and half our respondents noted that cash expenditures cannot be less than cash receipts plus net cash reserves. Another 16.7% of respondents noted that they are not subject to balanced budget requirements. While balanced budgets to appear binding on governmental behavior (Costello et al. 2017), the utilization of net debt to offset revenue shortfalls, and our survey evidence confirms that managers have tools at their exposure beyond expenditure reductions.

9. Conclusion

Using a large cross-sectional panel constructed from four Census Bureau surveys, we show that abnormal heat operates as a meaningful cash-flow shock for U.S. municipalities. Warmer-than-usual years significantly depress municipal revenues, with the largest effects in jurisdictions that rely on a small number of revenue streams. Municipalities largely offset these shocks in real time by cutting expenditures dollar-for-dollar, and they do so primarily by reducing capital spending rather than operating outlays. Survey evidence from municipal finance managers corroborates this mechanism: managers report that current-year capital projects are their primary margin of adjustment to unexpected shortfalls.

Our first contribution is to document that municipal revenues are systematically affected by within-jurisdiction variation in temperature. This result is not ex ante obvious given the many dimensions of municipal revenue, such as taxes, fees, utilities, and intergovernmental transfers, and it adds municipalities to the growing list of economic agents whose cash flows are significantly impacted by weather (e.g., Addoum, Ng, and Ortiz-Bobea 2023; Tran 2023; Dell et al. 2014). Our setting provides a clean source of non-fundamental cash-flow risk for an economically important class of issuers whose securities are widely held by households and institutions.

Our second contribution is to show that municipal spending adjusts quickly and likely represents a pass-through effect from temperature's revenue impact. Expenditures move in near lockstep with revenue declines, in terms of both the immediacy and magnitude of the response and the types of municipalities making the largest adjustments. In particular, the structure of municipal revenues strongly predicts the sensitivity of municipal spending to temperature shocks. This pattern suggests that short-run responses to non-fundamental weather shocks are driven by cash-flow considerations, not by direct physical effects of heat on operating costs, and contrasts with the gradual, multi-year adjustments documented in response to fundamental or permanent revenue changes (Buettner and Wildasin 2006; Helm and Stuhler 2024). In this sense, municipalities display a degree of financial flexibility that runs counter to canonical views of governmental inflexibility and slow adjustment.

Finally, our study provides the first evidence on the sensitivity of municipal investment to revenue shocks. Our findings indicate that short-run revenue shocks lead municipalities to forgo long-term investment in a manner that is broadly consistent with the behavior of financially constrained firms (Fazzari, Hubbard, and Petersen, 1988; Moyen, 2004; Brown, Fazzari, and Petersen, 20098). In fact, municipal capital spending is almost three times as sensitive as operating costs to temperature shocks. Thus, while municipalities are self-sufficient and able to manage temperature shocks, it comes at the cost of long-term investment projects. In the near term, our results indicate that municipalities largely shield their bondholders from thermal cash-flow risk by cutting investment rather than relaxing budget balance or increasing net borrowing. Over longer horizons, however, persistent heat exposure gradually surfaces on the balance sheet as higher net debt, suggesting that rising temperatures ultimately pose both real-side costs for residents and financial risks for municipal investors.

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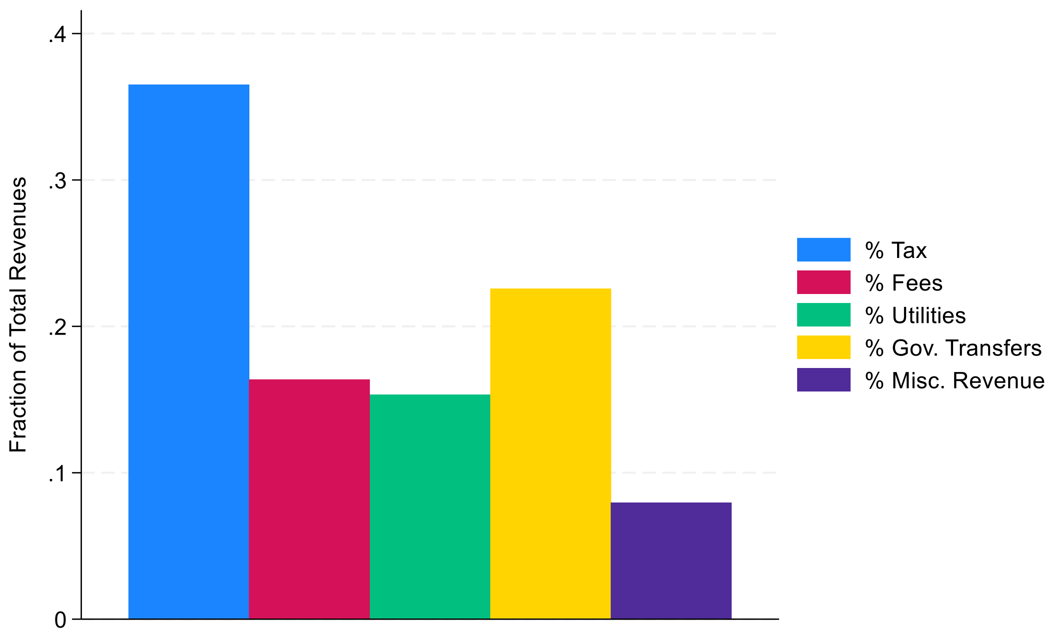
Figure 1: Municipal Revenue & Expenditure Breakdown

This figure decomposes municipal revenues (Panel A) and expenditures (Panel B) by type. The y-axis reflects the fraction of revenues or expenditures contained within each category. The various revenue, capital outlay, and expenditure subcomponents are derived from The Government Finance Database and described in detail in Appendix A.

Panel A: Revenue Breakdown



Panel B: Expenditure Breakdown

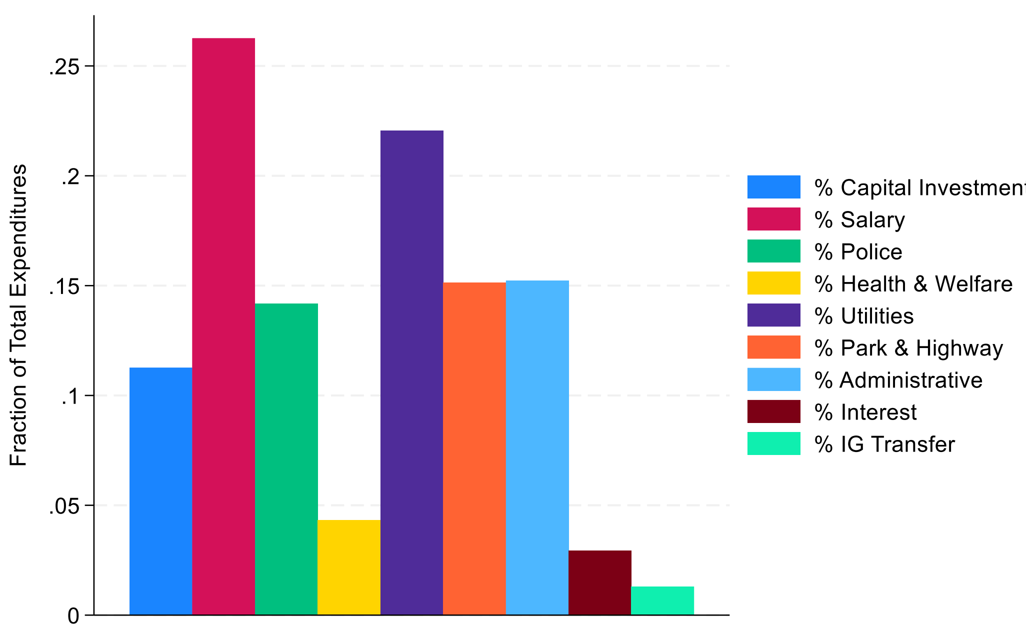


Figure 2: Revenue Decomposition

This figure decomposes the effect of CDDs on revenues by revenue type. Each point on the figure is generated from a separate regression, analogous to column 1 of Table 2, except the dependent variable measures only revenues of the type indicated on the x-axis. We restrict each regression to municipalities that have non-zero amounts of each respective revenue source. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level. The various revenue subcomponents are derived from The Government Finance Database and described in detail in Appendix A.

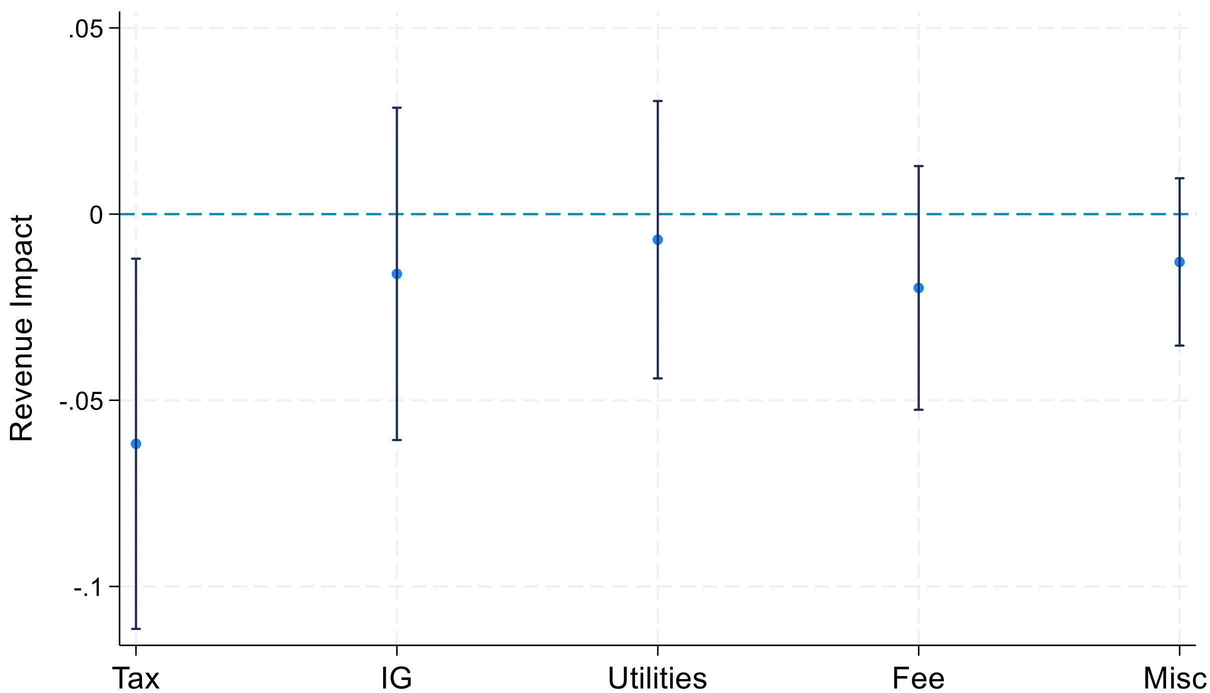


Figure 3: Dynamic Effect of Temperature on Municipal Revenues

This figure plots the estimated coefficients of contemporaneous, lead, and lagged annual cooling degree days (i.e., the number of degree days above 65 degrees Fahrenheit) on municipal revenues scaled by population. The estimates derive from an OLS regression model with municipality and state-year fixed effects and county level controls for the unemployment rate, per capita income, and the number of business establishments. We obtain municipal finance information from The Government Finance Database and temperature information from NOAA Monthly U.S. Climate Divisional Database. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

