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DOES URBAN SPRAWL INCREASE THE COSTS OF PROVIDING LOCALPUBLIC SERVICES? EVIDENCE FROM SPANISH MUNICIPALITIES

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CENTRE DE RECERCA EN FEDERALISME FISCAL I ECONOMIA REGIONAL

DOES URBAN SPRAWL INCREASE THE COSTS OF PROVIDING LOCALPUBLIC SERVICES? EVIDENCE FROM SPANISH MUNICIPALITIES[a,b]

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ABSTRACT: This paper examines the impact of urban sprawl, a phenomenon of particular interest in Spain, which is currently experiencing this process of rapid, low-density urban expansion. Many adverse consequences are attributed to urban sprawl (e.g., traffic congestion, air pollution and social segregation), though here we are concerned primarily with the rising costs of providing local public services. Our initial aim is to develop an accurate measure of urban sprawl so that we might empirically test its impact on municipal budgets. Then, we undertake an empirical analysis using a cross-sectional data set of 2,500 Spanish municipalities for the year 2003 and a piecewise linear function to account for the potentially nonlinear relationship between sprawl and local costs. The estimations derived from the expenditure equations for both aggregate and six disaggregated spending categories indicate that low-density development patterns lead to greater provision costs of local public services.

Keywords: Urban sprawl, local public spending.
JEL Codes: H1, H72, R51.

RESUMEN: En el presente trabajo se analiza el impacto de la dispersión urbana, un fenómeno de especial interés en España, donde destaca la rapidez con la que este proceso de desarrollo urbano de baja densidad esta teniendo lugar actualmente. A pesar de la diversidad de consecuencias atribuidas a la dispersión urbana (tales como congestión del tráfico, contaminación o segregación social), aquí nos centramos en analizar el incremento en el coste de provisión de los servicios públicos locales. Con este objetivo, en primer lugar definimos una medida precisa de dispersión urbana que nos permita analizar empíricamente su impacto sobre los presupuestos municipales. En segundo lugar, llevamos a cabo un análisis empírico con datos de corte transversal para 2.500 municipios españoles referidos al año 2003 y una función lineal por tramos que recoge la posible relación no lineal existente entre la dispersión urbana y los costes. Las estimaciones obtenidas para las ecuaciones de gasto tanto a nivel agregado como para las seis categorías de gasto consideradas muestran que los desarrollos urbanos de baja densidad incrementan el coste de provisión de los servicios públicos locales.

Palabras clave: Dispersión urbana, gasto público local.
Clasificación JEL: H1, H72, R51.

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1. Introduction

In recent years Europe has been involved in a far-reaching process of land use change. Its former compact, vertical pattern of urban growth has been replaced by a horizontal pattern, characterized by a rapid, low-density outward expansion, known as urban sprawl. This new urban development model, exclusive to U.S. cities since the beginning of the 20th century, has now become part of the European landscape. A recent report published by the European Environment Agency (EEA, 2006) asserts that the urbanized land consumed per person during the last 20 years has more than doubled. Specifically, during this period the extent of built-up areas has increased by 20%, while the population has grown by only 6%. Besides, as available data show, the situation acquires particular importance in the southern regions of the continent, with Spain being no exception. According to data provided by the aerial photographs of the *Corine Land Cover* project (Ministerio de Fomento, 2006), between 1987 and 2000 Spain's artificial land area grew by 29.5%, roughly one third of its overall historical record. Similarly, data from the Spanish Property Assessment Office reveal that developed land increased by an additional 11.5% during the period 2000-2004. Moreover, most of this development took the form of low density urban growth (up by 30% during the 1987-2000 period) and scattered growth (up by 26%), while the area undergoing compact development increased by a meagre 4.1%[1].

