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Relationships between Density and per Capita Municipal Spending in the United States

Jeremy Mattson

Upper Great Plains Transportation Institute, North Dakota State University, Fargo, ND 58105, USA; jeremy.w.mattson@ndsu.edu

Abstract: The objective of this research is to determine the relationship between land use, particularly density, and per capita spending levels in cities across the United States. A model was developed using data from the U.S. Census Bureau's Annual Survey of State and Local Government Finances to estimate the impacts of population-weighted density and other factors on per capita municipal spending. This study focused on municipal spending for eight categories that theoretically could be influenced by land use development: fire protection, streets and highways, libraries, parks and recreation, police, sewer, solid waste management, and water. Density was found to be negatively associated with per capita municipal expenditures for the following cost categories: operational costs for fire protection, streets and highways, parks and recreation, sewer, solid waste management, and water; construction costs for streets and highways, parks and recreation, sewer, and water; and land and existing facility costs for police, sewer, and water. Results were insignificant for other cost categories, and a positive relationship was found for police operations costs. In general, results support the conclusion that increased density is associated with reduced per capita municipal spending for several cost categories.

Keywords: land use; density; sprawl; municipal expenditures; budgets

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1. Introduction

Municipalities need to consider how the development of land use patterns influences municipal budgets. Land use characteristics relate to several aspects of urban planning. For example, land use patterns have been shown in many studies to impact travel behavior [1,2]. Some research has also examined how land use and neighborhood characteristics relate to household transportation expenditures [3,4]. While the impacts of land use patterns on travel behavior and household expenditures are important for policy makers to understand, land use characteristics can also affect city expenditures.

Lower density, auto-oriented developments require more infrastructure per capita than do more compact developments. Sprawling cities have more miles of streets and water and sewer pipes per person to maintain, and services such as trash collection and fire and police protection have more miles to cover per person. This can result in an increase in per capita infrastructure, maintenance, and service costs for cities. More compact developments can lead to cost savings through economies of scale and economies of geographic scope [5]. Economies of scale are exhibited when the marginal cost of providing services to each additional person decreases as more residents cluster within a smaller geographic area. Economies of geographic scope are found when the marginal cost decreases as each person locates more closely to existing major public facilities.

The research question that this study attempts to address is whether it costs more per capita for lower density cities in the United States to provide services and to build and maintain infrastructure, compared to cities with higher population densities. While research on the relationships between land use and municipal spending is not as extensive as that focused on travel behavior, some research has shown how more sprawling development patterns can increase costs for cities [5–9]. Most U.S. research has been on smaller studies or has relied on county-level data. Results have also been found to vary between studies. This study contributes to the literature by conducting a national study of cities across the United States.

The objective of this research is to determine the relationship between land use, particularly density, and per capita spending levels in cities across the United States for different spending categories. A model was developed using data for 2012–2016 from the U.S. Census Bureau's Annual Survey of State and Local Government Finances. This data source provides individual city spending levels for several different spending categories. This study focused on municipal spending for eight categories that theoretically could be influenced by land use development: fire protection, streets and highways, libraries, parks and recreation, police, sewer, solid waste management, and water. Results from the model show how density and other independent variables are associated with per capita municipal expenditures.

This paper is organized as follows. Section 2 provides a review of previous research related to density, the relationships between density and per capita municipal spending, and the effects of other factors on city expenditures. The research model and data are described in Section 3, while Sections 4 and 5 provide the results and a discussion.

2. Literature Review

Lower density developments are often characterized as auto-oriented, suburban types of development with larger lot sizes, single family homes, and noncontiguous development, while higher density developments are more compact with a mix of housing types. Density influences a city in many ways. Boyko and Cooper [10] conducted an extensive literature review examining both the advantages and disadvantages of higher urban densities. As they found, there are several advantages to higher urban densities with regard to mobility, efficient use of land or resources, social equity and diversity, economics, and others. For example, some of the economic advantages that they cited from the literature include enabling investments in new and better community amenities, promoting a critical mass needed to support local businesses, attracting additional businesses and other amenities, allowing for a more efficient use of urban services, increasing productivity levels, and others. Regarding use of land and resources, they found advantages from making better use of resources and infrastructure, reducing development pressure on agricultural and industrial land and existing greenspace, and others. Mobility and accessibility benefits result by reducing travel distances and creating an environment where transit is more viable and efficient, and more trips can be made by walking and bicycling. They also found environmental benefits from reduced fossil fuel emissions. Boyko and Cooper [10] also noted several disadvantages of higher urban densities found in the literature. These include disadvantages related to mobility (e.g., congestion), land use (e.g., limited recreational opportunities or availability of open space, pollution), social or psychological aspects (e.g., loss of privacy, noise and nuisance, stress, constraints on individual behavior, social inequality, decreased sense of community, crime), and economics (e.g., increased costs of housing and goods and services, costs to build and maintain high-density projects). Boyko and Cooper [10] examined many relationships with density but cited only a few studies related to local government expenditures. However, there has been additional research in this area.

