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Growing Resources for Growing Cities

Density and the Cost of Municipal Public Services in Brazil, Chile, Colombia, and Mexico

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Abstract[*]

This paper finds that per capita municipal spending on public services is strongly and non-linearly correlated to urban population density. Optimal expenditure levels for municipal services are achieved when densities are close to 9,000 residents per square kilometer. In this study of approximately 8,600 municipalities in Brazil, Chile, Ecuador, and Mexico 85 percent are below this ideal density level. This analysis provides strong policy support for densification, particularly for medium-sized cities in developing countries, which are currently absorbing most of the world's urban population growth.

JEL Codes: R12, R58

Keywords: optimal density, Latin America, urban services, public expenditures

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1. Introduction

Dense cities are a rational choice for the increasingly urban world, where concerns about environmental sustainability and urban sprawl are paramount (UN-Habitat, 2012). Among their many advantages, dense cities help preserve fertile rural lands (Jenks and Burgess, 2000), decrease overall commuting lengths (Gaigne, Riou, and Thisse, 2012), and contribute to reductions in greenhouse gas emissions (Stone et al., 2007). Along with its environmental benefits, density correlates positively with human capital accumulation (Glaeser, 1999), a higher rate of inventions (Carlino, Chatterjee, and Hunt, 2007), labor productivity (Ciccone and Hall, 1996), and social inclusiveness (Burton, 2000). On these grounds, and as development policies finally integrate environmental and social goals, urban policies are pushing for densification in both developed and developing countries. Multilateral organizations such as the IDB (2013), the OECD (2012), the United Nations (UN-Habitat, 2012), and the World Bank (2014a) are calling for denser cities. National development plans, including those of China (2011), Colombia (2011), Mexico (2013), and South Africa (2012), advocate urban densification. Even development plans of arguably already dense cities such as London (2013), Monterrey (2011), and New York (2011) pursue explicit policies for higher densities.

However, sustaining dense populations has its costs. Urban density increases land prices (Glaeser, Kolko, and Saiz, 2001), the wage premium (Wheaton and Lewis, 2001), congestion (Wheaton, 1998), and crime (Glaeser and Sacerdote, 1999). Its impact on public spending is inconclusive in the literature. Some studies show densification leads to savings in fire protection, waste collection, and education services (Bollinger et al., 2001). Yet, analogous research correlated density to diseconomies of scale for those same services (Abrate et al., 2012). In other studies, high densities have no impact on expenditures on fire protection and solid waste while reducing expenses on capital facilities, roadways, police, and education (Carruthers and Ulfarsson, 2003; 2008). Finally, others propose a U-shaped relationship between density and spending, implying that after an optimal density, expenditures and density would rise (Holcombe and Williams, 2008; Ladd, 1992).

Further, the literature disregards that density is endogenous to spending, assuming that public service spending is a function of density. Yet, it is also plausible that people move to places where public services are available. Latin American urban history provides specific examples for both scenarios: densification has led to investments in public service infrastructure; neighborhood upgrading programs in Brazil provide only one of many recent examples (Brakarz, Greene, and Rojas, 2002). Conversely, investments in public service infrastructure have led to densification, with the canonical example being planned cities such as Brasilia. Moreover, coverage of public services could be imperfect, which is often the case in developing countries. For example, about one-third of Latin American urban population suffers some deficit of urban services (Bouillon, 2012)—a condition that threatens smaller municipal governments now responsible for urban services (Campbell, 2012). If history provides guidance, the lack of municipal services would not deter population growth, but it would rather foster informal arrangements to provide these services.

Indeed, Latin America's urbanization is an ideal case for exploring the questions of endogeneity and imperfect coverage of urban services. Between 1960 and 2010, the Latin American and Caribbean (LAC) region's share of urban population rose from about 50 to 80 percent, making the region more urbanized than Europe and as urbanized as the United States (World Bank, 2014b). Although only a few cities currently account for the vast majority of urban population, that number is increasing. While in 1950 there were 12 cities with more than 500,000 residents, now there are almost 125. As expected, urbanization also increased the demand for urban services and the number of municipalities responsible for their provision (IDB, 2013). However, LAC municipalities' fiscal capacity tends to lag behind (Bonet et al., 2013); yet, urban immigration has not been detracted (Feler and Henderson, 2011). Today, the basic-service provision gap is considerable; more than 13 million urban residents lack access to improved water sources, while almost 64 million lack improved sanitation facilities in their dwellings (World Bank, 2014b). Closing the incremental water deficit demand that arises from urbanization, formalizing households' water connections, and eliminating deficits by 2030 will cost more than US$100 billion; another US$79 billion is needed just to close the current sanitation deficit (CAF, 2013).

In light of the gravity of these deficits, this study considers how current urban growth patterns would impact such deficits. Do dense municipalities have better coverage of basic services? How does density impact the per capita expenditure of these services? Our main contribution is to answer these questions by taking into account the issues of imperfect provision of public services and endogeneity, and relying on data sets form understudied developing countries. Therefore, we model public service spending as a function of its demand and cost, considering actual coverage levels. We also use climate as an instrumental variable to establish the causal effect of increases of density on municipal spending. We apply our model to a panel of approximately 8,600 municipalities in Brazil, Chile, Ecuador and Mexico, for years 2000 and 2010 (for a total of nearly 17,000 observations).We consider three basic services—water, sewage, and waste collection—the provision of which is organized and fully financed by municipal governments, unlike other services, such as education and health, whose costs are partly paid by the state and federal governments, the private sector, or directly by the homeowners.[1] [2]

[1] National constitutions mandate that municipalities ensure the provision of these services (see Article 30 of the Brazilian Constitution, Article 115 of the Mexican Constitution, Article 264 of the Ecuadorian Constitution, and Article 3 of the Chilean Constitutional Law for Municipalities).

[2] We attempted to include additional urban services, but data limitations did not allow for further disaggregation of urban services, given that some service categories overlap for some countries and are missing in others.

In the countries considered for this study, municipalities spend approximately one-seventh of their budget in these services (see Panel C in Table 2). The diversity of these countries provide a good background to test our model. Brazil and Mexico are large federal countries; Chile and Ecuador are small and quite centralized. The urbanization rates of these countries also differ, ranging from 68 and 78 percent in Ecuador and Mexico, to 85 and 89 percent in Brazil and Chile. Approximately 28 percent of Brazilian urban residents live in informal settlements lacking some basic service; this figure is 9 percent in Chile, 21 percent in Ecuador, and 14 percent in Mexico. The median GDP per capita in 2010 was US$10,978 in Brazil, US$12,685 in Chile, US$4,637 in Ecuador, and US$8,916 in Mexico (UNDP, 2005; UN-Habitat, 2014; World Bank, 2014b).[3] Significantly, the combined population of these four amounts for about 60 percent of LAC countries.

2. Population Density and the Cost of Public Services

As municipalities struggle to serve their current population, a critical issue is whether spatial factors pose a fiscal impact on public service delivery—this is precisely the matter we will address in this paper. Population density is a common indicator of the spatial distribution of residents (Forsyth, 2003). Its prominence in empirical studies suggests that—notwithstanding its shortcomings in depicting urbanization vis-à-vis more nuanced dimensions such as continuity, nuclearity, and centrality—it is still a useful metric of urban form (Angel, Sheppard, and Civco, 2005).

While nuanced spatial dimensions reveal how specific urban policies affect land use patterns and other particular local phenomena in developable and non-developable areas, density is a clearer concept to operationalize and compare, less prone to misinterpretations and more intuitive in general (Rapoport, 1977). Additionally, focusing on density rather than on population size makes sense from a development perspective as it relates to economic performance (Henderson, 2003). Moreover, in a context of a democratic society, policy tools for managing urban density are easier to implement than those restricting population growth.