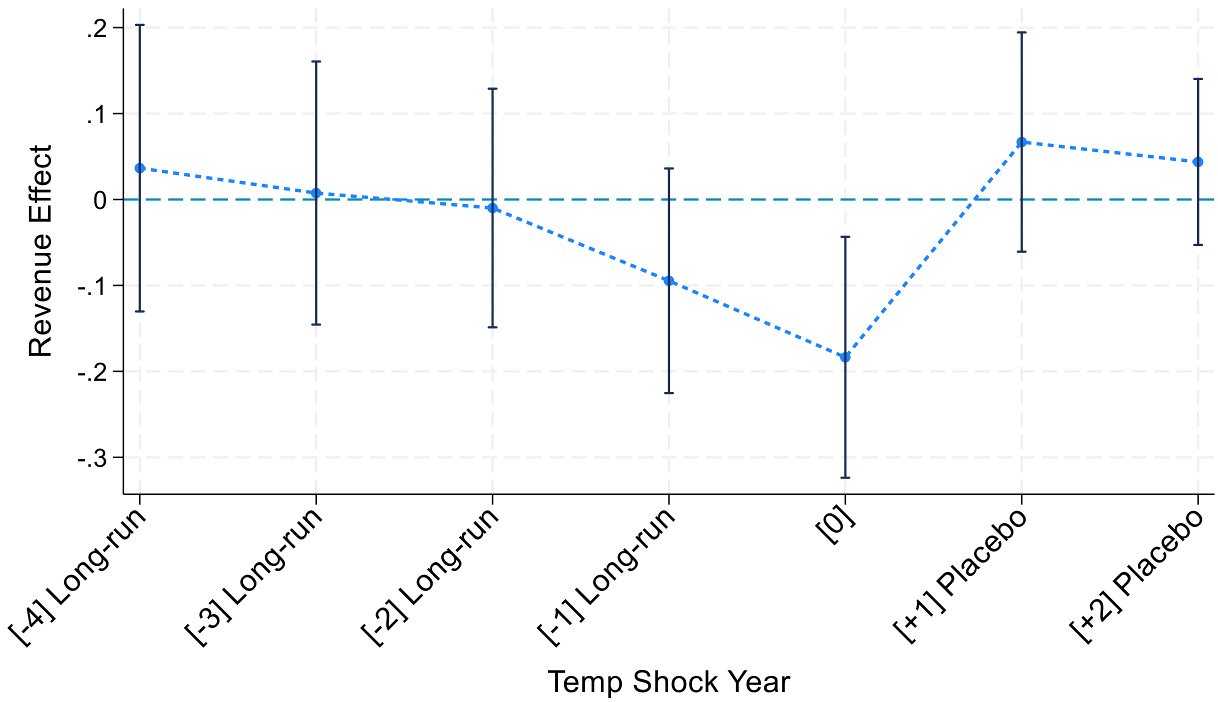


Figure 4: Dynamic Effect of Temperature on Capital Expenditures

This figure plots the estimated coefficients of contemporaneous, lead, and lagged annual cooling degree days (i.e., the number of degree days above 65 degrees Fahrenheit) on municipal capital expenditures scaled by population. The estimates derive from an OLS regression model with municipality and state-year fixed effects and county level controls for the unemployment rate, per capita income, and the number of business establishments. We obtain municipal finance information from The Government Finance Database and temperature information from NOAA Monthly U.S. Climate Divisional Database. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

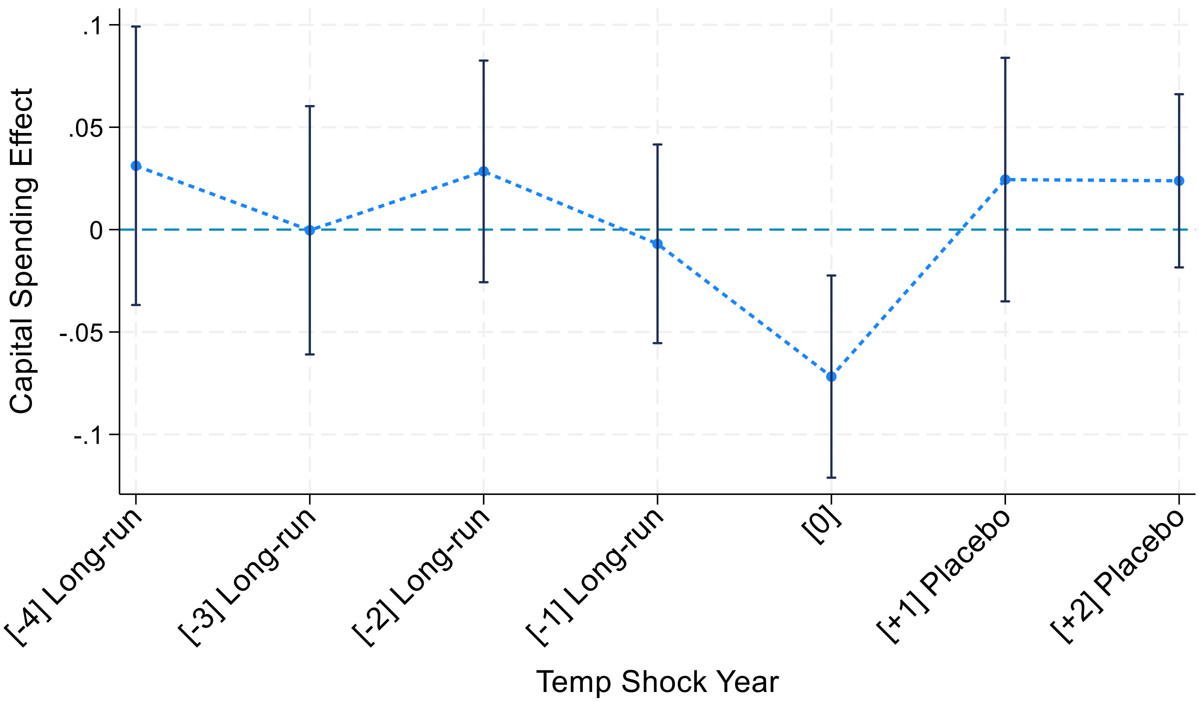


Figure 5: Dynamic Effect of Temperature on Municipal Spending

This figure plots the estimated coefficients of contemporaneous, lead, and lagged annual cooling degree days (i.e., the number of degree days above 65 degrees Fahrenheit) on municipal expenditures scaled by population. The estimates derive from an OLS regression model with municipality and state-year fixed effects and county level controls for the unemployment rate, per capita income, and the number of business establishments. We obtain municipal finance information from The Government Finance Database and temperature information from NOAA Monthly U.S. Climate Divisional Database. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

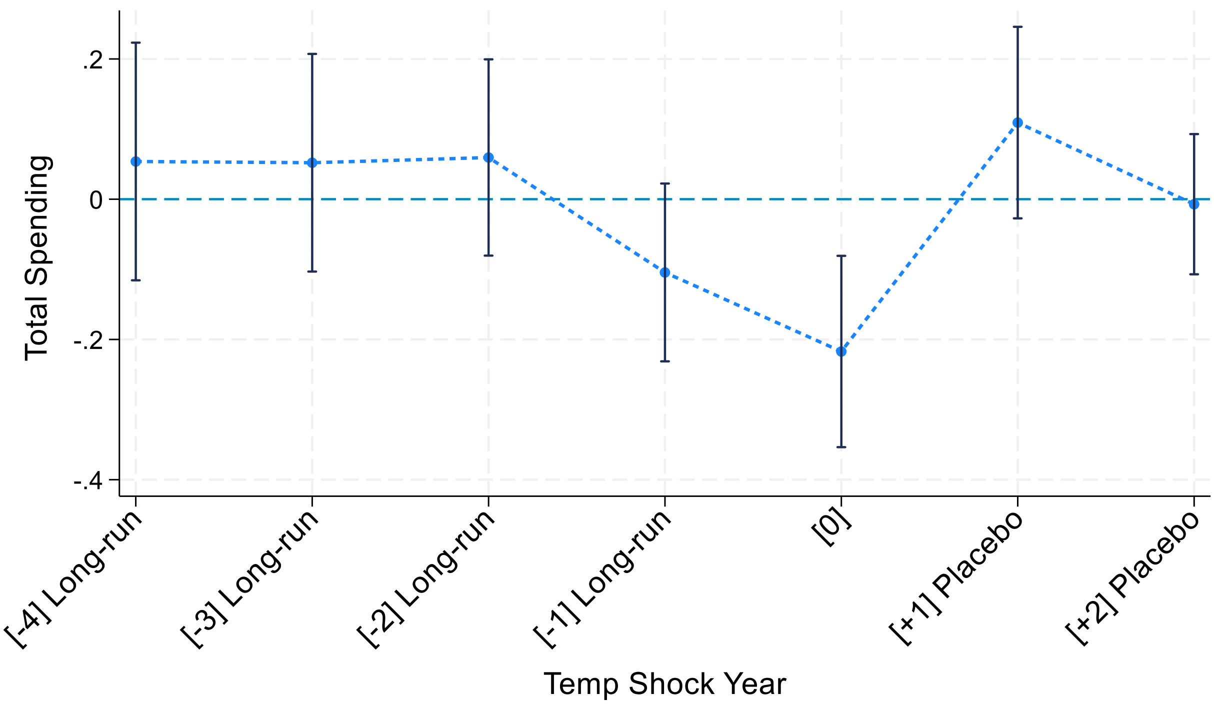


Figure 6: Dynamic Effect of Temperature on Municipal Debt Issuance

This figure plots the estimated coefficients of contemporaneous, lead, and lagged annual cooling degree days (i.e., the number of degree days above 65 degrees Fahrenheit) on municipal net debt issuance scaled by population. The estimates derive from an OLS regression model with municipality and state-year fixed effects and county level controls for the unemployment rate, per capita income, and the number of business establishments. We obtain municipal finance information from The Government Finance Database and temperature information from NOAA Monthly U.S. Climate Divisional Database. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