Lynch and Zimmerman [11] argued that large portions of the city budget, such as street construction and maintenance, water and sewer infrastructure, fire protection and police services, solid waste removal, and school transportation, are affected by the geographic pattern of development. The costs of many of these services depend, to some extent, on the distance traveled. For some services, such as fire and police, denser development could potentially reduce the number of facilities, vehicles, and personnel required.

While land use patterns and public expenditures are theoretically related, a review of early empirical research by Carruthers and Ulfarsson [7] concluded that the relationship between urban form and public service spending was ambiguous and controversial. Muro and Puentes [5], on the other hand, reviewed the literature and concluded that more compact developments can lead to cost savings for road building, water and sewer, and annual operations and service delivery. A number of additional studies have been conducted since these earlier literature reviews.

Burchell and Mukherji [12] examined the effects of sprawl versus managed, or smart, growth on land and infrastructure consumption as well as real estate development and public services costs in the United States. Sprawl was defined as including noncontiguous development, larger lot sizes, and lower floor-to-area ratios for nonresidential development. Smart growth was described as more compact and concentrated around existing urban centers, limiting peripheral developments and reducing the need for new infrastructure. Results showed the substantial savings for water and sewer infrastructure, road infrastructure, and local public service costs that would result by pursuing smart growth development instead of conventional sprawl.

Carruthers and Ulfarsson [7] conducted an empirical analysis of the relationship between alternative development patterns and spending, using data for a cross-section of 283 metropolitan counties for 1982–1992. They studied twelve measures of public spending: total direct spending, capital facilities, roadways, other transportation, sewerage, trash collection, housing and community development, police protection, fire protection, parks, education, and libraries. They found that the per capita cost of many services decreases with density, after controlling for property value. Specifically, they found that per capita costs for capital facilities, roadways, police protection, education, and total public spending declined with increases in density.

The authors of that study followed up with an analysis of per capita spending by all continental U.S. counties in 2002 [6]. In this study, they found that density is negatively associated with total direct spending and spending for education, parks and recreation, police protection, and roadways. For other costs, the effect of density was marginally significant or insignificant, and it was positively associated with spending for housing and community development. They also found that the percentage of county land that was developed had a positive effect on most types of spending. They concluded that, on balance, high-density, compact development costs less to support. Regarding the magnitude of the effect, Carruthers and Úlfarsson [6] estimated that, in 2002, if development everywhere was 25% more dense, public services would cost USD 3.63 billion less annually, and the average county would save USD 1.18 million, with the largest effect being for spending on roadways.

While the research by Carruthers and Úlfarsson [6,7] was based on county-level data across the United States, other studies have analyzed the effects of land use and urban form on spending in specific municipalities or counties. For example, the city of Halifax, Canada, studied how different settlement patterns affect the cost of services delivered by the city [13]. They studied eight different types of development patterns, and similar to other research, they found that cost decreases with density for many services, especially for roads but also for libraries, parks and recreation, police, fire, water, transit, and sewer. Specifically for roads, they estimated that the cost per household is $1053 CAD for low-density rural development (2.5 acres per dwelling unit), $280 CAD for low-density suburban (8100 sq ft per dwelling unit), $124 CAD for mid-density urban (2400 sq ft per dwelling unit), and $26 CAD for high-density urban (760 sq ft per dwelling unit). Total per household costs ranged from $5240 CAD for low-density rural to $1416 CAD for high-density urban. They also noted that operations and maintenance make up 60% to 90% of the overall service costs.

