Should French municipalities foster urban densification to reduce their expenditures?

Kakpo, Eliakim and Le-Gallo, Julie and Breuillé, Marie and Grivault, Camille

CESAER INRA

February 2019

Should French municipalities foster urban densification to reduce their expenditures?

Marie Breuillé, Camille Grivault, Eliakim Kakpo and Julie Le Gallo

CESAER, AgroSup Dijon, INRA, Université de Bourgogne Franche-Comté

Abstract

The relationship between population density and the costs of public services remains the subject of controversies due to the wide range of estimated elasticities. This disparity derives essentially from measurement and identification issues. Based on a sample of French municipalities for the period 2003-2015, this paper addresses both considerations and provides further evidence in support of a non-linear relationship between density and public expenditures per capita. First, we measure density differently from the traditional literature and consider two metrics. Second, to tackle endogeneity, we exploit historical records of population, settlements and soil characteristics as an exogenous source of variation. Our preferred specifications imply elasticity estimates equal to -0.13 and 0.12 for per capita current and capital expenditures respectively. Under a cubic B-spline specification, current spending initially decreases with density (up to 20 inhabitants plus jobs per ha) before increasing. In contrast, capital spending features several return points at 20, 30 and 50 inhabitants plus jobs per ha respectively.

Keywords: local public finance; population and employment density; capital expenditures; current expenditures

JEL Classification: H72, R14, R51

First draft, do not cite

1. Introduction

The debate on the relation between urban development and the costs of public goods has taken a different turn recently in the face of new patterns of habitat growth and the emphasis on densification as a way to counterbalance urban sprawl. Urban sprawl, usually defined as a discontinuous model of expansion, which features a multitude of low-density municipalities, is being described by many as inefficient and costly for local governments. For others, this simply reveals new preferences by economic agents and should not be the concern of public policy. On the empirical side, the literature has generally defended the presence of a non-linear relationship between density and the costs of public goods (Ladd 1992, 1994, 1998; Goodman 2008, 2015, 2017; Carruthers 1992; Carruthers et. al 2002, 2003), even though the estimated return points vary substantially.

In this paper, we estimate the relationship between density and the cost of public goods thanks to a panel of 3,037 French municipalities over the period 2003-2015. There are identification challenges that should be taken into account. First, since the costs of public services are not directly observed, economists are forced to rely on measures such as government expenditures per capita. This is not a perfect proxy but could be satisfying if appropriate controls are accounted for to capture differences on the demand and supply side of public services. Alternatively, if data on the quantity of public good or service are available, one should include them in the hope of holding the supply of public goods unchanged. This approach would justify the interpretation of public spending per capita as a reliable approximation of the costs of providing the public good. Most papers use spending per capita as the dependent variable but a few articles examine aggregate expenditures instead. In this paper, we analyze current, capital and total public spending per capita.

Second, the measurement of density still remains a subject of debate. Most empirical works measure density as a raw ratio of population and/or employment to the area of the spatial unit under consideration. This approach came under criticism especially in the fields of geography and urban studies. The measurement of density is particularly sensitive to the spatial unit over which human concentration is appreciated. Though the aggregate acreage remains the most commonly used benchmark, other indicators such as the number of housing units, or net acreage of the built space have been suggested as alternative denominators. As a result, there is a difference between net density, which refers to the occupied portion of the geography studied, and gross density, which includes the entire area of the considered unit.

Relatedly, the composition of the numerator is also subject to discussion. Many works only include a count of the resident population. This does not necessarily capture concentration since the existence of production infrastructures undoubtedly affect the urbanized area of a geography. To circumvent this shortcoming, other papers include both resident population and jobs. This alternative presents the benefit of capturing the role of productive concentration, but remains flawed due to the possibility of double counting units such as self-employed individuals. Also, due to the importance of bedroom communities, it might be appropriate to use daytime population instead of just considering residents in order to capture the effective demand for domestic public goods.

Using a net measure of density rather than gross density to evaluate the impact of human concentration on the costs of public goods presents several advantages. First, it better reflects the intensity of concentration in a municipality since only the occupied portion of the land is taken into account. Then, it better captures densification, which is a “vertical” notion, when the occupied portion of the land is also controlled for. It also limits to some extent, the potential bias introduced by the administrative identification of geographic boundaries. Last, this measure of density is not influenced by the rural nature of the considered unit, which in turn affects the use of land and could introduce significant biases in the measurement of density for rural areas. We adopt two measures of density in this paper: (i) a net human density corresponding to the ratio of the sum of population and jobs over the urban spot of the urbanized area of a municipality[1], and (ii) a net human density calculated as the ratio of the sum of population and jobs over the footprint of buildings in the urbanized area of a municipality[2].

Besides, the distribution of habitat in a locality, which influences the delivery of public utilities among other aspects is not necessarily linked to the intensity of density. Two jurisdictions with similar densities could be subjected to different costs of providing the same output due to differences in their internal structures. This suggests that it is necessary to account for the distribution of construction within the studied unit. For this consideration, we control for the average distance between residents in all specifications.

Third, though it is widely accepted that density probably influences the costs of public goods, there is a good reason to believe that the availability of local amenities stimulates the inflow of new residents. This creates a reverse causality that contaminates the estimated parameters. Empirically, this represents an important identification challenge and only exogenous variations in population and density can be exploited to investigate the relationship between the cost of public good provision and density. This issue has rarely been acknowledged and when it is (Holcombes and Williams, 2008; Benito et al., 2010), the lagged density is taken as an instrument, which is clearly unsatisfactory. Only Libertun de Duren and Campeán (2016) use climatic variables as an exogenous variation source for population density. In this paper, we use historical population and settlements along with soil characteristics in a municipality as instrumental variables for current levels of density. In geography, these features are known as "first" and "second" nature differences that make some places better disposed for habitation than others. These instruments have not been used much in this literature particularly in the French context. The first-stage regressions indicate that these features are relevant for this problematic.

Given that these variables are time-invariant, we leverage them to explain the average (between) level of density at the local level, before estimating the elasticity of interest in a second stage. This approach also helps to mitigate the potential errors present in the measurement of density on a yearly time step. However, we report and discuss the estimated results with both a traditional fixed effects (FE) and a Hausman-Taylor (HT) panel structure in the robustness checks.

In the French context, the analysis must account for the growing trend of cooperation among municipalities over the period, in particular with the adoption of a new legislation on the 16th of December 2010 requiring municipalities to belong to an inter-municipal group, with the objective of generating economies of scale in the provision of some services. Therefore, we consider in all regressions the aggregated (municipality plus inter-municipal) expenditures realized at the municipal scale. We also present in the appendix results that are solely based on municipal spending.

Our paper thus advances the literature in multiple ways. First, the set of instrumental variables used is unique in the literature that studies the relationship between density and public costs, since historical data on population, ancient settlements, and soil characteristics broken down by municipalities are hard to come by. France has been a fortiori little studied, the only available studies being confined to the typology of Guelton and Navarre (2010) and case-studies of

[1] It accounts for all of the surface of the parcels on which a local is present.
[2] The footprint of buildings is not directly provided in the land files and thus estimated by dividing the living space of the premises by their number of floors.

Morlet (2001) and Guengant (2005). Second, we use two separate measures of density and control for other attributes of the dispersion of habitat in a municipality following Breuillé et al. (2019) who showed using cross-sectional data that the density-public costs elasticity varies with respect to the distribution of dwellings in a geography. We also explore alternative functional specifications of the relationship through cubic B-splines in order to account for non-linearities in the association between density and public costs.

Our baseline results support the hypothesis of a log-linear relationship between density and several measures of public spending namely current, capital and total spending. The findings indicate that a one percent increase in density results in a -0.13, -0,12 and -0.09 percent decrease in current, capital and total expenditure per capita respectively. Under a cubic B-spline specification, current spending initially decreases with density (up to 20 inhabitants plus jobs per ha) before increasing. In contrast, capital spending features several return points at 20, 30 and 50 inhabitants plus jobs per ha respectively. The rest of the paper is organized as follows. Section 2 describes the policy context, sections 3 presents the identification strategy and empirical method while section 4 describes the data. In section 5 we discuss the main results while section 6 examines the robustness of these findings to alternative methodological considerations. We conclude with section 7 which also presents the limitations of the study and explores the avenues for future research.

2. Policy context: growing inter-municipal cooperation in France

Studying the impact of habitat structure on the delivery of local public services requires a thorough understanding of the institutional peculiarities of the jurisdictions under investigation. In the French context, the ever evolving inter-dependence between different levels of governmental entities represents such a distinctive feature. Municipalities in France get their resources from two main sources: (i) subsidies from the central state and (ii) local taxes. Over the last few years, subsidies from the state have shrunk due to fiscal austerity and the need to reduce national debt. This development contributed to a rise in cooperation between neighboring municipalities. As a result, several inter-municipal groups were formed. These represent an agglomeration of neighboring municipalities without enclaves that partake in a community to share the delivery of certain public goods. Jurisdictions are not allowed to belong to more than one group at a given time.

Besides, the generalization of inter-municipal cooperation adopted by the French parliament through the Law of the 16th of December 2010 required every municipality to be part of an inter-municipal group by 2013. This legislation rapidly accelerated participation into such cooperative clusters. For instance, back in 2003, 29,754 municipalities belonged to 2,360 inter-municipal groups across the country. By 2015, that number has jumped up to 36,588 municipalities being part of 2,133 inter-municipal groups. In the sample of perimeters considered for this study, 98.7% of municipalities are in such groups in 2015, compared to 70.6% in 2003.

Inter-municipal entities have their own tax system and some degree of autonomy when setting core competencies. Cooperation in some fields such as land-use planning or economic development is compulsory, while the provision of public goods like the construction of highways and cultural facilities, are optional and chosen from a predetermined list. These developments along with the rise of mutualized expenditures (e.g. in 2010, the share of municipal expenditures paid for by the inter-municipal groups was 22.3%) compel us to consider inter-municipal expenditures in this study. We do so through several methodological choices that we discuss below.

3. Identification strategy and empirical approach

3.1 Identification strategy

The association between the costs of public goods measured through public expenditures per capita and density is confounded by several factors. Some of these are observed and will be controlled for, while others are difficult to capture with a slim prospect of coming up with a relevant proxy. A few sources of endogeneity that are not always addressed in the literature relate to simultaneity and reverse causality. Both expenditures and density could be driven by unobserved factors related to residents' preferences or the qualitative composition of population to name a few.

Though there is substantial evidence in support of the claim that density influences the costs of public goods, it is more than appropriate to assume that population and density could just reflect the availability of certain public infrastructures. This implies that only exogenous variations in population and density should be exploited when measuring the density-public costs elasticity. The approach adopted in this paper consists of using sixteenth and seventeenth-century population, historic settlements of Romans, the presence of antic roads along with soil characteristics as instrumental variables for contemporary levels of density in a given municipality.

It is widely accepted that first nature characteristics of a place correlate with early settlements in a geography. Presumably, these features are expected to influence the contemporary concentration of human presence and activity in a given locality without directly altering the level of costs of public services. There is ample evidence suggesting that immigration and human settlements in a place are linked to geological characteristics such as the nature and type of the soil (Combes et al. 2010). However, considering that these indicators are time-invariant for a municipality, they can only be used to explain the average level of density over a given time-frame.

The other major concern that plagues the relevant empirical literature relates to the measurement of density. The attenuation bias that this entails could be non-negligible. As discussed earlier, the measurement of density is still subject to discussion. To address this possibility, we compare the elasticity estimates across alternative definitions of density. The goal is to highlight the consequences this choice bears on the estimated elasticities and to provide a more reliable range to the elasticity of interest. It also allows us to shed further light on the variation of estimates in the literature.

3.2 Empirical method

To measure the impact of density on the costs of public services (proxied by expenditures per capita), we adopt an econometric approach motivated by two concerns. Initially, the goal was to exploit both within and between municipality variation to estimate the elasticity of interest. Moreover, the available measurements of density do not vary much over the period 2003-2015 for a municipality. This implies that a significant share of the variation of density is between rather than within units. It also suggests that traditional panel fixed effects regressions might not be very informative, since only within variation would be used to identify our main parameters in this case. In addition, unobserved heterogeneity across municipalities is plausibly time-invariant, suggesting that identification should be based on capturing fixed attributes of each locality that are susceptible to affect both expenditures and population concentration. With those considerations in mind, we choose to only exploit the "between" variation of the dataset with the instrumental variables used to address the endogeneity between density and public spending. However, we estimate fixed effects and Hausman-Taylor regressions in the robustness analysis.