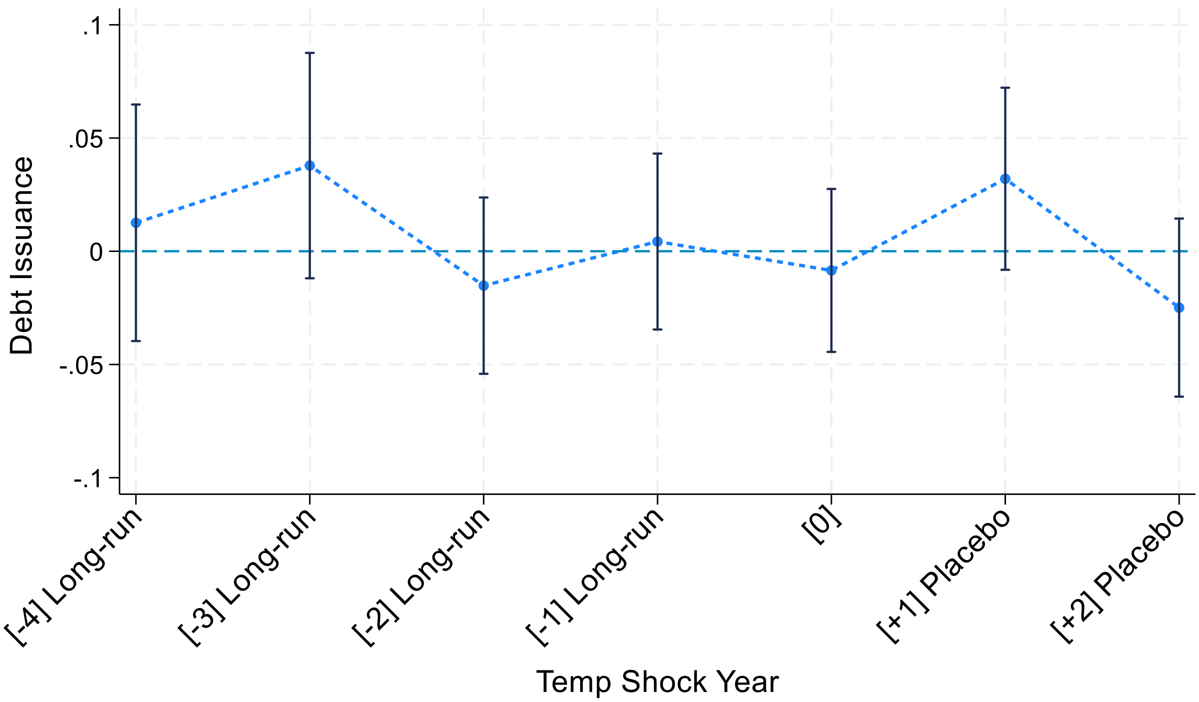


Table 1: Descriptive Statistics

This table presents descriptive statistics for the variables used in our analysis. The sample contains 87,500 municipality-years, where the years correspond to the three most recent Census Bureau's Census of Governments (CoG) in 2007, 2012, 2017, and 2022 as complied by The Government Finance Database. Appendix A provides detailed variable definitions along with data sources.

	Mean	Stan. Dev.	Median	p99	p1
Total Revenue	1.88	1.77	1.38	11.27	0.10
Total Expenses	1.91	1.80	1.42	11.16	0.03
Capital Expenditure	0.28	0.56	0.09	3.64	0.00
Revenue Dispersion	0.66	0.18	0.71	0.88	0.00
Cooling Degree Days	1,329.68	839.68	1,128.00	4,019.00	66.00
Population	21,434	140,063	1,691	338,018	37
Income per capita	49,417	12,418	46,988	94,699	29,735
Unemployment	6.20	2.52	5.60	14.20	2.40
Establishments	6,757	22,250	920	104,022	53

Table 2: Temperature Shocks and Municipal Revenues

This table presents output from estimating panel regressions using municipality and state-year fixed effects. Columns 1, 3, 4, and 5 employ an OLS regression, while column 2 employs a Poisson maximum likelihood model. The dependent variable is municipal revenues, scaled by municipal population only in the OLS specifications. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Our baseline CDD measure is standardized, whereas column uses raw CDD Extreme (i.e., CDDs excluding variation in years with less than 841 CDDs) and column 5 presents estimates for the non-linear (i.e., quadratic) effect of raw CDD counts. All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Column 3 further controls for HDDs (i.e., degree days below 65 degrees Fahrenheit), and two separate annual precipitation measures. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Total Revenue	(2) Total Revenue (Unscaled)	(3) Total Revenue	(4) Total Revenue	(5) Total Revenue
CDDs	-0.177***	-0.055**	-0.200***		
	(-2.73)	(-2.35)	(-3.03)		
CDD Extreme				-0.247***	
				(-3.34)	
CDD (raw count)					0.122
					(0.82)
CDD^2 (raw count)					-0.076**
					(-2.39)
Income per capita	0.089***	0.026***	0.088***	0.089***	0.088***
	(4.45)	(2.80)	(4.38)	(4.47)	(4.40)
Ln(Pop.)	-2.115***	0.908***	-2.116***	-2.114***	-2.115***
	(-15.07)	(8.46)	(-15.06)	(-15.07)	(-15.08)
Unemployment	0.013	-0.004	0.014	0.013	0.013
	(0.94)	(-0.75)	(0.97)	(0.94)	(0.93)
Ln(Estabs)	0.866***	0.525***	0.874***	0.872***	0.891***
	(5.01)	(7.06)	(5.08)	(5.05)	(5.17)
HDDs			-0.158*		
			(-1.69)		
Precipitation			-0.003		
			(-0.23)		
Cold Precipitation			-0.008		
			(-0.74)		
Model	OLS	Poisson	OLS	OLS	OLS
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	1.88	31,179	1.88	1.88	1.88
Adjusted (Pseudo) R^2	0.75	0.99	0.75	0.75	0.75
Observations	87,501	87,501	87,494	87,501	87,501

Table 3: Temperature Shocks and Capital Expenditures

This table presents output from estimating panel regressions using municipality and state-year fixed effects. Columns 1, 3, 4, and 5 employ an OLS regression, while column 2 employs a Poisson maximum likelihood model. The dependent variable is municipal capital expenditures (i.e., capex), scaled by municipal population only in the OLS specifications. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Our baseline CDD measure is standardized, whereas column 4 uses raw CDD Extreme (i.e., CDDs excluding variation in years with less than 860 CDDs) and column 5 presents estimates for the non-linear (i.e., quadratic) effect of raw CDD counts. All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Column 3 further controls for HDDs (i.e., degree days below 65 degrees Fahrenheit), and two separate annual precipitation measures. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Capital Expenditures	(2) Capital Expenditures (Unscaled)	(3) Capital Expenditures	(4) Capital Expenditures	(5) Capital Expenditures
CDDs	-0.057**	-0.188**	-0.064***		
	(-2.37)	(-2.53)	(-2.58)		
CDD Extreme				-0.088***	
				(-3.24)	
CDD (raw count)					0.080
					(1.17)
CDD^2 (raw count)					-0.034***
					(-2.60)
Income per capita	0.023***	0.032	0.023***	0.023***	0.022***
	(2.71)	(1.41)	(2.67)	(2.72)	(2.65)
Ln(Pop.)	-0.407***	0.199	-0.407***	-0.406***	-0.407***
	(-6.04)	(1.25)	(-6.03)	(-6.03)	(-6.03)
Unemployment	-0.001	-0.032*	-0.001	-0.001	-0.001
	(-0.22)	(-1.70)	(-0.20)	(-0.22)	(-0.23)
Ln(Estabs)	0.256***	0.773***	0.259***	0.258***	0.267***
	(3.91)	(4.61)	(3.96)	(3.95)	(4.07)
HDDs			-0.045		
			(-0.86)		
Precipitation			-0.003		
			(-0.43)		
Cold Precipitation			0.000		
			(0.01)		
Model	OLS	Poisson	OLS	OLS	OLS
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	0.28	4,261.96	0.28	0.28	0.28
Adjusted (Pseudo) R^2	0.32		0.32	0.32	0.32
Observations	87,501	79,041	87,494	87,501	87,501

Table 4: 2SLS Estimates of CDD-induced Revenue Shocks' effect on Investment

Column(s) 1 (2 and 3) presents (present) second stage 2SLS (OLS) estimates regarding the effect of revenues on capital expenditures. In the 2SLS models, the first stage for column 2 is column 1 of Table 2 and the first stage for column 3 is column 4 of Table 2. The instruments are CDDs and CDD Extreme, respectively. Thus, $\widehat{Total\ Revenue}$ isolates the impact of CDD-induced revenue on municipal capital investment scaled by municipal population. All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Capital Expenditures	(2) Capital Expenditures	(3) Capital Expenditures
Total Revenue	0.213***		
	(37.25)		
$\widehat{Total\ Revenue}$		0.320**	0.355***
		(2.46)	(3.26)
Income per capita	0.004	-0.006	-0.009
	(0.49)	(-0.41)	(-0.70)
Ln(Pop.)	0.043	0.270	0.343
	(0.74)	(0.96)	(1.44)
Unemployment	-0.004	-0.006	-0.006
	(-0.76)	(-0.94)	(-1.00)
Ln(Estabs)	0.070	-0.021	-0.051
	(1.32)	(-0.17)	(-0.46)
Model	OLS	2SLS	2SLS
First Stage		Table 2 Col. 1	Table 2 Col. 4
First Stage IV		CDDs	CDD Extreme
First Stage F-Stat		7.44	11.12
State-Year-Month FE	Y	Y	Y
Muni FE	Y	Y	Y
Mean Dependent	0.28	0.28	0.28
Adj. (Psd.) R-squared	0.44	0.12	0.10
Observations	87,501	87,501	87,501