Other municipalities and counties have conducted similar studies with similar results. Fulton et al. [8] compiled and analyzed 17 case studies conducted by municipalities as well as at regional, state, or national levels. They classified development patterns into two different categories and examined the costs associated with each. Developments were classified as either smart growth or conventional suburban. They defined smart growth as being characterized by more efficient use of land, greater land use mix, and better connections between streets and neighborhoods. Conventional suburban was then defined by less efficient use of land, separated land uses, and development designed primarily for driving. Their main findings were that smart growth development costs about one-third less for upfront infrastructure and saves an average of 10% on ongoing delivery of services, specifically for police, ambulance, and fire [8]. Edwards and Xiao [14] studied the fiscal impacts of annexation and found that the effects on municipal spending are impacted by changes in municipal density levels. They found that if annexation is accompanied by higher densities, the city will experience lower increases in per capita spending levels.

Several studies of Spanish municipalities have also shown a negative relationship between population density or spawl and per capita expenditures [9,15–17]. For example, Hortas-Rico and Solé-Ollé [9] conducted an empirical analysis of 2500 Spanish municipalities and found that low-density development patterns lead to greater costs for providing local public services. Gielen et al. [16] found that waste collection, sanitation, water, road cleaning, and public lighting were most sensitive to sprawl.

While much of the research has been focused on metropolitan areas, similar results have been found in mostly rural or nonmetropolitan areas of Montana and Wyoming [18–21]. In urban areas, developments with one-acre lots on the edge of the city would be considered sprawl, but in rural Natrona County, Wyoming, the issue is large 35–50-acre ranchettes or developments with 6–10-acre lots far from any city or the nearest highway. In this setting, encouraging developments with one-acre lots adjacent to a city was found to significantly reduce the budget gap for the county [19].

Most of the research has been focused on costs, but development patterns can also impact revenue potential. Some research has shown that denser development patterns produce an increase in property tax revenue per acre [8,22]. Fulton et al. [8] found that smart growth generates ten times more tax revenue per acre than conventional suburban development.

Not all research, however, has shown the financial benefits of increased density and smart growth development patterns. Kotchen and Schulte [23] conducted a meta-analysis of 125 cost-of-community-service studies conducted through 2007 that compared the ratio of expenditures to revenue. For residential areas, they estimated a negative relationship between density and this ratio, as expected, but they did not find it to be statistically significant. Further, they found a positive relationship for commercial/industrial and agricultural/open space areas.

Some costs could potentially increase with density. For example, crime could increase with density, resulting in greater police operation costs per capita. According to Glaeser and Sacerdote [24], crime may increase with density because of greater proximity between potential victims and criminals, lower transport costs, and greater returns to crime.

Holcombe and Williams [25] found mixed results. They found that for cities with population less than 500,000, higher population density was associated with lower per capita expenditures on highways and sewers, but this relationship did not hold for larger cities. Further, per capita expenditures on services, such as police, increased with density for cities with population above 500,000, and there was no relationship for smaller cities. Their general conclusion was that for cities larger than 50,000, per capita expenditures are not associated with density. Further research by Holcombe and Williams [26] found no relationship between sprawl and highway expenditures and, actually, a positive relationship between population density and highway expenditures.

The research is mixed, but there is some evidence that increased density and smart growth development patterns reduce public service expenditures for local governments. A number of studies have shown a reduction in total costs. With regard to specific services, different studies provide different results. While it may be expected that many costs would decrease with density, most studies tend to show some cost reductions to be significant and others not significant or nonexistent. Many studies find costs decrease with density for roadways, police, and fire protection, while others show similar results for parks and recreation, libraries, or education. Fewer studies have shown reductions in costs for water, sewer, or sold waste, though this may be expected. Some costs have also been shown to increase with density, such as housing and community development or police.

Besides density, previous research has examined several other factors that can influence per capita municipal expenditures. Many studies have examined the effect of population size and whether economies of scale exist. Some research shows that smaller municipalities exhibit higher per capita costs than larger municipalities [27]. The evidence is mixed, however, and many studies find that either economies of scale do not exist or that economies of scale exist up to a point, and if population grows past that point, per capita spending rises, resulting in a U-shaped cost function [15,28–30]. For example, research of Spanish municipalities found that economies of scale can be realized until the population reaches a critical size of about 10,800 [28], and a study of French communes found similar results but with a critical size of just 400, though the paper noted that about half of French communes have a population below this level [29]. Research in Queensland, Australia, found economies of scale up to about 99,000, with larger cities experiencing diseconomies [30].

Holcombe and Williams found constant returns to scale for U.S. cities with a population greater than 50,000 [31], and Drew et al. [32] found no evidence of economies of scale for local governments in New South Wales, Australia, after controlling for population density. Other research in Spain showed no clear relationship between population size and per capita spending [17]. Callanan et al. [33] found a weak link between population size and expenditures in Irish local governments. Their research mostly found limited economies of scale, with a few exceptions where it was more prominent. Tran et al. [34] found that population size has a positive effect for some types of spending and a negative effect for others for South Australian local governments.