Specifically, the econometric strategy consists of regressing the average level of expenditures per capita on the average level of density and a set of other controls over the period 2003-2015. Besides, working with averages presents several advantages. First, it helps mitigate errors present in annual density measurements. It also allows us to eliminate the cyclical component of expenditures (especially for capital expenditures that are highly cyclical) and explain a smoother measure of public spending. Besides, this approach is warranted given the time-invariant nature of our instrumental variables, which could only provide an exogenous source of variation for the time-invariant source of endogeneity. Formally, assume that the specification for expenditures per capita is defined as follows:

$$e=h(d,u,x,\varepsilon) \qquad (9)$$

where e represents expenditures per capita, d measures net density, u captures other urban shape attributes that influence the costs of public goods, x represents a set of controls affecting both the demand and supply for public goods, and ε refers to the classical idiosyncratic error term. Following Ladd (1992), we include in the control set x three types of variables: (i) demand side variables (median income, education, etc.), (ii) cost variables (population structure by age, number of jobs, socioeconomic characteristics of the area, etc.) and (iii) inter-governmental transfers (subsidies from the central government).

Several choices are possible for the functional form h. We first adopt a log-linear specification so the parameters estimated could be directly interpreted as elasticities. We set the following equation for municipality i:

$$\ln(\overline{e_i})=\alpha+\beta\ln(\overline{d_i})+\gamma\overline{u}_i+\theta\overline{x}_i+\eta_i+\overline{\varepsilon_i} \quad (10)$$

where $\overline{e_i}$ refers to the average expenditure per capita over the period 2003-2015 for municipality i; α is the constant term; β is the elasticity of public expenditures with respect to density; γ is the semi-elasticity of the dependent variable with respect to other urban forms variables; θ is a similar semi-elasticity with respect to the controls; η_i is the unobserved municipality fixed effect that captures heterogeneity across the observed units and $\overline{\varepsilon_i}$ is the error term averaged over the period of analysis. Equation (10) could be simplified as follows:

$$\overline{e_i}'=\alpha+\beta\overline{d}_i'+\gamma\overline{u}_i+\theta\overline{x}_i+\overline{v}_i \quad \text{with } \overline{v}_i=\eta_i+\overline{\varepsilon}_i \quad (11)$$

In order to capture the fact that the impact of density and other urban form variables on the cost of public goods may be non-linear, some authors (Ladd, 1992; Goodman, 2015) use polynomial functional forms of order 2 or 3 for the regression specification. We prefer flexible B-spline functions (Hastie and Tibshirani, 1990), which estimate a piecewise polynomial function with a smoothing stress at breakpoints, called nodes. This method calls for an exogenous choice of the number of nodes q and the order of the spline function p. We choose to estimate a cubic function while allowing the number of nodes to be selected to maximize the quality of the adjustment:

$$\overline{e_i}'=\alpha+\beta f(\overline{d_i}')+\gamma\overline{u}_i+\theta\overline{x}_i+\overline{v}_i \quad (12)$$

Notice that since $E\left[\overline{d}_i\eta_i\right]\neq 0$ and $E\left[\overline{d}_i v_i\right]\neq 0$, the traditional exogeneity assumption does not hold for the key variable of interest d, since place specific attributes that affect public expenditures could also motivate a relatively larger inflow of new residents. This implies that a simple OLS regression cannot identify the parameter β without bias. As discussed earlier, there are several reasons that justify the presence of η_i, which is meant to capture place attributes that influence density and migration but are also associated with the amount of public good provided. Like a few other empirical works (Holcombes & Williams 2008 and Goodman 2015), we choose to use an instrumental variable (IV) identification strategy but exploit exogenous sources of variation in density rather than using lagged density as has been the tradition in a number of previous works. The lagged explanatory IV approach came under intense scrutiny recently, with a series of papers (Bellemare et. al 2015) which suggest that this identification strategy does not fully address the endogeneity bias present in a causal estimate.

For municipality i, the set of instrumental variables selected here include the presence of a Roman settlement, the presence of a Cassini road during the eighteenth century, the presence of a Roman road, historic populations in the nineteenth century and some geomorphological characteristics. Collecting all these variables under the set Z_i, identification for this methodology relies on the assumptions (i) $E\left[Z_i v_i\right]=0$ and (ii) $E\left[Z_i\overline{d}_i\right]\neq 0$. Though we are able to test the relevance condition (ii) through the first-stage of this estimation, there is no way we could possibly reject the violation of the exclusion condition (i). It stands to reason that the soil attributes of a municipality that makes it more populous would not systematically be related to the amount of public good the locality is able to provide. In the robustness analysis, we also present panel regressions with municipality fixed effects (FE) illustrated as follows:

$$\ln(e_{it})=\alpha+\beta\ln(d_{it})+\gamma u_{it}+\theta x_{it}+\eta_i+\varepsilon_{it} \quad (13)$$

Although the limited within variation in our sample reduces the precision of the estimated FE elasticities, this approach provides a useful reference point for the estimates of the IV specification. Besides, standard errors are robust to the presence of heteroscedasticity and clustered at the municipality level in all panel regressions. We also present estimates derived using a Hausman-Taylor procedure.

4. Data sources and variables

Our panel dataset includes 3,037 municipalities in the ten most populous French metropolitan areas[3] over the period 2003-2015. The perimeters of analysis are displayed in Figure 1 in Appendix 1.

(a) Dependent variables

The data on municipal and inter-municipal expenditures were provided by the "*Direction Générale des Collectivités Locales*" (Ministry of the Interior) and the "*Direction Générale des Finances Publiques*" (Ministry of Finance). For each municipality, we calculate the aggregated annual current, capital, and total expenditures per capita that are carried out by the "municipal bloc"[4] over the period 2003-2015. Specifically, we add up per capita expenditures from the municipality and the inter-municipal group in the referenced municipality. The latter is estimated by multiplying the aggregate expenditures of the inter-communal group by the population share of the considered municipality. The municipal data comes from the primary budget and has not been consolidated. In contrast, inter-municipal data is consolidated with other budget sources.

(b) Independent variables

Two measures of density are used in this paper: (i) a net human density calculated as the ratio of the sum of population and jobs over the urban spot of the urbanized area[5], and (ii) a net human density calculated as the ratio of the sum of population and jobs over the footprint of buildings in the urbanized area[6]. The population and employment data come from the 1999 population census and various surveys of the National Statistics Office (INSEE) between 2006 and 2014. The data on population and employment over the period 2003-2005 are estimated by linear interpolation using the 1999 and 2006 census data as endpoints. The urbanized area is derived from the Land Files[7] (2015) of the "*Direction Générale des Finances Publiques*" (Ministry of Finance) and measures the total surface of land dedicated to housing and production. We use a method based on the CETE Nord-Picardie's approach (2012), which utilizes the date of construction of both the premise and the associated surface of a unit to retropolize municipal urbanized areas. We also include the population of the inter-municipal group as an independent variable in all regressions.

---

[3] For six metropolitan areas, we consider the boundaries of urban areas because they allow to include the perimeter of the inter-municipal group of the central city of the urban area. For three urban areas (Nice, Marseille/Aix-en-Provence and Lille), the perimeter of the central inter-municipal group exceeds that of the urban area, which leads us to retain the perimeter of the urban area increased by the member municipalities of the inter-municipal group that are beyond the urban area. Finally, the increased urban area of Paris encompasses all the municipalities of inter-municipal groups that are partly or totally located in the urban area.

[4] The term "municipal bloc" refers to the inter-municipal group and its member municipalities.

[5] It accounts for all of the surface of the parcels on which a local is present.

[6] The footprint of buildings is not directly provided in the land files and thus estimated by dividing the living space of the premises by their number of floors.

[7] The advantage of the Land Files is that they allow to reconstitute homogeneous annual urbanized areas throughout the entire perimeter of the study. Nevertheless, they present a certain number of limits and in particular the impossibility of integrating in the analysis non-cadastral surfaces (mainly roads) or surfaces not concerned by the tax (public facilities). Finally, one last limitation is that the date of construction available is that of premises still existing at the date of update of the land files. Thus, part of the urban renewal is not taken into account. For example, for a set of collective dwellings built in 1960 and rebuilt in 2004, the date of construction present in the land files will be 2004 and not 1960.

(c) Socio-economic controls

In addition to the main independent variables we include a set of socio-economic and geographic controls that affect the demand and supply for public services. The median disposable income in a municipality is calculated using data from the localized tax revenue (RFL) and Filosofi from INSEE. Other variables that have been controlled for include: (a) the age structure of the population, (b) the share of employed in the working age population, (c) the share of foreigners, (d) the share of residents living in social housing, (d) the share of population with higher education, and (e) the share of population with no degree. Plus, some features of the housing stock like the share of social and individual housing are also taken into account. Last, to capture the impact of non-resident users on local public expenditures, we include the number of jobs per capita and the touristic rate.

(d) Other controls

We also add the following variables as controls: (i) the distance between a municipality and the city-center of its urban area, estimated using the Odomatrix software (INRA-CESAER)[8], (ii) investment grants from the state in order to capture inter-governmental transfers (iii) the share of inter-municipal expenditures in the cumulative public expenditures (municipalities and their inter-municipal group) of a municipality, and (iv) the average distance between two inhabitants or jobs which we estimate by breaking down the population, employment and urbanized area of a municipality across 200-meter grids.

(e) Instrumental variables

To address endogeneity concerns between public expenditures, population and density, we use two categories of instruments. The first set includes topographic data from the IGN (National Geographic Institute) and soil data from the European Soil Database. The Digital Elevation Model (DEM) of the IGN is used to measure the average altitude, the amplitude of altitudes and the soil roughness index at the municipal level. Using the ESdat (Environmental Data Management Software) data, we assess for each municipality the dominant class for different soil characteristics namely: the depth of the substratum, the hydrological class, and the erodability class. This approach builds on the consideration that first nature characteristics which include soil type make some places better disposed for farming and habitation than others. This could explain early settlements in a locality (Bairoch 1988, Henderson et. al 2017). We complement these place specific attributes with “second nature” features on the premise that once agglomerations are established, they tend to persist over the long-run (Cronon 1992). This implies that history bears a significant incidence on the modern distribution of population across space.

As a result, the second set of instruments is constructed using historical data on transport networks and populations. Based on the 18th century digitized Cassini map routes compiled by the Geohistorical Data project[9], we compute for each municipality a binary variable corresponding to the presence of a road. We do the same for the network of the Roman and postal roads in 1833. Finally, using the same data from the Geohistorical Data project, we estimate for each municipality the average population over the periods 1793-1850, 1851-1880 1881-1913. Table 1 presents the descriptive statistics for all the instrumental variables used in the estimates.

[8] We thank Mohamed Hilal (CESAER) for providing these data.

[9] http://geohistoricaldata.org/

Table 1: Summary statistics of the instrumental variables

Variable	**Obs**	**Mean**	**S. D.**	**Min**	**Max**
Soil Roughness Index (meters)	3288	4.2	5.4	0.2	41.7
Average altitude (meters)	3288	178.5	191.9	1.6	2210.3
Amplitude of altitudes (meters)	3288	134.6	225.4	2.3	2491.0
Depth of rocks (5 classes)	3286	3.2	1.5	1	5
Erodability Class of the soil (5 classes)	3286	3.1	1.4	0	5
Hydrologic Class of the soil (10 classes)	3286	3.1	1.7	1	10
Presence of a roman road 16^{th} century	3288	0.2	0.4	0	1
Presence of a Cassini road 18^{th} century	3288	0.7	0.5	0	1
Presence of a postal road 19^{th} century	3288	0.3	0.5	0	1
Average population over 1793-1850	3182	1351.6	15000.9	30.2	800532.0
Average population over 1851-1880	3228	2072.5	32092.3	28.3	1743497.0
Average population over 1881-1913	3266	2800.1	47353.9	16.7	2584459.0

5. Results and discussion

For the baseline regressions, the dependent variables and the main independent variable “density” are included in logarithmic form implying that the coefficient associated with the density variable is an elasticity. For the non-linear B-spline specifications, we provide additional figures (in the Appendix B) to illustrate the impact of density on public costs depending on its level.

Tables 4 through 6 present the results of the regressions for the aggregated levels of current, capital and total expenditures per capita. Similar estimates, based solely on municipal expenditures, are presented in Appendix A (table 12). To emphasize the sensitivity of the estimated elasticities with respect to alternative measurements of density, we compare the results when density is based on the building footprint (columns 3 and 4) to those when density reflects the urban spot of the urbanized area (columns 1 and 2). In each regression, the estimates are obtained either using a log-linear specification (columns 1 and 3) or using a non-linear B-spline function of degree 3 (columns 2 and 4). In addition, several robustness checks have been added to test the validity of our findings to alternative methodological choices.

