Can municipalities weather the weather?

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Abstract: We examine the sensitivity of municipal cash flows and investment to temperature. Using a panel of approximately 56,000 U.S. municipality-years, we find that hotter temperatures predict lower municipal revenues, particularly for smaller municipalities among which a 5-degree temperature increase across a summer month predicts an approximate 2.5% revenue decline. Revenues decline across a range of categories, but the decline is largest (smallest) for non-property tax (utilities) revenues. Municipalities exhibit financial flexibility by offsetting revenue shocks in real-time with dollar-for-dollar changes in expenditures. Capital expenditures exhibit 2.5 times the sensitivity of operating expenditures, with salaries being the most sensitive category of operating expenses. We find strong evidence that the revenue and spending effects of temperature concentrate in the same subsamples and no evidence that municipalities turn to intergovernmental transfers, accumulate deficits, or manage temperature-induced revenue shocks dynamically over multiple years. These findings challenge conventional notions of governmental inflexibility and suggest that local governments actively manage weather-induced financial risks.

Keywords: Municipal financing; cash flow shocks; investment; municipal budgeting, climate change

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1. Introduction

How resilient are U.S. municipalities to warming temperatures? Despite U.S. municipalities raising and spending over $2 trillion per year to provide essential services like police, fire, utilities, and public works *and* mounting evidence on the adverse effects of rising temperatures, there is little empirical evidence on this question. Municipal revenues are well diversified across geographies and stem from economic agents with varying sensitivity to weather, making both the extent of their exposure to weather-induced financial shocks and how they manage weather-induced shocks empirical questions.[1] For instance, abnormally bad weather may adversely affect municipal revenues coming from sales and income taxes if it disrupts local businesses, but such variation in weather may have a positive effect on utilities revenues. Moreover, literature on municipalities' financial autonomy and dynamic adjustments to revenue shocks suggests that the manner in which weather-induced municipal revenue shocks translate to expenditure effects is also an important but answered empirical question.[2] On the one hand, expenditure impacts may be limited if revenues shocks are managed through balance sheet reductions, debt issuance, or intergovernmental transfers. On the other hand, weather-induced revenue shortfalls may lead municipalities to reduce current or future operating or capital expenditures.

In this paper, we provide the first empirical evidence on how daily variation in weather affects municipal finances. Specifically, we address three novel and important empirical questions: (1) to what extent are municipal revenues affected by temperature variation, (2) what levers to municipalities use to manage weather-induced shocks, and (3) is municipal capital investment

[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.
[2] See for example Buettner and Wildasin (2006), Helm and Stuhler (2024), and Mauri (2024).

insulated from short-run non-fundamental revenue shocks. We identify the effect of abnormal 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 55,940 municipality-years across 47 states from the Census Bureau's Census of Governments (CoG).[3] The median municipality in our local government sample (counties, cities, and towns) earns $3.3 million in revenues and provides services to 2,159 individuals. The explanatory variables of interest are the number of cooling or heating degree days in a county-year, where cooling (heating) degree days are the number of degree-days above (below) 65 degrees Fahrenheit. Our inclusion of municipality fixed effects allows us to the interpret the municipal financing responses to abnormal weather variation. As Dell, Jones, Olken (2014) explain in their survey, this reduced-form approach, which exploits the plausibly random variation in an area's weather over time, has become popular in recent decades and is able to draw plausible inference on the causal effects of weather with relatively few identifying assumptions. In our case, 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 the weather on these outcomes.

Our first main result is that hotter temperatures (i.e., more cooling degree days) predict lower municipal revenues. If an already warm month becomes ten degrees hotter, then our model predicts annual municipal revenues to be approximately 3.2% lower, or $50 per resident. This effect is significantly larger and concentrated in small municipalities. Splitting our sample at the median population suggests that the effect is approximately double in smaller municipalities and

[3] 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 three most recent CoG surveys in 2012, 2017, and 2022 as the data format remains relatively consistent over this time period.

virtually zero on larger areas. We find no consistent relation between cold weather and municipal revenues, although the limited evidence that does exist suggests a non-linear relation between temperature and municipal revenues in small areas whereby extreme weather in either direction has a negative revenue impact. The relation between abnormal heat and municipal revenues concentrates in the year of the heat event. Municipal revenues are neither affected by the previous years' temperature nor related to future temperature patterns.

Hot temperature's adverse effect on municipal revenues persists across most revenue categories but is largest and most significant within non-property tax revenues. Non-property tax revenues compromise approximately 13% of small municipality revenues and are over 50% more sensitive to temperature shocks than the average revenue dollar. Given that these taxes come from income and business sales, this result is consistent with existing evidence on the negative effect of adverse weather on local business cash flows (see e.g., Brown, Gustafson, and Ivanov, 2021; Tran 2023; Addoum, Gounopoulos, Gustafson, Lewis, and Nguyen, 2024). The least sensitive revenue category to temperature shocks is utilities revenues, which represents about 27% of small municipality revenues and exhibits a statistically insignificant positive relation with abnormal heat.

We next study the empirical question of how municipal spending and investment responds to everyday variation in temperature. Temperature changes may affect operating expenses either directly or through their effect on revenues. The signed impact of direct effects are unclear and will likely vary by expenditure type as temperature variation will differentially affect the cost and benefits of certain operating expenses. For example, while abnormal heat in an Alabaman summer could increase emergency service expenses, these expenses may be offset by lower expected public park attendance, leading to fewer employee staffing hours at these public parks. Given the negative relation between elevated temperature and municipal revenues, a revenue-based effect predicts a negative relation between heat and municipal spending. The extent and timing of this relation depends on complex and dynamic links between municipal revenues and expenditures (see e.g., Buettner and Wildasin, 2006; Helm and Stuhler, 2024) and may be mitigated to the extent that municipalities pre-emptively accumulate cash (see e.g., Gore, 2009).

We find that the effect of temperature shocks on total expenditures is strikingly similar to the corresponding revenue impact, supporting the dual conjecture that temperature shocks primarily affect expenditures via their effect on revenue and municipalities reduce expenditures in real time to in response to moderate non-fundamental revenue shocks. A ten-degree warming of an already hot month predicts a 3.8% or about $58 per resident decline in total municipal expenditures. Like the revenue impact, this effect is concentrated in small municipalities, which experience a 5.6% (or $82 per person) decline in expenditures for every ten degrees of elevated heat within a warm month. Consistent with municipalities effectively managing revenue shocks in real time via expenditure adjustments, we find no evidence that temperature shocks significantly predict deficit spending.

In our next set of tests, we further link temperature's spending effect to its impact on revenues by showing that the distribution of municipal revenues is by far the biggest predictor of temperature's impact on both municipal revenues and expenditures. In contrast, neither the breakdown of municipal spending nor climate, weather, urbanity, or political leaning significantly explain the observed relation between temperature and municipal financial outcomes. Moreover, a municipality's reliance on a given revenue source similarly predicts temperature's effect on both municipal revenues and spending. For example, areas that are more reliant on property taxes or utilities compared to non-property taxes exhibit a reduced sensitivity of both municipal revenues and spending. These findings offer both intuitive support for the effect of temperature on municipal spending and further suggest that revenue effects are the primary driver of the sensitivity of municipal spending to temperature.

A key difference between municipal operating expenses and their spending on capital investment is that there is arguably no direct relation between the everyday measure of elevated temperature that we employ and long-run capital investment opportunities. Under this assumption, which Brown, Gustafson, and Ivanov (2021) rely on in the case of adverse winter weather and small firms, our setting can shed new light on how insulated municipal capital investment is from short-term non-fundamental changes in revenue. In so doing, we provide perhaps the first evidence on the municipal investment cash flow sensitivity, which has received extensive attention in the corporate finance literature (see e.g., Fazzari, Hubbard, and Petersen, 1988; Erikson and Whited, 2000; Moyen, 2004).

We find that municipal capital investment is more than twice as sensitive to temperature shocks than the average dollar small municipalities spend. A ten-degree warming of an already hot month predicts a 12.1% reduction in capital expenditures. In dollar terms, reduced capital expenditures account for about $30 of the $82 reduction in spending in small municipalities even though capital expenditures comprise only approximately 22% of municipal expenditures. Aside from reduced capital expenditures, the reduction in expenditures persists (but is often statistically insignificant) across a range of expenditure categories. The most robust decline is with respect to salary spending, which responds to temperature shocks with a statistically significant decline that is in line with the overall expenditure reduction. The dollar-for-dollar expenditure adjustment combined with the concentration within capital expenditures mitigates the possibility that our findings primarily reflect elevated temperatures simply lead to event cancellations or facility closures that simultaneously reduce revenues and operating expenses. We expect that such closures do contribute to our findings, but it also appears that municipalities actively manage long-term spending in a manner that sacrifices long-term investments but indicates financial independence.

Our study makes several important contributions to the literature. First, we provide robust empirical evidence that abnormal weather shocks affect municipal finances, adding to the growing literature on the impact of exogenous weather shocks on economic activity. While prior work has explored these effects in the context of private firms and industries (e.g., Addoum, Ng, and Ortiz-Bobea, 2023, Hong, Li, and Xu, 2019) or broad economic outcomes (e.g. Dell et al. 2009, 2012, and 2014; Burke, Hsiang, and Miguel 2015), our analysis extends this line of inquiry by focusing on a novel setting: municipal governments, which represent a major component of the U.S. economy. Our findings underscore the importance of accounting for local environmental factors when assessing public finance management.