Urban sprawl has thus become a matter for concern, not only because of the intensity of the process but also because of its great environmental, social and economic impact. An increase in commuting due to the more scattered nature of urban areas also exacerbates traffic congestion and, in turn, air pollution (Sierra Club, 1998; Brueckner 2001; Glaeser and Khan, 2003). Excessive land conversion to urban use diminishes the extent of farmland and forests, which represents a loss of the amenity benefits from open space (Sierra Club, 1998). The claim is also made that urban sprawl reduces social interaction and contributes to socioeconomic segregation between the rich of the suburbs and the poor of the inner cities (Downs, 1999; Brueckner, 2000, 2001; Glaeser and Khan, 2003). Then, several poverty-related problems arise in low-income neighbourhoods, such as increasing crime rates, poor-quality public services and lack of fiscal resources. However, among the many consequences already mentioned the impact on municipal finances is perhaps the most relevant. Although many factors have an influence on the amount, allocation and distribution of local public spending, there is a growing conviction that urban spatial structure is gaining in importance. Low-density expansion increases the costs of providing local public services. Major investments are required to extend the highway network,

[1] The area devoted to transport infrastructure and to industrial and commercial uses also increased considerably during the period: 150 and 60%, respectively (Ministerio de Fomento, 2006).

and water, electricity or sewer lines to a relatively small number of residents (see., e.g., Carruthers, 2002). Likewise, as a result of the greater dispersion of population in the municipality, such districts fail to capitalize on economies of scale and optimise on facility location of several public services, including public education, police protection or public transportation (Carruthers and Ulfarsson, 2006).

Thus, the aim of this paper is to determine empirically the impact of urban sprawl on the costs of providing local public services. Specifically, we estimate a *per capita* local public spending equation both for aggregate spending and for six disaggregated spending categories that intuitively should be more markedly influenced by urban sprawl: *Community Facilities, Basic Infrastructures and Transport, Local Police, Culture and Sports, Housing and Community Development* and *General Administration.* Four variables are introduced in measuring urban sprawl. The main one is a measure of density, defined as the urbanized land per person. This variable is measured at the municipal level, i.e. where the policy decisions concerning the above spending functions are taken. Note that this variable represents an improvement on that adopted in previous empirical analyses. First, the data available for Spain allow us to use the urbanized or developed area instead of the developable land area or even the total land area of the municipality[2] and, second, we are able to employ a more highly disaggregated spatial unit of analysis than that used in previous studies, which had to work with data at the county level (see Ladd 1992, 1994; Carruthers and Ulfarsson, 2002, 2003). Besides, so as to capture the relationship between this variable and the dependent variable more accurately, we use a highly flexible approach that allows our data to determine this functional form. The number of population centres and the number of residential housing units per capita, as well as the percentage of scattered population are additionally included in the model as sprawl measures. Further, we also introduce a number of control variables in the expenditure function so as to take into account the effect of different potential users, other cost factors and fiscal capacity on expenditure. Having controlled for these effects, we are then in a position to identify the specific impact of urban sprawl on local costs. In other words, we can determine whether among municipalities with the same characteristics the more sprawled ones have to deal with extra costs in providing certain local services.

While much has been written about the causes of urban sprawl, little attention has been paid to its implications, especially to its impact on local budgets. Empirical evidence regarding the fiscal consequences of sprawl is scarce and remains inconclusive (see Ladd, 1992, 1994;

[2] Developable land is defined as the total amount of land that is legally recognized as having been developed or which is available for development in each municipality. As such it includes both the built-up and the non built-up areas that are nevertheless available for construction purposes.

Carruthers and Ulfarsson, 2006). Therefore, the present study seeks to extend the empirical literature that examines the costs of urban development of this nature. Further, this is a relatively new study for the Spanish case, since the literature to date has largely focused on the American case and previous analyses conducted in Spain have not examined the effects of sprawl directly. Existing economic studies investigate the determinants of total and current local public spending in Spain (see Solé-Ollé and Bosch, 2005), and include a measure of sprawl as one of its control variables. Solé-Ollé (2001) uses more highly disaggregated measures of spending, but focuses only on the province of Barcelona. Therefore, the present study seeks to provide a more accurate measure of sprawl, as well as undertaking an analysis not only of total and current spending but also of several disaggregated expenditure functions for all of Spain's municipalities. Should our results suggest that urban sprawl is more expensive to maintain than a more compact development, this would then be a starting point for discussing the role that local and regional governments should play in regulating the outcome of this pattern of growth. In this sense, the increasing provision costs of public goods and services, as well as additional consequences related to urban sprawl, have been used by critics of this phenomenon to justify the use of growth control programs and cooperation policies among jurisdictions that promote more compact urban areas (Katz, 2002; Carruthers, 2002; Carruthers and Ulfarsson, 2003).