Table 5: Temperature Shocks and Total Municipal Spending

This table presents output from estimating OLS panel regressions using municipality and state-year fixed effects. In columns 1 and 2 (3 through 5) the dependent variable is non-capital (total) municipal expenditures, scaled by municipal population. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Our baseline CDD measure is standardized, whereas column 5 uses raw CDD Extreme (i.e., CDDs excluding variation in years with less than 860 CDDs). All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Columns 2 and 4 further controls for HDDs (i.e., degree days below 65 degrees Fahrenheit), and two separate annual precipitation measures. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Non-capital Expenditure	(2) Non-capital Expenditure	(3) Total Expenditure	(4) Total Expenditure	(5) Total Expenditure
CDDs	-0.136***	-0.141***	-0.193***	-0.205***	
	(-2.66)	(-2.71)	(-3.02)	(-3.17)	
CDD Extreme					-0.248***
					(-3.39)
Income per capita	0.052***	0.052***	0.075***	0.075***	0.075***
	(3.27)	(3.23)	(3.76)	(3.72)	(3.78)
Ln(Pop.)	-1.707***	-1.708***	-2.114***	-2.115***	-2.113***
	(-15.92)	(-15.92)	(-13.89)	(-13.88)	(-13.89)
Unemployment	0.008	0.008	0.006	0.007	0.006
	(0.69)	(0.70)	(0.44)	(0.46)	(0.44)
Ln(Estabs)	0.708***	0.710***	0.963***	0.969***	0.968***
	(5.20)	(5.23)	(5.44)	(5.48)	(5.46)
HDDs		-0.049		-0.094	
		(-0.64)		(-0.92)	
Precipitation		0.003		0.000	
		(0.27)		(0.00)	
Cold Precipitation		-0.005		-0.005	
		(-0.54)		(-0.42)	
Model	OLS	OLS	OLS	OLS	OLS
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	1.63	1.63	1.91	1.91	1.91
Adjusted (Pseudo) R^2	0.77	0.77	0.72	0.72	0.72
Observations	87,501	87,494	87,501	87,494	87,501

Table 6: Temperature Shocks and Municipal Debt

This table presents output from estimating OLS panel regressions using municipality and state-year fixed effects. The dependent variable is net debt issuance in column 1 and net debt level in columns 2 through 4, all scaled by population. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 5-year CDDs is this same count summed over the five years ending in the current year. Our baseline CDD measures are standardized, whereas column 4 presents estimates for the non-linear (i.e., quadratic) effect of raw 5-year CDD counts. All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Net Debt Issuance	(2) Net Debt Level	(3) Net Debt Level	(4) Net Debt Level
CDDs	-0.010	0.057		
	(-0.56)	(0.60)		
5-year CDD			0.245**	
			(2.32)	
5-year CDD (raw count)				-0.000
				(-0.71)
5-year CDD^2 (raw count)				0.000**
				(2.19)
Income per capita	0.015***	-0.061*	-0.063*	-0.061*
	(2.63)	(-1.73)	(-1.78)	(-1.75)
Ln(Pop.)	-0.065	1.263***	1.260***	1.260***
	(-1.62)	(5.68)	(5.66)	(5.66)
Unemployment	-0.003	-0.012	-0.011	-0.010
	(-0.77)	(-0.53)	(-0.48)	(-0.44)
Ln(Estabs)	-0.054	-0.296	-0.303	-0.323
	(-1.35)	(-0.98)	(-1.01)	(-1.07)
Model	OLS	OLS	OLS	OLS
State-Year-Month FE	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y
Mean Dependent	0.00	-0.13	-0.13	-0.13
Adjusted (Pseudo) R^2	0.01	0.58	0.58	0.58
Observations	87,501	61,365	61,365	61,365

Table 7: The Role of Revenue Composition

This table presents output from estimating panel regressions using OLS with municipality and state–year fixed effects. The dependent variable is total revenues (total expenditures) scaled by municipal population in columns 1 and 3 (2 and 4). CDDs are Cooling Degree Days and are standardized measures of the number of degree days above 65 degrees Fahrenheit in the year over which the dependent variable is measured. **Rev. Dispersion** is a measure of revenue concentration computed as one minus the Herfindahl index across positive revenue sources in The Government Finance database. Columns 3 and 4 add interactions between CDDs and the local economic controls, institutional variables, and demographic characteristics. **% Rev. Insulated** is the percentage of revenues coming from property taxes, intergovernmental transfers, utilities, and other non-tax, non-fee sources that we predict to be relatively insensitive to CDDs. **Balanced Budget Req.** is a count variable in increasing levels of balanced budget restrictiveness. **TEL Index** is an indicator variable equal to 1 if a municipality resides in a more restrictive state in terms of capturing the intensity of limits on a municipalities ability to raise taxes or increase spending as imposed by their state, and equal to 0 otherwise. **Chapter 9** is an indicator variable equal to 1 when a municipality has unconditional access to Chapter 9 bankruptcy within a state, and equal to zero otherwise. **Rural Code** is the rural–urban continuum code as of 2013, ranging from 1 (large metro) to 9 (extremely remote rural area). **Democrat Area** is an indicator equal to one for municipalities located in states with above-median Democratic vote share (40.6%) in the 2012 presidential election. All models include county-level controls for the unemployment rate, per capita income, population, and the number of business establishments, as well as controls for all variables that enter as CDD interactions. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: *** p<0.01, ** p<0.05, * p<0.10.

	(1) Total Revenue	(2) Total Expenditure	(3) Total Revenue	(4) Total Expenditure
CDDs	-0.435***	-0.347***	-0.428	0.155
	(-5.30)	(-4.57)	(-1.05)	(0.36)
CDDs X Rev. Dispersion	0.390***	0.239***	0.537***	0.320***
	(4.47)	(3.22)	(5.58)	(3.88)
Rev. Dispersion	-0.490***	0.100	-0.497***	0.153**
	(-5.60)	(1.41)	(-5.37)	(2.00)
CDDs X % Rev. Insulated			0.577***	0.335***
			(7.49)	(4.51)
CDDs X Balanced Budget Req			-0.010	-0.108
			(-0.10)	(-1.06)
CDDs X Tax & Expenditure Limit			-0.271	-0.263
			(-1.48)	(-1.39)
CDDs X Chapter 9 State			0.161	0.094
			(1.04)	(0.58)
CDDs X Rural Code			-0.031**	-0.026**
			(-2.53)	(-2.00)
CDDs X Democrat Area			-0.037	-0.017
			(-0.20)	(-0.09)
Model	OLS	OLS	OLS	OLS
Controls	Y	Y	Y	Y
Controls & CDD Interactions	N	N	Y	Y
State-Year-Month FE	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y
Mean Dependent	1.88	1.91	1.88	1.91
Adjusted R^2	0.76	0.75	0.76	0.75
Observations	87,501	87,501	87,501	87,501

Table 8: Survey of Municipal Finance Managers

This table presents responses to two key questions from our survey of municipal managers. Appendix B provides a complete list of the questions and answers to our survey to 184 municipal finance managers distributed on 4/28/2025 (follow-up email on 5/8/2025). Panel A below presents the range of answers we received for our question "How important are the following mechanisms for adjusting to unexpected revenue changes?" In Panel B we present response to the question "Do you believe that weather contributes to revenue shortfalls?" For both panels we had 13 managers respond to the question.

Panel A: How important are the following mechanisms for adjusting to unexpected revenue changes?

Expenditure Adjustment	Very Important	Somewhat Important	Not Important
Current year capital expenditures	69.2%	23.1%	7.7%
Cash reserves, credit lines, or debt issuances	61.5%	23.1%	15.4%
Current year non-salary spending	46.2%	53.8%	0.0%
Next year operating spending	46.2%	46.2%	7.7%
Next year capital expenditures	46.2%	30.8%	23.1%
Current year salary spending	23.1%	61.5%	15.4%

Panel B: Do you believe that weather contributes to revenue shortfalls?

	Yes, Regularly	There have been years when weather has affected a small portion of revenue	Sometimes, but I cannot imagine the effect is large	It has never come to my mind
% of Respondents	7.7%	38.5%	23.1%	30.8%

Appendix A: Variable Definitions

Variable	Description	Source
Outcome Variables		
Total Revenue	Total CPI-adjusted municipal evenue (Total_Revenue) scaled by the municipal's population (Population). Revenue is defined by the Census Bureau as all amounts of money received by a government from external sources (i.e., those originating from "outside the government"), net of refunds and other correcting transactions, proceeds from issuance of debt, the sale of investments, agency or private trust transactions, and intragovernmental transfers.	Census Bureau's CoG/The Government Finance Database (TGFD)
Capital Expenditures	Total CPI-adjusted capital outlays (Total_Capital_Outlays) scaled by the municipal's population (Population). Capital outlays consist of expenditures for purchase or construction, by contract or government employee, construction of buildings and other improvements; for purchase of land, equipment, and existing structures; and for payments on capital leases.	Census Bureau's CoG/TGFD
Total Expenditures	Total CPI-adjusted municipal expenditures (Total_Expenditures) scaled by the municipal's population (Population). Expenses include all amounts of money paid out by a government during its fiscal year – net of recoveries and other correcting transactions – other than for retirement of debt, purchase of investment securities, extension of loans, and agency or private trust transactions.	Census Bureau's CoG/TGFD
Net Debt Issuances	Total CPI-adjusted difference between debt issued (Total_LTD_Issued) and debt retired (Total_LTD_Retired) scaled by the municipal's population (Population). This variable is set to zero when missing.	Census Bureau's CoG/TGFD
Net Debt Level	Total CPI-adjusted total debt (Total_Debt_Outstanding) and less cash outstanding (Total_Cash___Securities) scaled by the municipal's population (Population). This variable is set to missing if cash outstanding is equal to zero.	Census Bureau's CoG/TGFD
Weather Variables		
CDDs	The number of degree days above 65 degrees Fahrenheit in the municipality's county during a given fiscal year. For example, if the temperature were 75 degrees every day for a year, this value would be (75-65)*365 = 3,650. The baseline measure is standardized by subtracting the sample mean and dividing by the sample standard deviation.	NOAA Supplemented with PRISM post-2022
CDD Extreme	The raw annual CDD count minus 841 (i.e., the bottom tercile of the CDD distribution) and then set to zero is negative.	NOAA Supplemented