Second, more generally, our study contributes to the literature on how organizations respond to non-fundamental cash-flow shocks (Almeida and Campello, 2007*;* Dambra 2018*;* Brown et al. 2021). We find that, unlike common perceptions of bureaucratic inflexibility, municipalities demonstrate surprisingly adaptive financial behaviors when faced with weather-induced revenue shocks, which are short-run and arguably exogenous to municipal fundamentals. The real time expenditure adjustments in response to revenue shocks that we observe differs from studies suggesting that municipalities take several years to stabilize in response to fundamental or permanent shifts in revenue (Holtz-Eakin, Newey, and Rosen, 1989; Buettner and Wildasin, 2006; Helm and Stuhler, 2024), challenging the commonly held notions of governmental inflexibility (Niskanen, 1971) and bureaucratic incentives to maintain current expenditures (Hayes, Razzolini, and Ross, 1998; Wu et al., 2020). An interesting question for future research is whether the differences between our findings and others in the literature are due to the non-fundamental nature, type, or magnitude of the revenue shocks that we study.

Finally, our study adds to the literature on how local municipalities respond to climate change. The business press and extant literature largely focuses on the financial constraints imposed on municipalities from large natural disasters (Jerch, Kahn, and Lin, 2023) or long-run climate risks such as sea level rise (e.g., Painter, 2020; Goldsmith-Pinkham, Gustafson, Lewis, and Schwert, 2023). Unlike the natural disaster setting, the municipal budget deficits from intertemporal temperature variation are not offset by increased state and Federal aid (Jerch et al., 2023). By establishing a causal relationship between temperature shocks and municipal finances, we underscore the importance of integrating climate-related risks into public sector fiscal management. Our study speaks to the extant climate finance literature by showing local governments appear more resilient to climate change than commonly perceived (e.g., Gillers 2024).

2. Identification Strategy

Our research objective is to explore if and how municipal finance outcomes respond to everyday changes in temperature. Our identification strategy exploits plausibly random variation in an area's weather in a panel regression over three distinct Census Bureau surveys. Our methods mirror those discussed in Dell, Jones, Olken (2014), which are becoming increasingly popular in studies trying to draw causal inference regarding the effects of weather. Our main empirical specifications take the following form,

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

where Y_{mt} equals the revenues or expenditures of municipality *m* in year *t*, scaled by the population that they serve. Our baseline analyses employ a Poisson maximum likelihood estimator to account for skew in our dependent variables as recommended by Cohn, Liu, Wardlaw (2022). We find qualitatively similar results using an ordinary least squares estimator and a natural log transformation of scaled municipal revenues and expenditures as the dependent variable.

Our main explanatory variables of interest are cooling degree days (CDDs) and heating degree days (HDDs). These temperatures measures estimate the demand for air conditioning or heating based on outdoor temperatures. Specifically, CDD_{mt} (HDD_{mt}) counts the number of cooling (heating) degree days above (below) 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 365 days in year *t*. 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 our various municipalities.[4]

The inclusion of municipality fixed effects (δ_m) ensures that we identity off of within municipality variation in temperature. State-year fixed effects (α_{st}) control for time varying climates and local economic conditions. As Dell, Jones, Olken (2014) discuss, this framework requires few explicit identifying assumptions when identifying 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 the weather on these outcomes.

We supplement our main empirical tests with regressions that augment Eq. (1) with lead and lagged temperature measures. The lagged temperature outcomes shed light on the longevity of temperature's effect on municipal financial outcomes, while the future temperature shocks act

[4] We also partition our sample in Eq. 1 by municipal population in subsequent tests in order to examine whether are empirical findings vary as a function of municipal size.

as placebo tests that help validate our identifying assumptions. Our non-discrete outcome variables are winsorized at the top and bottom percentile and we cluster our standard errors by county.

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). 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 survey questionnaires, direct data feeds, and online data collection from annual financial reports and other Federal agency data to compile the CoG. For our analysis, we focus on the fiscal years 2012, 2017, and 2022 because these years provide a consistent format in which municipalities' revenues and expenses are measured and studied. The CoG allows for a large cross-sectional panel, covering 18,871 different municipalities across 47 states. Within the CoG data, we analyze county level governments (Unit Type Code = 1) and municipalities (Unit Type Code = 2).[5] Our revenue and expense definitions generally follow the aggregation instructions of the Census Bureau. For control variables, we also 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. Finally, we obtain county-month measures of heating and cooling degree days from the NOAA Monthly U.S. Climate Divisional Database. Our final sample includes 55,940 municipal-year observations.

3.2 Descriptive Statistics

[5] According to the Census Bureau, municipal governments are sub-county general purpose governments established to provide general services for a specific population and defined area (Census Bureau 2006). Municipalities includes cities, boroughs, villages, and towns.

Panel A of Table 1 presents the descriptive statistics for the full sample, revealing substantial heterogeneity in financial scale and scope across our sample. The average total revenue for a municipality in our sample is approximately $53.5 million, with a standard deviation of $885.1 million, underscoring the heterogeneity of our municipal government sample. On a per capita basis, the average municipality in our sample collects revenues of $1,715 per individual. The average municipality in our sample incurs expenses of $51.7 million, in-line with the scale of average revenues.[6]

[INSERT TABLE 1 HERE]

Panels B Table 1 restricts our sample to municipalities below the median population of 2,159. As a point of reference, the median population in our sample is the city of Oxford in Georgia, which is part of the greater Atlanta metropolitan area. Oxford had revenues of $1.6 million and 13 full-time employees, including its own city council, judicial court, public works department, parks department, and police department.[7] For this below-median sample in Table B1, mean total revenue is approximately $1.38 million. While the population of these municipalities appears small, it obscures their economic impact in their community. Over our panel, the aggregate revenue of municipalities with a below median population constitutes $38.5 billion. On a per resident basis, smaller municipalities take in and spend about 10% less than their larger counterparts (untabulated).

In Figure 1 we decompose municipal revenues and expenses into subcomponents. Panel A decomposes revenues into property and non-property taxes, fees, utilities, and intergovernmental transfers. Together, these revenue sources comprise over 85% of municipal revenues in our

[6] 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.
[7] See Oxford's website.

sample. The breakdown between these five sources is similar across categories and across municipalities with above and below median population in our sample. The key difference in funding sources between small and large municipalities is a shift away from property taxes towards utilities revenues as municipalities become smaller. On the expense side, small and large areas again look similar, with small areas again being slightly more reliant on utilities. Approximately 10% of spending is in the form of capital investment for both small and large municipalities and 25% to 30% of spending is in the form of salary for both small and large municipalities.[8] Together, the statistics in Figure 1 are qualitatively similar to those discussed in Ross and Peng (2023).

[INSERT FIGURE 1 HERE]

In terms of temperature outcomes, average municipalities in the full sample experience 1,400 cooling degree days and 4,539 heating degree days annually, with considerable variation around both averages. Again, these represent 1,400 (4,539) degree days above (below) 65 degrees for the average municipality's fiscal year. These figures are similar for small and large municipalities, suggesting a comparable geographic spread across the country.

4. Results

4.1 Municipal Revenue

Our study investigates the impact of weather shocks on municipal financing. *Ex ante*, it is unclear whether and how abnormal weather variation will impact municipal revenues. Extant literature studying the private sector offers mixed evidence as to the effect of varying temperature on retail sales activities and productivity (Addoum et al. 2020, Addoum et al. 2023, Dell et al. 2012, Tran 2023). Although this literature weakly suggests that personal and business income (and

[8] Note that the way that salary (code: Z00) is reported in the CoG survey is not mutually exclusive of other expenditures. In other words, the Census Bureau's measure of police expenses cannot be further decomposed into police equipment and police employment expenses (codes: E62 and F62). However, the salary measure will include all salaries from a given municipality.

the accompanying taxes received by municipalities) will be reduced, Figure 1 shows that non-property tax revenues comprise less than 18% of municipal revenues and abnormal weather shocks may have different effects on similarly important revenue streams derived from fees or utilities.

We begin our empirical analysis by assessing the impact of both cooling and heating degree days on municipal revenues in our full sample. In column 1 of Table 2, we observe a statistically significant negative relationship between cooling degree days (CDDs) and municipal revenues. A one standard deviation (or 913 unit) increase in cooling degree days results in an approximate 9.2% decrease in total revenues, calculated as 1 minus the exponential of the coefficient in the Poisson regression. A 913-unit shift in CDDs corresponds to the daily average temperature in a hot month becoming 30 degrees hotter. A more reasonable interpretation is that a one standard deviation increase in within-municipality CDDs (or about a 115 unit increase in CDDs) leads to a 1.2% revenue decline. Our results are qualitatively similar using OLS in column 2. The OLS estimates show that this effect, resulting from a warmer month being 3 degrees warmer than usual, translates to approximately $19 less per capita revenue for the municipality. We find limited evidence of a statistical relation between municipal revenues and heating degree days, with column 2 showing only a marginal relation between HDDs and decreasing revenues (p-value < 0.10).

[INSERT TABLE 2 HERE]

Prior macroeconomic research indicates that wealthier economies are more resilient to the economic impacts of global warming compared to their less affluent counterparts (Dell, Jones, and Olken 2012). Along this line of reasoning, we bifurcate our sample across population size, which strongly corresponds to the capacity for revenue generation and available resources of a given municipality.