The article is organized as follows. In the next section we provide a brief overview of previous theoretical studies that have examined the causes and consequences of urban sprawl as well as the existing empirical studies that have analysed the impact of such sprawl on the costs of providing local public services. In the third section we explain the methodology and the data used in carrying out our empirical analysis, and we discuss the main results. Finally, in the last section, we conclude.

2. Literature review

Several benefits have been attributed to urban sprawl in terms of the fulfilment of residents' preferences for larger, single-family detached housing, greater proximity to open spaces, and segregation from some of the problems suffered by the inner city such as pollution, crime and congestion. Nonetheless, these benefits can be offset by a wide variety of social costs, including traffic congestion, air pollution and social segregation[3]. In addition to these negative

[3] For a further review of the main consequences of urban sprawl, see Mieszkowski and Mills (1993), Brueckner (2000, 2001 and 2001b), Brueckner and Kim (2003), Song and Zenou (2006), Carruthers (2002), Carruthers and Ulfarsson (2002), Glaeser and Khan (2003), McGuire and Sjoquist (2002). Besides, Gordon and Richardson (1997), Downs (1998, 1999), Burchell et al (2002), Glaeser and Khan (2003), Nechyba and Walsh (2004), Brueckner (2000, 2001), Brueckner and Largey (2006), Sierra Club (1998), Khan (2000) and Henderson and Mitra (1996), among others, also offer an explanation of the many factors that might be considered the driving force behind this phenomenon.

consequences, there is one economic impact which is of particular concern: the impact of urban sprawl on the cost-effective provision of local public services. When a city expands, its infrastructure together with certain public goods and services need to be increased to maintain a given level of public services for all its residents. Consequently, suburbanization leads to a marked increase in the provision costs of local public services, such as trash collection, police and fire protection, public transport and road cleaning services. In such cases, the lower density of individual consumers undermines economies of scale in the provision of public services, resulting in inefficient cost increases (Elis-Williams, 1987; McGuire and Sjoquist, 2002; Carruthers and Ulfarsson, 2003). Consider for instance two municipalities with the same characteristics (in terms of both size and population) but different densities. In the less dense of the two, there will be a need for more garbage trucks or, alternatively, the trucks available will have to cover longer routes in order to provide the same quality of trash collection to all its residents. Trash collection costs, as well as road cleaning or police protection costs, vary directly with distance. Therefore, the provision of such services is more expensive in less dense municipalities. Spatially expansive development patterns also lead to greater costs because of the larger investments required in extending basic infrastructure (roadways, sewerage, electricity) over greater distances to reach relatively fewer numbers of residents (Carruthers, 2002).

The empirical literature that examines the impact of urban sprawl on the provision costs of local public services and on local budgets in general is relatively scarce and focuses primarily on U.S. cities. This research, moreover, does not always lead to the same conclusions and so we can make no claims as to the presence of a causal relationship between urban sprawl and the provision costs of certain public goods and services. In fact, this relationship remains ambiguous and controversial[4].

Several studies have analysed the effect of different development patterns (urban sprawl versus compact development) on the provision costs of public services using cost simulation models (see Burchell and Mukherji, 2003; Speir and Stephenson, 2002). Other studies have adopted an alternative approach based on econometric techniques in order to analyse the relationship between *per capita* local spending and various density measures, while controlling for other

[4] Note that part of this ambiguity is due to a lack of a consensus in the accepted definition of sprawl (Ewing, 1997; McGuire and Sjoquist, 2002; Carruthers and Ulfarsson, 2003; Muñiz et al, 2006). Thus, sometimes it is defined as a cause of an externality (Sierra Club, 1998, 2000; Downs, 1999), as the consequence of particular land use practices (Downs, 1998, 1999; Burchell et al, 1998; Ewing 1997; Glaeser and Khan (2003) or it is associated with different patterns of development (Nelson et al, 1999; Pendall, 1999). However, as noted in Galster et al (2001), a clearer conceptual and operational definition would be useful for research purposes. If sprawl is a concept that describes a process that occurs within an urban area, it should include objective conditions based on the morphology of the landscape, which should enable it to be measured empirically (Muñiz et al, 2006).