One might think that because population density is so consequential for many aspects of urban processes it would mean that it is well understood, particularly when it comes to its effect on local public finance. This is not the case. The hypotheses that urban economists and planners have proposed for cost structure dynamics are remarkably inconsistent. The impact of population density on government spending patterns, albeit widely studied and documented, is the subject of empirical controversy. The literature on the effects of density is—ironically—notoriously sprawled, with clear discrepancies both in terms of magnitude and sign. Although the notion that there is an adequate density level that makes the

[3] We harmonize the data based on IMF (2014).

provision and delivery of public services economically efficient is consensual, different studies diverge in their recommendations for the most efficient use of economic resources.

Advocates for densification argue that population density decreases the per capita cost of service provision. Sprawl would require infrastructure to be expanded to sparsely populated locations, increasing per capita costs. Coyne (2003) reports that between 1980 and 2000, densification policies in Colorado led to a 27 percent increase in population density and a 7 percent reduction in per capita spending. This coincides with a report for the City of Calgary (IBI Group, 2009) claiming that a 25 percent densification would reduce public expenditure on the provision of roads, fire protection, and water by 36, 46, and 54 percent respectively. Burchell and Mukherji (2003) find that moving 11 percent of households from sprawling counties to denser ones decreases the costs of water and sewer infrastructure by 7 percent, local road costs by 12 percent, and housing costs by 8 percent. Carruthers and Ulfarsson (2003) show that a 1 percent rise in the population density of US counties is associated with a 2 to 4 percent decrease in the cost of police protection and education, and an overall 3 percent decrease in the combined cost of 12 urban services. Likewise, Hortas-Rico and Sole-Olle (2010) find that in Spain a twofold expansion of urbanized land—that is, sprawl, increases community facilities costs by 11 percent, local police costs by 9 percent, housing costs by 8 percent, culture and sports costs by 15 percent, and general administration costs by 11 percent.

Conversely, some researchers argue density does not necessarily lead to economies of scale. Pineda (2005) indicates that labor-intensive urban services (e.g., police, fire protection, healthcare) increase their per capita costs with population density. Ladd and Yinger (1989) demonstrate that a higher average density increases the public services costs owing to a "harsher environment." Cameron (1989) finds that higher density implies higher costs for police services. Holcombe and Williams (2008, 2010) show that in municipalities larger than 500,000 residents, higher population density is associated with higher per capita government expenditures, particularly for sewer, police and highway spending. Carruthers and Ulfarsson (2003) show that transportation cost increases with density when roads are excluded.

A third view is that densification has efficiency advantages in the provision of public services, but these dissipate as city size continues to increase. This suggests a U-shaped relationship between urban density and spending, and consequently that there is an optimal density level. Werner Hirsch (1959) performed one of the first empirical analyses in support of this theory based on fire protection data. Ladd's (1992) seminal piece demonstrates that the operating expenditure function of US counties is approximated by a parabola whose trough is at a population density of 250 residents per square mile. She finds that the average current spending per head in very low- and very high-density counties (i.e., up to 125, and more than 24,000 residents per square mile) is 14 and 43 percent higher than in counties within the optimal density range. She gets a similar finding for safety spending, with the lowest costs at a density of 250 residents per square mile. Alvarez, Prieto, and Zofio (2013) show that optimum density levels vary for each service provided, ranging from 2,800 residents per square kilometer for paving and lighting, to 3,100 residents per square kilometer for water provision, to 4,400 residents per square kilometer for sewerage.

In sum, the relationship between density and per capita public spending is significant despite its dynamics remaining ambiguous (Boyko and Cooper, 2011; Ewing, 1994). At best, this empirical inconsistency could be due to different data definitions and units of analysis considered. A far more serious concern is that the regression equation may be one of several structural equations of a simultaneous model; in that case, such a model would contain current endogenous explanatory variables that result in a lack of identification. Especially in the light of recent empirical evidence, such ambiguity has led to questions about whether any actual relationship between urban form and the cost of services exists at all (Carruthers and Ulfarsson, 2003). What is all too clear from surveying this body of research is that two critical challenges remain. The first one is empirical. Data availability constraints have restricted most empirical work on the density-to-spending relationship to developed countries, particularly United States counties. In addition, it would also appear that high-quality data at a large scale are required—regardless of the region of study—given the propensity in the literature to approach density as a categorical condition (Ladd, 1992) or resort to aggregate data that are likely to conceal relevant functional patterns (Buttner Schwager, and Stegarescu, 2004). The evident lack of empirical research on the urbanization patterns in developing countries has often led to ill-fitted policy recommendations (Angel et al., 2005). Models should include specific variables ad hoc for developing countries—variables such as percentage of poor households and percentage of households without access to basic services—which reflect a distinct urbanization dynamic (Libertun de Duren, 2011). In effect, how density impacts the per capita cost of public services is yet to be determined where service coverage is incomplete.

The second challenge is methodological. We believe that more nuanced approaches to the relationship between urban population density and fiscal outcomes are in order. As argued above, with the exception of Ladd (1992) and Álvarez Prieto, and Zofio (2013), we find that the study of nonlinear relationships is absent in the literature, with most studies assuming an overall linear linkage between density and service expenditures. Empirical research on alternative dynamics would constitute a much needed advancement in the field, particularly given the subjacent theoretical body on the cost structure of, and demand for, services provided at the local level. Furthermore, while the literature has devoted much attention to the analysis of the fiscal impacts of density (urban and otherwise), it has given rather little consideration to the endogenous determination of costs and the densification process. This is a handicap because density and fiscal outcomes are simultaneously determined. Unfortunately, too little research provides unbiased evidence on the population density dynamics. We address both issues below.

3. Methodology

We only account for households receiving coverage of urban services at the highest available quality. The assumption is that informal and rural households are more likely to access these services through other delivery modes. Informal urban households often rely on water trucks, open sewerages and public waste containers, while rural ones depend on dug wells, individual septic cameras, and waste containers (World Bank, 2014b). In addition, focusing on high-quality coverage improves the comparability of estimates when assessing public spending. Finally, from a normative standpoint, high-quality services are the expectation for urban areas.

We specify municipal public service spending as a function of the costs for water, sanitation, and waste collection service provision and an individual household's demand.[4] We assume the cost of producing these services (C) depends on an input cost index (w) and on municipal primacy (m), since primate cities act as focal points for the delivery of public services (equation 1). Coverage (c) is a function of the public resources to provide such coverage (e), divided by population density (d) and other cost factors (z), assuming constant returns to scale (equation 2):

$$C = c \cdot f(d) \cdot g(z) \ \cdot wm \qquad (1)$$

$$c = \frac{e}{f(d) \cdot g(z)} \qquad (2)$$

We combine the cost function with a demand model maximizing the utility of municipal residents. Thus, the demand for coverage increases with the preferences of a resident (v), and it decreases with her share of the marginal cost of providing such coverage (c). A resident's budgetary constraint (yr) depends on consumption (xrÞ), the municipal tax rate (t), and her individual tax rate (br) (equation 3). A municipal government budgetary constraint (C) depends on its total tax base (B) and the intergovernmental transfer it receives (G) (equation 4). Equation 5 expresses a municipal government maximizing the utility of its representative resident, constrained by the residents' budgetary constraints(yr), the municipal government's budgetary constraint (C), and the cost function of public service coverage (equation 2):

$$y_r = x_r + tb_r \qquad (3)$$

$$C = tB + G \qquad (4)$$

$$x_r + c \cdot f(d) \cdot g(z) \cdot wm \ \cdot \frac{b_r}{b} = y_r + t \ \cdot \frac{b_r}{b} \qquad (5)$$

[4] We follow Hortas-Rico and Sole-Olle's (2010) specification, which relies on Borcheding and Deacon (1972) and Bergstrom and Goodman (1973).