In column 3 of Table 2, we interact our degree days with the municipality's population, and find that the sensitivity of municipal revenues to weather variation strengthens among smaller communities. Columns 4 and 5 partition the sample at the median municipal population of 2,159. As compared to the full sample estimate in column 1, the coefficient on *Cooling Degree Days* nearly doubles in column 4 for smaller municipalities. Within the small municipality subsample, a one standard deviation increase in within-municipality CDDs leads to over a 2% revenue decline. In contrast, larger municipalities exhibit no significant relation between municipal revenues and cooling or heating days. This asymmetric vulnerability of different types of jurisdictions to the same environmental shock provides a within country parallel to cross-country evidence indicating that nations with smaller or less developed economies are more economically exposed to weather shocks as compared to their wealthier nation counterparts (Dell et al. 2009, 2012, and 2014; Burke, Hsiang, and Miguel 2015).

In contrast to the consistent evidence suggesting that abnormally warm weather predicts lower revenue for small municipalities, we find little consistent evidence of a significant relation between abnormally cold weather and municipal revenue in either subsample. To the extent that HDDs do exist, for example the marginally significant OLS estimate in column 2 and the significant interaction in column 3, the estimates are consistent with extreme warmth having an adverse effect on municipalities' revenues. Although we continue to control for HDDs throughout our analyses, we focus most remaining discussion on the relation between CDDs and municipal finances both because this relation is more statistically significant and robust and because it ties into the global trend toward rising temperatures.

The municipality and state-year fixed effects in our specification allow us to interpret the CDD effects we estimate as the effects of "abnormal" CDDs. Specifically, our estimates exploit variation in a municipality's CDDs (relative to other municipalities in the same state-year) across the three years in our sample period. The identifying assumption is that this variation is unrelated to municipal finance except through its direct effect. A potential violation of this assumption would occur if the variation we identify off of was trending in a manner that correlates with municipal growth. For example, certain regions may be heating up and contracting in population over our 2012-2022 sample period. To alleviate this alternative explanation for our results, we next conduct a dynamic analysis in which we regress municipal revenue on the CDDs in the current year as well as CDDs in the previous and future two years. Under our identifying assumptions, we expect future CDDs to have no significant effect on municipal revenues.

Figure 2 presents the dynamic relation between CDDs and municipal revenues, plotting the coefficients obtained by regressing municipal revenue on CDDs in the simultaneous year as well as the two previous and subsequent years. Figure 2 illustrates that the impact of CDDs on municipal revenues are immediate and limited to the contemporaneous period, as the coefficients of lagged and leading temperature shocks are statistically indistinguishable from zero. These findings help to confirm that municipalities' responses to weather shocks are indeed driven by real-time weather effects rather than regional trends. In addition, the findings suggest that there are limited long-run effects of temperatures on municipal revenues, which suggests that the revenue shocks that we explore are responded to differently than other (perhaps more fundamental) revenue shifts which municipalities adjust dynamically to over the course of several years (see e.g., Buettner and Wildasin, 2006; Costello et al. 2017; Helm and Stuhler, 2024).

[INSERT FIGURE 2 HERE]

4.1.1 Decomposing the revenue effect by revenue and expenditure sources

We next decompose revenues across different categories in Table 3 to investigate which component of total revenues is most adversely affected by the CDDs. We focus this analysis on our below-median county population, as our prior results suggest that smaller municipalities' revenues are more susceptible to CDDs.[9] The benchmark for the CDD coefficients across the first row of Table 3 is the total revenue impact of CDDs on small municipalities of -0.169 obtained in column 4 of Table 2. We find that non-property tax revenues, which comprise about 17% of total revenues, are about 50% more sensitive than the typical revenue dollar to CDDs. This is consistent with the joint hypothesis that (1) excessive heat limits local economic activity and (2) that these revenues are more reliant on the local economy. In contrast, utilities and fee revenues are largely insensitive to CDDs. Other categories of revenues, such as property taxes and miscellaneous revenues exhibit similar point estimates to the overall revenue benchmark, although the estimates are statistically insignificant. Notably, we find no evidence that Federal or State aid is deployed to offset the revenue effects that we attribute to weather variation. This lack of aid highlights the everyday (and arguably non-fundamental) nature of the temperature shocks we examine, drawing a contrast between the often significant role of governmental transfers and aid mitigating municipal financial shocks (Clemens and Veuger, 2023; Jerch, Kahn, and Lin, 2023).

[INSERT TABLE 3 HERE]

We next examine how the relation between a municipality's total revenue exposure to CDDs depends on the sources of revenue they rely on. We view these tests as descriptive given the clear correlation between revenue source reliance and other factors such as political orientation, population density, and climate. Table 3 documents variation in the effect of CDDs across revenue types, with non-property taxes being the most affected revenue category. In Table 4 we leave the percent of revenue accruing from non-property taxes as the omitted category (i.e., the 'base' effect), and thus expect that the negative effect of CDDs on revenue will attenuate as the

[9] In Appendix Table 1, we provide a similar decomposition for our above median population municipalities. We fail to find consistent evidence that abnormally warm or cool days significantly relate to any category of revenue in our large municipality sample. If anything, we find marginal evidence that miscellaneous (non-property tax) revenue increases on years with more abnormally cold (warm) days.

percentage of revenue that accrues from other sources rises, leading to a series of positive interactions between various revenue sources and CDDs.

[INSERT TABLE 4 HERE]

Column 1 of Table 4 shows that the effect of CDDs on municipal revenue is most negative to the extent that revenues rely upon non-property taxes. All of the interactions between other revenue sources and CDDs are positive and highly statistically significant. The largest positive coefficients appear on utilities and property taxes, which is intuitive since utilities revenues may actually rise as demand for cooling increases and property taxes are unlikely to be highly sensitive to temperature fluctuations in real time. Comparing the coefficient of -0.545 on the CDDs variable with the baseline estimate of -0.169 in Column 4 of Table 2 suggests that municipalities would be approximately three times as sensitive to CDDs if their revenues were entirely comprised of non-property taxes. Column 2 indicates qualitatively similar results after also controlling for the interaction between municipalities' spending type and CDDs.

[INSERT TABLE 4 HERE]

In columns (3) and (4) we conduct a similar analysis using the subsample of large municipalities, which exhibit no significant overall relation between CDDs and revenues. This offers insight regarding the extent to which the differential impact of CDDs on small and large areas is driven by their reliance on different revenue sources. The results in columns (3) and (4) are qualitatively similar to those in columns (1) and (2). The results descriptively suggest that large municipalities would also exhibit a significant negative relation between CDDs and revenues if their revenues were entirely comprised of non-property taxes. However, the magnitude is only approximately 30% to 40% the size of the effect observed among smaller municipalities. The increased sensitivity of smaller areas could be due to their increased exposure to weather fluctuations or larger areas having more flexibility to adjust and smooth their revenue streams over the course of a year. The corroborates our illustrative evidence in Figure 1, where we show that larger municipalities are more dependent on property taxes.

Overall, the evidence in Tables 2 through 4 suggests that increased CDDs predict a revenue decline that concentrates in smaller municipalities. The effect spans most revenue categories, especially for smaller areas, but is most pronounced for areas that rely on non-property tax revenues.

4.2 Municipal Spending

We next study how municipal spending responds to temperature shocks. Temperature changes may affect operating expenses either directly or through their effect on revenues, but the magnitude and direction of these effects are *ex-ante* unclear.

The directional impact of any direct effect is unclear and will likely vary by expenditure type. As we show in Figure 1, municipal operating expenses are spread across many categories with almost 30% being salaries and between 10% and 20% being dedicated to police, utilities, and park and highway spending. Apart from utilities expenditures, municipalities have discretion over all these spending categories in the sense that hot temperature cannot cause them to change. However, elevated temperatures may change the cost and benefits of certain operating expenses, such as salaries or park operations.

Given the negative relation between elevated temperature and municipal revenues, a revenue-based effect predicts a negative relation between heat and municipal spending, but the extent and timing of this relation is an empirical question. For instance, the immediate expenditure impact of revenue shocks may be muted because municipalities with volatile revenues pre-emptively accumulate cash to manage revenues shocks (see e.g., Gore, 2009) or view municipal expenditures, such as salaries, as fixed costs (Wu, Young, Yu, and Hsu 2020). The expenditure impact of revenue changes may also be spread over several years (see e.g., Buettner and Wildasin, 2006; Helm and Stuhler, 2024), unless municipalities prioritize a balanced budget in real time. That being said, prior literature finds that traditional tax increases and expense reductions occur with a lag in response to operating deficits (e.g., Costello, Petacchi, and Weber 2017).

We explore this empirical question in Table 5. Our full sample estimates in column 1 indicate a significant negative relation between CDDs and municipal spending. The magnitude of the coefficient is remarkably similar to the revenue effect we document in Table 2, suggesting that municipalities reduce spending approximately dollar-for-dollar in response to a temperature-induced revenue change. Given that the standard deviation of our CDD measure is approximately 900, the coefficient of -0.122 indicates that an increase in temperature by 100 degree days lower total spending by 1.3% or as column 2 suggests about $19 per resident.