The effect of population growth has also been studied. Rapid growth could create a need for increased infrastructure investment. Some research has shown that greater population growth is related to increased per capita spending [15,17]. On the other hand, some studies have shown that growth reduces per capita cost as the added population helps share in the cost of services [6]. Other research has found mixed effects of population growth [34] or no effects [25].

The economic level of a community is also a likely contributor to per capita spending. Areas with higher income levels or greater per capita GDP are likely to demand a higher level of services and infrastructure and have a greater ability to support it. Research has shown that higher levels of income or per capita GDP generally relate to higher government expenditures [15,17,35]. Rios et al. [35] found that economic factors were more important than demographic or political factors in determining spending for Spanish municipalities.

Many of the previous studies have been conducted in Europe or Australia. Research in the United States on density by Holcombe and Williams [25] found contradictory results. Their research was limited to cities with a population of 50,000 or larger. Other U.S. studies have relied on county-level data or examined a smaller sample of cities, and many are based on older data. The current study contributes to the literature by researching a larger sample of U.S. cities and providing additional evidence regarding the unsettled question of how population density relates to per capita expenditures for U.S. cities.

3. Methods and Data

A model was developed to estimate the impacts of land use and other factors on per capita municipal spending. The model was used to estimate spending for eight categories of expenditures that could be influenced by land use development. These included fire protection, streets and highways, libraries, parks and recreation, police, sewer, solid waste management, and water.

Municipal expenditures can be influenced by both demand and cost factors. If there is a greater demand for services, expenditures may increase. Likewise, if costs to provide the service increase, expenditures would also likely increase. Land use can be considered a cost factor, because as densities decrease, it may become more costly for cities to provide services, as measured per capita. Other cost factors include labor costs and other input costs. Demand may be influenced by income levels. Areas with higher income levels may demand and have the capacity to support increased spending on services and infrastructure. As noted in the previous section, some studies have shown a positive relationship between income and per capita spending. The age of a neighborhood could also impact demand for some services, though fewer studies have considered this factor. Older neighborhoods may have greater needs for some services, such as fire protection and infrastructure maintenance and repair. Population growth could also impact per capita expenditures, either positively or negatively, as discussed in the previous section [6,15,17]. Total population may also have an impact on per capita expenditures, either positive or negative, if either economies or diseconomies of size exist.

Municipal expenditure data are available from the U.S. Census Bureau's Annual Survey of State and Local Government Finances. Expenditure data were obtained for five years, 2012–2016, for a cross-section of municipalities for the eight expenditure categories previously listed. For each spending category, the survey further categorized the expenditures as being for current operations, construction, and land and existing structures. Therefore, with eight categories and three different types of expenditures, there are 24 outcome variables.

Population-weighted density was used as a measure of land use. To calculate weighted density, the density of each Census block group in the city was first calculated. Then, a weighted average of the block group densities was calculated, with each block group weighted by its population. The population-weighted density provides a more accurate description of the density where people live, as compared to the conventional population density.

Population data were obtained from the 2016 American Community Survey (ACS) 5-year data. Population change was measured as the percentage difference from the 2010 Census to the 2016 ACS 5-year data. Data for per capita income and median house age were also obtained from the ACS. Because wage data were correlated with income, and appropriate wage data for each municipality could not be obtained, it was excluded from the model.

The final model included log forms of the dependent variable and for population, density, and per capita income. The equation is as follows:

$$\mathrm{lnME_{ij}} = \beta_0 + \beta_1\mathrm{lnPOP_i} + \beta_2\mathrm{POPCH_i} + \beta_3\mathrm{lnWDEN_i} + \beta_4\mathrm{lnPCI_i} + \beta_5\mathrm{HAGE_i} + \varepsilon_i \quad (1)$$

where:

$\mathrm{lnME_{ij}}$ = log of per capita municipal expenditures in city i for spending category j;
$\mathrm{lnPOP_i}$ = log of population for city i;
$\mathrm{POPCH_i}$ = percentage change in population for city i from 2010 to the 2016 5-year estimate;
$\mathrm{WDEN_i}$ = log of weighted population density for city i;
$\mathrm{lnPCI_i}$ = log of per capita income for city i;
$\mathrm{HAGE_i}$ = median house age in city i.