Maximizing the utility function (equation 3) gives us the first-order condition (equation 6) where the tax price (pr) is the product of the marginal cost of public service coverage and the tax share. Assuming that the demand function is log-linear (equation 7), and substituting equation (6) in equation (7), and the resulting formulation in equation (2), we get the log per capita spending function (equation 8):

$$\frac{\partial U_r/\partial c}{\partial U_r/\partial x_r} = f(d) \cdot g(z) \cdot wm \cdot \frac{b_r}{b} \equiv p_r \qquad (6)$$

$$c = k \cdot p_r^{\alpha} \cdot \left(y_r + g \cdot \frac{b_r}{b}\right)^{\beta} \cdot v_r^{\gamma} \qquad (7)$$

$$\ln \varphi = \ln k + (\alpha+1) \cdot \ln\big(f(d)\big) + (\alpha+1) \cdot \ln g(z) + (\alpha+1) \cdot \ln w + (\alpha+1) \cdot \ln m + \alpha \ln\left(\frac{b_r}{b}\right) + \beta \ln y_r + \beta \cdot \left(\frac{g}{y_r}\right)\left(\frac{b_r}{b}\right) + \gamma \cdot \ln v_r \qquad (8)$$

The last equation (8) underscores that in a given municipality, per capita spending in public services depends both on the cost of providing such coverage and on its social, economic, and urban characteristics. Besides density of population with coverage (f (d)), these characteristics include the potential number of service users, average household size, percentage of urban households, percentage of unemployment, municipal average wage (w), and whether a municipality belongs to a metropolitan area or it is primate.

Equation (8) also reflects that demand for public services determines municipal spending. Therefore, it includes income (yr), average resident's tax share (br/b), and local tax bill. The local tax bill is operationalized as per capita property tax divided by per capita tax revenue. The tax price equals the product of the marginal cost of coverage and the tax share. We include per capita intergovernmental transfers relative to income (g/yr) to account for the positive effect of transfers on municipal revenue. Finally, the municipal poverty rate is an indication of resident preferences, as income level determines decisions on household expenditures (Gilens, 2009).

Prices and geography, among other variables, may impact local spending. Therefore, higher spending may not imply better public services inasmuch as input prices or municipal characteristics differ. To prevent confounding the influence of these factors with that of density, we include municipal fixed effects. These effects control for the average differences across municipalities in any characteristic influencing municipal spending. Likewise, we include unrestricted time fixed effects to control for time-varying differences in public spending across municipalities. As is customary, we also include an error term with typical properties.

Last, we use an exogenous source of variation in population density to sort out the simultaneous determination of density and public spending. In practice, municipalities with a better provision of municipal public services may attract new residents and therefore become denser; however, it may as well be the case that the governments of denser municipalities may spend more on public services to catch up with their growing population. Following Rosenthal and Strange (2003), Combes et al. (2010), and Glaeser and Gottlieb (2009) we employ climatic variables to instrument for current population density levels. Specifically, we use lagged mean temperatures, precipitation, and soil moisture levels as instruments. Our identification strategy relies on the orthogonality of climatic variables to changes in public service expenditures at the municipal level, except insofar as the expenditure changes are due to population density. Although in rural areas climate has a direct effect on income (Guerrero Compeán, 2013), our identification strategy is plausibly appropriate for urban Latin America since climate is a determinant of settlement patterns but not strongly linked to income growth (Miguel, Satyanath, and Sergenti, 2004).

4. Data Concepts, Collection, and Limitations

We work with data on demographics and public services as well as economic and urban data from the national censuses, data on municipal budgets from municipal account databases, and climatic indicators from the University of East Anglia (UEA) and the National Oceanic and Atmospheric Administration (NOAA). Although we recognize that national statistics are different by nature, we combine information sources, resolve semantic conflicts, and harmonize concepts as much as is feasible to produce consistent variables.

4.1 Demographic Characteristics

We collect data for each municipality from two census waves (2000 and 2010): total residents, poor residents, urban residents, and average household size. For Mexico, we adjust estimates based on the most recent immigration data by the United States Census Bureau.

4.2 Access to Municipal Public Services

We construct a high-quality service coverage index based on population census and surveys at the municipal level. A coefficient of zero indicates that no household has access to water distribution, sanitation, or waste collection services. Conversely, an index of one (100 on the percentile scale) indicates a municipality with universal coverage of those services. Each of the three services carries equal weight and in all cases we only consider high-quality coverage levels. Recall that high-quality water coverage is defined as the percentage of households in each municipality with a water service pipe connected with in-house plumbing to one or more taps, high-quality sanitation coverage is the percentage of households with a piped sewer system, and high-quality waste collection coverage is the percentage of households provided with curbside collection. We build this index for each municipality for each available census year.

4.3 Fiscal and Economic Characteristics

We utilize municipal revenue and spending data on public services for years 2000 and 2010. We employ data on annual tax revenue, property taxes, intergovernmental transfers and employee compensation. In particular, municipal spending comprises employee compensations, administrative costs, urban services, public investments, and other public services partially financed by the state and federal governments (i.e., education, health, and others), financial investments, and public debt. Additionally, we obtain data on the municipal average wage and income (approximated by the per capita gross domestic product). Wages are defined as the remuneration before deductions per employee. Following Borcheding and Deacon (1972), we assume that production functions over municipalities are identical and exhibit constant returns to scale (in the form of Cobb–Douglas) so that capital is assumed to be perfectly mobile while labor is not. Therefore, the wage rate per unit of labor differs across jurisdictions and as such captures input costs, which affect the cost of producing public services.

Income is approximated by calculating the sum of gross value added in the economy (i.e., gross domestic product) and dividing it by the total population. In its logarithmic form, this variable permits the estimation of the income elasticity of demand, which illustrates the responsiveness of the demand for urban public services to a change in the average income ceteris paribus (Hortas-Rico and Sole-Olle, 2010). For Brazil, Chile, and Ecuador, we deflated monetary values by using national implicit price indices. For Mexico, we constructed a 32-state price index based on INEGI’s 46-city national consumer price sample. Final data are expressed in 2010 U.S. dollars (INEGI, 2011).[5]

4.4 Urban Indicators

The municipality is the smallest available geographical unit we can document. While our data do not categorize cities per se, we use Landsat images and GIS data to identify urban areas within a municipality and obtain urban spatial indicators. Furthermore, we create two separate dummy variables indicating whether a municipality is a primate city, and whether it belongs to a metropolitan area. These concepts are defined differently across countries and we follow each country’s definition (CONAPO, 2010; IBGE, 2008; INE, 2005; SENPLADES, 2009).

[5] We harmonize the data based on IMF (2014).