[INSERT TABLE 5 HERE]

In column 3 of Table 5, we again find that the relation between abnormal weather and municipal expenses attenuates for larger municipalities. When we split our sample into small municipalities (column 4) and large municipalities (column 5), we find that the CDD-spending concentrates in smaller municipalities, further underscoring that smaller local economies are disproportionately affected by temperature shocks.

In Figure 3 we augment Eq. (1) by including lead and lag *Cooling Degree Days* and we plot the coefficients to study the dynamic effect of temperature on municipal spending. Similar to our revenue results, we only find the relation between total expenditures and abnormal cooling degree days in the concurrent period. These results further support our argument that our results are not an artifact of trends in local economies, as the relation between municipal financing and weather only holds in the contemporaneous period. Similar to our main findings in Table 3, we continue to find limited evidence on the relation between HDDs and municipal revenues across Table 5.

[INSERT FIGURE 3 HERE]

This real-time management of municipal spending is consistent with local governments imposing fiscal austerity in response to temperature-induced revenue variation. To the extent that this is indeed going on, our results indicate that on the margin municipal spending may be less sticky than previously suggested (Wu et al. 2020). Interestingly, our results are more consistent with how private sector firms manage their expenditures in the face of non-fundamental negative cash flow shocks (e.g., Rauh 2006; Bakke and Whited, 2012; Lamont 2012).

In Table 6, we examine how temperature fluctuations affect specific categories of municipal expenditure outcomes for our smaller municipalities. In column 1 of Table 6, we start by deploying *Current Operations* as the outcome variable. The Census Bureau defines *Current Operations* as direct expenditures for employees, supplies, materials, and contractual services; excluding capital expenditures. While the coefficient in column 1 on *CCDs* is negative, it is not statistically significant at conventional levels (t-stat = 1.54). This statistical insignificance is especially notable because current operation expenses represent 77% of total municipal spending, with the majority of non-current expenses being in the form of capital expenditures.

[INSERT TABLE 6 HERE]

The Census Bureau provides a decomposition separate variable capturing only the employee expenditures component of *Current Operations*. In column 2 we focus in on *Salary Expenses*, which constitutes the largest discretionary component of local municipal expenditures.[10]

[10] Our sample size for column 2 is slightly smaller for *Salary Expenses* given the data availability of the Census Bureau's CoG code "*Z00*".

We find evidence that smaller governments respond to negative weather shocks by reducing personnel costs, as the coefficient on *Salary Expenses* is negative and statistically significant (coef. = -0.187, p-value < 0.05). Thus, increasing our CDD measure by 100 units (or approximately 0.11 standard deviations) predicts an approximate 2% reduction in annual salary spending.

Across columns 3 through 6 we observe negative relations between CDDs and spending on police, health and welfare, utilities, and park & highway, although the only significant estimate is with respect to police spending. *Police Expenses*, which are driven in large part by salary expenses, decline about 50% more than overall salary expenses, perhaps because one lever municipalities exploit is adjustments to overtime pay.

5.1.1 Linking the expenditure effect to revenue and expenditure composition

Figure 3 provides striking support for the idea that the primary way that CDDs affect municipal spending is through their effect on revenues as the CDD effect on revenues and expenditures move in lock-step. To the extent that CDDs do indeed influence municipal spending via their effect on revenues, we expect an area's revenue composition to moderate the effect of CDDs on municipal spending. If instead CDDs effect on spending arises via direct effects or non-revenue channels, then we expect no significant relation between municipality's revenue source reliance and the CDD-expenditure relation. We test this conjecture in Table 7.

[INSERT TABLE 7 HERE]

Again, we utilize the percent of revenue accruing from non-property taxes as the omitted category (i.e., the 'base' effect) in Table 7. Column 1 Table 7 shows that CDD's effect on spending is significantly related to the sources of revenues that a municipality relies upon. In column 2 of Table 7, we find that our results are similar whether or not we simultaneously control for the effect of an area's spending breakdown. Moreover, the magnitude of the CDD-revenue type interactions observed in Table 4 closely tracks the corresponding effect on expenditures. In columns (1) and (2) we find that an elevated reliance on property taxes leads to the most significant attenuation of CDDs financial impact, with reliance on utilities and fees also demonstrating a significant attenuation.

Columns (3) and (4) again indicate a similar, albeit smaller in magnitude relation between CDDs and spending for larger municipalities. These findings offer two key pieces of evidence that support of expenditures being primarily impacted by CDDs through CDDs effect on revenues. First, there is a persistent similarity between the revenue and expenditure impacts across subsamples and interaction variables. Second, and perhaps more importantly, the breakdown of municipal revenues appears to be a more significant driver of CDDs effect on spending than the breakdown of municipal spending.

4.3 Municipal Capital Investment

The striking similarity between the effect of temperature on municipal revenues and expenses is consistent with the expense effects being driven at least in part by the direct effect of temperature on municipal revenues. For instance, consider a municipality operated concession stand in a park. In days with excessive heat, there may be lower attendance at a park. The decline in attendance leads to lower municipality revenues from concession sales, lower employee expenditures, and lower inventory costs on these days. This matching between revenues and expenses in the private sector is extensively studied in the accounting literature (i.e., Dichev and Tang 2008), and thus our results could be construed as mechanical. In this section, we abstract from direct expenditures and focus on capital outlays.

The key difference between municipal current operating expenses and their spending on capital investment is that there is arguably no direct relation between the everyday measure of elevated temperature that we employ and long-run capital investment opportunities. Indeed, existing literature such as Brown, Gustafson, and Ivanov (2021), assumes that routine variation in winter weather is a shock to private sector cash flows, but does not otherwise affect investment opportunities. Under this assumption, our setting can not only shed new light on the relation between temperature fluctuations and municipal capital investment, but also the more general question of how insulated municipal capital investment is from short-term non-fundamental changes in revenue. We explore this question in Table 8, deploying municipal capital expenditures as our outcome variable.

Table 8 finds strong evidence that municipalities reduce capital expenditures in response to abnormally warm weather. Specifically, the full sample coefficient on *CDDs* when capital expenditures in the outcome variable is -0.298 in column 1 of Table 6, 244% the size of the corresponding effect on total expenditures in column (1) of Table 5. Column (2) indicates a similar 245% increase within the small municipality subsample, while column (3) corroborates the lack of a significant effect of temperature on larger municipalities. Columns (4) and (5) provide continued evidence of a significant relation between temperature fluctuations and capital investment for smaller municipalities using a measure of net investment and either a Poisson or OLS specification.

[INSERT TABLE 8 HERE]

Figure 4 illustrates the outsized effect of CDDs on capital expenditures, relative to other expenditure types. The solid line presents the dynamic effect of CDDs on capital expenditures (along with the corresponding 95% confidence interval), while the dashed line presents the same for non-capital spending (i.e., total expenditures minus Capital Expenditures). Both expenditure series exhibit qualitatively similar patterns whereby (1) the most negative and most statistically significant estimate corresponds to the current year's CDDs, (2) future CDDs exhibit no significant relation or any observable trends, and (3) there is no evidence of significant long-run effects.

[INSERT FIGURE 4 HERE]

Overall, our results provide three important takeaways. First, municipal revenues are significantly affected by variation in temperature, with warm weather negatively predicting revenues. This result, which is not ex-ante obvious due to the many revenue streams that municipalities receive and depend upon. Our results suggest that that municipalities should be included in the list of economic agents whose cash flows are significantly impacted by the weather (see e.g., Addoum, Ng, and Ortiz-Bobea, 2023; Tran, 2023; Dell et al. 2014). Second, we show that expenditures move in lockstep with the revenue decline, suggesting that municipal responses to short-run non-fundamental weather shocks occur quickly. These findings highlight the flexible manner with which small municipalities manage their financial resources when faced with short-run non-fundamental shocks and contrast with longer-run dynamic responses to fundamental or permanent revenue shock (see e.g., Buettner and Wildasin (2006), Helm and Stuhler (2024)). Finally, we provide 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).

5. Conclusion

Using a large cross-sectional panel across three distinct Census Bureau surveys, we find robust and consistent evidence that smaller municipalities incur revenue declines in response to abnormally warm weather. Smaller municipalities exhibit financial flexibility, fully offsetting the revenue declines by reducing labor expenses and capital expenditures.

Our first contribution is to provide novel evidence that municipal revenues are significantly affected by variation in temperature, with warm weather negatively predicting revenues. This result, which is not ex-ante obvious due to the many dimension of municipal revenues adds municipalities to the list of economic agents whose cash flows are significantly impacted by the weather (see e.g., Addoum, Ng, and Ortiz-Bobea, 2023; Tran, 2023; Dell et al. 2014).

Our second contribution arises from the somewhat surprising result that municipal expenditures move in lockstep with the revenue decline, suggesting that municipal spending responses to short-run non-fundamental weather shocks occur quickly and are predominantly driven by revenue changes not direct effects of temperature on spending. This takeaway becomes particularly clear from our finding that the type of revenues municipalities rely on is a key predictor of CDDs effect on both municipal revenue *and* spending. In particular municipalities' revenue reliance better predicts CDDs effect on spending compared to their spending breakdown. These findings highlight the flexible manner with which small municipalities manage their financial resources when faced with short-run non-fundamental shocks and contrast with longer-run dynamic responses to fundamental or permanent revenue shock (see e.g., Buettner and Wildasin (2006), Helm and Stuhler (2024)).