First, we relax the assumption of a homogenous elasticity across perimeters, by interacting our density variables with perimeter dummies. This approach is motivated by the consideration that the relationship between density and expenditures could be influenced by unobservable features of the perimeter. Next, we also report the results with the exclusion of municipalities belonging to the agglomeration of Paris. Finally, we explore the sensitivity of our results to alternative assumptions and estimation approaches. These involve respectively a fixed effect model that addresses the time invariant source of endogeneity but remains less precise due to the limited within variability of the dataset, and a Hausman-Taylor regression which exploits the full extent of the variability in the dataset but presents others flaws inherent to the discretion associated with the identification of the endogenous variables.

5.1 The impact of density

The results in table 10 in the Appendix A describe the first-stage of the IV regressions. It could be noticed that the instrumental variables do explain a non-negligible share of the variation of average densities across municipalities regardless of the definition of density considered. Also the diagnostic informations presented at the bottom of the table do not warrant any concerns regarding an over-identification of the independent endogenous variable. However, it is worth noting that the soil and historical features appear to explain density better when it is measured through the urban spot approach. The ensuing sections interpret and discuss the results of the baseline specification.

(i) Log-linear specification

Using a log-linear specification, our results suggest a negative relationship between current expenditures and net human density (Table 4, columns 1 and 3), regardless of the measure adopted for the latter. However, this relationship is only significant at 5 percent when density is measured based on the urban spot. Specifically, it appears that a 1 % increase in net human density (based on the urban spot) results in a 0.13% decrease in per capita current expenditures.

The results for capital expenditures depend on the measurement of density used. The relationship is negative and significant when density is measured using the footprint of buildings, with an elasticity of -0.26 suggesting that a 1% increase in net density leads to a 0.26% decrease in capital expenditures (Table 3, column 3). In contrast, when density is measured using the urban spot, the estimated elasticity equals 0.13 but is not statistically significant (column 1).

As for the relationship between total expenditures (current + capital) and density (Table 4, columns 1 and 3), the estimate is negative regardless of how we measure density but remains significant only when density is measured through the footprint of buildings. Specifically, a 1 % increase in density measured by the urban spot results in a 0.29 % decrease in total expenditures which is notoriously different from de -0.09 elasticity observed when density is appreciated by the footprint of the built-up area.

The log-linear functional specification might not fully reflect the correct association between density and the cost of public goods. Below, we present results based on more flexible cubic B-spline functional forms.

(ii) Cubic B-spline specification

Under the hypothesis of a cubic B-spline specification, we observe a non-linear relationship between current expenditures and density (Table 4, columns 2 and 4). Irrespective of the definition of density adopted, current expenditures first decrease with density before increasing. Specifically, when human density is measured by the urban spot, the relationship is initially negative (up to 20 inhabitants + jobs per ha) and then becomes positive (Figure 2.a and Figure 2.b). This U-shaped dependence reflects the initial presence of increasing returns that are gradually overtaken by the costs of congestion.

For relatively low levels of density, economies of scale seem to dominate, while beyond the critical threshold of about 20 inhabitants + jobs per ha the additional costs of congestion outweigh the former. A similar non-linear relationship is found when the regression is based solely on municipal expenditures. We also measure a non-linear relationship between capital expenditures and density, regardless of the measure of density considered (Table 5, columns 2 and 4). When the measurement is based on the urban spot, the elasticity is negative for low-density levels (less than 20 inhabitants + jobs per ha), becomes positive between 20 and 30 inhabitants + jobs per ha, turns negative again until approximately 50 inhabitants + jobs per ha before striking a positive dynamic from this threshold.

In contrast, when density is measured by the footprint, we observe a V-shaped relationship with a return threshold of 150 inhabitants + jobs per ha. For total expenditures and using a definition of density based on the footprint of buildings, we estimate a relationship that is negative initially and increases with a fairly steep slope for high densities (greater than 160 inhabitants + jobs per ha) (Figure 3.b). Similarly, when density is measured based on the urban spot, the relationship is initially negative (up to 20 inhabitants + jobs per ha) before turning positive (Figure 4.a).

The results for current expenditures are robust to the measurement of density considered, and appear consistent with similar empirical works on the topic who observe a negative (Carruthers and Ulfarsson, 2003, Bastida et al., 2013), or a non-linear (Ladd, 1992, 1994, Sole Olle et al., 2008, Goodman, 2015) association between current expenditures and human density. Irrespective of the measurement of density, our results complement the U-shaped relationship suggested by Ladd (1992, 1994) and Goodman (2015). In contrast, the results for capital expenditures are very sensitive to the way we measure density with different signs associated with the elasticities of either approach.

5.2 The impact of the urban form

The effect of the urbanized area on current, capital and total expenditures is positive and better modeled under a non-linear form. With a log-linear specification, the urbanized area bears a positive impact on current expenditures regardless of the measurement of density adopted. It should also be noted that this effect is slightly more pronounced when density is measured based on the urban spot. In contrast, for capital expenditures, the estimate is very imprecise and is statistically significant only when the footprint of buildings is used in the definition of density.

With a non-linear B-spline specification, and using the footprint of buildings to assess density, the estimated impact of the urbanized area is remarkably high and equals 0.7% for current expenditures compared to -8.1% for capital expenditures. Likewise, with density measured through the urban spot, this elasticity remains statistically significant only for current expenditures.

For current expenditures, the coefficient associated with the total area of a municipality remains imprecise in the baseline log-linear specification, regardless of the measure of density. As for capital expenditures per capita, the impact of the land area is negative and significant with a log-linear specification but remains insignificant with a B-spline non-linear functional form. The impact of the average distance between inhabitants is positive but highly imprecise for capital spending but negative and significant for current expenditures.

5.3 The impact of other control variables

The population of a municipality has a positive effect on per capita current expenditures when we consider a log-linear specification but a negative effect with a B-spline non-linear model. A 1% increase in a municipality's population results in an increase of public spending of 0.05%, irrespective of the measurement of density used. For capital expenditures, the effect is negative but not significant. The result for capital expenditures might be reflecting the presence of economies of scale inherent to larger cities.

The inter-municipal population, introduced to capture the effects of inter-municipal cooperation on expenditures, has a positive and significant impact on current expenditures. Assuming a log-linear specification, we noticed that a 1% increase in the inter-municipal population leads to a 0.09% rise in per capita current expenditures regardless of the measurement of density used. These effects are less pronounced but remain positive and significant with a non-linear B-spline specification. In contrast, for capital expenditures, the estimated effect is negative but not significant. These patterns of expenditures can be explained by the nature and type of goods that are mutualized.

The impact of the demographic structure of population depends on both the category of expenditures considered as well as the functional specification adopted. We notice that a larger share of old-age residents leads to an insignificant impact on both current and capital spending irrespective of the way density is defined. With regards to capital expenditures, a positive and significant effect is observed exclusively for the 11-17 age group.

In all specifications, the share of foreigners and the proportion of social housings in the housing stock have a positive and generally significant effect on all categories of expenditures. As for the median disposable income, the effect is positive for capital expenditures and volatile for current and total expenditures. The distance to the city center of the agglomeration is associated with higher levels for all categories of public expenditures whereas the effect of the touristic rate is not significant.

Besides, as anticipated, inter-governmental investment grants have a positive effect on all categories of expenditures regardless of the functional specification and measurement of density selected. However, the effects are more pronounced for capital expenditures even if the estimated elasticity of 0.13 remains below 1, suggesting that municipal capital outlays are partly financed using subsidies allocated to this end by the State.

The results also indicate that the pooling of expenditures within an inter-municipal jurisdiction positively affects the level of expenditures per capita in a municipality. However, this impact appears to be more significant for capital expenditures. Finally, we also note significant differences in the average per capita municipal expenditures across perimeters. Localities in the perimeters of Paris and Nice have higher levels of current expenditures per capita, while those in Bordeaux, Marseille, Paris, and Toulouse feature relatively lower capital expenditures per inhabitant.

6. Robustness analysis

We explore in this section the incidence of the relaxation of three critical methodological choices on our findings. First, we assume that unobserved heterogeneity across perimeters affects not only the average municipal public spending per capita but could also shape the association between population density and the costs of public goods. This would imply different elasticities across perimeters.

Second, as our empirical strategy only exploits the "between" variation in our dataset due notably to the nature of the instruments used and the limited variability of density over time within a municipality. We estimate as a robustness check, a panel fixed effects model that wipes out the time-invariant heterogeneity across municipalities but only exploits the variability within units to identify the elasticities of interest, along with a Hausman-Taylor estimation procedure which uses both variations.

Last, we exclude the perimeter of Paris from the sample to examine how this agglomeration influences our estimates. About 38% of the municipalities in our sample are located in the perimeter of Paris, implying that the average estimated elasticities might be highly influenced by developments in this area.

6.1 Heterogeneity of elasticities across perimeters

To estimate the density-public spending elasticity by perimeter, we interact the density variable with perimeter dummies. The goal is to explore if the average estimates described above are masked by the existence of a meaningful heterogeneity across agglomerations. The results in table 6 suggest that though the overall signs of the estimates remain unchanged, there are significant differences across perimeters. When density is measured through the urban spot, the elasticities for current spending are negative for all areas; but remain significant only for Lyon, Rennes, and Strasbourg. The same conclusions emerge for a density based on the footprint of buildings.

In contrast, for capital expenditures, the estimated elasticity when density is captured through the urban spot is generally positive but significant only for the perimeters of Lyon, and Rennes. This disparity could just be reflecting a difference in the average size of municipalities across areas or might be indicative of heterogeneity in the composition of population across perimeters. If residents in a particular area are more averse to population concentration, this might induce a higher willingness to increase the provision of public services to offset the disutility of a larger density. As a result, the elasticity of public spending with respect to density may very well vary across areas.

6.2 Regressions without the perimeter of Paris

The perimeter of Paris is not only the largest in our sample but it is also peculiar in many regards. The average population in a municipality in this area (8,910) is 75% higher than the average population in all other municipalities (5,087). Likewise, the urban spot-based density of population is twice as large for a municipality in the agglomeration of Paris. In contrast, the average public expenditure per capita is only 18% higher for municipalities in this area. All these facts, along with the consideration that Paris makes up around 38% of the municipalities in our sample suggest that this agglomeration will heavily influence our estimates.

To verify the credibility of this claim, we exclude the perimeter of Paris from the analysis as a robustness check. The results in table 7 partly confirm this presumption with a significant loss of precision for all estimates; though the signs remain unchanged. For current expenditures the associated elasticity estimates for density measured using the urban sport and the footprint of buildings equal -0.16 and -0.49 respectively (vs. -0.13 and -0.49 respectively for the full sample). For capital expenditures, the elasticities for the restricted sample equal 0.03 and -0.36 respectively compared to 0.13 and -0.26 for the full sample. All estimates feature a higher variance for the restricted sample due to the reduction in the number of observations. The findings from this limited sample remain qualitatively similar to those presented above.

6.3 Panel fixed effects regressions (FE)

In this paper, we leverage time-invariant historic settlements and soil characteristics as instruments for contemporary levels of density. Though we gather a panel dataset, this approach led us to exploit exclusively the variation of average public expenditures and density between jurisdictions to identify the elasticities of interest. Alternatively, we could estimate a fixed effects panel regression which makes use of the within variation across units to estimate our parameter of interest while addressing the time-invariant source of the endogeneity of density. We explore this approach as a robustness check. The results in table 6 indicate a negative elasticity of both categories of public expenditures with respect to density regardless of the measurement of density considered.

For current expenditures, the estimates equal -0.12 irrespective of the way density is measured. This value differ considerably from the IV equivalent specifically when density is captured through the footprint of the buildings (-0.41). It is critical to recall that the panel fixed effects regression only considers within variability while the IV estimates use between unit variation. For capital expenditures, the panel (FE) estimates equal -0.29 and -0.24 respectively compared to 0.13 and -0.21 with an IV specification. The results associated with a density measure based on the urban spot is quite intriguing for capital expenditures. However, we are also aware of the consideration that municipal capital expenditures are volatile and sensitive to the political climate, implying a significant "within" variation for this variable (See table 8 for summary statistics). This suggests that the FE estimates might be more informative for capital expenditures.

Overall, these two sets of estimates can be used in conjunction to draw a more accurate picture of the association between density and public expenditures. We could have also included a random effects panel regression. This approach will exploit both types of variations but cannot eliminate the time-invariant source of endogeneity. Future works on the topic should be directed at finding instruments that vary over time and can be used to explain changes in density within a unit. In this case, both sources of variation would be used, and the estimated elasticities will certainly be more precise and informative. However, we present below estimates derived from a Hausman-Taylor (HT) procedure which not only addresses the unit specific heterogeneity but exploits both sources of variation to identify the coefficients of both time-variant and time-invariant variables.