Table 1. Data Variables and Sources Employed, by Country

<table>
<tr><th></th><th>Brazil</th><th>Chile</th><th>Ecuador</th><th>Mexico</th></tr>
<tr><td colspan="5">A. Demographics (2000–2010)</td></tr>
<tr><td>Number of poor urban; and total municipal residents</td><td rowspan="2">IBGE[1]</td><td rowspan="2">INE[1]</td><td rowspan="2">INEC[1]</td><td rowspan="2">INEGI[1]</td></tr>
<tr><td>Average household size</td></tr>
<tr><td colspan="5">B. Public services (2000–2010)</td></tr>
<tr><td>Number of households with access to piped water; to network sanitation and to curbside trash collection</td><td>IBGE</td><td>INE</td><td>INEC</td><td>INEGI</td></tr>
<tr><td colspan="5">C. Fiscal and economic indicators (2000–2010)</td></tr>
<tr><td>Tax revenue and property tax revenue</td><td rowspan="3">Tesouro Nacional. Finanças do Brasil. Dados Contábeis dos Municípios.</td><td rowspan="3">SUBDERE. Sistema Nacional de Información Municipal.</td><td rowspan="3">SENPLADES. Ingresos y gastos del sector público a nivel cantonal.</td><td rowspan="3">INEGI. Estadística de finanzas públicas estatales y municipales.</td></tr>
<tr><td>Intergovernmental transfers</td></tr>
<tr><td>Total spending, and spending in public services</td></tr>
<tr><td>Compensation to municipal employees</td><td rowspan="6">IBGE</td><td>MIDEPLAN. Encuesta de Caracterización Socioeconómica Nacional 2003, 2009</td><td rowspan="2">INEC</td><td rowspan="2">INEGI. Censos Económicos 1999, 2009[a]</td></tr>
<tr><td>Average wage</td><td rowspan="6">MINSAL. Base de datos del país a nivel comuna 2009, 2011 Observatorio Social, Ministerio de Desarrollo Social. Pobreza por comunas 2003, 2009</td></tr>
<tr><td rowspan="2">Gross domestic product</td><td rowspan="2">Banco Central del Ecuador. Valor agregado bruto cantonal 2007 and Cuentas Provinciales 1999</td><td>CONEVAL. ICTPC anual 2010</td></tr>
<tr><td>UNDP México. Índice de desarrollo humano municipal 2000–2005</td></tr>
<tr><td>Employment in agriculture</td><td rowspan="3">INEC</td><td rowspan="2">INEGI</td></tr>
<tr><td>Unemployment rate</td></tr>
<tr><td>Poverty rate</td><td>UNDP Brazil. Atlas do Desenvolvimento Humano, 2013</td><td>CONEVAL. Estimaciones de pobreza alimentaria 2000, 2010</td></tr>
<tr><td>Implicit price deflator</td><td>IBGE</td><td>INE. Estadísticas de Precio</td><td>INEC. Índice de Precios al Consumidor</td><td>Banco de México. Índices de precios al consumidor</td></tr>
</table>

D. Urban indicators (2000–2010)				
Geographical coordinates	UNDP Brazil Caracterização do Município	Instituto Geográfico Militar. MAPAS IGM.	INEC. División Político Administrativa del Ecuador	INEGI. Marco geo-estadístico 2010 versión 5.0 AGEM
Territorial extension				
Urban territorial extension	Empresa Brasileira de Pesquisa Agropecuária. Mapeamento e estimativa da área urbanizada do Brasil	Corporación Nacional Forestal. Sistema de Información Territorial	INEC. Archivo Nacional de Datos y Metadatos Estadísticos. Censo de Información Ambiental Económica	INEGI. Información Vectorial de Localidades Urbanas
Primacy definition	IBGE. RIDES and Regiões de Influência das Cidades	INE. Ciudades, pueblos, aldeas y caseríos 2002	Gobierno de Ecuador. Constitución de Ecuador de 2008	CONAPO. Delimitación de las zonas metropolitanas de México 2000, 2010
Metropolitan area definition	IBGE. Organização Territorial e Composição das Regiões Metropolitanas		SENPLADES. Estrategia Territorial Nacional	
E. Climate indicators (1910–1930, 2010–2030)				
Monthly average daily temperature; rainfall; soil moisture	UEA Climatic Research Unit			
	NOAA’s National Center for Atmospheric Research			

Source: Authors’ elaboration.
[a] We prefer INEGI’s data to ENOE’s data because it collects this information at the municipal level.

4.5 Climate Indicators

We use monthly average daily temperature and precipitation data generated from the University of East Anglia Climatic Research Unit (CRU) (2014) time-series data sets spanning the period 1910–1930. These are calculated on high-resolution (0.5^0 by 0.5^0) grids. Similarly, we obtain monthly self-calibrated average Palmer Drought Severity12 Index values (Palmer, 1965) to proxy for soil moisture, obtained from NOAA’s National Center for Atmospheric Research. These are calculated on 2.5^0 latitude by 2.5^0 longitude global grid (NOAA, 2014). We construct our municipal data by applying a spherical interpolation routine: weighted averages of the 10-year climatology of temperature, rainfall, and soil moisture for every gridded point within 150 km of each municipality’s geographic center, with the inverse squared haversine distance between the grid point and the municipality centroid as the weighting factor.

Table 2. Descriptive Statistics

	Mean	Standard deviation	Observations
	A. Demographics (2000–2010)		
Population density	175.90	919.20	17,092
Urban population density	13,121.19	85,583.85	15,439
Covered urban population density	8,447.19	47,152.56	14,795
Potential service users (all municipal residents)	36,574	174,349	17,096
Urban population (and)	54	29	17,092
Average household size	3.89	0.65	17,082
Poverty rate	0.37	0.24	17,105
	B. Public service (2000–2010)		
Municipal coverage–three services (high quality)	0.51	0.24	17,087
Urban	0.69	0.21	15,268
Piped water	0.67	0.24	17,087
Urban	0.87	0.19	15,268
Network sanitation	0.31	0.31	17,087
Urban	0.44	0.38	15,268
Curbside trash collection	0.55	0.28	11,507
Urban	0.77	0.28	11,506
	C. Fiscal and economic indicators (2000–2010) in USD		
Municipal spending	18.51	169.22	16,731
Municipal spending in public services	2.61	17.70	16,710
Water	0.76	5.69	16,210
Sanitation	0.70	6.74	11,130
Trash collection	0.88	9.97	16,210
Tax revenue	3.08	69.56	16,738
Property tax revenue	1.15	23.95	15,287
Intergovernmental transfers	12.49	73.00	16,738
Average wage	4,710	3,211	16,785
Unemployment rate	0.07	0.06	16,814
Income	5,089	5,733	17,014
	D. Municipal characteristics: 2000–2010		
Territorial extension (km2)	1,484	14,303	17,168
Urbanized area (and)	3	12	17,020
Metropolitan municipality indicator	0.11	0.31	17,172
Primate municipality indicator	0.05	0.22	16,588
	E. Climate measures (1910–1930 and 2012)		
Lagged average annual temperature (°C)	21.0	4.3	17,042
Lagged soil moisture (Palmer Drought Index)	0.2	1.0	16,239
Lagged annual rainfall (mm)	1,197.0	490.1	17,042
Current average annual temperature (°C)	22.1	5.2	17,042
Current annual rainfall (mm)	1,102.5	870.9	17,042

Source: Authors' elaboration (data sources are already clarified).