Variable	Description	Source
		with PRISM post-2022
HDDs	The number of degree days below 65 degrees Fahrenheit in the municipality’s county during a given fiscal year. For example, if the temperature were 55 degrees every day for a year, this value would be (65-55)*365 = 3,650.	NOAA Supplemented with PRISM post-2022
Precipitation	The total precipitation in the municipality’s county during a given fiscal year.	PRISM
Cold Precipitation	The total precipitation in the municipality’s county during a given fiscal year that occurs during months with an average minimum daily temperature below freezing.	PRISM
<u>Revenue and Expenditure Subcomponents</u>		
Tax	Total CPI-adjusted municipal taxes (Total_Taxes) less property taxes (Property_Tax) scaled by the municipal’s population (Population). This variable is set to zero when missing or negative.	Census Bureau’s CoG/TGFD
Fees	Total CPI-adjusted municipal charges (Tot_Chgs_and_Misc_Rev) less miscellaneous general revenues (Misc_General_Revenue) scaled by the municipal’s population (Population). This variable is set to zero when missing or negative. Municipal charges include fees, maintenance assessments, and other reimbursements for current services; rents and sales derived from commodities or services furnished incident to the performance of particular functions; gross income of commercial enterprises; and the like.	Census Bureau’s CoG/TGFD
Utilities	Total CPI-adjusted utility charges (Total_Utility_Revenue) scaled by the municipal’s population (Population). This variable is set to zero when missing or negative. Utility revenues are gross receipts from sale of utility commodities or services to the public or other governments by publicly-owned and controlled utilities.	Census Bureau’s CoG/TGFD
Gov. Transfers	Total CPI-adjusted intergovernmental revenues (Total_IG_Revenue) scaled by CPI-adjusted Total_Revenue. This variable is set to zero when missing or negative. The intergovernmental revenue category consists of amounts received from other governments, whether for use in performing specific activities, for general financial assistance, or as a share of tax proceeds.	Census Bureau’s CoG/TGFD
Misc. Revenue	Total CPI-adjusted total revenue (Total_Revenue) less the revenue subcomponents listed above scaled by the municipal’s population (Population). This variable is set to zero when missing or negative.	Census Bureau’s CoG/TGFD
Health Welfare Expenses	Total CPI-adjusted health and welfare expenses (Health_Direct_Expend, Total_Hospital_Dir_Exp, Public_Welf_Direct_Exp, Tot_Assist___Subsidies, Hous___Com_Direct_Exp, Prot_Insp_Direct_Exp) scaled by the municipal’s population (Population). This variable is set to zero when missing or negative.	Census Bureau’s CoG/TGFD
Park / Highway Expenses	Total CPI-adjusted transportation and park expenses (Parks___Rec_Direct_Exp, Natural_Res_Direct_Exp, Total_Highways_Dir_Exp, Parking_Direct_Expend,	Census Bureau’s CoG/TGFD

Variable	Description	Source
	Air_Trans_Direct_Expend, Water_Trans_Direct_Exp) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	
Police Expenses	Total CPI-adjusted public safety expenses (Police_Prot_Direct_Exp, Correct_Direct_Exp, fire_prot_direct_exp) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	Census Bureau's CoG/TGFD
Utilities Expenses	Total CPI-adjusted utilities expenses (Total_Util_Total_Exp, Sewerage_Direct_Expend) less utilities interest expense (Total_Util_Inter_Exp) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	Census Bureau's CoG/TGFD
Admin. Expenses	Total CPI-adjusted administrative expenses (CEN_STAFF_DIRECT_EXP, fin_admin_direct_exp, judicial_direct_expend, Libraries_Direct_Exp, Total_Educ_Direct_Exp) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	Census Bureau's CoG/TGFD
Interest Expenses	Total CPI-adjusted interest expenses (Interest_on_Gen_Debt, Total_Util_Inter_Exp) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	Census Bureau's CoG/TGFD
IG Transfer Expenses	Total CPI-adjusted intergovernmental expenditures (Total_IG_Expenditure) scaled by the municipal's population (Population). This variable is set to zero when missing or negative.	Census Bureau's CoG/TGFD
Salary Expenses	Total CPI-adjusted *non-zero* salaries and wages (Total_Salaries___Wages) scaled by the municipal's population (Population)**.**	Census Bureau's CoG/TGFD
<u>Modifiers and Controls</u>		
Rev. Dispersion	A measure of revenue concentration using 1 - Herfindahl Index based on the count of revenue categories > 0 for a given municipality. The revenue categories comprise of the following variables in The Government Financial Database: Property_Tax, Total_Gen_Sales_Tax, Alcoholic_Beverage, Tax Amusement_Tax, Insurance_Premium_Tax, Motor_Fuels_Tax, Pari_mutuels_Tax, Public_Utility_Tax, Tobacco_Tax, Other_Select_Sales_Tax, Alcoholic_Beverage_Lic, Amusement_License, Corporation_License, Hunting___Fishing_License, Motor_Vehicle_License, Motor_Veh_Oper_License, Public_Utility_License Occup_and_Bus_Lic_NEC, Other_License_Taxes, Individual_Income_Tax, Corp_Net_Income_Tax, Death_and_Gift_Tax, Docum_and_Stock_Tr_Tax, Severance_Tax Taxes_NEC, Chg_Air_Transportation, Chg_Misc_Com_Activ, Chg_Elem_Ed_Sch_Lunch, Chg_Elem_Ed_Tuition, Chg_Elem_Ed_NEC, Chg_Total_High_Ed, Chg_Hospitals, Chg_Regular_Highways, Chg_Toll_Highways, Chg_Housing___Comm_Dev, Chg_Total_Nat_Res, Chg_Parking, Chg_Parks___Recreation, Chg_Sewerage, Chg_Solid_Waste_Mgmt, Chg_Water_Transport, Chg_All_Other_NEC, Special_Assessments, Prop_Sale_Other Interest_Revenue, Fines_and_Forfeits, Rents_and_Royalties Net_Lottery_Revenue Misc, General_Rev_NEC, Liquor_Stores_Revenue, Water_Utility_Revenue, Electric_Utility_Rev, Gas_Utility_Rev, Transit_Utility_Rev,	Census Bureau's CoG/TGFD

Variable	Description	Source
	Emp_Ret_Total_Ctrib, Emp_Ret_Loc_To_Loc_Sys, Emp_Ret_Sta_To_Sta_Ctr, Emp_Ret_Int_Rev, Unemp_Payroll_Tax, Unemp_Int_Revenue, and Unemp,Federal_Advances	
% Rev. Insulated	The percentage of an area's revenue stemming from property taxes, utilities and intergovernmental transfers.	Census Bureau's CoG/TGFD
Balanced Budget	An indicator variable equal to 1 when executed budget at year-end required to be balanced a for State government, and equal to zero otherwise.	The National Association of State Budget Officers (2021), Table 9
Balanced Budget Req.	A count variable in increasing levels of balanced budget restrictiveness contingent upon: (1) whether an executed budget at year-end required to be balanced a for state government, (2) whether a state legislature is required to pass a balanced budget, (3) whether a budget signed by the governor is required to balanced, and (4) whether the executed budget at year-end is required to be balanced.	The National Association of State Budget Officers (2021), Table 9
TEL Index	An indicator variable equal to 1 whether a municipality resides in one of the top 10 (top 13 with ties) most restrictive states in terms of the intensity of limits on municipalities ability to raise taxes or increase spending as imposed by their state and equal to zero otherwise.	Wen, Xu, Kim, and Warner (2020)
Chapter 9	An indicator variable equal to 1 when a municipality has unconditional access to Chapter 9 bankruptcy within a state, and equal to zero otherwise.	Gao, Lee, and Murphy (2019)
Metro Area	An indicator for a municipality in an area with a rural-urban continuum code of less than four as of 2013.	U.S. Department of Agriculture.
Democrat Area	An indicator for a municipality located in a state with above the median Democratic vote share (of 40.6%) in the 2012 presidential election.	MIT Election Data & Science Lab
Rural Code	The 2013 Rural-Urban Continuum Code (RUCC). Value ranges from 1 to 9 with 1 being a large metropolitan area and 9 being the most remote rural areas.	U.S. Department of Agriculture's Economic Research Service
Income per Capita	Personal income per capita in a municipality's county measured as of July 1st of the previous non-overlapping year.	Bureau of Economic Analysis [CAINC1]

Variable	Description	Source
Ln(Pop.)	The natural log of 1 plus a municipality's population. Population refers to a concentration of individuals for which the municipality provides services.	Census Bureau's CoG/TGFD
Ln(Estabs)	The natural log of 1+ the number of business establishments in a municipality's county measured in March of the previous non-overlapping year.	Census Bureau's CBP
Unemployment	The average monthly unemployment rate in a municipality's county measured in December of the previous non-overlapping year.	Bureau of Labor Statistics (LAUS)

Appendix B: Survey of Municipal Finance Managers

The appendix below provides the questions and answers to our survey to 184 municipal finance managers distributed on 4/28/2025 (follow-up email on 5/8/2025). Panels A – G present our survey questions with the number responses in parentheses.

Panel A: What is the approximate population of your municipality (N=13)?

Response	Less than 1,000	1,000 to 3,000	3,000 to 10,000	10,000 to 25,000	Over 100,000
# Responses	3	3	3	3	1
% of Respondents	23.1%	23.1%	23.1%	23.1%	7.7%

Panel B: How often do municipal revenues significantly deviate from expectations in a manner that affects municipal spending? (N = 13).

Response	Less than one in ten years	10% to 25% of Years	25 to 50% of years	Almost every year
# Responses	6	4	1	2
% of Respondents	46.2%	30.8%	7.7%	15.4%

Panel C: How often do the following revenue categories significantly deviate from your budgeted projection due to unpredictable factors? State N/A if your municipality does not rely on a given revenue source (N=13).

Revenue Category	Always/Usually	Sometimes	Rarely/Never	Not Applicable
Property Taxes	7.7%	30.7%	53.8%	7.7%
Non-Property Taxes	7.7%	46.2%	38.4%	7.7%
Fees	7.7%	46.2%	46.2%	0.0%
Utilities	0.0%	46.2%	30.7%	23.1%
Intergov. Transfers	0.0%	30.7%	61.5%	7.7%

Panel D: How important are the following mechanisms for adjusting to unexpected revenue changes? (N=13).