6.4 Regressions with the Hausman-Taylor (HT) approach

A major limitation of the FE estimator is that it cannot identify the coefficients of time-invariant variables. Plus, only within variation is exploited to estimate the parameters of the model. This is problematic particularly when the variables of interest do not vary much over time. The Hausman-Taylor (HT) approach attempts to circumvent this constraint, and makes use of both sources of variation while controlling for unit specific effects. The challenge here is to identify the variables that are endogenous in the sense that they correlate with the municipality specific heterogeneity.

Apart from the first and second nature features (used as IV in the previous sections) that we consider to be critical in the spatial variation of density, we consider additional sources of heterogeneity at the municipal scale. Following the hypothesis long established by Tiebout, which defends that individuals sort themselves out across jurisdictions in a fashion that reflects their preferences for the public good, there is a need to identify the variables that could potentially be linked to the unobserved taste for public spending. We consider all socio-economic controls to be endogenous to the municipality specific fixed effects. Only distance to the center of the extended agglomeration, total land area, perimeter, touristic rate, share of foreigners and intergovernmental subsidies per capita are treated as exogenous.

The results of these regressions are described in table 8. For current expenditures, the estimates which are statistically significant equal -0.12 and -0.14 when density is measured based off the urban spot and the footprint of buildings respectively. For capital expenditures, the estimated elasticity remains negative but is only significant when density is measured using the footprint of buildings. This confirms the previously established finding that the measurement of density adopted influences the estimated elasticity. In general, the more sophisticated definition of density which builds on topographic and satellite imagery to provide a more accurate reflection of the spatial concentration of human presence in a locality, yields elasticity estimates that are not very precise especially for capital expenditures. The following section compares the elasticity estimates across alternative identification approaches and discusses the sources and implications of the range of empirical values on the true parameter of interest.

6.5 Taking stock of the elasticity estimates and avenues for future research

The previous robustness checks further illustrate the necessity to keep hold of measurement challenges when studying the incidence of population density on public expenditures. Tables 2 and 3 provide a summary of the elasticity estimates. In general, all regressions across the three identification approaches (Panel FE, Panel HT, IV Between) indicate a negative elasticity between current spending per capita and our density metrics irrespective of the way the latter is accessed. Using a definition based off the footprint of buildings results in an estimated point elasticity that ranges between -0.49 and -0.12 depending on the identification strategy.

These estimates remain statistically significant and the combined 95 % confidence intervals suggest that the true parameter lies between -0.67 and -0.04. In contrast, with the more sophisticated measurement of density based off the urban spot of the urbanized area, the point estimate of the same elasticity varies between -0.11 and -0.13 with an associated 95 % confidence interval that lies between -0.26 and -0.00. The imprecise estimate of the IV Between regression explains the right segment of the combined confidence interval. The extent to which the instrumental variables explain the independent variable of interest, could be the source of this imprecision. Future works on this topic should be directed at using other IVs such as features related to legislations and residential or commercial zoning rules with unintended implications on the size of local populations.

As for capital expenditures, the picture is a bit unclear. The estimated elasticity is statistically negative when the footprint of buildings is used to measure density, with an elasticity that varies between -0.22 and -0.27 and a combined 95 % confidence interval which lies within the bounds -0.46 and -0.04. However, when density is defined through the urban spot, the estimated elasticity is very imprecise and remains significant only under the panel fixed effects specification. As discussed earlier, capital expenditures are highly volatile with a relatively important share of their variance occurring within rather than between units. It stands to logic therefore that the Panel FE estimates are more precise than the others. The search for time-variant informative instruments appears to be more warranted for capital expenditures.

Table 2: Summary of point estimates and t-statistics of the elasticity

	Log (Current Exp.)		Log (Capital Exp.)	
Elasticity	Urban Spot	Foot. of Build.	Urban Spot	Foot. of Build.
IV Between	-0.133**	-0.493***	0.126*	-0.268***
	[-2.07]	[-5.23]	[1.67]	[-2.69]
Panel FE	-0.117***	-0.117***	-0.291***	-0.237***
	[-3.44]	[-2.93]	[-3.09]	[-2.39]
Panel HT	-0.119***	-0.139***	-0.127	-0.224***
	[-3.51]	[-3.32]	[-1.47]	[-2.48]
t-statistics in brackets				

**p<0,01, **p<0,05 et ***p<0,01.*

Table 3: Summary of point estimates and confidence intervals (C.I.) of the elasticity

	Log (Current Exp.)		Log (Capital Exp.)	
Elasticity and 95% CI	Urban Spot	Foot. of Build.	Urban Spot	Foot. of Build.
IV Between	-0.133**	-0.493***	0.126*	-0.268**
	[-0.26, -0.00]	**[-0.67,-0.30]**	[-0.02, 0.27]	**[-0.46,-0.07]**
Panel FE	-0.117***	-0.117***	-0.291***	-0.237**
	[-0.18,-0.05]	**[-0.19,-0.04]**	**[-0.47,-0.11]**	**[-0.43,-0.04]**
Panel HT	-0.119***	-0.139***	-0.127	-0.224**
	[-0.18,-0.05]	**[-0.22,-0.06]**	[-0.29, 0.04]	**[-0.40,-0.05]**
C.I. in brackets				

**p*<0,01, ***p*<0,05 et ****p*<0,01

7. Conclusion

In this paper, we explore the relation between the costs of public goods and density using a panel of 3,037 French municipalities over the period 2003-2015. We address a couple of methodological considerations and provide further evidence in support of a non-linear relationship between the density of cities and public expenditures per capita. Our contributions to the existing literature are two-fold. First, we adopt two measures of density in this paper: (i) a net human density corresponding to the ratio of the sum of population and jobs over the urban spot of the urbanized area of a municipality, and (ii) a net human density calculated as the ratio of the sum of population and jobs over the footprint of buildings in the urbanized area of a municipality. Second, to address the reverse causality between the cost of public good provision and density, we use historical population and settlements along with soil characteristics in a municipality as instrumental variables for current levels of density. These instruments have not been used much in this literature particularly in the French context. The first-stage regressions indicate that these features are relevant for this problematic. Our preferred specifications imply a -0.13 and 0.12 elasticities for per capita current, and capital expenditures respectively.

Specifically, using a log-linear specification, it appears that a one percent increase in net human density (based on the urban spot) results in a 0.13 percent decrease in per capita current expenditures. For capital expenditures, when density is measured using the footprint of buildings, the estimated elasticity equals -0.27, suggesting that a one percent increase in net density leads to a 0.27 percent decrease in capital expenditures. In contrast, when density is measured through the urban spot, the estimated elasticity equals 0.12 but is not significant.

Under a cubic B-spline functional specification, we notice that when human concentration is measured by the urban spot, the relationship between public current expenditures and density is initially negative (up to 20 inhabitants + jobs per ha) and then becomes positive. This U-shaped dependence reflects the initial presence of increasing returns that are gradually overtaken by the costs of congestion. For capital expenditures, the relationship is more flexible. When the measurement is based on the urban spot, the association is negative for low-density levels (less than 20 inhabitants + jobs per ha), becomes positive between 20 and 30 inhabitants + jobs per ha, turns negative again until approximately 50 inhabitants + jobs per ha before striking a positive dynamic from this threshold.

The baseline findings were derived by exploiting the variability of density and public expenditures across municipalities. The IV elasticity estimates presented in this paper did not make use of the variability within a jurisdiction over time due to the time-invariant nature of the instrumental variables. Going forward, it would be appropriate to consider dynamic sources of exogenous variations that could be used to capture both within and between municipality evolutions of density. For instance, there might be policies at the national level with unintended implications with regards to the spatial allocation of individuals and density. Future works on this topic could exploit such exogenous variations in a panel set-up to control for both time-invariant and time-variant heterogeneity. Also, the elasticity of density with respect to public expenditures could very well vary by spending category. It will be interesting to focus on a selected set of public services and explore the impacts of population concentration on both the amount spent and the quality of the service provided.

Appendix A: Tables

Table 4: IV Regressions on the Log of Public Current Expenditures per capita (Municipalities + inter-municipal group)

	Urban Spot	**Urban Spot**	**Foot. of build.**	**Foot. of build.**
Log (Net Density)	-0.133**		-0.493***	
	[-2.07]		[-5.23]	
Log (Inter-municipal Pop.)	0.0937***	0.0846***	0.0896***	0.0826***
	[19.19]	[14.41]	[18.34]	[14.00]
Spline 1 Net Density		-0.0603**		-0.0169***
		[-2.01]		[-4.23]
Spline 2 Net Density		6.848***		0.486***
		[3.07]		[4.02]
Spline 3 Net Density		-15.78***		-1.987***
		[-3.22]		[-3.79]
Spline 4 Net Density		10.50***		2.093***
		[3.42]		[3.55]
Urbanized Land	0.00201**	0.00764***	0.00248***	0.00669***
	[2.04]	[4.94]	[3.23]	[4.19]
Avg. Dist. Between residents	-0.119***	0.0924	-0.125***	-0.0585
	[-3.28]	[1.69]	[-3.90]	[-1.50]
% Employed workforce	0.00189	-0.000628	0.00563*	0.00653*
	[0.66]	[-0.19]	[1.89]	[1.88]
% Group Housing	0.00933***	0.00799**	0.0153***	0.0223***
	[2.72]	[2.07]	[3.18]	[3.46]
% Individual Housing	0.00447	0.00237	0.00725	0.0125**
	[1.40]	[0.67]	[1.60]	[2.08]
% Public Housing	0.00906***	0.00796***	0.0105***	0.0132***
	[9.20]	[6.27]	[10.06]	[6.51]
% Foreigners	0.00604**	0.00853***	0.00802***	0.00981***
	[2.36]	[3.02]	[3.05]	[3.35]
Touristic Rate (%)	0.000855***	0.000621***	0.000297***	0.000160
	[7.91]	[4.24]	[2.74]	[1.09]
Distance to the center	0.000915**	0.00134***	0.00166***	0.000762
	[2.14]	[2.54]	[3.67]	[1.27]
Log (Median Income)	0.157	-0.0807	0.130	-0.171
	[1.83]	[-0.76]	[1.50]	[-1.48]
Log (Subsidies per capita)	0.0295***	0.0172**	0.0285***	0.0146
	[4.05]	[2.16]	[3.88]	[1.67]
Log (Total Area)	0.000475	0.120***	-0.00414	0.0640***
	[0.02]	[3.62]	[-0.28]	[2.80]
% Higher education	-0.00176	0.00165	-0.00118	0.00547***
	[-1.28]	[0.98]	[-0.82]	[2.73]
Log (Municipal Population)	0.0584**	-0.0666	0.0551***	-0.0328
	[2.18]	[-1.85]	[3.93]	[-1.32]
% pop more than 65	0.00183	-0.00531	-0.00131	-0.00114
	[0.80]	[-1.92]	[-0.52]	[-0.37]
% pop between 0 and 10	-0.00645	-0.00896**	-0.00305	-0.00569
	[-1.95]	[-2.19]	[-0.86]	[-1.27]
% pop between 11 and 17	-0.00490	-0.0139***	-0.00677	-0.0144***
	[-1.08]	[-2.72]	[-1.53]	[-2.74]
% pop between 18 and 24	0.00264	-0.0130***	0.00529	0.000323
	[0.69]	[-2.57]	[1.31]	[0.07]
% without a diploma	-0.00262	-0.00214	-0.00124	0.000872
	[-1.35]	[-1.00]	[-0.62]	[0.38]
Share inter-mun. serv. Expend.	0.00940***	0.00876***	0.00939***	0.00862***
	[20.49]	[16.15]	[18.04]	[14.00]
Intercept	3.378***	6.467***	5.100***	6.716***
	[3.54]	[5.57]	[4.81]	[5.20]

Perimeter Dummies	Yes	Yes	Yes	Yes
Number of observations	3037	3037	3037	3037
Adjusted R^2	0.695	0.618	0.658	0.522

t-statistics in brackets. Coefficients of Perimeter dummies not reported for clarity. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of Roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01.