public spending determinants (see Carruthers and Ulfarsson, 2003, 2006). All of these studies provide evidence of the positive impact of urban sprawl on the provision costs of certain local public services. However, we also find contradictory findings regarding the impact of urban sprawl on local public finance (Ladd and Yinger, 1989; Ladd 1992, 1994). These authors find that costs rise with high densities, and they attribute this result to social factors, as poverty or crime. But this means that once the researcher has appropriately controlled for these environmental factors, the results should say that sprawl raises costs. This also suggest therefore that both views might be correct, the relationship between sprawl and costs being possibly non-linear. The approach followed will take this into account. Finally, empirical studies conducted in Spain, in common with the studies cited above, do not analyse urban sprawl directly, but rather their main objective is to analyse the determinants of local public spending. However, they do provide some indirect evidence as their demand functions include explanatory variables that proxy urban sprawl (see Solé-Ollé, 2001 and Solé-Ollé and Bosch, 2005).

Given that the empirical evidence available remains poor and, to some extent, controversial, we believe a study of the Spanish case makes an interesting complement to the existing literature. In the section that follows we outline the methodology used in carrying out our study and describe the variables included in the model and the sources used in constructing them.

3. Empirical analysis

3.1 The model

The analysis proposed here requires the estimation of a very similar demand model to that commonly used in the extensive literature on local public spending. This enables us to separate the effects of urban sprawl on local costs from those of other factors[5]. In such models, the desired level of *per capita* spending is specified as a function of the demand for public services and their provision costs. Therefore, the estimated expenditure function results from combining a cost and a demand model. Below, and in line with the research developed by Borcheding and Deacon (1972), we specify the empirical model used in analysing the determinants of local public spending.

The cost model. The starting point is the cost model, where the outcome of local public services (q), understood as a measure of the quantity/quality of services enjoyed by the citizen, depends

[5] Ladd (1992, 1994), Solé-Ollé (2001) and Solé-Ollé and Bosch (2005), for example, adopt this methodology.

on the level of output or activity performed by the government (*o*), urban sprawl (*d*) and a group of environmental cost factors (*z*):

$$q = \frac{o}{f(d) \cdot h(z)} \tag{1}$$

In the case of the production technology of local public services, we assume that the output (*o*) is produced under constant returns to scale, so that the cost function to produce this output, given an input costs index (*w*), and an indicator that captures the level of responsibilities of each municipality (*s*) (see *Dependent variables* in Section 3.2. for an explanation), can be expressed as:

$$C(o, w, s) = o \cdot w \cdot s \tag{2}$$

Obtaining *o* from equation (1) and substituting it in (2), the output cost function (*C(o,w,s)*) can be transformed in an outcome cost function, *C*(*q,d,z,w,s*):

$$C = q \cdot f(d) \cdot h(z) \cdot w \cdot s \tag{3}$$

In order to estimate this cost function we need data on the outcome of local public services (*q*). Given that these data are not generally available, an alternative involves combining this cost model with a demand model. In so doing, we are able to obtain an expression without the outcome variable and, as such, it can be easily estimated.

The demand model. We start from an outcome demand function of public services, where the residents' desired level of outcome is negatively correlated with their share of the marginal provision cost, and positively correlated with the given resource level and their preferences.

To combine the cost model with the demand model, we use a theoretical model that describes the decision-making process of local governments. Although there is no agreement as to which model is best, the most commonly used in the literature is the model based on the median voter theorem (Bergstrom and Goodman, 1973). Unfortunately, we are unable to identify the median voter empirically, so we assume that the aim of the local government is to maximize the utility of a representative voter, given by the following expression:

$$
\begin{aligned}
&\underset{x_r q}{Max} \;\; U_r(x_r, q, v_r) \\
&s.t. \\
&x_r + t \cdot b_r = y_r; \\
&C = t \cdot B + G; \\
&C = q \cdot f(d) \cdot h(z) \cdot w \cdot s
\end{aligned}
\tag{4}
$$