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 more than twice 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.

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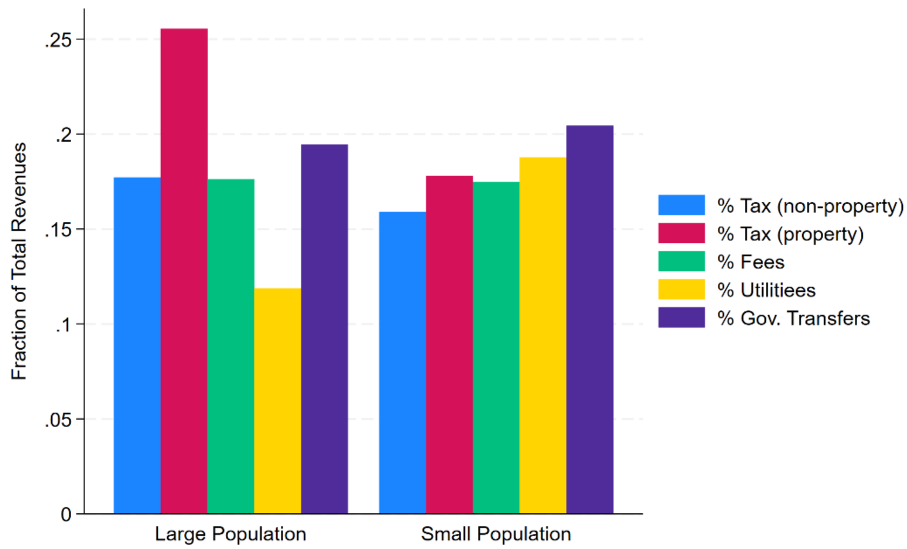
Figure 1: Revenue & Expenditure Breakdown by Municipality Size

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. Each panel partitions the sample based on whether a municipality is above or below the median size of 2,159 residents.

Panel A: Revenue Breakdown



Panel B: Expenditure Breakdown

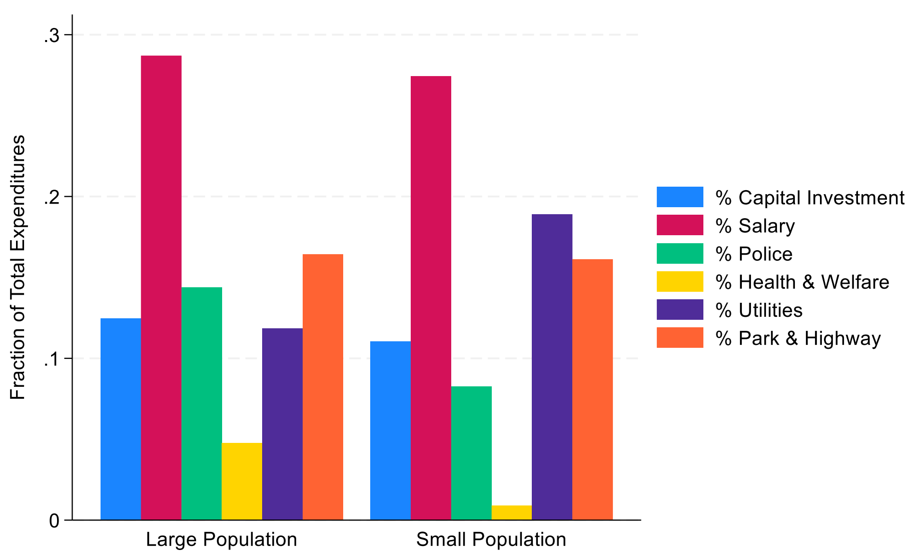


Figure 2: Dynamic Effect of Temperature on Municipal Revenues

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 a Poisson maximum likelihood 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 Census Bureau's Census of Governments 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 municipality level.

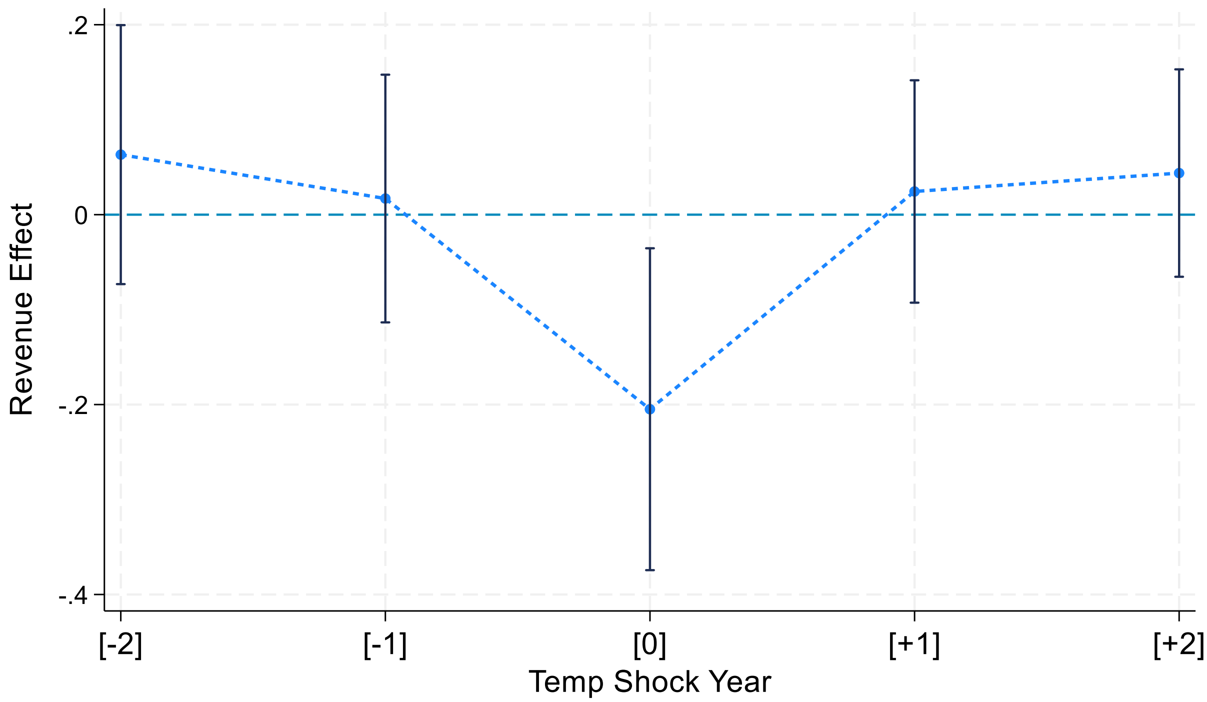


Figure 3: Dynamic Effect of Temperature on Municipal Spending

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 a Poisson maximum likelihood 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 Census Bureau's Census of Governments 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 municipality level.

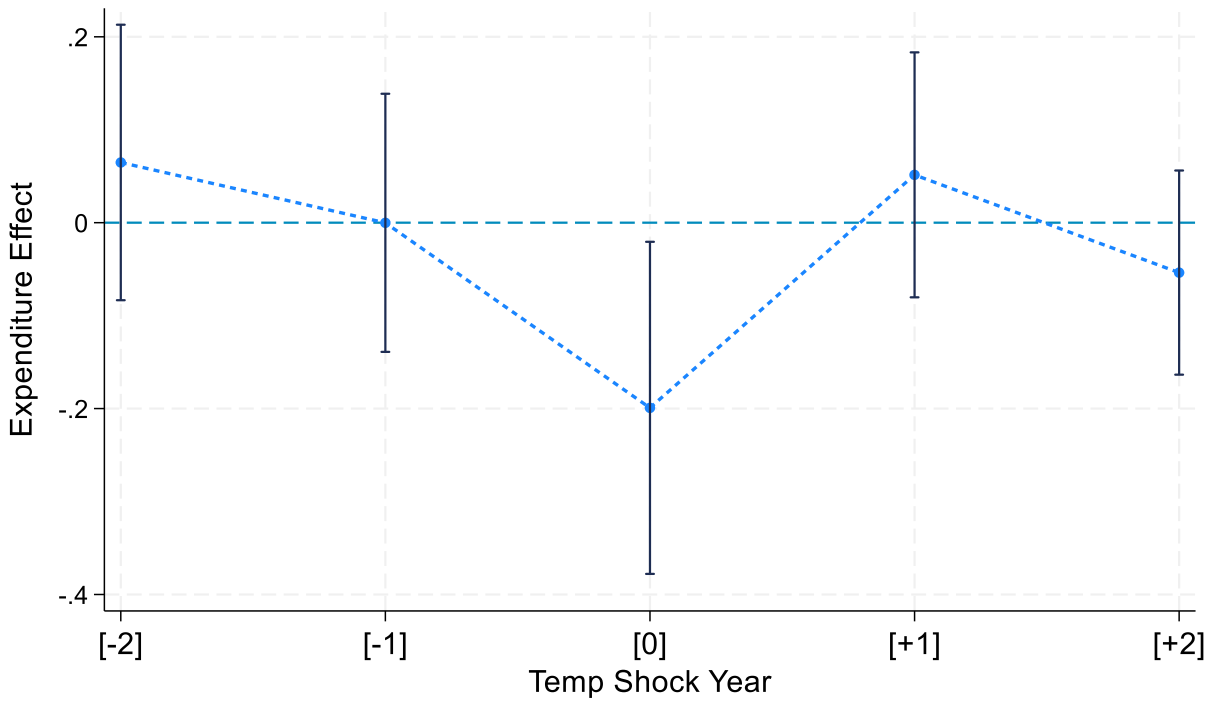


Figure 4: Dynamic Effect of Temperature on Municipal Capital Expenditures

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 investment and non-capital expenses, each scaled by population. The estimates derive from a Poisson maximum likelihood 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 Census Bureau's Census of Governments 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 municipality level.