5. Results

5.1 Density and Coverage

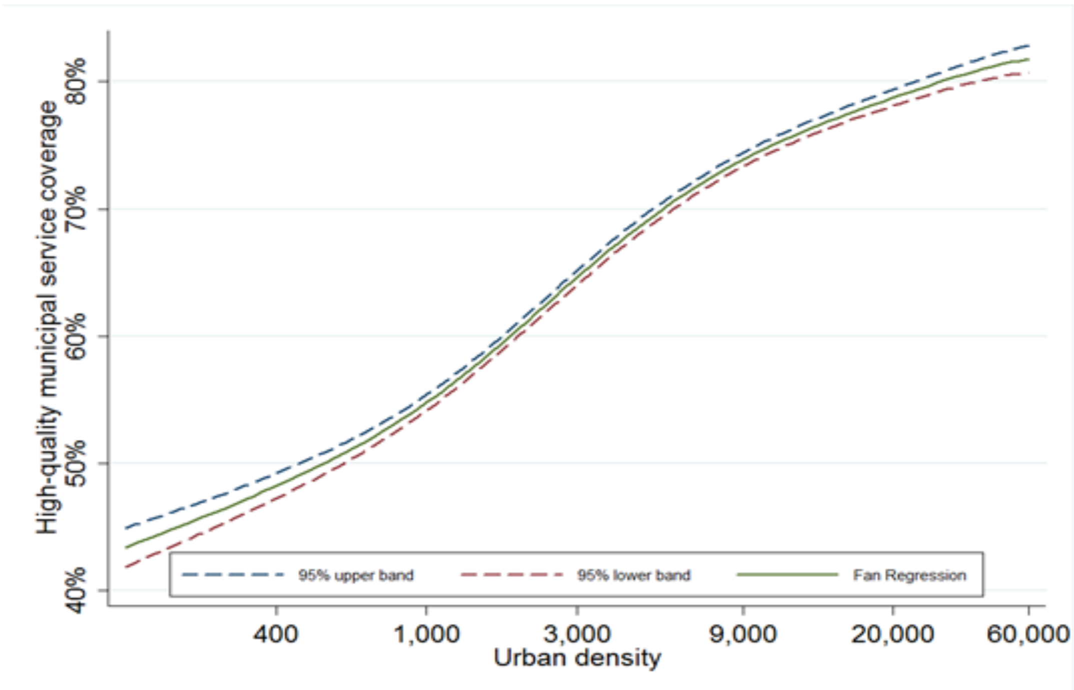
We begin our analysis with a simple question: In which municipalities do households have more access to high-quality water, sanitation, and waste collection services? We estimate a nonparametric locally weighted regression (Fan, 1992) with an Epanechnikov kernel to display municipal coverage levels as a function of urban density. We restrict the sample to 90 percent of the observations. Figure 1 indicates that a larger share of the urban population with access to high-quality services is observed in denser urban areas. More than two-thirds of the municipalities whose coverage level is below 10 percent are in the first quartile of the urban population density distribution. Conversely, over 43 percent of the municipalities enjoying coverage levels above 90 percent are in the top quartile. This relation is consistent and holds when disaggregating coverage by type of service (Figure 2), but sanitation coverage is much lower than that of the other two and water coverage is high even for sparsely populated urban areas. From these figures alone, it is impossible to determine to which extent urban density affects municipal spending patterns, particularly its magnitude at different parts of the distribution. Figure 3 illustrates a locally weighted regression that shows the relationship between urban density (percentiles) and municipal expenditures in public services per head. It would seem that the relationship is U-shaped, yet the statistical significance of a causal effect of urban density on local spending should be verified, given the endogeneity of density to spending patterns. We turn now to our empirical strategy to address this issue.

Table 3. Percentage of Residents with Access to Municipal Public Services, by Coverage Level and Urban Population Density Quartile

Households covered	Urban population density (pop/km^2)			
	Q1 0-2,333	Q2 2,334-3,960	Q3 3,961-6,378	Q4 over 6,378
	A. All municipal services			
Under 10%	68.4	21.9	6.9	2.8
Over 90%	3.7	15.0	38.0	43.4
	B. Piped water			
Under 10%	66.3	17.8	9.2	6.7
Over 90%	16.9	23.4	28.8	31.0
	C. Network sanitation			
Under 10%	59.7	24.5	10.8	5.0
Over 90%	4.8	15.0	36.7	43.5
	D. Curbside trash collection			
Under 10%	60.8	25.5	9.8	3.9
Over 90%	10.1	20.8	36.8	32.3

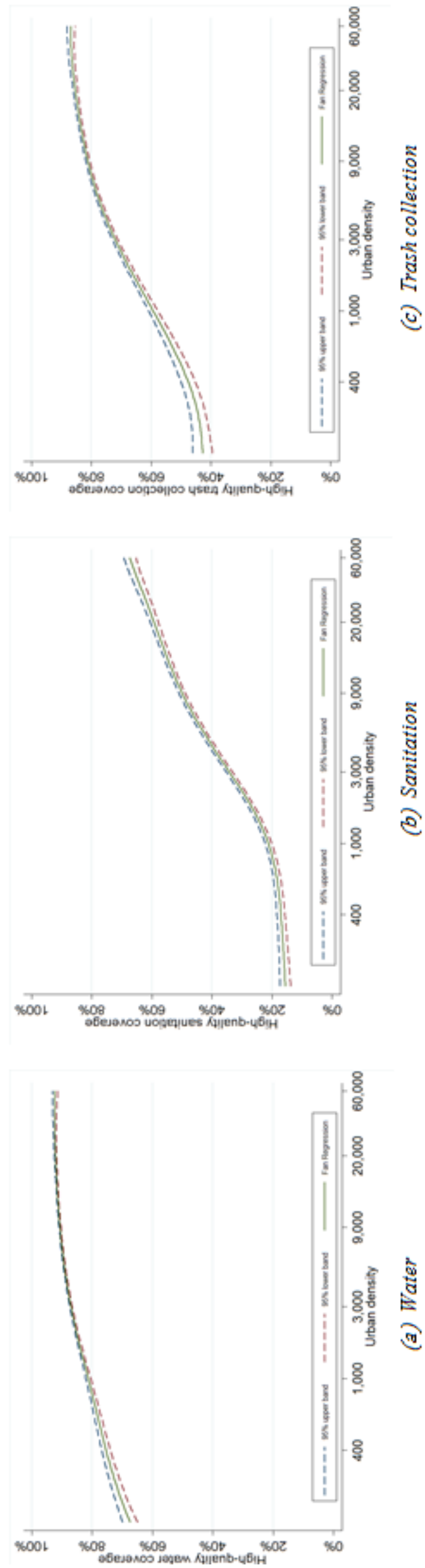
Source: Authors' elaboration

Figure 1. High Quality Municipal Service Coverage on Urban Density



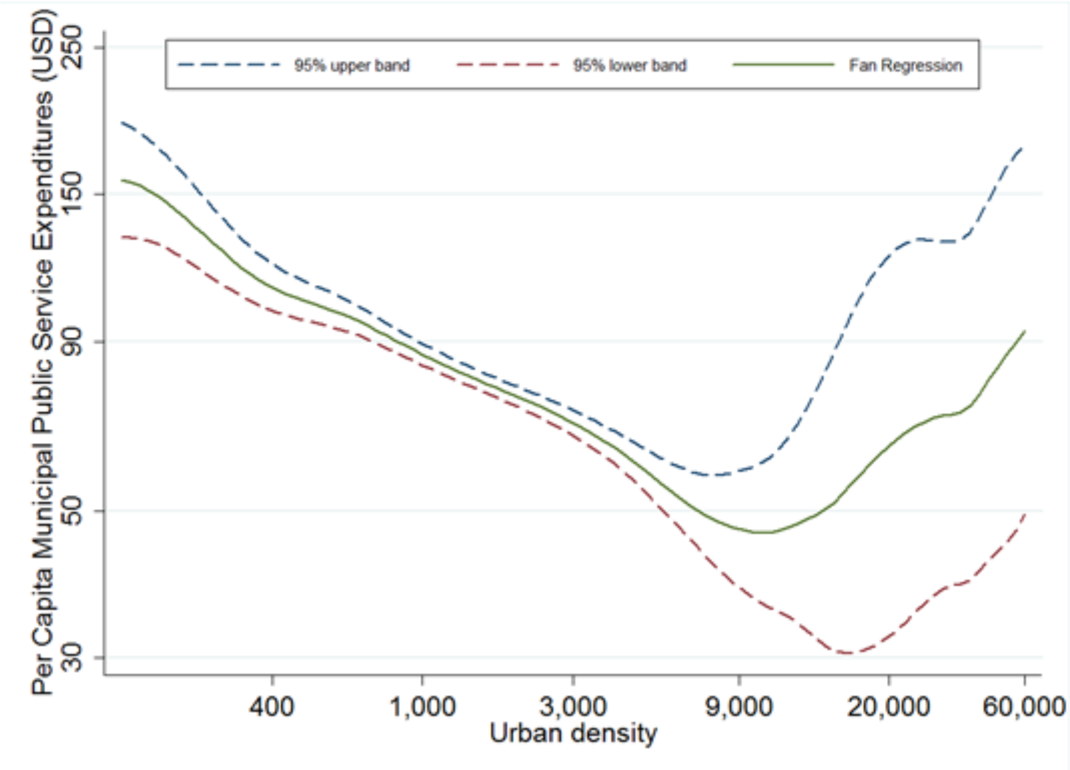
Source: Authors' elaboration
Notes: Non-parametric fan locally weighted regression, using an Epanechnikov kernel and a bandwidth of 1 with bootstrapped standard errors, conditional on regional fixed effects and country-specific time trends.