Expenditure Adjustment (N=13)	Very Important	Somewhat Important	Not Important
Current year capital expenditures	69.2%	23.1%	7.7%
Cash reserves, credit lines, or debt issuances	61.5%	23.1%	15.4%

Current year non-salary spending	46.2%	53.8%	0.0%
Next year operating spending	46.2%	46.2%	7.7%
Next year capital expenditures	46.2%	30.8%	23.1%
Current year salary spending	23.1%	61.5%	15.4%

Panel E: How important are the following forces in explaining why your county responds to a cash shortfall by adjusting expenditures (N =12)?

Explanation	Very Important	Somewhat Important	Not Important
We believe that scaling spending to revenues is what our constituents want.	100.0%	0.0%	0.0%
Requirements to maintain a balanced budget.	83.3%	8.3%	8.3%
Financial constraints (we do not have cash flows available to pay for certain expenditures).	75.0%	25.0%	0.0%
We believe that fiscal austerity is important.	58.3%	25.0%	16.7%
We do not want to borrow money (or draw from cash reserves).	41.7%	58.3%	0.0%

Panel F: What does your municipality consider to be a "balanced budget"? Check all that apply (N = 12).

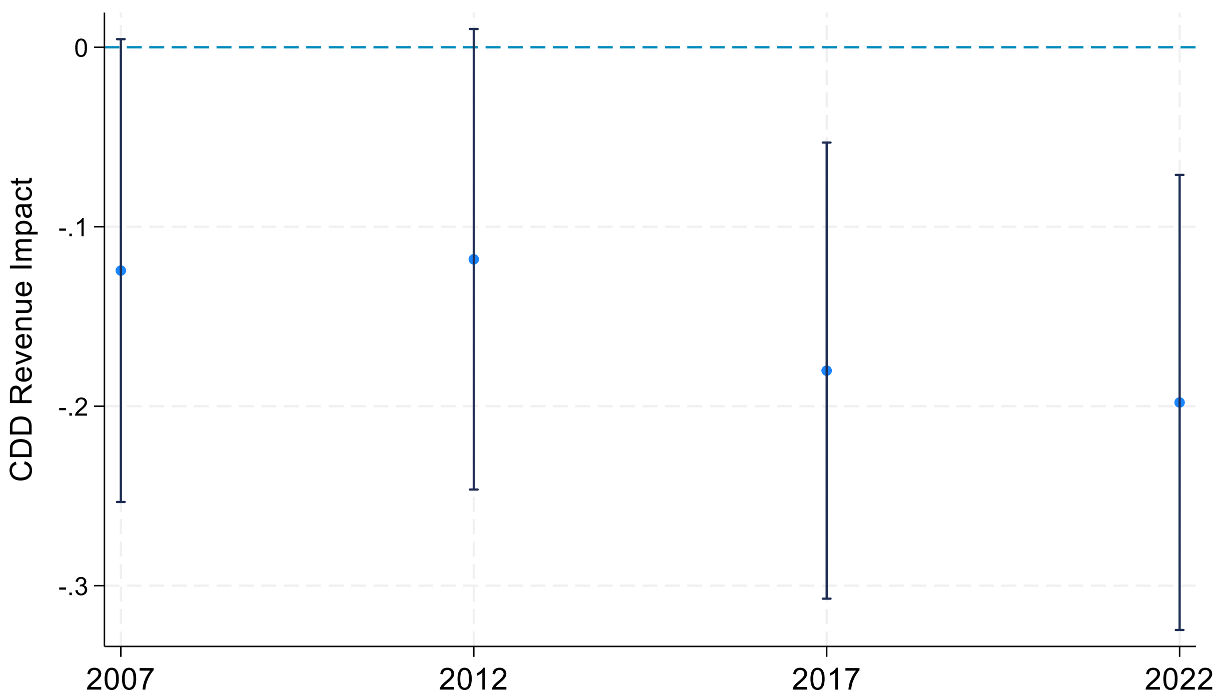
Explanation	% Respondent Selection
We do not project spending above our projected receipts	58.3%
Cash expenditures are less than cash receipts + cash reserves and debt issuances at the end of the year	50.0%
Cash expenditures are less than cash receipts at the end of the year	25.0%
We do not project spending above our projected receipts + cash reserves	16.7%
We are not restricted to a balanced budget provision	16.7%

Panel G: Do you believe that weather contributes to revenue shortfalls (N = 13) ?

Response	Yes, Regularly	There have been years when weather has affected a small portion of revenue	Sometimes, but I cannot imagine the effect is large	It has never come to my mind
# Responses	1	5	3	4
% of Respondents	7.7%	38.5%	23.1%	30.8%

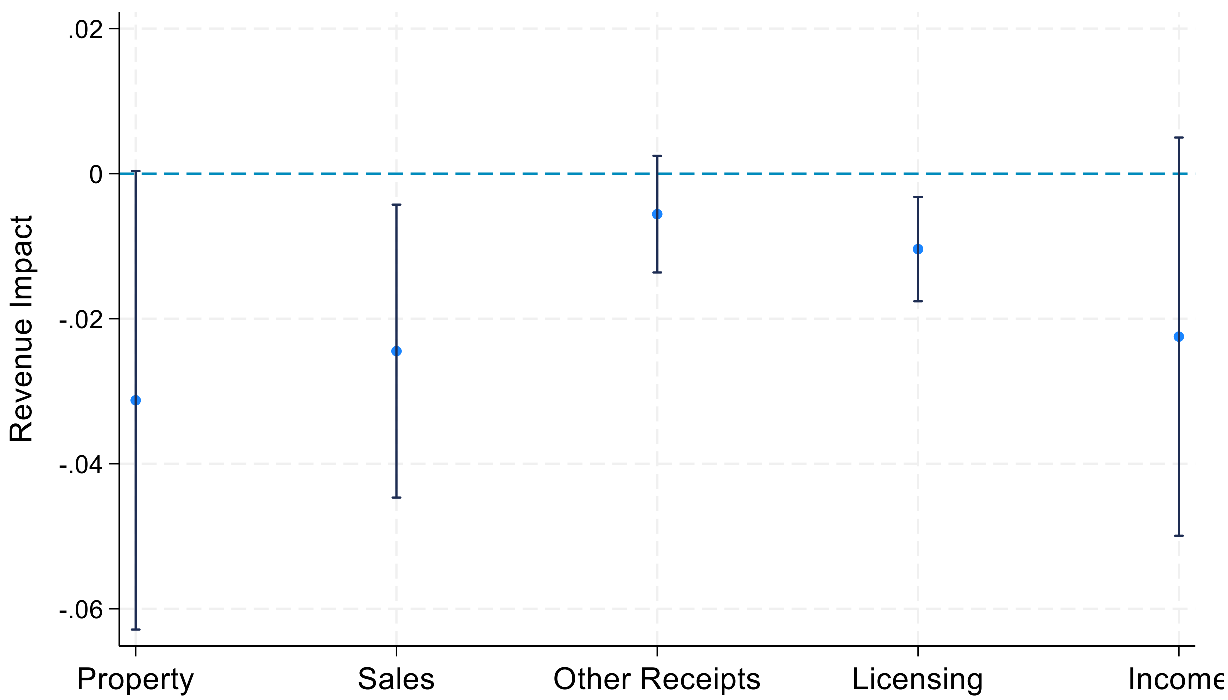
Appendix Figure A1: Revenue Impact of CDDs over time

This figure examines the relation between CDDs and municipal revenues for each of the four years in our primary sample. Each point on the figure represents a coefficient estimate (coupled with its 95% confidence interval based on standard errors clustered at the county level) from a model identical to that in column 1 of Table 2, after interacting CDDs with categorical variables for each year in our sample period. Four separate regressions are conducted with the reference group for the CDD effect interacting across the four years denoted on the x-axis.



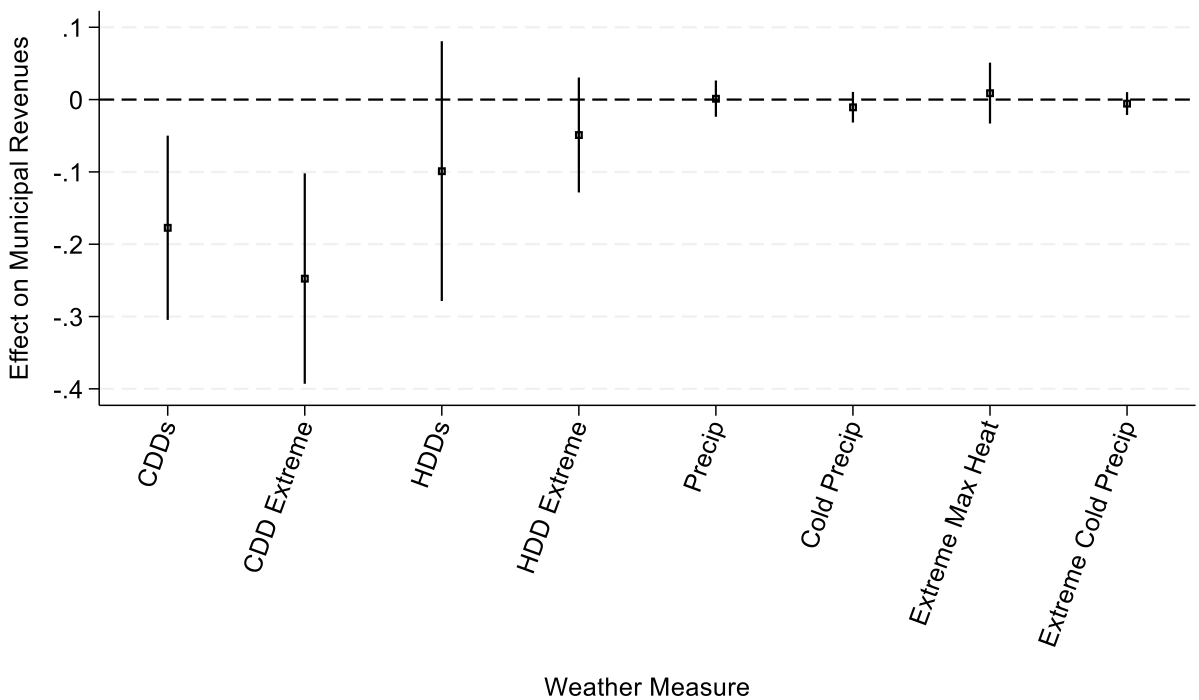
Appendix Figure A2: Tax Revenue Decomposition

This figure decomposes the effect of CDDs on tax revenues by the type of taxes. Each point on the figure is generated from a separate regression, analogous to column 1 of Table 2, except the dependent variable measures only revenues of the type indicated on the x-axis. We restrict each regression to municipalities that have non-zero amounts of each respective tax revenue source. Tax revenue sources are derived from The Government Finance database. *Property* comprises inflation-adjusted property taxes (Property_Tax) per capita, *Sales* comprises inflation-adjusted general sales taxes (Total_Gen_Sales_Tax) per capita, *Other Receipts* comprises inflation-adjusted other sales taxes (Total_Select_Sales_Tax) per capita, *Licensing* comprises inflation-adjusted licensing taxes (Total_License_Taxes) per capita, and *Income* comprises inflation-adjusted income taxes (Total_Income_Taxes) per capita. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.