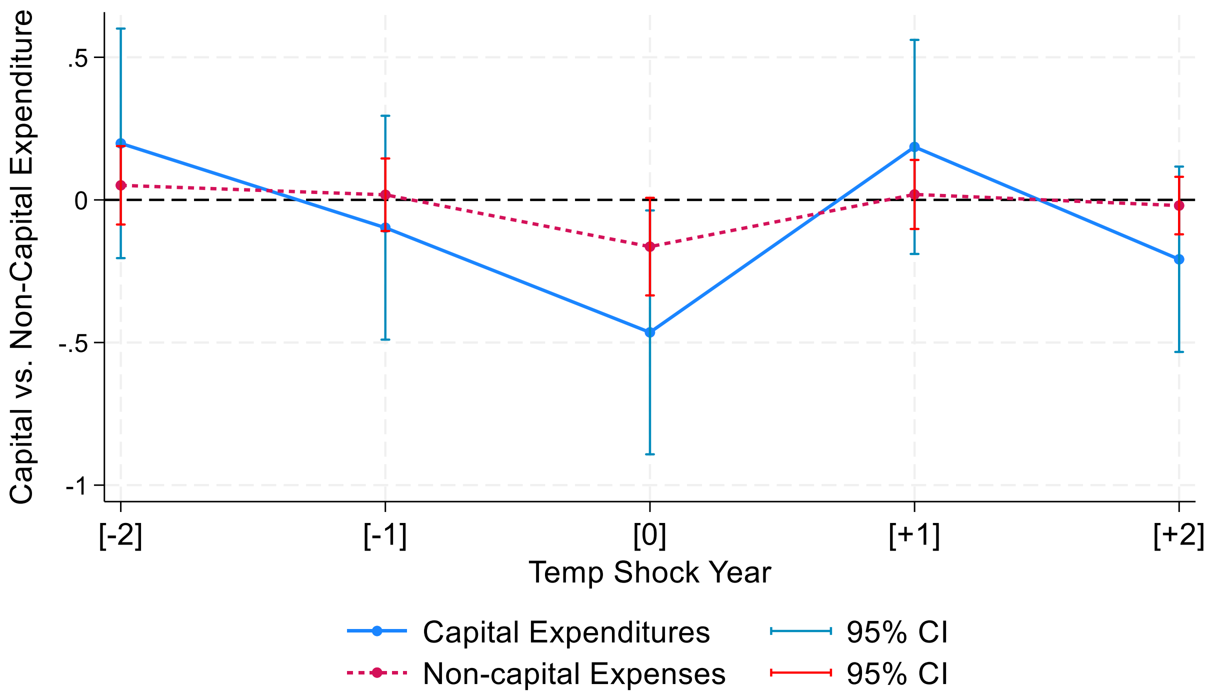


Table 1: Descriptive Statistics

This table presents descriptive statistics for the variables used in our analysis. For municipal finances, we show the mean, standard deviation, median, 99th percentile, and 1st percentile of total revenue, total expenditures, and population for both the full sample and municipalities below the median size. Similarly, measures of weather are also presented, which include cooling degree days and heating degree days. Appendix A provides detailed variable definitions along with data sources.

Panel A: Full sample (n=55,940)

	Mean	Stan. Dev.	Median	p99	p1
Total Revenue (Unscaled)	53,476,069	885,137,997	3,320,500	693,978,000	25,000
Total Expenditure	51,694,040	912,387,863	3,069,500	679,303,000	16,000
Population	25,163	153,245	2,159	403,505	113
Total Revenue	1,715	1,597	1,262	9,945	95
Total Expenses	1,618	1,536	1,178	9,321	50
Cooling Degree Days	1,400	913	1,175	4,233	62
Heating Degree Days	4,539	2,203	4,610	9,563	394

Panel B: Below Median Population (n=27,836)

	Mean	Stan. Dev.	Median	p99	p1
Total Revenue (Unscaled)	1,378,373	4,364,994	628,000	10,095,000	16,000
Total Expenditure	1,275,184	3,826,606	561,000	9,535,000	8,000
Population	741	554	569	2,108	107
Total Revenue	1,559	1,669	1,069	9,945	95
Total Expenses	1,461	1,606	972	9,321	50
Cooling Degree Days	1,334	820	1,139	3,620	65
Heating Degree Days	4,810	2,188	4,949	9,777	792

Table 2: Temperature Shocks and Municipal Revenues

This table presents output from estimating panel regressions using municipality and state-year fixed effects. All columns except Column (2) employ a Poisson maximum likelihood model, while Column 2 uses an ordinary least squares estimator. Columns (4) and (5) contain municipalities with below and above the sample median population of 2,159, respectively. The dependent variable is municipal revenues scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality 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 Revenue	(4) Total Revenue	(5) Total Revenue
CDDs	-0.096**	-150.230**	-0.307***	-0.169**	0.010
	(-2.37)	(-2.16)	(-3.39)	(-2.14)	(0.36)
HDDs	0.009	-188.751*	-0.227***	-0.006	0.041
	(0.17)	(-1.76)	(-2.63)	(-0.07)	(0.78)
CDDs X Ln(Pop.)			0.026***		
			(3.07)		
HDDs X Ln(Pop.)			0.031***		
			(3.81)		
Unemployment	-0.000	5.799	-0.001	0.003	-0.004
	(-0.00)	(0.97)	(-0.32)	(0.63)	(-1.18)
Income per capita	0.000**	0.006***	0.000**	0.000	0.000***
	(2.01)	(2.81)	(2.04)	(0.29)	(2.86)
Ln(Pop.)	-0.295***	-624.043***	-0.305***	-0.435***	-0.263***
	(-5.12)	(-5.49)	(-5.26)	(-3.90)	(-2.71)
Ln(Estabs)	0.176***	298.323**	0.166***	0.139	0.237***
	(3.04)	(2.42)	(2.86)	(1.47)	(3.74)
Model	Poisson	OLS	Poisson	Poisson	Poisson
Sample	Full	Full	Full	Small Area	Large Area
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	1,715.14	1,715.14	1,715.14	1,557.27	1,872.98
Pseudo R-squared	0.88		0.88	0.85	0.92
Observations	55,940	55,940	55,940	27,836	27,785

Table 3: Disaggregating the Effects of Temperature Shocks on Small Municipal Revenues

This table presents output from estimating panel regressions using municipality and state-year fixed effects. All columns employ a Poisson maximum likelihood model and contain municipalities with below the sample median population of 2,159. The dependent variable is municipal revenues that accrue from the listed source at the top of each column scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Non-Property Tax Revenue	(2) Property Tax Revenue	(3) Fee Revenues	(4) Utilities Revenues	(5) Misc. Revenues	(6) Intergov. Revenue
CDDs	-0.271***	-0.160	-0.017	0.041	-0.159	-0.203
	(-2.72)	(-1.40)	(-0.16)	(0.49)	(-1.15)	(-1.43)
HDDs	-0.096	0.166*	-0.087	0.004	0.225	-0.083
	(-0.61)	(1.73)	(-0.77)	(0.05)	(1.57)	(-0.45)
Unemployment	-0.010	0.013*	-0.001	0.001	-0.005	-0.005
	(-1.20)	(1.86)	(-0.10)	(0.19)	(-0.41)	(-0.41)
Income per capita	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.91)	(0.00)	(-1.38)	(-0.10)	(-0.03)	(-1.35)
Ln(Pop.)	-0.309**	-0.402***	-0.306**	-0.479***	-0.273	-0.703***
	(-2.46)	(-3.55)	(-2.23)	(-3.41)	(-1.57)	(-3.21)
Ln(Estabs)	0.124	-0.038	0.289**	0.088	-0.231	0.357*
	(0.94)	(-0.33)	(2.45)	(0.84)	(-1.32)	(1.88)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Sample	Small Area	Small Area	Small Area	Small Area	Small Area	Small Area
State-Year-Month FE	Y	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y	Y
Mean Dependent	206.16	271.01	307.51	425.73	123.12	303.78
Pseudo R-squared	0.86	0.90	0.83	0.86	0.77	0.71
Observations	26,875	25,723	25,285	20,775	26,846	27,316