The dependent variable is the annual average per capita expenditures by a city on a given spending category over the 2012–2016 period. Population will be negatively related to per capita spending if economies of size exist and positively related if diseconomies exist. Population growth could have either positive or negative effects on per capita spending levels, depending on if the increased needs for investment and services is outweighed by the added population that helps share the costs. It is hypothesized that density is negatively related to per capita expenditures, meaning that spending is expected to decrease as density increases. Income is hypothesized to be positively related to spending, as income may be an indicator of demand, or ability to pay for services and infrastructure. Median house age is hypothesized to be positively related to spending, holding other variables constant, because older neighborhoods may have a greater need for some services.

Cities with a population below 25,000 were excluded from the analysis, which resulted in a total of 1102 cities in the dataset. However, not every city provided data for every category. Most cities provided data for operations spending for most categories, with the exception of library expenditures, which had 535 responses. Fewer cities provided data for construction or for land and existing facilities, and some categories had especially fewer responses, such as libraries and solid waste. Table 1 provides descriptive statistics for per capita spending for each category. Average per capita expenditures for operations ranged from USD 37 for libraries to USD 253 for police. Capital expenditures were greatest for streets and highways, sewer, and water.

Table 1. Per capita municipal spending data, cities with population greater than 25,000.

Spending Category	N	Mean	Median	Standard Deviation	Minimum	Maximum
				dollars per capita		
Operations						
Fire	942	164.55	157.13	76.51	1.99	567.97
Streets/highways	994	93.32	81.06	55.15	2.64	457.33
Libraries	535	37.01	30.52	28.17	0.09	206.58
Parks and recreation	954	88.92	74.11	78.19	0.60	1331.94
Police	998	253.06	232.74	108.28	2.13	1077.97
Sewer	902	111.19	98.22	72.36	0.64	619.49
Solid waste	814	69.70	61.74	48.39	0.07	594.77
Water	826	139.48	121.39	84.71	0.12	746.93
Construction						
Fire	114	7.68	5.36	7.35	0.04	38.92
Streets/highways	593	87.55	67.95	77.12	0.04	578.89
Libraries	58	9.34	3.61	14.09	0.13	81.43
Parks and recreation	382	33.02	18.05	79.70	0.15	1406.53
Police	120	13.29	6.66	18.85	0.01	111.86
Sewer	418	71.92	44.14	82.96	0.02	673.67
Solid waste	68	16.43	7.14	37.77	0.09	294.83
Water	416	79.66	52.34	112.26	0.51	1356.78
Land and Existing Facilities						
Fire	357	7.40	5.36	7.88	0.01	53.29
Streets/highways	362	14.58	7.03	24.83	0.01	219.23
Libraries	84	3.26	1.68	4.15	0.06	24.18
Parks and recreation	373	8.84	4.41	12.44	0.06	98.39
Police	471	7.72	5.96	6.90	0.04	53.14
Sewer	222	25.95	9.17	61.91	0.13	694.14
Solid waste	138	7.84	5.58	8.23	0.03	52.17
Water	218	19.68	9.77	28.72	0.11	217.38

The average city in the dataset had a population of 116,256, 5.3% population growth from 2010 to the 2016 ACS 5-year estimate, a population-weighted density of 5309 people per square mile, per capita income of USD 28,985, and median house age of 43 years (Table 2). Median values were 53,280 for population and 3644 for population-weighted density.

Table 2. Descriptive statistics for independent variables, cities with population greater than 25,000.

	N	Mean	Median	Standard Deviation	Minimum	Maximum
Population	1102	116,256	53,280	336,038	25,031	8,550,405
Population change	1094	5.3%	3.9%	7.3%	−9.5%	83.3%
Population-weighted density	1097	5309	3644	5830	602	74,473
Per capita income	1097	28,985	26,553	9768	12,747	82,350
Median house age	1097	43	41	16	10	77

4. Results

Results show that density has a significant effect for many spending categories. The estimated coefficient for density is negative and statistically significant for six of the eight operational cost categories (Table 3). Density is shown to be negatively associated with per capita operational costs for fire protection, streets and highways, parks and recreation, sewer, solid waste management, and water. Density, on the other hand, was found to be positively related to police operational costs. A possible explanation for this positive effect is that denser areas may have higher crime rates due to increased interaction between people. The effect of density was not statistically significant for library operational costs.

Table 3. Results for models of per capita municipal expenditures, operational costs.