Appendix Figure A3: Revenue Impact of CDDs versus other dimensions of municipal weather

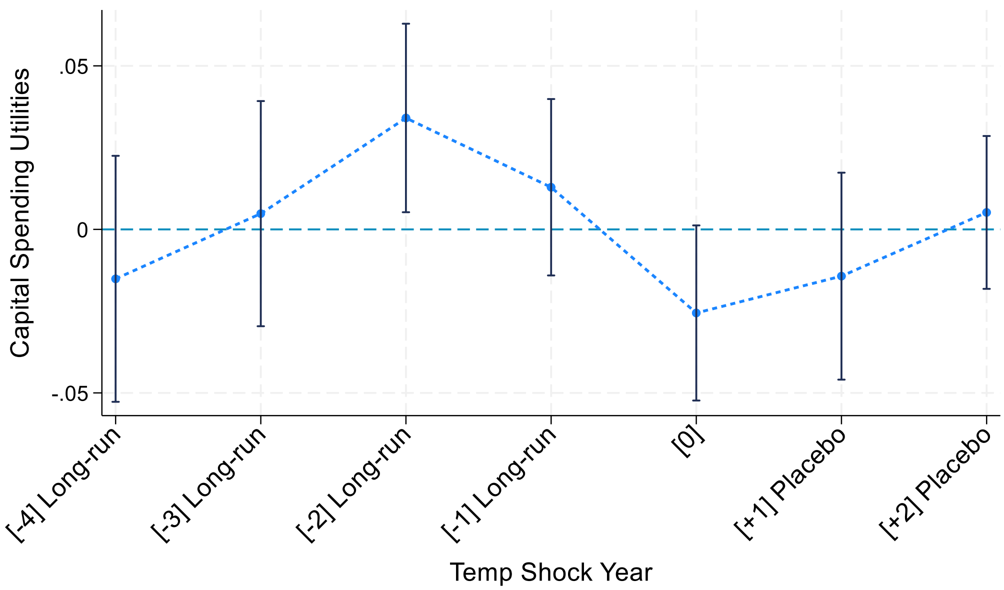
This figure examines the municipal revenue impact of various dimensions of the weather. Each point on the figure represents a coefficient estimate (coupled with its 95% confidence interval based on standard errors clustered at the county level) from a model identical to that in column 1 of Table 2 replacing our "Hot days" measure with the weather measure denoted on the x-axis. Thus, the coefficient on "Hot days" precisely replicates the result in column 1 of Table 2. *Cold Days*, is defined as heating degree days (i.e., degree-days below 65 degrees Fahrenheit. *Precip* is the total precipitation during the year, while *Cold Preci*p only sums precipitation during months with average minimum temperatures below freezing. *Extreme Max Heat* measures the average temperature during the hottest month of the year, while *Extreme Cold Precip* captures maximum monthly level of cold precipitation during the year.



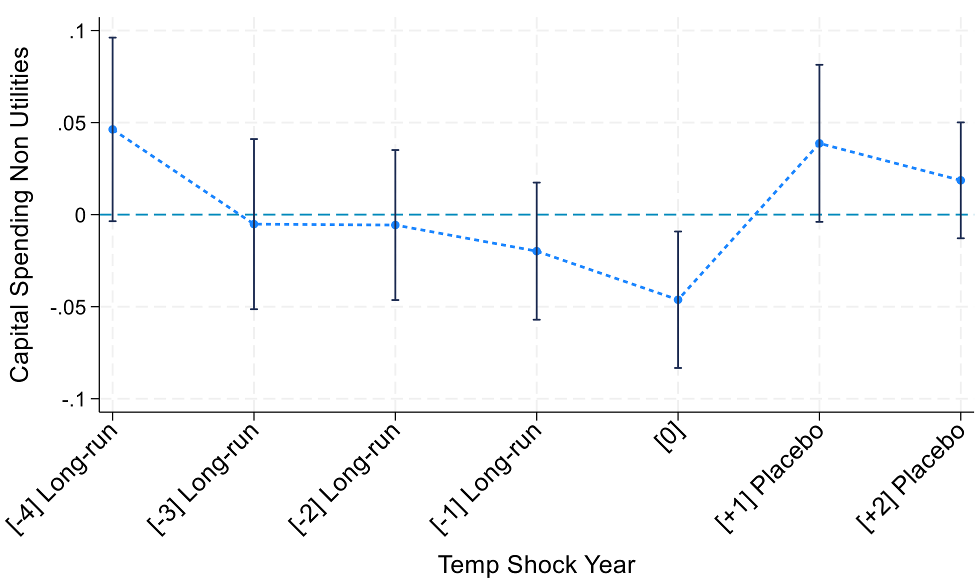
Appendix Figure A4: Dynamic Effect of Temperature on Capital Expenditures, Utilities Decomposition

This figure plots the estimated coefficients of contemporaneous, lead, and lagged annual cooling degree days (i.e., the number of degree days above 65 degrees Fahrenheit) on municipal capital expenditures scaled by population. Panel A (B) restricts utilities spending to utilities (non-utilities). We obtain municipal finance information from The Government Finance Database and temperature information from NOAA Monthly U.S. Climate Divisional Database. Capital Spending on Utilities comprises of inflation adjusted sewerage (Sewerage_Cap_Outlay), waste management (SW_Mgmt_Capital_Outlay), and utilities (Total_Util_Cap_Outlay) per capita. The estimates derive from an OLS regression model with municipality and state-year fixed effects and county level controls for the unemployment rate, per capita income, and the number of business establishments. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