Table 5: IV Regressions on the Log of Public Capital Expenditures per capita (Municipalities + inter-municipal group)

	Urban Spot	**Urban Spot**	**Foot. of build.**	**Foot. of build.**
Log (Net Density)	0.126^{*}		-0.268^{***}	
	[1.67]		[-2.69]	
Log (Inter-municipal Pop.)	0.00630^{***}	0.00954^{***}	0.00452^{***}	0.00915^{***}
	[5.03]	[4.95]	[4.81]	[4.39]
Spline 1 Net Density		-0.0680		-0.0159^{***}
		[-1.80]		[-3.58]
Spline 2 Net Density		7.922^{***}		0.562^{***}
		[2.74]		[3.74]
Spline 3 Net Density		-18.04^{***}		-2.463^{***}
		[-2.83]		[-3.70]
Spline 4 Net Density		11.79^{***}		2.738^{***}
		[2.94]		[3.62]
Urbanized Land	-0.0401	0.113	-0.117^{***}	-0.0810
	[-0.91]	[1.60]	[-3.30]	[-1.64]
Avg. Dist. Between residents	0.000141	0.00137	0.00658	0.00797
	[0.04]	[0.33]	[1.87]	[1.69]
% Employed workforce	-0.00127	-0.00136	0.00433	0.0153^{**}
	[-0.31]	[-0.28]	[0.88]	[2.07]
% Group Housing	-0.00233	-0.00302	-0.000962	0.00662
	[-0.61]	[-0.67]	[-0.22]	[0.98]
% Individual Housing	0.00431^{***}	0.00291^{**}	0.00463^{***}	0.0102^{***}
	[3.66]	[2.06]	[3.72]	[3.91]
% Public Housing	0.00679^{**}	0.00816^{**}	0.00990^{***}	0.0100^{**}
	[1.97]	[2.22]	[2.90]	[2.55]
% Foreigners	0.000703^{***}	0.000329^{*}	0.000310^{**}	0.0000253
	[5.40]	[1.90]	[2.36]	[0.16]
Touristic Rate (%)	-0.000176	0.000323	-0.000253	-0.0000524
	[-0.34]	[0.50]	[-0.48]	[-0.07]
Distance to the center	0.536^{***}	0.329^{***}	0.403^{***}	0.231
	[4.72]	[2.53]	[3.88]	[1.58]
Log (Median Income)	0.328^{***}	0.326^{***}	0.331^{***}	0.319^{***}
	[27.62]	[24.99]	[28.61]	[22.92]
Log (Subsidies per capita)	0.123^{***}	0.198^{***}	0.0493^{***}	0.106^{***}
	[3.98]	[4.63]	[3.04]	[3.47]
Log (Total Area)	-0.00454^{***}	-0.00216	-0.00400^{**}	0.00101
	[-2.64]	[-1.05]	[-2.38]	[0.37]
% Higher education	-0.0715^{**}	-0.141^{***}	0.00114	-0.0784^{**}
	[-2.20]	[-3.04]	[0.07]	[-2.37]
Log (Municipal Population)	-0.000846	-0.00572	-0.00392	-0.00108
	[-0.31]	[-1.77]	[-1.41]	[-0.27]
% pop more than 65	-0.000733	0.00181	0.000528	0.00300
	[-0.17]	[0.35]	[0.12]	[0.51]
% pop between 0 and 10	-0.0115^{**}	-0.0176^{***}	-0.0140^{***}	-0.0207^{***}
	[-2.14]	[-2.83]	[-2.86]	[-2.99]
% pop between 11 and 17	0.00949^{**}	0.000392	0.0125^{***}	0.0132^{**}
	[2.35]	[0.07]	[2.97]	[2.19]
% pop between 18 and 24	-0.00187	-0.000476	-0.00123	0.00205
	[-0.72]	[-0.16]	[-0.47]	[0.63]
% without a diploma	0.0307^{***}	0.0270^{***}	0.0357^{***}	0.0278^{**}
	[4.61]	[3.32]	[5.85]	[3.13]
Share inter-mun. serv. Expend.	0.0156^{***}	0.0153^{***}	0.0153^{***}	0.0158^{***}
	[34.80]	[28.64]	[33.92]	[26.38]
Intercept	-1.344	1.394	0.910	1.686
	[-1.08]	[1.00]	[0.75]	[1.06]
Perimeter Dummies	Yes	Yes	Yes	Yes
Number of observations	3037	3037	3037	3037

Adjusted R^2	0.712	0.663	0.702	0.566

t-statistics in brackets. Coefficients of Perimeter dummies not reported for clarity. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of Roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01.

Table 6: IV Regressions on the Log of Total Public Expenditures per capita (Municipalities + inter-municipal group)

	Urban Spot	Urban Spot	Foot. of build.	Foot. of build.
Log (Net Density)	-0.093		-0.294**	
	[-0.96]		[-2.24]	
Log (Inter-municipal Pop.)	0.169***	0.166***	0.169***	0.163***
	[20.55]	[17.47]	[22.06]	[19.59]
Spline 1 Net Density		-0.0462		-0.00772
		[-1.10]		[-1.83]
Spline 2 Net Density		3.480		0.107
		[1.06]		[0.76]
Spline 3 Net Density		-7.497		-0.284
		[-1.03]		[-0.44]
Spline 4 Net Density		4.519		0.171
		[0.97]		[0.23]
Urbanized Land	-0.00143	-0.0000927	-0.000891	-0.00117
	[-0.82]	[-0.04]	[-0.63]	[-0.57]
Avg. Dist. Between residents	-0.0319	0.0111	-0.0387	-0.0285
	[-0.60]	[0.15]	[-0.83]	[-0.56]
% Employed workforce	0.00422	0.00420	0.00748	0.00785
	[0.96]	[0.85]	[1.63]	[1.66]
% Group Housing	-0.000982	-0.00232	0.00227	0.00477
	[-0.21]	[-0.43]	[0.36]	[0.63]
% Individual Housing	-0.00217	-0.00295	-0.000615	0.00276
	[-0.52]	[-0.59]	[-0.11]	[0.40]
% Public Housing	-0.00102	-0.00280	-0.0000985	-0.00170
	[-0.61]	[-1.45]	[-0.06]	[-0.62]
% Foreigners	-0.00233	-0.00198	-0.00201	-0.000768
	[-0.52]	[-0.42]	[-0.44]	[-0.16]
Touristic Rate (%)	0.000312**	0.000155	0.0000345	0.0000422
	[2.70]	[1.36]	[0.24]	[0.25]
Distance to the center	0.00336***	0.00328***	0.00378***	0.00318***
	[6.09]	[4.84]	[6.84]	[4.50]
Log (Median Income)	-0.225	-0.384**	-0.279**	-0.386**
	[-1.59]	[-2.19]	[-2.11]	[-2.29]
Log (Subsidies per capita)	0.0239**	0.0222**	0.0232**	0.0194**
	[2.61]	[2.20]	[2.53]	[1.97]
Log (Total Area)	-0.0341	-0.00430	-0.0316	-0.0304
	[-0.91]	[-0.10]	[-1.54]	[-1.16]
% Higher education	-0.00774***	-0.00590**	-0.00746***	-0.00517**
	[-3.89]	[-2.46]	[-3.71]	[-2.02]
Log (Municipal Population)	0.0433	0.0207	0.0357	0.0303
	[1.10]	[0.42]	[1.85]	[1.08]
% pop more than 65	-0.00336	-0.00534	-0.00489	-0.00503
	[-0.94]	[-1.33]	[-1.30]	[-1.15]
% pop between 0 and 10	-0.000304	0.000124	0.00170	0.000295
	[-0.07]	[0.02]	[0.37]	[0.06]
% pop between 11 and 17	-0.0117	-0.0148	-0.0122	-0.0126
	[-1.56]	[-1.82]	[-1.69]	[-1.68]
% pop between 18 and 24	0.00224	-0.00275	0.00366	-0.000597
	[0.44]	[-0.45]	[0.68]	[-0.09]
% without a diploma	-0.00846***	-0.00820***	-0.00782**	-0.00723**
	[-3.43]	[-3.05]	[-3.08]	[-2.78]
Share inter-mun. serv. Expend.	0.0544***	0.0541***	0.0545***	0.0545***
	[79.85]	[72.72]	[76.99]	[74.62]
Intercept	5.290***	7.138***	6.546***	6.721***
	[3.68]	[3.88]	[4.32]	[3.81]
Perimeter Dummies	Yes	Yes	Yes	Yes
Number of observations	3037	3037	3037	3037

Adjusted R^2	0.860	0.856	0.857	0.850

t-statistics in brackets. Coefficients of Perimeter dummies not reported for clarity. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of Roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01.

Table 7: IV Regressions of the Log of Public Expenditures per capita (Municipalities + inter-municipal group) assuming heterogeneity of elasticities across perimeters (Municipalities + inter-municipal group)

	Log (Current expenditures)		**Log (Capital expenditures)**	
	Urban Spot	Foot. of build.	Urban Spot	Foot. of build.
Log (Net Density)	-0.0350	-0.793***	0.0459	-0.574***
	[-0.31]	[-5.06]	[0.33]	[-3.63]
Bordeaux*Density	-0.0418	-0.00126	0.00172	0.0169
	[-1.32]	[-0.05]	[0.04]	[0.54]
Lille* density	-0.0722	-0.0223	0.0306	0.0440
	[-1.85]	[-0.79]	[0.58]	[1.26]
Lyon* density	-0.0939***	-0.0635***	0.0840*	0.0447
	[-2.63]	[-2.41]	[1.71]	[1.39]
Marseille* density	-0.0271	-0.0459	-0.0463	-0.0553
	[-0.46]	[-1.02]	[-0.59]	[-1.03]
Nice* density	-0.00731	0.0324	0.0748	0.0720**
	[-0.19]	[1.23]	[1.55]	[2.36]
Paris* density	-0.0571	-0.00829	-0.0172	0.00263
	[-1.34]	[-0.27]	[-0.31]	[0.08]
Rennes* density	-0.0863**	-0.0465*	0.108**	0.0574*
	[-2.36]	[-1.69]	[2.07]	[1.65]
Strasbourg* density	-0.162***	-0.149***	0.0367	-0.00400
	[-4.10]	[-4.89]	[0.69]	[-0.11]
Toulouse*density	-0.0302	0.00399	0.0159	0.0207
	[-1.01]	[0.17]	[0.38]	[0.70]
Urbanized Land	0.00107	-0.000209	0.00491***	0.00249*
	[0.75]	[-0.18]	[2.78]	[1.87]
Avg. Dist. Between residents	-0.171***	-0.237***	-0.0822	-0.173***
	[-3.49]	[-5.34]	[-1.37]	[-3.58]
% Employed workforce	-0.0000520	0.00961**	0.0000303	0.00763
	[-0.01]	[2.25]	[0.01]	[1.50]
% Group Housing	0.00955**	0.0221***	-0.000377	0.00764
	[2.61]	[3.44]	[-0.08]	[1.07]
% Individual Housing	0.00385	0.00953	-0.00205	-0.000559
	[1.21]	[1.65]	[-0.53]	[-0.09]
% Public Housing	0.00878***	0.00931***	0.00344**	0.00358**
	[7.42]	[7.02]	[2.28]	[2.26]
% Foreigners	0.0123*	0.00973*	0.0106	0.0112**
	[2.43]	[1.84]	[1.73]	[2.07]
Touristic Rate (%)	0.000939***	-0.0000736	0.000696***	-0.0000800
	[7.06]	[-0.36]	[4.68]	[-0.41]
Distance to the center	0.000587	0.00176***	0.0000537	0.000158
	[0.96]	[2.45]	[0.07]	[0.20]
Log (Median Income)	0.452**	0.0271	0.479**	0.209
	[2.71]	[0.13]	[2.33]	[1.05]
Log (Inv. Subsidies per capita)	0.0275***	0.0331***	0.337***	0.342***
	[3.30]	[3.55]	[25.78]	[25.56]
Log (Total Area)	-0.00537	-0.0577***	0.0825*	0.00705
	[-0.15]	[-2.67]	[1.85]	[0.30]
% Higher education	-0.00710*	-0.00607	-0.00634*	-0.00653*
	[-2.44]	[-1.78]	[-1.87]	[-1.95]
Log (Municipal Population)	0.0459	0.109***	-0.0264	0.0566***
	[1.13]	[4.53]	[-0.53]	[2.40]
% pop more than 65	0.00245	-0.00121	-0.00178	-0.00400
	[0.92]	[-0.38]	[-0.56]	[-1.11]
% pop between 0 and 10	-0.00907*	-0.00705	-0.00480	-0.00239
	[-2.29]	[-1.50]	[-0.93]	[-0.42]
% pop between 11 and 17	-0.00395	-0.00837	-0.0182***	-0.0207***
	[-0.74]	[-1.53]	[-2.79]	[-3.46]
% pop between 18 and 24	0.00569	0.00614	0.00677	0.0108**
	[1.39]	[1.24]	[1.45]	[2.04]

% without a diploma	-0.00436	-0.00716*	-0.00503	-0.00733*
	[-1.42]	[-2.06]	[-1.33]	[-1.83]
Log (Inter-municipal Pop.)	0.0921***	0.103***	0.0352***	0.0481***
	[11.27]	[10.97]	[3.35]	[5.01]
Share inter-mun. cap. Spend	0.00934***	0.0104***		
	[14.09]	[12.73]		
Share inter-mun. cur. Spend			0.0157***	0.0156***
			[28.75]	[25.88]
Intercept	0.937	7.282**	-0.576	4.047
	[0.53]	[3.25]	[-0.26]	[1.93]
N	3037	3037	3037	3037
adj. R^2	0.682	0.494	0.696	0.636

t statistics in brackets. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01. Excluded perimeter is Nantes.