Independent Variable	Fire	Streets/ Highways	Libraries	Parks and Recreation	Police	Sewer	Solid Waste	Water
Intercept	−4.424 *** (−6.25)	−5.668 *** (−8.48)	−16.007 *** (−10.37)	−9.087 *** (−8.92)	−4.685 *** (−9.56)	1.800 * (1.78)	−2.405 * (−1.94)	−1.867 ** (−2.20)
Population	0.163 *** (6.41)	−0.014 (−0.58)	0.052 (1.03)	0.200 *** (5.54)	0.088 *** (5.02)	0.105 *** (2.88)	0.108 ** (2.53)	0.055 * (1.84)
Population change	−0.340 (−1.06)	−0.742 ** (−2.39)	−1.926 *** (−2.68)	0.084 (0.18)	−0.794 *** (−3.51)	0.329 (0.73)	0.379 (0.69)	0.314 (0.84)
Density	−0.132 *** (−3.57)	−0.266 *** (−7.61)	−0.059 (−0.78)	−0.209 *** (−3.97)	0.090 *** (354)	−0.314 *** (−5.71)	−0.203 *** (−3.25)	−0.141 *** (−3.04)
Per capita income	0.105 (1.61)	0.488 *** (7.89)	1.160 *** (8.25)	0.593 *** (6.27)	0.124 *** (2.75)	−0.311 *** (−3.30)	−0.067 (−0.58)	0.001 (0.01)
Median house age	0.016 *** (9.15)	0.013 *** (7.63)	0.011 *** (3.01)	−0.005 * (−1.94)	0.006 *** (5.12)	0.008 *** (3.21)	0.014 *** (4.60)	0.006 *** (2.98)
N	936	988	531	948	992	897	808	821
R^2	0.1549	0.1475	0.1481	0.1187	0.1908	0.0554	0.0349	0.0148

* $p < 10\%$, ** $p < 5\%$, *** $p < 1\%$; t-values are in parentheses.

In the construction costs models, density is negative and statistically significant for streets/highways, parks and recreation, sewer, and water, indicating that per capita construction costs are lower in these categories as densities increase, while the relationship is insignificant for the other cost categories (Table 4). In the land and existing facilities costs models, density is negative and statistically significant for police, sewer, and water, indicating that per capita land and existing facility costs are lower in these categories as densities increase (Table 5). For police costs, while the results show a positive correlation between density and operational costs, there was a negative relationship between density and land/existing facility costs.

Table 4. Results for models of per capita municipal expenditures, construction costs.

Independent Variable	Fire	Streets/ Highways	Libraries	Parks and Recreation	Police	Sewer	Solid Waste	Water
Intercept	−11.65 *** (−2.75)	−11.39 *** (−7.46)	−3.401 (−0.42)	−15.20 *** (−6.44)	−8.581 * (−1.75)	−4.637 ** (−2.13)	−10.962 (−1.26)	−4.172 ** (−2.25)
Population	−0.016 (−0.13)	0.047 (0.93)	−0.263 (−1.46)	0.231 *** (3.20)	−0.066 (−0.47)	0.358 *** (5.08)	−0.069 (−0.39)	0.195 *** (3.29)
Population change	−0.071 (−0.05)	1.145 (1.62)	10.678 * (1.76)	0.453 (0.45)	0.778 (0.41)	1.435 (1.55)	−1.747 (−0.34)	4.033 *** (3.45)
Density	−0.133 (−0.61)	−0.316 *** (−3.94)	0.283 (0.59)	−0.259 ** (−2.02)	−0.164 (−0.59)	−0.544 *** (−4.89)	−0.395 (−1.01)	−0.391 *** (−3.83)
Per capita income	0.679 (1.64)	0.993 *** (7.03)	−0.175 (−0.21)	1.024 *** (4.56)	0.495 (1.00)	0.100 (0.48)	0.911 (1.02)	0.121 (0.69)
Median house age	0.015 (1.29)	0.010 *** (2.63)	−0.006 (−0.24)	0.002 (0.25)	0.012 (0.98)	0.019 *** (3.53)	0.022 (0.99)	0.018 *** (3.60)
N	111	589	56	379	117	414	66	411
R^2	0.0352	0.0998	0.1525	0.0911	0.0235	0.0794	0.0737	0.0629

* $p < 10\%$, ** $p < 5\%$, *** $p < 1\%$; t-values are in parentheses.