Figure 2. High Quality Municipal Service Coverage on Urban Density, by Type of Service



Source: Authors' elaboration
Notes: Non-parametric fan locally weighted regression, using an Epanechnikov kernel and a bandwidth of 1 with bootstrapped standard errors, conditional on regional fixed effects and country-specific time trends.

Figure 3. High Quality Municipal Public Service Coverage per Head on Urban Density, by Type of Service



Source: Authors' elaboration.
Notes: Non-parametric fan locally weighted regression, using an Epanechnikov kernel and a bandwidth of 1 with bootstrapped standard errors, conditional on regional fixed effects and country-specific time trends.

6. First-Stage Relationship and Reduced-Form Results

We now discuss the ability of our instruments to predict current population density. Remember that our instrument set includes lagged municipal temperature, rainfall, and soil moisture conditions. The first-stage relationship between our set of instruments and population density is always significant, with the strongest association being observed between soil moisture, temperature, and urban density (Table 4). The relationship is also robust and equally significant when we add controls for municipal characteristics and two-way fixed effects, as well as country-specific time trends (Regressions 5–7, Table 4).

Notice that the first-stage relationship remains strong and significant when rainfall substitutes soil moisture conditions as part of the instrument set. Although statistical tests show that climate instruments are moderately strong (F-statistics ranging from 9.0 to 18.9), we estimate as an identification check a false experiment specification in which future climatic conditions, which should be orthogonal to current urban density, are used as instruments. We find that coefficient estimates are indeed statistically equal to zero

(Regression 8, Table 4). Lower lagged temperatures are strongly associated with higher municipal spending in the reduced-form regressions. A 1 percent increase in lagged temperature is associated with a 10 percent decrease in per capita municipal spending in public services. Similarly, a 1 percent increase in lagged soil moisture is associated with a 0.1 percent increase in municipal spending in public services per head (Regressions 1 and 2, Table 5). These relationships are statistically significant at the 99 percent confidence.

As expected, when only urban municipalities are considered[6], the point estimates decrease in magnitude, but the relationship remains statistically strong (Regressions 6 and 7, Table 5). Similarly, reduced-form regressions indicate that our instrument sets are also associated with total municipal spending per head, but at lower magnitudes and somewhat lower statistical significance (Regressions 8 and 9, Table 5).

7. Main Empirical Results

We perform both ordinary least squares (OLS) and instrumental-variable two-stage least squares (IV-2SLS) estimations. Given our previous theoretical discussion and nonparametric analysis, a nonlinear IV 2SLS with municipal fixed effects, country-specific time trends, and controls specification are taken as our benchmark. We will focus on the results of this specification from this point forward. (Table 7b, column 10). Our results are similar when time fixed effects are included. We find that the relationship between urban density and municipal spending in public services per head is strong and U-shaped, suggesting there is an optimal density point (the vertex of the parabola) beyond which economies of scale are exhausted. An increase in urban density leads to lower per capita municipal public service spending in sparse and medium-sized urban areas, but a further increase in population density significantly raises the costs of providing public services in already dense jurisdictions. We identify an optimum density point at approximately 9,000 inhabitants/km2.14 Belem (Brazil), Santiago (Chile) and Puebla (Mexico), are among those municipalities near the optimal density range (see Table 6). We find that the average municipality exhibits economies of scale near 8,450 residents, spending US$75 per resident in basic municipal service provision.

Our benchmark specification shows that a 1 percent point increase in population density leads to a 0.99 percent point decline in per capita expenditures in public services. This is equal to a decrease in current municipal service spending per resident from US$75 to US$67, given a 10 percent increase in urban density. In a municipality with lower-than-average densities, such as those in the first quartile (i.e., 2,334 inhabitants per km2), a 1 percent increase in urban density would decrease per capita spending by

[6] We consider a municipality as urban when at least 50 percent of its residents live in urban areas. We considered other cutoff points with virtually identical results.

almost 1.4 percent. Conversely, in a very dense municipality, such as those in the ninth decile (i.e., 9,659 inhabitants per km2), a 1 percent increase in urban density leads to an increase in per capita spending by almost 0.1 percent. All these associations are significant at the 95 percent level (see Table 7a/b).

The impact of urban density on municipal public service spending per head is significant in alternative specifications. To further assuage potential violations to the exclusion restriction (i.e., climate should affect municipal spending patterns only through density), we restrict our sample to urban municipalities. In our view, the most serious violation to the exclusion restriction is a potential climate effect on income. However, while there is evidence that climate is robustly related to income in rural areas, it has not been found to exert a clear effect in urban centers (Guerrero Compeán, 2013). When non-urban municipalities are excluded, the elasticity of population density, based on our preferred benchmark framework, is approximately 21.5 for the average municipality (Regression 2, Table 8). The results remain statistically significant at the 95 percent level.

Again, we find evidence in support of a U-shaped relationship, with low-(high-) density urban municipalities exhibiting economies (diseconomies) of scale. For sparsely populated urban municipalities—at the first decile—a 1 percent point increase in population density leads to a 3.4 percent point decline in per capita municipal spending in public services. Conversely, for the urban municipality at the ninth decile, a 1 percent point increase in population density leads to a 0.4 percent point increase in municipal public service expenditures per head.

The IV-2SLS fixed-effects results are robust to an alternative dependent variable. When the relationship between urban density and total municipal spending per head—as opposed to per capita spending in public services—is considered, we find that most municipalities exhibit economies of scale, with the trough being at a population density of over 50,000 people per square kilometer (Regression 4, Table 8). Similarly, the choice of instruments does not change the statistical significance of our results. Urban population density does not have a statistically differential impact on public service spending per head (for either the pooled or urban-only specifications) when rainfall is included as an additional instrument (Regressions 1 and 3, Table 8).

Table 4. Climate and Population Density (first stage)

Explanatory variable	Ordinary least squares							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Temperature	0.0230**	0.162***	0.173***	0.133***	0.0753***	0.100***	0.0701***	
	(0.0108)	(0.0411)	(0.0364)	(0.0333)	(0.0240)	(0.0279)	(0.0234)	
Soil moisture	-0.267***	0.0629***	0.0517***		0.0289***	0.0235***		
	(0.0634)	(0.00929)	(0.00922)		(0.00577)	(0.00593)		
Rainfall				0.0002*			0.0002**	
				(0.0001)			(0.0001)	
Future temperature								0.0231
								(0.0187)
Future rainfall								0.0001
								(0.0001)
F-test of excluded instruments	9.05	23.23	18.92	14.25	13.26	10.35	10.02	1.12
Full controls	No	No	No	No	Yes	Yes	Yes	Yes
Country-specific time trends	No	Yes	No	No	Yes	No	No	No
Two-way fixed effects	No	No	Yes	Yes	No	Yes	Yes	Yes
Observations	13004	12030	12030	12812	10024	10024	10722	10722
R^2	0.0438	0.367	0.378	0.378	0.584	0.588	0.595	0.593
Root mean square error	1.241	0.912	1.028	1.399	0.926	1.090	1.103	1.026

Source: Authors' elaboration.