Table 8: Fixed Effects panel regressions of the Log of Public Expenditures per capita (Municipalities + inter-municipal group)

	Log (Current Expenditures)		**Log (Investment Expenditures)**	
	Urban Spot	Foot. of Build.	Urban Spot	Foot. of Build.
Log (Net Density)	-0.117***	-0.117***	-0.291***	-0.237**
	[-3.44]	[-2.93]	[-3.09]	[-2.39]
Avg. Dist. Between residents	0.118	0.0844	0.130	0.0513
	[1.17]	[0.93]	[0.41]	[0.17]
Urbanized Land	-0.00586***	-0.00520***	-0.00769	-0.00544
	[-4.12]	[-3.70]	[-1.85]	[-1.41]
% Employed workforce	0.00250**	0.00244**	-0.000378	-0.000542
	[3.21]	[3.14]	[-0.15]	[-0.22]
% Group Housing	0.000241	0.000187	-0.00663	-0.00676
	[0.27]	[0.21]	[-1.91]	[-1.94]
% Individual Housing	-0.000781	-0.000791	-0.00767*	-0.00768*
	[-0.95]	[-0.97]	[-2.39]	[-2.39]
% Public Housing	0.00224**	0.00224**	0.00750**	0.00751**
	[2.86]	[2.85]	[2.93]	[2.93]
% Foreigners	-0.00474*	-0.00487**	-0.00378	-0.00424
	[-2.55]	[-2.60]	[-0.76]	[-0.85]
Touristic Rate (%)	0.000192	0.000163	-0.00119	-0.00124
	[0.85]	[0.73]	[-1.85]	[-1.95]
Log (Median Income)	0.181***	0.178***	-0.0883	-0.0920
	[6.37]	[6.21]	[-0.98]	[-1.02]
Log (Subsidies per capita)	0.00405***	0.00398***	0.156***	0.156***
	[6.42]	[6.31]	[49.38]	[49.45]
% Higher education	0.00223***	0.00211**	0.00123	0.000978
	[3.40]	[3.22]	[0.58]	[0.46]
Log (Municipal Population)	-0.222***	-0.241***	-0.234*	-0.311**
	[-6.20]	[-7.10]	[-2.25]	[-3.12]
% pop more than 65	-0.000663	-0.000526	-0.00439	-0.00421
	[-0.75]	[-0.60]	[-1.58]	[-1.51]
% pop between 0 and 10	-0.000207	-0.0000651	-0.00239	-0.00211
	[-0.16]	[-0.05]	[-0.59]	[-0.52]
% pop between 11 and 17	0.00141	0.00171	-0.00466	-0.00407
	[1.08]	[1.32]	[-1.06]	[-0.92]
% pop between 18 and 24	-0.00183	-0.00151	-0.00922	-0.00873
	[-1.03]	[-0.85]	[-1.88]	[-1.78]
% without a diploma	-0.0000792	-0.000117	-0.00362*	-0.00374*
	[-0.15]	[-0.22]	[-2.03]	[-2.10]
Log (Inter-municipal Pop.)	0.0306***	0.0311***	-0.0258*	-0.0247
	[4.74]	[4.85]	[-1.99]	[-1.92]
Share inter-mun. cur. Spend	0.0125***	0.0125***		
	[48.57]	[48.54]		
Share inter-mun. cap. Spend			0.0163***	0.0162***
			[57.21]	[57.15]
Trend	0.0202***	0.0201***	0.00130	0.00102
	[19.26]	[18.94]	[0.41]	[0.32]
Intercept	5.874***	6.292***	10.10***	11.04***
	[14.99]	[16.21]	[8.14]	[8.96]
N	32592	32592	32592	32592
adj. R^2	0.604	0.604	0.251	0.251

Fixed effects Panel regressions: * p<0.1; ** p<0.05; *** p<0.01

Table 9: IV Regressions on the Log of Public Expenditures per capita (Municipalities + inter-municipal group) without the municipalities in Paris.

	Log (Current expenditures)		**Log (Capital expenditures)**	
	Urban spot	Footprint of building	Urban spot	Footprint of building
Log (Net Density)	-0.165*	-0.491***	0.0352	-0.356***
	[-1.93]	[-4.60]	[0.39]	[-2.90]
Urbanized Land	0.00122	0.00191**	0.00692***	0.00616***
	[1.04]	[2.16]	[5.19]	[5.07]
Avg. Dist. Between residents	-0.113**	-0.101***	-0.118**	-0.167***
	[-2.35]	[-2.81]	[-2.13]	[-3.87]
% Employed workforce	0.00154	0.00354	-0.000759	0.00369
	[0.46]	[1.11]	[-0.19]	[0.95]
% Group Housing	-0.00141	0.00497	-0.00166	0.00351
	[-0.22]	[0.72]	[-0.21]	[0.45]
% Individual Housing	-0.00675	-0.00225	-0.00314	-0.00114
	[-1.08]	[-0.34]	[-0.41]	[-0.15]
% Public Housing	0.0124***	0.0140***	0.00775***	0.00859***
	[9.43]	[10.63]	[5.01]	[5.30]
% Foreigners	-0.00272	-0.00312	-0.0158***	-0.0148***
	[-0.71]	[-0.77]	[-3.21]	[-2.91]
Touristic Rate (%)	0.000628***	0.000229**	0.000485***	0.000151
	[7.45]	[2.19]	[4.18]	[1.18]
Log (Median Income)	0.00179**	0.00183***	0.000256	-0.000421
	[2.33]	[2.58]	[0.29]	[-0.50]
Log (Subsidies per capita)	0.0851	0.0981	0.452***	0.288**
	[0.72]	[0.93]	[3.28]	[2.22]
% Foreigners	0.0278**	0.0248***	0.289***	0.280***
	[2.94]	[2.77]	[20.95]	[19.93]
Log (Total Land Area)	-0.00812	0.0121	0.119***	0.0855***
	[-0.27]	[0.82]	[3.73]	[4.63]
% Higher education	0.000273	0.000405	-0.00480***	-0.00396**
	[0.17]	[0.24]	[-2.46]	[-2.04]
Log (Municipal Population)	0.0695**	0.0438***	-0.0585	-0.0258
	[2.21]	[3.05]	[-1.75]	[-1.45]
% pop more than 65	0.00452	-0.00170	0.00172	-0.00203
	[1.64]	[-0.55]	[0.57]	[-0.62]
% pop between 0 and 10	-0.00859**	-0.00823**	-0.00285	-0.00206
	[-2.23]	[-2.22]	[-0.64]	[-0.46]
% pop between 11 and 17	-0.00455	-0.00798	-0.0175***	-0.0180***
	[-0.88]	[-1.62]	[-2.93]	[-3.30]
% pop between 18 and 24	-0.00854	-0.00370	0.00465	0.00924**
	[-1.77]	[-0.87]	[1.04]	[2.00]
% without a diploma	-0.00316	-0.000625	-0.00372	-0.00230
	[-1.46]	[-0.28]	[-1.51]	[-0.90]
Log (Inter-municipal Pop.)	0.106***	0.101***	0.0485***	0.0537***
	[17.73]	[19.25]	[6.71]	[8.07]
Share inter-mun. cur. Spend	0.00973***	0.00993***		
	[17.51]	[17.06]		
Share inter-mun. cap. Spend			0.0148***	0.0145***
			[32.06]	[29.70]
Intercept	5.171***	6.467***	0.00927	2.879*
	[3.70]	[4.71]	[0.01]	[1.65]
N	1841	1841	1841	1841
adj. R^2	0.756	0.745	0.741	0.728

t statistics in brackets. Coefficients of Perimeter dummies not reported for clarity. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01.

Table 10: Panel Regressions on the Current and Capital expenditures using the Hausman-Taylor (HT) approach

	Log (Current Exp.)		**Log (Investment Exp.)**	
	Urban Spot	Foot. of Build.	Urban Spot	Foot. of Build.
Log (Net Density)	-0.119***	-0.139***	-0.127	-0.224**
	[-3.51]	[-3.32]	[-1.47]	[-2.48]
Avg. Dist. Between residents	0.237**	0.199**	0.231	0.156
	[2.46]	[2.31]	[0.77]	[0.57]
Urbanized Land	-0.000123	0.000267	0.00702	0.00631
	[-0.08]	[0.18]	[1.78]	[1.64]
% Employed workforce	0.00231***	0.00226***	-0.000684	-0.000683
	[2.90]	[2.84]	[-0.27]	[-0.27]
% Group Housing	0.00124	0.00117	-0.00303	-0.00304
	[1.30]	[1.24]	[-0.91]	[-0.92]
% Individual Housing	-0.000293	-0.000317	-0.00635**	-0.00648**
	[-0.34]	[-0.37]	[-2.04]	[-2.08]
% Public Housing	0.00379***	0.00378***	0.0128***	0.0129***
	[4.66]	[4.64]	[5.02]	[5.06]
% Foreigners	-0.00373**	-0.00382**	-0.00126	-0.00104
	[-1.99]	[-2.02]	[-0.25]	[-0.20]
Touristic Rate (%)	0.000392	0.000351	-0.0000812	-0.000191
	[1.93]	[1.76]	[-0.29]	[-0.70]
Log (Median Income)	0.178***	0.173***	-0.0924	-0.107
	[6.14]	[5.92]	[-1.03]	[-1.19]
Log (Subsidies per capita)	0.00449***	0.00440***	0.158***	0.158***
	[7.10]	[6.95]	[50.34]	[50.46]
% Higher education	0.000934	0.000818	-0.00162	-0.00173
	[1.39]	[1.22]	[-0.77]	[-0.82]
Log (Municipal Population)	-0.0224	-0.0324	-0.0997	-0.0899
	[-0.75]	[-1.19]	[-1.59]	[-1.75]
% pop more than 65	0.000368	0.000554	-0.00380	-0.00352
	[0.40]	[0.61]	[-1.37]	[-1.27]
% pop between 0 and 10	-0.00344**	-0.00324**	-0.00653*	-0.00589
	[-2.63]	[-2.47]	[-1.65]	[-1.48]
% pop between 11 and 17	-0.000737	-0.000346	-0.00721	-0.00634
	[-0.56]	[-0.26]	[-1.65]	[-1.44]
% pop between 18 and 24	-0.00292	-0.00249	-0.0106**	-0.00960**
	[-1.65]	[-1.40]	[-2.18]	[-1.97]
% without a diploma	-0.000492	-0.000515	-0.00516***	-0.00512***
	[-0.90]	[-0.94]	[-2.91]	[-2.89]
Log (Inter-municipal Pop.)	0.0334***	0.0340***	-0.0162	-0.0153
	[5.10]	[5.23]	[-1.26]	[-1.20]
Share inter-mun. cur. Spend	0.0125***	0.0125***		
	[48.87]	[48.86]		
Share inter-mun. cap. Spend			0.0163***	0.0163***
			[60.27]	[60.30]
Trend	0.0169***	0.0167***	-0.00361	-0.00385
	[16.85]	[16.63]	[-1.24]	[-1.33]
Distance to the Center	-0.00442***	-0.00364***	-0.00578***	-0.00502***
	[-6.40]	[-5.37]	[-5.84]	[-5.28]
Log (Total Area)	0.0977***	0.109***	0.0775	0.0732
	[3.65]	[4.65]	[1.36]	[1.60]
Intercept	3.333***	3.755***	8.007***	8.883***
	[9.48]	[9.55]	[7.89]	[8.23]
N	32567	32567	32567	32567

t-statistics in brackets. Hausman-Taylor Estimator. All socioeconomic variables are treated as endogenous and considered to be correlated with the municipality fixed effect. Only intergovernmental subsidies per capita, the share of foreigners, the touristic rate, distance to the center of the agglomeration, log of the land area, and perimeter dummies are treated as exogenous. The standard errors are clustered at the municipality level. The following historic and soil characteristics of a municipality:

Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of roman settlement, presence of a Cassini Road, presence of a Roman road have been included as regressors $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 11: First-stage of the (IV) regressions