Panel A: Capital Spending on Utilities

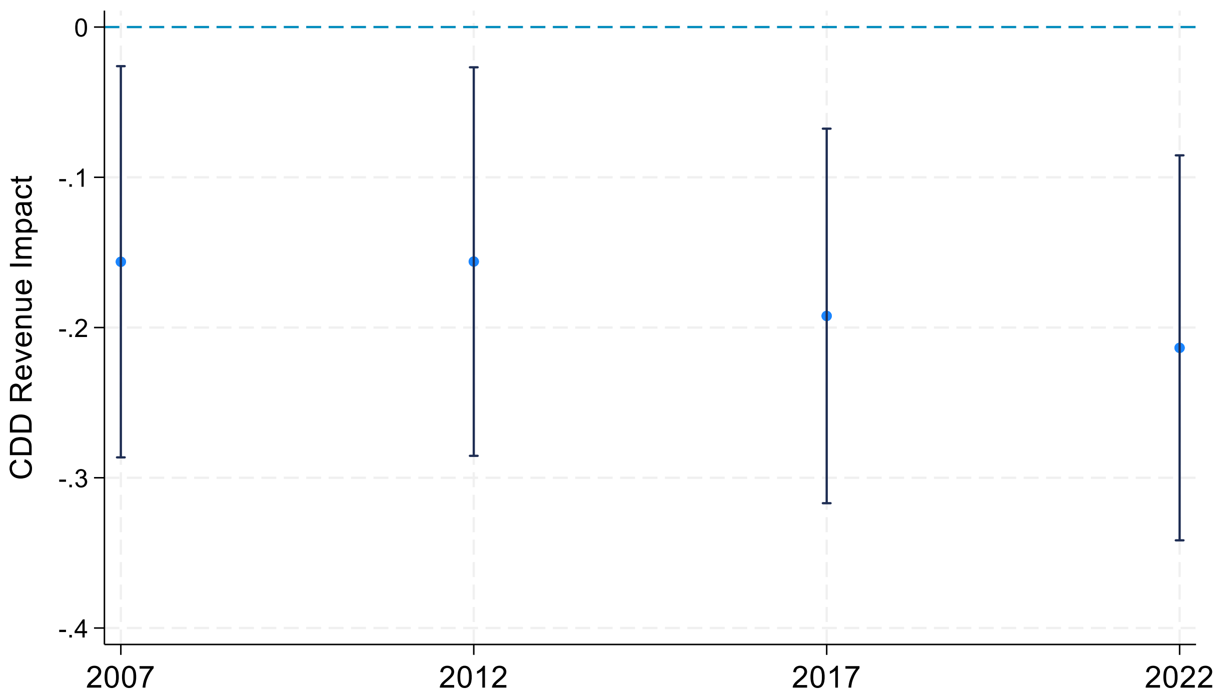


Panel B: capital Spending on Non-utilities



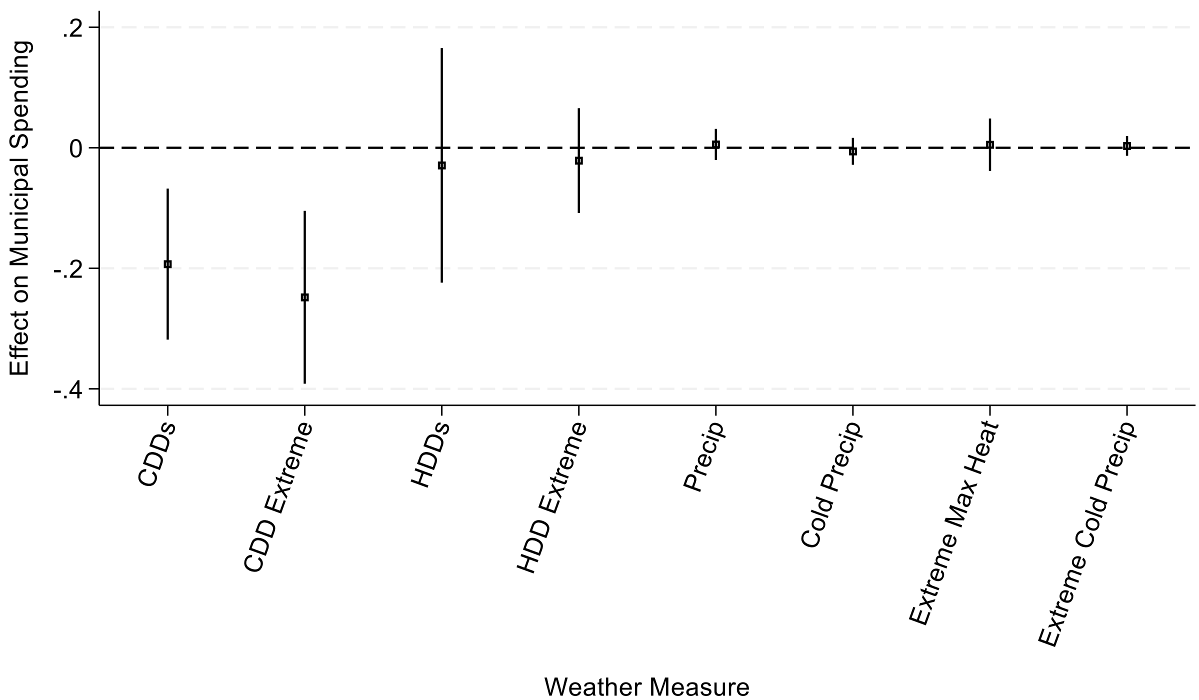
Appendix Figure A5: Expenditure Impact of CDDs over time

This figure examines the relation between CDDs and municipal expenditures for each of the four years in our primary sample. Each point on the figure represents a coefficient estimate (coupled with its 95% confidence interval based on standard errors clustered at the county level) from a model identical to that in column 1 of Table 2, after interacting CDDs with categorical variables for each year in our sample period. Four separate regressions are conducted with the reference group for the CDD effect interacting across the four years denoted on the x-axis.



Appendix Figure A6: Expenditure Impact of CDDs versus other dimensions of municipal weather

This figure examines the municipal expenditure impact of various dimensions of the weather. Each point on the figure represents a coefficient estimate (coupled with its 95% confidence interval based on standard errors clustered at the county level) from a model identical to that in column 1 of Table 2 replacing our "Hot days" measure with the weather measure denoted on the x-axis. Thus, the coefficient on "Hot days" precisely replicates the result in column 1 of Table 2. *Cold Days*, is defined as heating degree days (i.e., degree-days below 65 degrees Fahrenheit. *Precip* is the total precipitation during the year, while *Cold Preci*p only sums precipitation during months with average minimum temperatures below freezing. *Extreme Max Heat* measures the average temperature during the hottest month of the year, while *Extreme Cold Precip* captures maximum monthly level of cold precipitation during the year.



Appendix Figure A7: Expenditure Decomposition

This figure decomposes the effect of CDDs on expenditures by expenditure type. Each point on the figure is generated from a separate regression, analogous to column 1 of Table 4, except the dependent variable measures only revenues of the type indicated on the x-axis. Error bars represent 95 percent confidence intervals based on standard errors clustered at the county level.

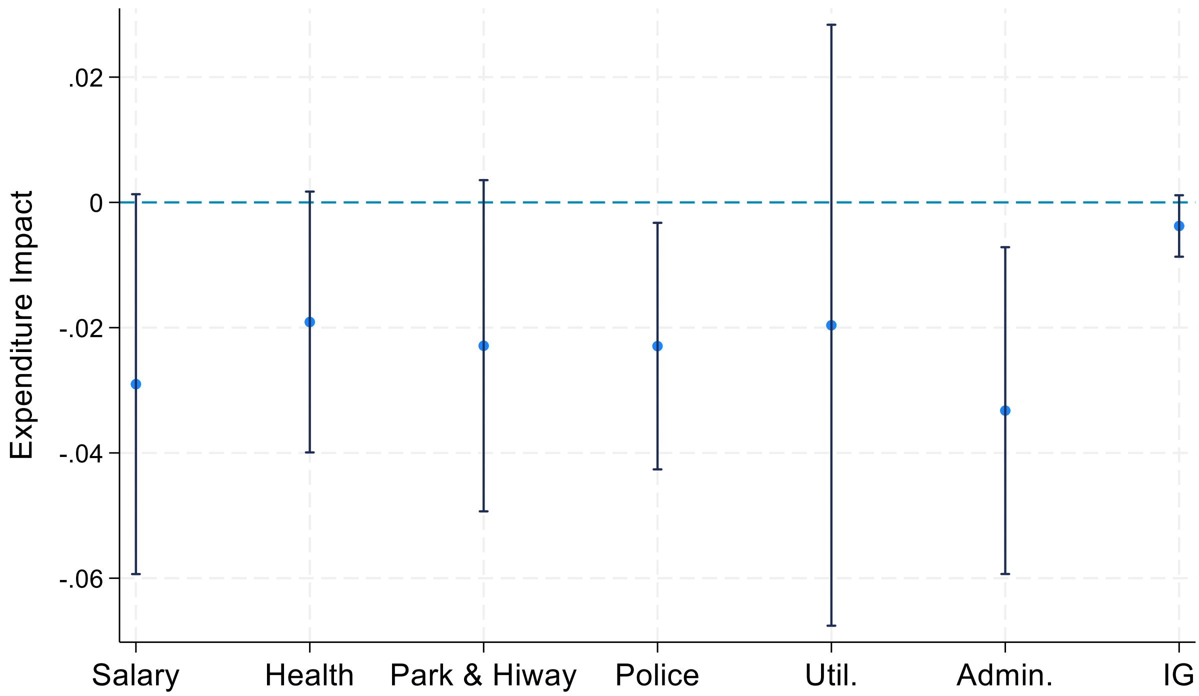


Table A1: Robustness to adjusted state-year fixed effects

State-year fixed effects are an important aspect of our empirical design, controlling for time varying policies and local economic conditions. However, they reduce the influence of smaller states, which have less within state variation in CDDs. To ensure that this does not materially affect our findings, this table estimates columns 1 and 4 of Table 2 columns 3 and 5 of Table 5 using adjusted state-year fixed effects that combine the smallest states into combined geographic blocks. We combine VT, NH, MA, RI, and CT into a single block with combined square mileage of approximately 35,000. This is about the size of Maine, which is the 39th largest state. We also combine NJ, MD, and DE into a 23,000 square mile block that is about the size of West Virginia. After these adjustments the smallest states in our sample are West Virginia (24,000 sq. miles), South Carolina, and Maine. All models present output from estimating panel regressions using municipality and state-year fixed effects, after adjusting the state as described above. The dependent variable is municipal revenues, scaled by municipal population, in columns 1 and 2 and municipal spending, similarly scaled, in columns 3 and 4. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Our baseline CDD measure is standardized, whereas columns 2 and 4 use raw CDD Extreme (i.e., CDDs excluding variation in years with less than 841 CDDs). All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Total Revenue	(2) Total Revenue	(3) Total Expenses	(4) Total Expenses
CDDs	-0.170***		-0.189***	
	(-2.62)		(-2.96)	
CDDs Extreme		-0.239***		-0.242***
		(-3.23)		(-3.31)
Income per capita	0.091***	0.091***	0.075***	0.076***
	(4.52)	(4.53)	(3.78)	(3.79)
Ln(Pop.)	-2.128***	-2.127***	-2.120***	-2.119***
	(-15.09)	(-15.10)	(-13.90)	(-13.90)
Unemployment	0.012	0.012	0.004	0.004
	(0.88)	(0.88)	(0.27)	(0.27)
Ln(Estabs)	0.822***	0.828***	0.926***	0.931***
	(4.74)	(4.78)	(5.22)	(5.24)
Model	OLS	OLS	OLS	OLS
Muni FE	Y	Y	Y	Y
Other FE	Adj. State-Time	Adj. State-Time	Adj. State-Time	Adj. State-Time
Mean Dependent	1.88	1.88	1.91	1.91
Adjusted (Pseudo) R-squared	0.75	0.75	0.72	0.72
Observations	87,501	87,501	87,501	87,501

Table A2: Robustness to extended panel

This table replicates our main results using an extended panel with 7 observations per municipality, corresponding to fiscal years 1992, 1997, 2002, 2007, 2012, 2017, and 2022. The rest of our analyses focus on the last four years in this sample due to enhanced data accuracy and comparability, however here we show qualitatively similar results using an extended panel. All models present output from estimating panel regressions using municipality and state-year fixed effects, after adjusting the state as described above. The dependent variable is municipal revenues, scaled by municipal population, in columns 1 and 2 and municipal spending, similarly scaled, in columns 3 and 4. CDDs are Cooling Degree Days and are standardized measures of the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Our baseline CDD measure is standardized, whereas columns 2 and 4 use raw CDD Extreme (i.e., CDDs excluding variation in years with less than 841 CDDs). All models include county level controls for the unemployment rate, per capita income, and the number of business establishments. Appendix A provides detailed variable definitions along with data sources. Standard errors clustered at the county level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Total Revenue	(2) Total Revenue	(3) Total Expenses	(4) Total Expenses
CDDs	-0.080*		-0.127***	
	(-1.71)		(-2.72)	
CDDs Extreme		-0.153***		-0.202***
		(-3.09)		(-3.93)
Income per capita	0.121***	0.121***	0.119***	0.119***
	(7.40)	(7.41)	(7.50)	(7.52)
Ln(Pop.)	-1.338***	-1.339***	-1.367***	-1.368***
	(-16.85)	(-16.83)	(-17.15)	(-17.13)
Unemployment	0.001	0.001	0.006	0.006
	(0.08)	(0.13)	(0.61)	(0.64)
Ln(Estabs)	0.626***	0.627***	0.594***	0.594***
	(7.40)	(7.43)	(7.07)	(7.09)
Model	OLS	OLS	OLS	OLS
Muni FE	Y	Y	Y	Y
State-Year FE	Y	Y	Y	Y
Mean Dependent	1.71	1.71	1.72	1.72
Adjusted (Pseudo) R-squared	0.71	0.71	0.68	0.68
Observations	152,598	152,598	152,598	152,598