Notes: Dependent variable: Covered urban population density. Regression disturbance terms are clustered at the regional level. Huber-White robust standard errors in parentheses. * p<0.10 ** p<0.05 *** p<0.01.

Table 5. Climate and Municipal Spending in Public Services (Reduced Form)–Part 1

Explanatory variable	Dependent variable: Municipal spending in public services per capita — Pooled (OLS)				
	(1)	(2)	(3)	(4)	(5)
Temperature	-0.965***			-0.987***	-0.965***
	(0.182)			(0.180)	(0.195)
Soil moisture		0.129***			0.0643*
		(0.0405)			(0.0375)
Rainfall			0.000425*	0.00069*	
			(0.000274)	(0.00037)	
Two-way fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	15580	14839	15580	15580	14832
R^2	0.107	0.0846	0.0768	0.109	0.114
Root mean square error	0.691	0.703	0.703	0.690	0.692

Source: Authors' elaboration.

Notes: Regression disturbance terms are clustered at the regional level. Huber-White robust standard errors in parentheses.
* p<0.10 ** p<0.05 *** p<0.01.

Table 5. Climate and Municipal Spending in Public Services (Reduced Form)–Part 2

Explanatory variable	Dependent variable: Municipal spending in public services per capita — Urban (OLS)		Total municipal spending per capita — Pooled (OLS)	
	(6)	(7)	(8)	(9)
Temperature	-0.475***	-0.320*	-0.278***	-0.284***
	(0.153)	(0.182)	(0.0481)	(0.0507)
Soil moisture		0.0982*		0.00348
		(0.0561)		(0.0105)
Rainfall	0.000954**		0.000264*	
	(0.000433)		(0.000144)	
Two-way fixed effects	Yes	Yes	Yes	Yes
Observations	1129	1104	16149	15359
R^2	0.191	0.189	0.279	0.277
Root mean square error	0.423	0.425	0.260	0.260

Source: Authors' elaboration.

Table 6. Urban Population Density in Selected Municipalities, 2010

Municipality	Urban population density (pop/km^2)
Brazil	
São Paulo	11,047
Rio de Janeiro	10,928
Belém	8,984
Brasília	3,544
Chile	
Santiago	8,681
Valparaíso	6,686
Viña del Mar	6,025
Concepción	4,871
Ecuador	
Guayaquil	7,082
Cuenca	4,395
Quito	4,059
Ambato	3,340
Mexico	
Benito Juárez (Mexico City)	13,221
Guadalajara	10,445
Puebla	8,983
Monterrey	7,678

Source: Authors' elaboration (data sources are already clarified).

Table 7a. Population Density and Municipal Spending in Public Services–Part 1

Explanatory variable	Dependent variable: Municipal spending in public services per capita				
	Ordinary least squares				
	(1)	(2)	(3)	(4)	(5)
Covered urban population density	-0.645***	-0.774***	-0.414**	-0.521***	-0.850***
	(0.0641)	(0.0742)	(0.178)	(0.192)	(0.205)
Covered urban population density (squared)			-0.0189	-0.0220	0.00985
			(0.0129)	(0.0153)	(0.0156)
Potential service users		-0.735***		-0.680***	-0.823***
		(0.214)		(0.213)	(0.216)
Urban population		0.489***		0.538***	0.396**
		(0.171)		(0.164)	(0.197)
Household size		0.361		0.312	0.654
		(0.400)		(0.397)	(0.409)
Unemployment		0.212***		0.209***	0.0287
		(0.0307)		(0.0314)	(0.0239)
Poverty		-0.0313		-0.0251	-0.117**
		(0.0440)		(0.0444)	(0.0516)
Agricultural employment		0.0549***		0.0546***	-0.00409
		(0.0154)		(0.0155)	(0.0150)
Average wage		-0.0434		-0.0453	-0.167**
		(0.0743)		(0.0741)	(0.0718)
Income		0.517***		0.532***	0.589***
		(0.159)		(0.156)	(0.143)
Tax share		-0.341***		-0.341***	-0.310***
		(0.0773)		(0.0776)	(0.0711)
Intergovernmental transfers		0.733***		0.732***	0.623***
		(0.157)		(0.158)	(0.142)
Metropolitan area		0.00425		0.00899	0.0160
		(0.0806)		(0.0803)	(0.0841)
Primacy		-0.470*		-0.464*	-0.492**
		(0.246)		(0.247)	(0.236)
Density elasticity			-0.721***	-0.878***	-0.690***
			(0.079)	(0.105)	(0.094)

Country-specific time trends	No	No	No	No	Yes
Two-way fixed effects	Yes	Yes	Yes	Yes	No
Observations	13744	12172	13744	12172	12172
R^2	0.0912	0.169	0.0920	0.170	0.201
Root mean square error	0.647	0.598	0.647	0.598	0.587
Anderson-Rubin *F*-test *p*-value					
Anderson-Rubin χ^2 test *p*-value					
Stock-Wright *S* statistic *p*-value					
Anderson LR statistic *p*-value					
Kleibergen-Paap *F* statistic					
Hansen *J* statistic *p*-value					

Source: Authors' elaboration.

Notes: Regression disturbance terms are clustered at the regional level. Density elasticities are evaluated at the covered population density mean values and estimated from model specifications. Huber-White robust standard errors in parentheses.

* p<0.10 ** p<0.05 *** p<0.01.

Table 7b. Population Density and Municipal Spending in Public Services–Part 2

Explanatory variable	Dependent variable: Municipal in public services per capita				
	Instrumental-variable two-stage least-squares				
	(6)	(7)	(8)	(9)	(10)
Covered urban population density	-2.095***	-3.561***	-12.84***	-6.982***	-9.304**
	(0.683)	(1.299)	(3.374)	(2.238)	(4.094)
Covered urban population density (squared)			0.863***	0.351**	0.512*
			(0.244)	(0.158)	(0.276)
Potential service users		-1.178***		-2.034***	-2.643**
		(0.357)		(0.646)	(1.091)
Urban population		3.735**		2.294	2.369*
		(1.502)		(1.491)	(1.392)
Household size		-0.0413		0.830	1.544
		(0.471)		(0.717)	(1.143)
Unemployment		0.201***		0.246***	0.0897
		(0.0358)		(0.0432)	(0.0580)
Poverty		0.223*		0.0729	-0.0236
		(0.123)		(0.124)	(0.0888)
Agricultural employment		0.0805***		0.0788***	0.0291
		(0.0245)		(0.0227)	(0.0265)

Average wage		0.00144		0.0110	-0.179
		(0.105)		(0.110)	(0.113)
Income		0.754***		0.471*	0.683***
		(0.249)		(0.281)	(0.238)
Tax share		-0.391***		-0.384***	-0.342***
		(0.0968)		(0.0886)	(0.0866)
Intergovernmental transfers		0.782***		0.796***	0.657***
		(0.184)		(0.169)	(0.161)
Metropolitan area		-0.0145		-0.0947	-0.0478
		(0.0872)		(0.0892)	(0.0944)
Primacy		-0.574**		-0.659**	-0.723**
		(0.290)		(0.288)	(0.316)
Density elasticity			-1.177	-1.276	-0.995
			(1.069)	(1.427)	(1.194)
Country-specific time trends	No	No	No	No	Yes
Two-way fixed effects	Yes	Yes	Yes	Yes	No
Observations	12030	10024	12030	10024	10024
R^2					
Root mean square error	1.072	1.138	1.654	1.146	1.240
Anderson-Rubin *F*-test *p*-value	0.000	0.001	0.000	0.001	0.009
Anderson-Rubin χ^2 test *p*-value	0.000	0.000	0.000	0.000	0.008
Stock-Wright *S* statistic *p*-value	0.000	0.000	0.000	0.000	0.010
Anderson LR statistic *p*-value	0.000	0.000	0.000	0.000	0.000
Kleibergen-Paap *F* statistic	18.92	10.35	16.70	9.903	11.18
Hansen *J* statistic *p*-value	0.000	0.018			

Source: Authors' elaboration.