	Log (density)	
	Urban Spot	Footprint of building
Soil Roughness Index	-0.000969	0.0000656
	[-0.26]	[0.03]
Average Altitude	0.000368***	0.000309***
	[2.93]	[3.99]
Amplitude of altitude	0.000132	-0.0000812
	[1.23]	[-1.45]
Presence of a postal road	-0.0178	-0.0123
	[-1.52]	[-1.23]
Presence of a Roman road	0.0221*	-0.0237**
	[1.84]	[-2.13]
Presence of a Cassini road	0.0171	-0.0195*
	[1.41]	[-1.88]
Erodability Soil Class		
dumerodi1	-0.120	0.138***
	[-1.01]	[3.12]
dumerodi2	0.262***	0.0959***
	[7.30]	[3.09]
dumerodi3	-0.00866	0.0391
	[-0.35]	[1.40]
dumerodi4	0.00904	-0.0376*
	[0.39]	[-1.74]
dumerodi5	0.0283	0.0144
	[1.52]	[0.76]
Depth of rocks		
dumdr1	0.0301	-0.00795
	[1.59]	[-0.47]
dumdr2	0.165	-0.00676
	[1.43]	[-0.16]
dumdr3	-0.0498**	-0.00995
	[-2.37]	[-0.53]
dumdr4	0.0111	-0.0215
	[0.25]	[-0.40]
Hydrological Class of Soil		
dumhg1	0.0565	0.0360
	[1.58]	[1.31]
dumhg2	0.172***	0.0464**
	[5.40]	[1.97]
dumhg3	0.114***	0.0944***
	[3.37]	[3.80]
dumhg4	0.161***	0.109**
	[3.21]	[2.32]
dumhg5	-0.130	0.305
	[-0.33]	[0.81]
Historic Populations		
Log (Pop 1793-1850)	-0.0234	-0.0212
	[-1.16]	[-1.32]
Log (Pop 1851-1880)	-0.124***	-0.0408
	[-3.32]	[-1.32]
Log (Pop 1881-1913)	0.158***	0.0744***
	[5.37]	[2.91]
Intercept	5.919***	4.722***
	[4.86]	[3.86]

Number of observations	3037	3037
Adj. R-squared	0.871	0.686
Partial R-squared	0.0640	0.0411
Robust F-statistic	11.653***	6.915***
Hansen's J (overid)	122.869***	94.8378***

t-statistics in brackets. Only the estimates of the instruments are reported for simplicity of output. All exogenous variables of the second stage equation included in this first-stage regression. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 12: Summary statistics of main variables

Variable	Description		Mean	Std. Dev.	Min	Max
Depftctot	Current expenditure per capita (euros)	overall	1003.064	542.7985	207.6271	12540.9
		between		499.2563		
		within		224.394		
Depinvtot	Capital expenditure per capita (euros)	overall	674.7507	809.7131	0	65336.87
		between		523.4832		
		within		634.2549		
Denspopemp_m2	Net Density (Footprint of buildings hbt per ha)	overall	166.5731	100.4895	5.420657	1299.832
		between		99.70671		
		within		12.63332		
Denspopemp_m1	Net Density (Urban Spot hbt per ha)	overall	30.66094	45.71802	1.712202	833.3929
		between		45.68489		
		within		1.901221		
Pop_epci	Inter-municipal Population (hbt)	overall	146552	305695.5	85	1370678
		between		264538.1		
		within		40006.94		
Pbattot1	Urbanized Land (ha)	overall	16.77139	17.94958	0.0931506	82.89821
		between		17.92599		
		within		0.9677475		
Distmoy_popempn_m1	Average Distance Between residents (meters)	overall	0.6411801	0.2108921	0.0588271	2.117328
		between		0.2104354		
		within		0.0143125		
Actoccup1564	% Employed workforce	overall	91.40919	3.447992	67.8266	101.7391
		between		2.991041		
		within		1.715678		
Collectif	% Group Housing	overall	16.42101	21.25923	0	97.72388
		between		21.01422		
		within		3.226332		
Maison	% Individual Housing	overall	80.56959	21.39056	0.8323511	104.7554
		between		20.90128		
		within		4.554569		
HLM	% Public Housing	overall	5.961313	9.971879	0	77.68066

		between		9.892437		
		within		1.260661		
Etranger	% Foreigners	overall	3.720794	3.892457	0	37.40702
		between		3.782274		
		within		0.9208291		
Sup	% population with a Higher education	overall	22.63664	10.45466	1.058201	70.41847
		between		8.783316		
		within		5.671895		
Pmun	Municipal population (hbt)	overall	6573.837	44760.99	24	2249975
		between		44748.02		
		within		1319.989		
Pop65p	Share of population older than 65	overall	13.80506	4.727214	0	52.87664
		between		4.304822		
		within		1.956135		
Pop1824	Share of population between the ages 18-24	overall	7.540777	2.155723	0	38.75361
		between		1.765616		
		within		1.237024		
Diplmin	% population with no degree	overall	35.67025	10.64537	6.187291	81.86985
		between		7.373399	12.99165	62.56619
		within		7.678926	-15.97102	73.34005
Mutdepfonc	Share of capital expenditures in inter-municipal capital expenditures (%)	overall	23.27501	14.99851	0	72.208
		between		13.00897	0	57.72988
		within		7.429245	-23.02557	64.99569
Mutdepinv	Share of current expenditures in inter-municipal current expenditures (%)	overall	26.58341	21.92151	0	95.72342
		between		18.2941	0	83.77358
		within		12.02477	-49.51746	84.66697

Table 11. IV Regressions on the Log of Public Expenditures per capita (For Municipalities only)

	Log (Current expenditures)		**Log (Capital expenditures)**	
	ldepftc	ldepftc	ldepinv	ldepinv
Log (Net Density)	-0.223***	-0.631***	0.0358	-0.400**
	[-2.92]	[-5.73]	[0.39]	[-3.04]
Urbanized Land	0.00387***	0.00490***	0.00772***	0.00652***
	[3.28]	[5.35]	[5.13]	[5.69]
Avg. Dist. Between residents	-0.185***	-0.170***	-0.0757	-0.130**
	[-4.26]	[-4.49]	[-1.47]	[-3.07]
% Employed workforce	0.00219	0.00699**	0.00267	0.00995**
	[0.64]	[1.98]	[0.62]	[2.19]
% Group Housing	0.0110***	0.0168***	-0.00178	0.00313
	[2.65]	[2.91]	[-0.40]	[0.53]
% Individual Housing	0.00442	0.00670	-0.00445	-0.00398
	[1.14]	[1.23]	[-1.11]	[-0.75]
% Public Housing	0.0107***	0.0126***	0.00166	0.00261
	[9.54]	[10.75]	[1.16]	[1.73]
% Foreigners	0.00479	0.00698**	0.00695*	0.00957**
	[1.60]	[2.28]	[1.73]	[2.37]
Touristic Rate (%)	0.000923***	0.000310**	0.000549***	0.0000529
	[8.17]	[2.41]	[4.16]	[0.37]
Log (Median Income)	0.000804	0.00186***	-0.000906	-0.000564
	[1.59]	[3.50]	[-1.47]	[-0.87]
Log (Subsidies per capita)	0.154	0.147	0.489***	0.369***
	[1.48]	[1.41]	[3.61]	[2.80]
% Foreigners	0.0442***	0.0403***	0.454***	0.457***
	[4.87]	[4.50]	[30.47]	[31.00]
Log (Total Land Area)	-0.00207	0.0114	0.127***	0.0719***
	[-0.07]	[0.66]	[3.42]	[3.50]
% Higher education	-0.00319*	-0.00263	-0.00424**	-0.00348
	[-1.91]	[-1.54]	[-2.02]	[-1.61]
Log (Municipal Population)	0.0856**	0.0607***	-0.0402	0.0119
	[2.69]	[3.69]	[-1.02]	[0.59]
% pop more than 65	0.00243	-0.000932	-0.00160	-0.00465
	[0.88]	[-0.31]	[-0.49]	[-1.37]
% pop between 0 and 10	-0.00400	0.000607	-0.000486	0.00164
	[-1.00]	[0.14]	[-0.10]	[0.31]
% pop between 11 and 17	-0.00603	-0.00656	-0.0157**	-0.0179***
	[-1.10]	[-1.25]	[-2.42]	[-2.82]
% pop between 18 and 24	0.0107**	0.0139***	0.0147**	0.0175***
	[2.28]	[2.95]	[3.14]	[3.51]
% without a diploma	-0.00325	-0.00167	0.000671	0.00182
	[-1.39]	[-0.71]	[0.21]	[0.56]
Log (Inter-municipal Pop.)	0.0511***	0.0461***	0.0171**	0.0195***
	[8.32]	[7.71]	[2.25]	[2.71]
Share inter-mun. cur. Spend	-0.00615***	-0.00605***		
	[-11.34]	[-9.72]		
Share inter-mun. cap. Spend			-0.00288***	-0.00278***
			[-4.27]	[-3.96]
Intercept	3.852***	5.741***	-1.222	1.283
	[3.31]	[4.53]	[-0.83]	[0.83]
N	3037	3037	3037	3037
adj. R^2	0.603	0.555	0.565	0.542

t statistics in brackets. Coefficients of Perimeter dummies not reported for clarity. Instrumental variables include the following historic and soil characteristics of a municipality: Average altitude, the amplitude of altitudes, Soil Roughness Index, Depth of Rocks, Hydrologic Class of the soil, Erodability Class of the soil, presence of roman settlement, presence of a Cassini Road, presence of a Roman road, and Populations in 1783, 1850 and 1885. Regressions based on averages (Between) over the period 2003-2015. Standard errors generated by Bootstrap and are robust to heteroscedasticity. $^{*}p$<0,01, $^{**}p$<0,05 et $^{***}p$<0,01.