Table 5. Results for models of per capita municipal expenditures, land and existing facilities costs.

Independent Variable	Fire	Streets/ Highways	Libraries	Parks and Recreation	Police	Sewer	Solid Waste	Water
Intercept	−3.699 (−1.47)	−5.651 * (−1.81)	−12.549 ** (−2.18)	−5.103 * (−1.87)	−4.850 ** (−2.58)	−3.917 (−0.90)	5.303 (0.97)	−5.248 (−1.38)
Population	−0.124 (−1.48)	−0.373 *** (−3.64)	−0.303 * (−1.97)	−0.129 (−1.40)	−0.104 * (−1.66)	−0.140 (−1.06)	0.005 (0.04)	0.023 (0.21)
Population change	−2.744 * (−1.89)	−2.378 (−1.35)	−6.668 ** (−2.27)	−2.306 (−1.57)	−2.328 ** (−2.32)	0.829 (0.55)	0.261 (0.09)	1.643 (1.03)
Density	−0.119 (−0.87)	−0.202 (−1.21)	−0.148 (−0.47)	−0.013 (−0.09)	−0.243 ** (−2.38)	−0.217 (−0.96)	−0.557 ** (−2.54)	−0.542 *** (−2.77)
Per capita income	0.171 (0.73)	0.663 ** (2.30)	1.117 ** (2.04)	0.219 (0.84)	0.314 * (1.78)	0.153 (0.36)	−0.659 (−1.19)	0.403 (1.08)
Median house age	−0.024 *** (−3.60)	−0.008 (−1.05)	−0.006 (−0.41)	−0.024 *** (−3.41)	−0.009 * (−1.77)	0.022 ** (2.34)	0.011 (0.91)	0.013 (1.48)
N	353	359	83	368	466	221	135	215
R^2	0.1103	0.1064	0.2159	0.0658	0.0863	0.0467	0.1098	0.0532

* $p < 10\%$, ** $p < 5\%$, *** $p < 1\%$; t-values are in parentheses.

Overall, the models clearly show a general negative relationship between density and per capita municipal expenditures for several cost categories. Since the dependent variable and density are both in log form, the estimated parameters can be interpreted as elasticities. Statistically significant elasticities of per capita costs with respect to population-weighted density are shown in Table 6, based on the overall results shown in Tables 3–5. Elasticities for operations costs ranged from −0.13 for fire protection to −0.31 for sewer and was 0.09 for police. These results indicate that a 10% increase in density would reduce operational costs for fire protection by 1.3%, streets and highways by 2.7%, sewer by 3.1%, etc. Greater elasticities were found for capital costs, where significant, such as −0.32 for streets/highways construction, −0.39 for water construction, −0.54 for sewer construction, and −0.56 for solid waste land/existing facilities.

Table 6. Estimated elasticities of per capita expenditures with respect to population-weighted density.

Cost Category	Operations	Construction	Land and Existing Facilities
Fire	−0.132	ns	ns
Streets/highways	−0.266	−0.316	ns
Libraries	ns	ns	ns
Parks and recreation	−0.209	−0.259	ns
Police	0.090	ns	−0.243
Sewer	−0.314	−0.544	ns
Solid Waste	−0.203	ns	−0.557
Water	−0.141	−0.391	−0.542

ns = Not statistically significant.

Results also show significant relationships for other variables. Population was found to have a positive and statistically significant relationship for many of the operational costs and some construction costs, suggesting per capita costs increase with increases in population, but negative relationships were found for some land and existing facility costs. Population change was found to have a negative effect for some operational costs and land and existing facilities costs, consistent with findings from previous studies, suggesting per capita costs are lower for cities experiencing greater growth. On the other hand, population change was positively associated with per capita construction costs for water and libraries. Per capita income was found to be positively associated with per capita costs in many cases, as expected, though it was negative for sewer construction.

Median house age was positive and statistically significant in all operational cost models except for parks and recreation. This suggests older neighborhoods require increased operational expenditures, except that parks and recreation expenditures were higher in cities with newer housing. Construction costs for streets/highways, sewer, and water were also higher in cities with older housing, everything else equal. There is some correlation between the age of a neighborhood and density, as older neighborhoods tend to be denser. The density contributes to lower costs, while the age of the buildings and infrastructure may contribute to higher costs.