Note: Regression disturbance terms are clustered at the regional level. Density elasticities are evaluated at the covered population density mean values and estimated from model specifications. Huber-White robust standard errors in parentheses. Columns 6–7 present estimates for linear specifications for illustrative purposes. * p<0.10 ** p<0.05 *** p<0.01. (P-values for columns 8–10 are not reported because specifications are not overidentified).

Table 8. Population Density and Municipal Spending *(alternative specifications)*

Explanatory variable	Dependent variable			
	Public service spending			Total spending
	Pooled	Urban		Pooled
	(1)	(2)	(3)	(4)
Covered urban population density	-7.948***	-16.17**	-21.32**	-1.571***
	(2.596)	(6.643)	(10.10)	(0.463)
Covered urban population density (squared)	0.476**	0.904**	1.280**	0.0723**
	(0.233)	(0.396)	(0.651)	(0.0340)
Potential service users	-2.236***	0.0377	0.169	-0.215
	(0.751)	(0.507)	(0.546)	(0.219)
Urban population	1.383	-0.323	-1.703	0.244
	(2.558)	(2.226)	(1.961)	(0.348)
Household size	1.225	0.217	0.508	-0.598***
	(0.937)	(0.759)	(0.947)	(0.229)
Unemployment	0.265***	0.214***	0.225***	0.0482***
	(0.0491)	(0.0498)	(0.0558)	(0.00953)
Poverty	-0.0108	-0.0465	-0.142	0.00553
	(0.217)	(0.163)	(0.152)	(0.0247)
Agricultural employment	0.0745***	0.0786***	0.0819***	-0.0167***
	(0.0238)	(0.0246)	(0.0254)	(0.00611)
Average wage	0.00753	0.102	0.139	-0.000996
	(0.118)	(0.176)	(0.172)	(0.0265)
Income	0.352	0.193	0.0849	0.351***
	(0.372)	(0.274)	(0.267)	(0.0695)
Tax share	-0.371***	-0.308***	-0.297***	-0.196***
	(0.0809)	(0.0888)	(0.0735)	(0.0234)
Intergovernmental transfers	0.778***	0.626***	0.605***	0.387***
	(0.157)	(0.157)	(0.142)	(0.0463)
Metropolitan area	-0.104	0.113	0.0735	0.0199
	(0.0974)	(0.138)	(0.135)	(0.0247)
Primacy	-0.669**	-0.893**	-0.993**	-0.108**
	(0.276)	(0.423)	(0.483)	(0.0456)
Two-way fixed effects	Yes	Yes	Yes	Yes

Observations	10722	6192	6698	10616
Root mean square error	1.150	0.988	1.088	0.240
Anderson-Rubin *F*-test *p*-value	0.000	0.006	0.002	0.006
Anderson-Rubin χ^2 test *p*-value	0.000	0.006	0.002	0.005
Stock-Wright *S* statistic *p*-value	0.000	0.003	0.001	0.004
Anderson LR statistic *p*-value	0.034	0.000	0.001	0.000
Kleibergen-Paap *F* statistic	2.358	7.710	5.011	10.25

Source: Authors' elaboration.
Note: Regression disturbance terms are clustered at the regional level. Temperature is employed as an instrument in all regressions. Rainfall is included as an additional instrument in Regressions (1) and (3). Soil moisture is included as an additional instrument in Regressions (2) and (4). See text for details. Huber-White robust standard errors in parentheses.
* $p<0.10$ ** $p<0.05$ *** $p<0.01$.

8. Conclusion and Policy Implications

Current policies promote density on the grounds of its environmental and productivity paybacks. While these are important benefits, we should also acknowledge the cost of density. In this paper, we focused on how urban density impacts per capita municipal spending on public services. In particular, we highlighted the dynamics of density where public service coverage is not universal, since the bulk of policy advice recipients are developing countries.

We found that population density is strongly linked to coverage. More than 90 percent of the municipalities whose coverage level is below 10 percent are below the median of the urban population density distribution. Conversely, four out of five municipalities enjoying coverage levels above 90 percent are above the median. This same pattern holds true when considering only municipalities with a majority of urban residents, and when counting each service on its own. We found that the relationship between density and per capita spending in services is U-shaped, with an increase in urban density lowering spending in sparse and medium density municipalities; yet, further densities significantly increase the costs of providing urban public services. Based on our empirical study of more than 17,000 municipalities, the threshold between these two conditions is approximately 9,000 residents per square kilometer.

We addressed the endogeneity of density to public service spending by relying on climate variation as an instrumental variable. We hypothesized that density increases per capita spending in urban services in already dense areas because these places host diverse building typologies and population needs; therefore, they require a wider and costlier set of technologies to provide coverage. Land and labor might also factor in the higher cost as these are usually more expensive in dense places.

We analyzed the fiscal impact of density for municipalities providing coverage of urban services at the highest available quality, on both comparability and policy-targeting grounds. In addition to density, it is important to include other formal attributes when analyzing municipal expenditures. Future studies should examine the impact of density on the structure of municipal expenditures, distinguishing capital from operational costs; current data do not allow us to perform such studies. Last, an important future contribution will be to examine how density impacts the costs of delivering urban services in informal settlements, given that delivering services ex post is more expensive.

From a policy perspective, the association between municipal spending and density is good news. We have better tools to control population density than to limit population sizes. Building codes and performance zoning are useful tools in regulating densities. On the other hand, the cost of changing the existing status-quo needs to be considered when planning for density. While densification should lead to economies of scale in sparsely populated areas, expanding coverage may be harder. Conversely, increasing coverage in a dense area might be easier, even if it is more expensive. This is true inasmuch as local governments fiscally capitalize the benefits of a more comprehensive coverage, and urban areas are already zoned for higher densities.

The fact that density increases per capita public service spending in highly dense urban areas does not mean it is bad policy. It just underscores that growing cities need growing resources. A finer-grain study of where it makes sense to densify within a single municipality is needed. It may be more effective to promote density in certain neighborhoods with a given set of spatial features. This may require assembling land in low dense areas—where it should have a lower market price—and then rezoning it for higher densities. Tools for promoting density—such as master plans—should be reconsidered in light of their impacts in other dimensions, as well as the delay between their publication and actual implementation. It would be more effective to promote density by increasing the quality and access to urban services. In that sense, quantitative references here should be taken as part of a larger picture in the analysis of each city, in which history, culture, and geography play a key role. In all cases, governments should take a long, strategic view toward urban growth.

Finally, this study calls for an integral approach to determining ideal densities. Herein, we have limited our analysis to municipal spending on certain services, but density has other costs and benefits too. Among the costs, is the evident impact on land values; among the benefits, is the containment of the urban environmental footprint. The power of density as a planning tool deserves a careful, site-specific consideration. Overall, city density is not homogeneous but an abstraction of a variety of urban forms; similar density levels could be achieved through different configurations and new technologies could alter current public services cost structures. A good policy would preserve urban diversity.

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