Table 4: Revenue effect partitioned by cash flows sources

This table presents output from estimating panel regressions with a Poisson maximum likelihood estimator using municipality and state-year fixed effects. The sample contains municipalities with below the sample median population of 2,159 in columns (1) and (2) and above this threshold in columns (3) and (4). The dependent variable is Total Revenues, scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Each column interacts CDDs with the percent of municipal revenue arising from the indicated sources. The excluded revenue category is non-property taxes. Columns (2) and (4) further interact CDDs with the percentage of spending that comes in each designated category. 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 municipality 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 Revenue	(4) Total Revenue
CDDs	-0.545***	-0.593***	-0.198***	-0.249***
	(-6.62)	(-5.12)	(-3.42)	(-3.52)
CDDs X % Utilities	0.506***	0.884***	0.363***	0.290***
	(5.57)	(7.40)	(4.61)	(2.86)
CDDs X % Tax (property)	0.938***	0.738***	0.254***	0.241**
	(7.73)	(4.93)	(3.13)	(2.39)
CDDs X % Fee	0.223***	0.353***	0.225***	0.302***
	(2.67)	(2.65)	(3.22)	(3.44)
CDDs X % Gov. Transfers	0.351***	0.389***	0.263***	0.163**
	(5.20)	(3.85)	(4.40)	(2.25)
CDDs X % Other	0.259***	0.294**	0.149*	0.121
	(2.94)	(2.41)	(1.75)	(1.13)
CDDs X % Spending Salary		0.001		-0.012
		(0.03)		(-0.42)
CDDs X % Spending Police		0.184		0.060
		(1.55)		(0.75)
CDDs X % Spending Health		0.454		0.142
		(1.48)		(1.16)
CDDs X % Spending Utilities		0.051		0.122**
		(0.90)		(2.21)
CDDs X % Spending Parks		0.087*		0.008
		(1.77)		(0.23)
HDDs	0.082	0.072	0.039	0.018
	(1.22)	(0.74)	(0.83)	(0.30)
Model	Poisson	Poisson	Poisson	Poisson
Sample	Small Area	Small Area	Large Area	Large Area
State-Year-Month FE	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y
Mean Dependent	1,557.27	1,479.74	1,872.98	1,911.90
Pseudo R-squared	0.89	0.90	0.93	0.94
Observations	27,836	16,915	27,785	18,676

Table 5: Temperature Shocks and Municipal Spending

This table presents output from estimating panel regressions using municipality and state-year fixed effects. All columns except Column (2) employ a Poisson maximum likelihood model, while Column 2 uses an ordinary least squares estimator. Columns (4) and (5) contain municipalities with below and above the sample median population of 2,159, respectively. The dependent variable is municipal expenditures scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1*.

	(1) Total Expenses	(2) Total Expenses	(3) Total Expenses	(4) Total Expenses	(5) Total Expenses
CDDs	-0.122***	-175.756***	-0.273***	-0.184**	-0.023
	(-2.91)	(-2.64)	(-2.85)	(-2.18)	(-0.69)
HDDs	-0.005	-131.014	-0.223**	-0.016	0.034
	(-0.09)	(-1.13)	(-2.38)	(-0.17)	(0.59)
CDDs X Ln(Pop.)			0.019**		
			(2.06)		
HDDs X Ln(Pop.)			0.029***		
			(3.32)		
Unemployment	-0.001	4.066	-0.002	0.001	-0.004
	(-0.28)	(0.70)	(-0.53)	(0.14)	(-1.22)
Income per capita	0.000*	0.004*	0.000*	0.000	0.000***
	(1.70)	(1.88)	(1.72)	(0.09)	(3.07)
Ln(Pop.)	-0.373***	-710.674***	-0.382***	-0.492***	-0.335***
	(-5.73)	(-5.76)	(-5.90)	(-3.83)	(-3.15)
Ln(Estabs)	0.276***	459.837***	0.267***	0.281***	0.296***
	(4.40)	(3.77)	(4.27)	(2.81)	(4.19)
Model	Poisson	OLS	Poisson	Poisson	Poisson
Sample	Full	Full	Full	Small Area	Large Area
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	1,617.59	1,617.59	1,617.59	1,459.64	1,776.50
Pseudo R-squared	0.86		0.86	0.83	0.91
Observations	55,940	55,940	55,940	27,836	27,785

Table 6: Disaggregating the Effects of Temperature Shocks on Small Municipal Expenditures

This table presents output from estimating panel regressions using municipality and state-year fixed effects. All columns employ a Poisson maximum likelihood model and contain municipalities with below the sample median population of 2,159. The dependent variable is municipal expenditures that accrue from the listed source at the top of each column scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Current Operations	(2) Salary Expenses	(3) Police Expenses	(4) Health Welfare Expenses	(5) Utilities Expenses	(6) Park / Highway Expenses
CDDs	-0.116	-0.187**	-0.260***	-0.201	-0.128	-0.039
	(-1.54)	(-1.97)	(-2.65)	(-0.71)	(-1.14)	(-0.32)
HDDs	-0.023	-0.070	0.061	0.059	-0.055	0.128
	(-0.33)	(-0.64)	(0.45)	(0.19)	(-0.36)	(0.89)
Unemployment	0.003	0.006	0.006	-0.033	-0.016	-0.010
	(0.56)	(0.83)	(0.91)	(-1.33)	(-1.50)	(-1.04)
Income per capita	0.000	-0.000	0.000	-0.000	-0.000	0.000
	(0.26)	(-0.17)	(1.11)	(-0.45)	(-0.85)	(0.93)
Ln(Pop.)	-0.474***	-0.135	-0.355***	-0.604**	-0.619***	-0.105
	(-4.60)	(-0.84)	(-2.64)	(-2.04)	(-3.09)	(-0.61)
Ln(Estabs)	0.104	0.131	-0.054	0.584	0.379***	0.299*
	(1.28)	(1.12)	(-0.45)	(1.32)	(2.72)	(1.91)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Sample	Small	Small	Small	Small	Small	Small
State-Year-Month FE	Y	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y	Y
Mean Dependent	1,126.20	302.24	153.59	41.45	413.07	225.90
Pseudo R-squared	0.86	0.87	0.81	0.82	0.79	0.77
Observations	27,836	16,915	20,168	12,474	21,436	26,653

Table 7: Expenditure effect partitioned by cash flows sources

This table presents output from estimating panel regressions with a Poisson maximum likelihood estimator using municipality and state-year fixed effects. The sample contains municipalities with below the sample median population of 2,159 in columns (1) and (2) and above this threshold in columns (3) and (4). The dependent variable is Total Expenditures, scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. Each column interacts CDDs with the percent of municipal revenue arising from the indicated sources. The excluded revenue category is non-property taxes. Columns (2) and (4) further interact CDDs with the percentage of spending that comes in each designated category. 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 municipality level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Total Expenses	(2) Total Expenses	(3) Total Expenses	(4) Total Expenses
CDDs	-0.444***	-0.393***	-0.163***	-0.217***
	(-4.90)	(-3.39)	(-2.76)	(-3.32)
CDDs X % Utilities	0.334***	0.483***	0.313***	0.225**
	(3.38)	(4.27)	(3.98)	(2.55)
CDDs X % Tax (property)	0.814***	0.354**	0.167**	0.094
	(6.87)	(2.50)	(2.10)	(1.07)
CDDs X % Fee	0.207**	0.321**	0.190***	0.241***
	(2.31)	(2.46)	(2.77)	(2.91)
CDDs X % Gov. Transfers	0.080	0.179*	0.071	0.076
	(1.22)	(1.84)	(1.17)	(1.09)
CDDs X % Other	0.117	0.198*	0.107	0.038
	(1.24)	(1.72)	(1.37)	(0.38)
CDDs X % Spending Salary		0.056		-0.003
		(0.80)		(-0.08)
CDDs X % Spending Police		0.289**		0.128
		(2.16)		(1.29)
CDDs X % Spending Health		0.746**		0.161
		(2.33)		(1.34)
CDDs X % Spending Utilities		0.091		0.061
		(1.54)		(1.07)
CDDs X % Spending Parks		-0.074		0.001
		(-1.26)		(0.04)
HDDs	0.065	0.099	0.048	-0.010
	(0.74)	(1.00)	(0.88)	(-0.19)
Model	Poisson	Poisson	Poisson	Poisson
Sample	Small Area	Small Area	Large Area	Large Area
State-Year-Month FE	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y
Mean Dependent	1,459.64	1,403.55	1,776.50	1,828.63
Pseudo R-squared	0.85	0.91	0.91	0.95
Observations	27,836	16,915	27,785	18,676

Table 8: The Sensitivity of Municipal Capital Expenditures to Temperature Shocks

This table presents output from estimating panel regressions using municipality and state-year fixed effects. Columns (1) through (4) employ a Poisson maximum likelihood model, while column (5) uses an ordinary least squares estimator. Columns (2), (4), and (5) contain municipalities with below the sample median population of 2,159, while Column (3) contains larger municipalities and Column (1) contains municipalities of all populations. The dependent variable is Capital Expenditures scaled by municipal population in columns (1) through (3). Columns (4) and (5) subtract divestment from Capital Expenditures, with column (4) setting this difference to zero when negative. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality 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	(4) Net Investment (if >0)	(5) Net Investment
CDDs	-0.298***	-0.451**	-0.094	-0.435**	-91.729**
	(-2.60)	(-2.24)	(-0.70)	(-2.15)	(-2.03)
HDDs	0.010	-0.061	0.151	-0.054	-34.757
	(0.05)	(-0.22)	(0.81)	(-0.19)	(-0.34)
Unemployment	-0.002	0.015	-0.027**	0.016	3.468
	(-0.24)	(0.81)	(-2.48)	(0.81)	(0.79)
Income per capita	0.000	-0.000	0.000	-0.000	-0.000
	(1.11)	(-0.12)	(1.64)	(-0.10)	(-0.23)
Ln(Pop.)	-0.215	-0.369	-0.202	-0.390	-119.606*
	(-1.39)	(-1.11)	(-0.68)	(-1.16)	(-1.65)
Ln(Estabs)	0.957***	0.991***	0.896***	0.980***	255.524***
	(5.50)	(3.59)	(4.04)	(3.52)	(3.33)
Model	Poisson	Poisson	Poisson	Poisson	OLS
Sample	Full	Small	Large	Small	Small
State-Year-Month FE	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y
Mean Dependent	278.07	311.08	251.50	309.47	244.98
Pseudo R-squared	0.68	0.67	0.71	0.67	
Observations	49,684	22,150	27,215	22,044	27,836