5. Discussion

This study attempts to understand the relationship between population density and per capita expenditures for U.S. cities. Results show that weighted population density is significantly associated with many municipal spending categories. This confirms the study's hypothesis. Density is shown to be negatively associated with per capita operational costs for fire protection, streets and highways, parks and recreation, sewer, solid waste management, and water, while being positively related to police operational costs. Density is also negatively associated with per capita construction costs for streets/highways, parks and recreation, sewer, and water and with per capita land and existing facilities costs for police, sewer, and water. The negative relationship can be explained by a need for less infrastructure in a denser city to serve a given population, and economies can be achieved in providing services by reducing the distance traveled.

The findings are consistent with those of previous studies showing a negative association between density and public service expenditures for local governments [5–9,12,15–21]. This study contributes to the literature by conducting a large-scale analysis of cities across the United States. While many previous studies found costs decreased with density for roadways and fire protection, this study also found the same for sewer, water, solid waste, and parks and recreation.

The results from this study may differ from those found by Holcombe and Williams [25], but there are some similarities. They found infrastructure expenditures to decline with density for cities with a population less than 500,000, which is consistent with our results, but no such relationship for larger cities. It should be noted that most of the cities in our study had a population below 500,000, with the median population being 53,280. This study had a greater focus on smaller cities. Unlike Holcombe and Williams [25], our study found negative relationships regarding per capita costs for some services, but similar to Holcombe and Williams, a positive association between police costs and density was found.

The positive association between density and police operational costs is also consistent with research by Glaeser and Sacerdote [24] that found higher crime rates in large cities due to several reasons, including higher pecuniary benefits for crime in large cities and lower probabilities of arrest and recognition. They argued that returns to crime increase with density, and density provides greater proximity between potential victims and criminals. On the other hand, our results show that land and existing facilities costs for police decrease with density. This may be because denser cities need less land or facilities to serve a given population.

The study also provides additional evidence regarding other factors such as population, population change, income, and median house age. The study found economies of scale for some costs for land and existing facilities, but for most cost categories, the study found either no effect or diseconomies. These findings are consistent with the literature, which has generally shown either little or no evidence of economies of scale or evidence of diseconomies for cities above a threshold size [15,17,28–33]. Results are also consistent with previous studies showing the effect is different for different spending categories [33,34]. There are mixed results in the literature regarding the effect of population growth on per capita spending. The results from this study are also mixed, showing that population growth can reduce some costs per capita by spreading out the expenditures over a growing population, but it can also lead to an increased need for construction to meet the needs of the growing city, thereby raising costs. This study found that to be the case for water and library construction costs, but no effect was found for other construction costs. The effect of income was positive in many cases, which was expected and is consistent with previous findings [15,17,35].

Lastly, the study also showed a positive relationship between median house age and per capita spending for most operational costs studied. The effect of house or neighborhood age has not been as widely studied. The result differs from research in Spain by Bastida et al. [17] that found a negative relationship, but it is consistent with Carruthers and Ulfarsson [6] who found a positive relationship between spending and the percentage of houses built before 1940. This finding is expected because older neighborhoods may have greater needs for some services. Controlling for housing age is also important for understanding the impact of density, because older neighborhoods often have a greater population density.

One limitation of this study is that it focused on weighted population density as a measure of land use, though there are many other measures of land use that could also be considered, such as land use mix, accessibility, street network characteristics, street length per dwelling unit, etc. Because this study consisted of a large-scale, city-level analysis of cities across the country, data for other land use characteristics were lacking. Additional study could focus on these other factors, though density tends to be correlated with other land use characteristics. Areas with greater density tend to have more land use mix, better accessibility, better transit services, shorter blocks, and better options for walking or biking. Further analysis could also consider other explanatory variables such as crime rate, poverty rate, tax rates, age of the population, public sector union strength, share of voters who are Democratic or Republican, city industrial composition, and local labor market conditions. Large-scale data for many of these factors were not available for this analysis but could provide some additional insights.

The findings have important implications for the fiscal sustainability and resiliency of cities. By increasing population density, cities can use resources more efficiently and reduce the cost per person of constructing and maintaining infrastructure and providing services. Practices that cities can employ to achieve these outcomes include focusing on infill development, providing a diversity of housing types beyond single family homes, avoiding noncontiguous development, promoting more compact development with smaller lot sizes and multiple-use buildings, and building cities at a human scale, where distances between buildings and activities are shorter. Many cities are pursuing these strategies to promote sustainability, reduce automobile use, and create more vibrant, livable communities. This research provides further evidence that these strategies also lessen the burden on taxpayers and reduce some types of municipal spending.

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