Appendix B: Figures

Figure 1: Perimeters of analysis

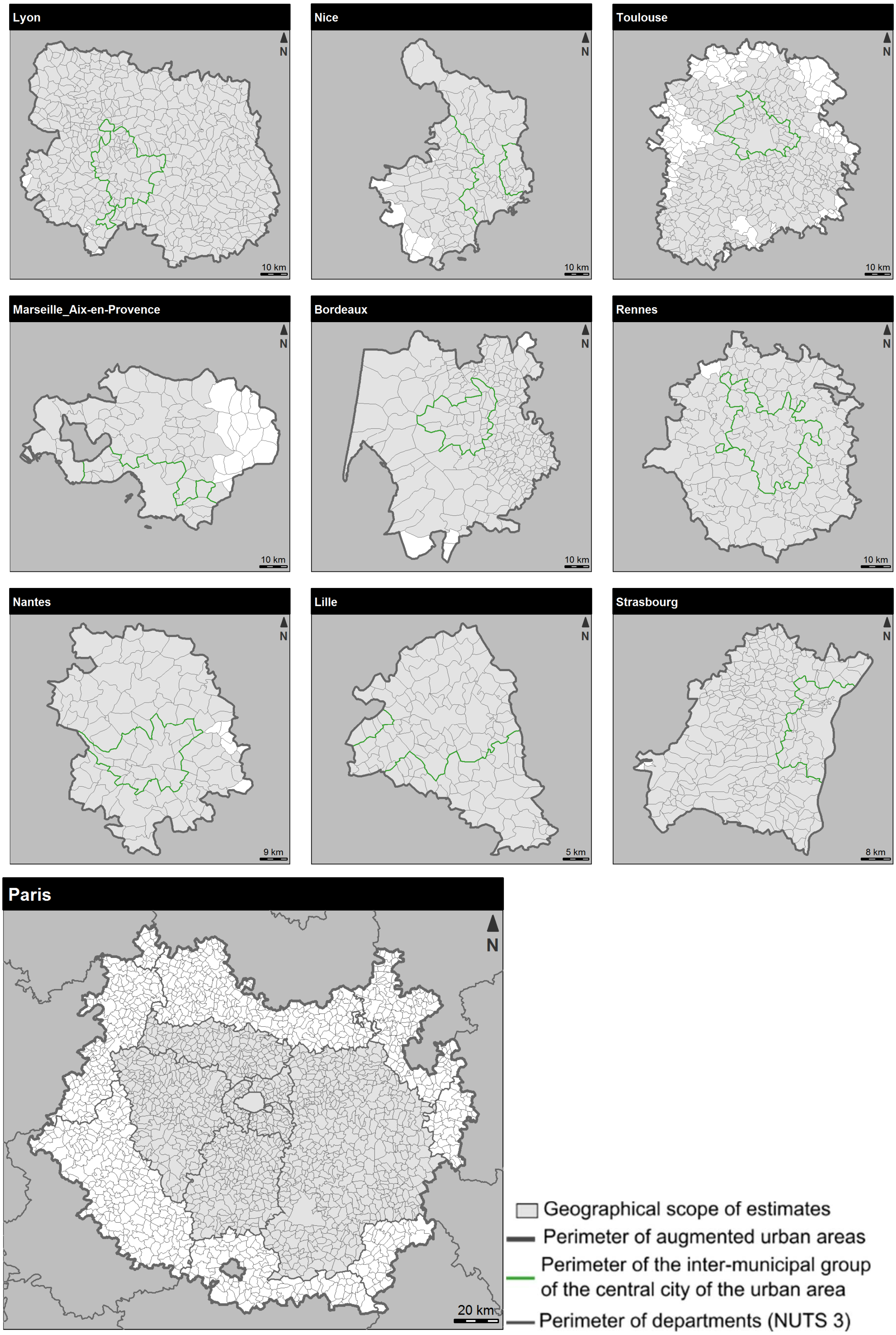


Figure 2: Impact of density on Current expenditures

a) Urban Spot b) Footprint of buildings

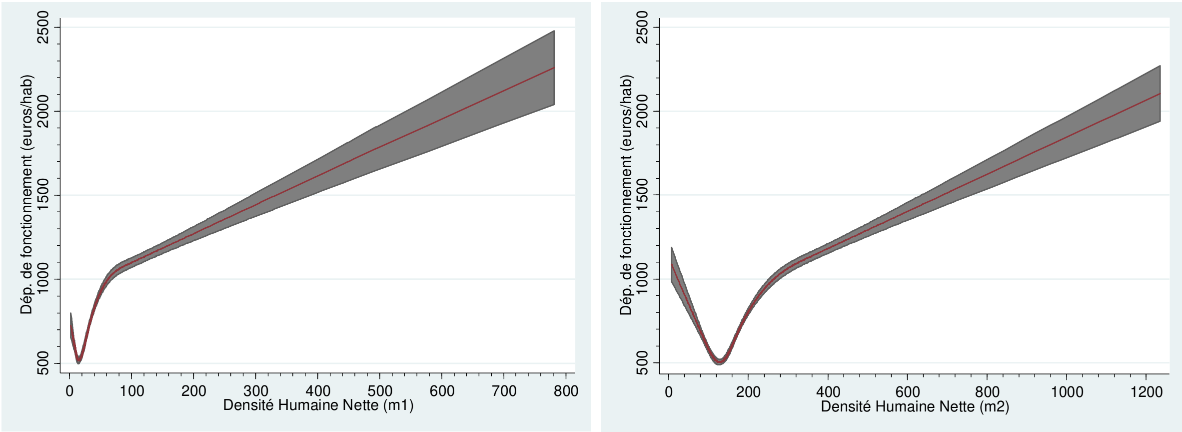


Figure 3: Impact of density on Capital expenditures

a) Urban Spot b) Footprint of buildings

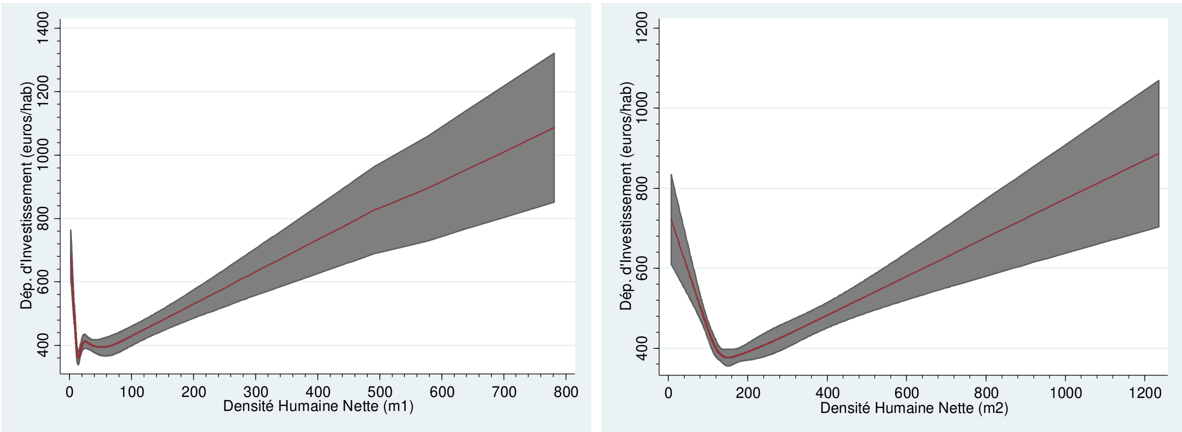
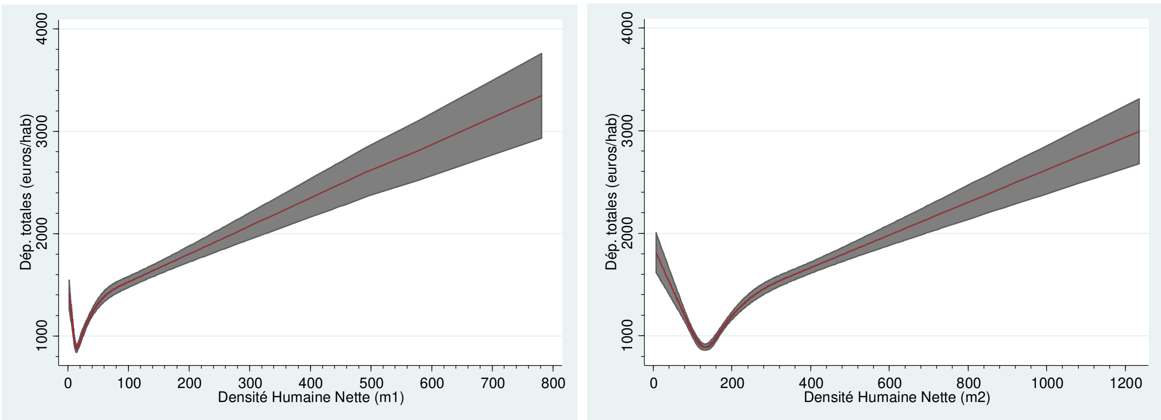


Figure 4: Impact of density on total expenditures

a) Urban Spot b) Footprint of buildings



References

Bailly E. (1996) Position de recherche sur une méthode de détermination d'un contour urbain, *Cybergeo*, 10(2235), DOI: 10.4000/cybergeo.2235

Bastida F., Guillamón M.-D. and Benito B. (2013) Municipal spending in Spain: spatial approach, *Journal of Urban Planning and Development*, 139(2), pp. 79-93.

Benito B., Bastida F. and Guillamón M.-D. (2010) Urban sprawl and the cost of public services: an evaluation of Spanish local governments, *Lex localis-Journal of Local Self-Government*, 8(3), pp. 245-264.

Bertaud A. and Malpezzi S. (2003) The spatial distribution of population in 48 world cities : Implications for economies in transition », http://alain-bertaud.com/AB_Files/Spatia_%20Distribution_of_Pop_%2050_%20Cities.pdf

Breuillé M.-L., Grivault C., Le Goix R. and Le Gallo J. (2019) Impact de la densification sur les coûts des infrastructures et services publics, Revue économique, forthcoming.

Carruthers J.I. and Ulfarsson G.F. (2002) Fragmentation and sprawl: Evidence from interregional analysis, *Growth and change*, 33(3), pp. 312-340.

Carruthers J.I. and Ulfarsson G.F. (2003) Urban sprawl and the cost of public services, *Environment and Planning B: Planning and Design*, 30(4), pp. 503-522.

Carruthers J.I. and Ulfarsson G.F. (2008) Does smart growth'matter to public finance? *Urban Studies*, 45(9), pp. 1791-1823.

Cirilli A. and Veneri P. (2009) Spatial structure and mobility patterns: Towards a taxonomy of the Italian urban system, *Rivista Di Economia et Statistica Del Territorio*, 1, p. 41.

Combes P.-P., Duranton G., Gobillon L. and Roux S. (2010). Estimating agglomeration economies with history, geology, and worker effects. In *Agglomeration economics*, pp. 15-66: University of Chicago Press.

Derycke P.H. (1979) *Economie et planification urbaines. 1. L'espace urbain*, Paris : Presses Universitaires de France, 412 p.

Duranton G. and Turner M.A. (2012), Urban growth and transportation, *Review of Economic Studies*, 79(4), pp. 1407-1440.

Frankhauser P. (1994) *La fractalité des structures urbaines*, Paris : Anthropos, 291 p.

Fregolent L. and Tonin S. (2016) Local public spending and urban sprawl: Analysis of this relationship in the Veneto region of Italy, *Journal of Urban Planning and Development* 142(3).

Garcia-López M.À., Holl A. and Viladecans-Marsal E. (2015) Suburbanization and highways in Spain when the Romans and the Bourbons still shape its cities, *Journal of Urban Economics*, 85, pp. 52-67.

Garcia-López M.À., Hémet C. and Viladecans-Marsal E (2017). How does transportation shape intrametropolitan growth? An answer from the regional express rail, *Journal of Regional Science* 57(5), pp. 758-780.

Goodchild M. and Janelle D. (2004) *Spatially Integrated Social Science*. Oxford; New York: Oxford University Press.

Goodman C. (2017) The fiscal impacts of urban sprawl: Evidence from US county areas, available at SSRN: https://ssrn.com/abstract=1944994

Grasland C. (2009) Spatial analysis of social facts. A tentative theoretical framework derived from Tobler's first law of geography and Blau's multilevel structural theory of society, in: F. Bavaud et C. Mager (Eds) *Handbook of Quantitative Geography*, pp. 46: University of Lausanne.

Guelton S. and Navarre F. (2010), Les coûts de l'étalement urbain : urbanisation et comptes publics locaux, *Flux*, 1, pp. 34-53.

Guengant A. (2005), Des coûts d'urbanisation aux coûts de congestion des services publics locaux », in: Les nouvelles frontières de l'économie urbaine, pp. 88-100, Editions de l'Aube.

Guérois M. (2003) *Les formes des villes européennes vues du ciel. Une contribution de l'image CORINE Land cover à la comparaison morphologique des grandes villes d'Europe occidentale*: Thèse Université Panthéon-Sorbonne - Paris I, (2003-12-16), https://tel.archives-ouvertes.fr/tel-00004303.

Haggett P. (1973) *L'Analyse spatiale en géographie humaine*, Paris : A. Colin, 390 p.

Hastie T. and Tibshirani R. (1990) *Generalized additive models*, John Wiley & Sons, Inc.

Holcombe R.G. and Williams D.W. (2008) The impact of population density on municipal government expenditures, *Public Finance Review*, 36(3), pp. 359-373.

Hortas-Rico M. and Solé-Ollé A. (2010) Does urban sprawl increase the costs of providing local public services? Evidence from Spanish municipalities, *Urban Studies*, 47(7), pp. 1513-1540.

Ihlanfeldt K. and Willardsen K. (2017) Local public services costs and the geography of development: Evidence from Florida counties, *Journal of Regional Science*, à paraître, DOI:10.1111/jors.12333

Ladd H.F. (1992) Population growth, density and the costs of providing public services, *Urban Studies*, 29(2), pp. 273-295.

Ladd H.F. (1994) Fiscal impacts of local population growth: A conceptual and empirical analysis, *Regional Science and Urban Economics*, 24(6), pp. 661-686.

Le Néchet F. (2015) De la forme urbaine à la structure métropolitaine : une typologie de la configuration interne des densités pour les principales métropoles européennes de l'Audit Urbain, *Cybergeo : European Journal of Geography* [En ligne], 709, DOI : 10.4000/cybergeo.26753

Lieske S., McLeod D. and Coupal R. (2015) Infrastructure development, residential growth and impacts on public service expenditure, *Applied Spatial Analysis and Policy,* 8(2), pp. 113-130.

Lieske S., McLeod D., Coupal R. and Srivastava S. (2012) Determining the relationship between urban form and the costs of public services, *Environment and Planning B: Planning and Design,* 39(1), pp. 155-173.

Loriot P. (2008) *Etude expérimentale : détermination d'un MOS et calcul d'une tache urbaine à partir de la BD TOPO® d'IGN*. Rapport technique, CERTU.

McMillen D.P. (2001) Nonparametric employment subcenter identification, *Journal of Urban economics*, 50(3), pp. 448-473.

McMillen D.P. (2003) Identifying sub-centres using contiguity matrices, *Urban Studies*, 40(1), pp. 57-69.

Morlet O. (2001) Coûts-avantages des basses densités résidentielles: état des lieux, Rapport de l'Adef.

Schwarz N. (2010) Urban Form revisited-Selecting indicators for characterising European cities, *Landscape and Urban Planning*, 96(1), pp. 29-47.

Solé-Ollé A. and Bosch N. (2005) On the relationship between authority size and the costs of providing local services: lessons for the design of intergovernmental transfers in Spain. *Public Finance Review* 33(3), pp. 343–384.

Southworth M. and Owens P.O. (1993) The evolving metropolis: Studies of community neighborhood and street form at the urban edge, *Journal of American Planning Association*, 59(3), pp. 271-287.

Wassmer R.(2008) Causes of urban sprawl in the United States: auto reliance as compared to natural evolution, flight from blight, and local revenue reliance, *Journal of Policy Analysis and Management*, 27(3), pp. 536-555.

Weber C. (2001) Remote sensing data used for urban agglomeration delimitation », in Donnay, Barnsley, Longley (dir.), *Remote Sensing and Urban Analysis,* London and New York: Taylor and Francis, pp. 155-171.