Appendix A: Variable Definitions

Variable	Description	Source
Total Revenue	Total municipal revenue as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. Revenue is defined 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. For example, the numerator of *Total Revenues* for the 2022 survey year is the sum of the following CoG codes: A01, A03, A09, A10, A12, A16, A18, A36, A44, A45, A50, A59, A60, A61, A80, A81, A87, A89, A90, A91, A92, A93, A94, B89, C89, T01, T09, T10, T11, T12, T13, T14, T15, T16, T19, T20, T21, T22, T24, T25, T27, T28, T29, T40, T41, T50, T51, T53, T99, U01, U11, U20, U30, U40, U41, U50, U95, U99, X01, X30, X50, X62, Y01, Y02, and Y04.	Census Bureau's CoG
Non-Property Tax Revenue	Total municipal taxes less property taxes as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Non-Property Tax Revenue* for the 2022 survey year is the sum of the following CoG codes: T09, T10, T11, T12, T13, T14, T15, T16, T19, T20, T21, T22, T24, T25, T27, T28, T29, T40, T41, T50, T51, T53, T99. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Property Tax Revenue	Total municipal property taxes (CoG code T01) scaled by population. This variable is set to zero if missing from the CoG database.	
Fee Revenues	Current municipal charges as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Fee Revenues* for the 2022 survey year is the aggregate of the following CoG codes: A01, A03, A09, A10, A12, A16, A18, A36, A44, A45, A50, A59, A60, A61, A80, A81, A87, and A89.	Census Bureau's CoG
Utility Revenues	Utility charges (CoG codes: A91, A92, A93, and A94) as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Misc. Revenues	Miscellaneous revenues (CoG codes: U01, U11, U20, U21, U30, U40, U41, U50, U95, U99) as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Intergov. Revenues	Intergovernmental revenue from State and Federal governments as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Intergov. Revenues* for the 2022 survey year is the sum of the following CoG codes: B89 and C89. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Total Expenses	Total expenditures as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. Expenditures includes 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,	Census Bureau's CoG

Variable	Description	Source
	purchase of investment securities, extension of loans, and agency or private trust transactions. For example, the numerator of *Total Expenses* for the 2022 survey year is the sum of the following CoG codes: E01, E03, E04, E05, E12, E16, E18, E22, E23, E24, E25, E29, E31, E32, E36, E44, E45, E50, E52, E59, E60, E61, E62, E66, E77, E79, E80, E81, E87, E89, E90, E91, E92, E93, E94, F01, F03, F04, F05, F12, F16, F18, F22, F23, F24, F25, F29, F31, F32, F36, F44, F45, F50, F52, F59, F60, F61, F62, F66, F77, F79, F80, F81, F87, F89, F90, F91, F92, F93, F94, I89, I91, I92, I93, I94, J19, L89, and S67 .	
Current Expenses	Current operating expenditures as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. These are direct expenditures for compensation of own officers and employees and for supplies, materials, and contractual services except any amounts for capital outlay (i.e., for personal services or other objects used in contract construction or government employee construction of permanent structures and for acquisition of property and equipment). For example, the numerator of *Current Expenses* for the 2022 survey year is the sum of the following CoG codes: E01, E03, E04, E05, E12, E16, E18, E22, E23, E24, E25, E29, E31, E32, E36, E44, E45, E50, E52, E59, E60, E61, E62, E66, E77, E79, E80, E81, E87, E89, E90, E91, E92, E93, E94. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Salary Expenses	Salary expenses (CoG codes: Z00) as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population.	Census Bureau's CoG
Police Expenses	Police expenses as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Police Expenses* for the 2022 survey year is the sum of the following CoG codes: E62 and F62.	Census Bureau's CoG
Health Welfare Expenses	The sum of health expenses, public welfare expenses, and public inspection expenses as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Health Welfare Expenses* for the 2022 survey year is the sum of the following CoG codes: E32, F32, E66, E77, E79, F66, F77, and F79. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Utilities Expenses	Utilities expenses as defined by the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Utilities Expenses* for the 2022 survey year is the sum of the following CoG codes: E91, E92, E93, E94, F91, F92, F93, F94, I91, I92, I93, and I94. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Park/Highway Expenses	The sum of parks and recreation expenses and highway expenses as defined by on the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. For example, the numerator of *Park/Highway Expenses* for the 2022 survey year is the sum of the following CoG codes: E44, E45, F44, F45, E61, and F61. This variable is set to zero if missing from the CoG database.	Census Bureau's CoG
Capital Expenditures	Capital outlays as defined by on the CoG's Finance Aggregate Lines for that survey scaled by the municipal population. Capital outlays are direct expenditures for purchase or construction, by contract or	Census Bureau's CoG

Variable	Description	Source
	government employee, construction of buildings and other improvements; for purchase of land, equipment, and existing structures; and for payments on capital leases. For example, the numerator of *Capital Expenditures* for the 2022 survey year is the sum of the following CoG codes: F01, F03, F04, F05, F12, F16, F18, F22, F23, F24, F25, F29, F31, F32, F36, F44, F45, F50, F52, F59, F60, F61, F62, F66, F77, F79, F80, F81, F87, F89, F90, F91, F92, F93, F94. This variable is set to zero if missing from the CoG database.	
Net Investment	*Capital Expenditures* less asset sales (CoG code: U11) scaled by population. This variable is set to zero if *Capital Expenditures* or asset sales are missing from the CoG database	Census Bureau's CoG
Net Investment (if > 0)	*Capital Expenditures* less asset sales (CoG code: U11) scaled by population. This variable is set to zero if *Capital Expenditures* or asset sales are missing from the CoG database or if asset sales exceed *Capital Expenditures*.	Census Bureau's CoG
Deficit	*Total Expenditures* less *Total Revenue* scaled by population.	Census Bureau's CoG
Deficit Ind.	Indicator variable equal to 1 if the municipalities *Total Expenses* exceed their *Total Revenues*, and equal to zero otherwise.	Census Bureau's CoG
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.	NOAA Monthly U.S. Climate Divisional Database
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 Monthly U.S. Climate Divisional Database
Unemployment	The average annual unemployment rate in percentage terms in a municipality's county in the previous non-overlapping calendar year.	Bureau of Labor Statistics – Local Area Unemployment
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]
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
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

Appendix Table 1: Revenue Effect Breakdown, Large Firms

This table presents output from estimating panel regressions using municipality and state-year fixed effects. All columns employ a Poisson maximum likelihood model and contain municipalities with above the sample median population of 2,159. The dependent variable is municipal revenues that accrue from the listed source at the top of each column scaled by municipal population. CDDs (HDDs) are Cooling (Heating) Degree Days and are the number of degree days above (below) 65 degrees Fahrenheit in the year over which the dependent variable is measured. 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 municipality level are shown in parentheses. Statistical significance is indicated as follows: ***: p<0.01, **: p<0.05, *: p<0.1.*

	(1) Non-Property Tax Revenue	(2) Property Tax Revenue	(3) Fee Revenues	(4) Utilities Revenues	(5) Misc. Revenues	(6) Intergov. Revenue
CDDs	0.019	-0.016	-0.053	0.035	0.167*	0.008
	(0.48)	(-0.38)	(-0.82)	(0.59)	(1.77)	(0.10)
HDDs	0.217**	0.060	-0.046	-0.062	-0.141	0.177*
	(2.27)	(0.92)	(-0.42)	(-0.66)	(-0.88)	(1.95)
Unemployment	-0.027***	0.004	-0.007	-0.007	-0.009	-0.006
	(-6.23)	(0.95)	(-1.24)	(-1.08)	(-1.11)	(-0.96)
Income per capita	0.000	0.000	0.000*	0.000***	-0.000	-0.000
	(1.52)	(0.71)	(1.94)	(3.61)	(-1.55)	(-0.85)
Ln(Pop.)	-0.147	-0.327***	-0.132	-0.505***	0.133	-0.260
	(-1.26)	(-3.26)	(-1.05)	(-3.84)	(0.75)	(-1.19)
Ln(Estabs)	0.471***	0.171*	0.118	0.282***	0.100	0.133
	(5.13)	(1.84)	(1.06)	(2.64)	(0.54)	(1.00)
Model	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
Sample	Large Area	Large Area	Large Area	Large Area	Large Area	Large Area
State-Year-Month FE	Y	Y	Y	Y	Y	Y
Muni FE	Y	Y	Y	Y	Y	Y
Mean Dependent	288.57	416.47	361.52	476.00	113.13	344.41
Pseudo R-squared	0.92	0.92	0.89	0.93	0.73	0.85
Observations	27,607	27,273	27,536	17,404	27,754	27,712