where U_r is the utility function of the representative voter, which depends on the consumption of the private good (x_r), the public good outcome (q) and their preferences (v_r). Three constraints are imposed on this representative voter: first, a budgetary constraint, where t is the tax rate, b_r the voter's tax base and y_r his level of income; second, a local government budgetary constraint, where B is the total tax base of the jurisdiction and G the total amount of transfers received by the local government; and, finally, an outcome cost function (explained above in equation 3). The combination of these three constraints yields the following expression:

$$x_r + q \cdot f(d) \cdot h(z) \cdot w \cdot s \cdot \frac{b_r}{b} = y_r + g \cdot \frac{b_r}{b} \tag{5}$$

The mean tax base per head is given by $b = B/N$, and transfers received per head by $g = G/N$. So the right-hand side of expression (5) measures the overall income of the representative voter. Besides, b_r/b indicates the influence of the tax system on the representative voter's choice (tax share).

The fist order condition obtained by maximizing the utility function, subject to the constraint given in equation (5) is:

$$\frac{\partial U_r / \partial q}{\partial U_r / \partial x_r} = f(d) \cdot h(z) \cdot w \cdot s \cdot \frac{b_r}{b} \equiv p_r \tag{6}$$

where p_r denotes the tax price, which is defined as the product of the marginal cost of q ($\partial C/\partial q$) and the tax share (b_r/b).

In order to adapt this model to an easily estimable framework, we assume that the demand function is log-linear:

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

Equation (7) indicates that the level of outcome depends on the tax price, on the level of income of the representative voter and on his preferences. Substituting (6) in (7) and the result in (3), we obtain the *per capita* expenditure function:

$$c = k \cdot \left(f(d) \cdot h(z) \cdot w \cdot s\right)^{(\alpha+1)} \left(\frac{b_r}{b}\right)^{\alpha} \cdot (y_r)^{\beta} \left(1 + \frac{g}{y_r} \cdot \frac{b_r}{b}\right)^{\beta} \cdot v_r^{\gamma} \tag{8}$$

Finally, taking logs we obtain the estimable spending equation:

$$\begin{aligned} \ln c = \ln k + (\alpha+1) \cdot \ln(f(d)) + (\alpha+1) \cdot \ln h(z) + (\alpha+1) \cdot \ln w + (\alpha+1) \cdot \ln s \\ + \alpha \cdot \ln(b_r/b) + \beta \cdot \ln y_r + \beta \cdot (g/y_r)(b_r/b) + \gamma \cdot \ln v_r \end{aligned} \tag{9}$$

Therefore, *per capita* local spending depends, on the one hand, on a group of cost factors: urban development patterns, other environmental cost factors (such as population or potential users, among others), input costs and responsibilities. On the other hand, *per capita* local spending is a function of three demand factors: income, tax share and transfers received and preferences.

Note that estimated parameters cannot be interpreted in terms of their direct effect on the costs of providing public services, since the price elasticity of demand (parameter α) is involved in the specification. Cost variables increase service costs and, as a consequence, this reduces the demand for these services. Despite this, and thanks to the log-linear form assumed, it is possible to obtain the direct effect on costs by simply dividing the coefficients of the cost variables by (α+1) (Solé-Ollé and Bosch, 2005).

3.2 Data

We estimate equation (9) by employing a cross-sectional data set of the Spanish municipalities, the structure of which can be described briefly as follows. First, local governments have similar spending responsibilities to those in other countries (i.e. basic infrastructures, social promotion, public safety, community facilities or housing) with the exception of education, which corresponds to regional governments (see the Section on *Dependent Variables* below for a further explanation of the responsibilities structure). Second, there is a high degree of local fragmentation, since 90% of the approximately 8,100 existing municipalities have fewer than 5,000 inhabitants and represent just 5% of the total population. Finally, the services provided at the local level are financed mainly out of taxes (including the property tax, the local business tax and the local motor vehicle tax) and unconditional grants (roughly one third of current revenues).

Thus, the model given by equation (9) is estimated using a cross-sectional sample of 2,500 Spanish municipalities for the year 2003. Data availability has, however, forced us to reduce the size of our data set. Specifically, data regarding several explanatory variables are not available for municipalities with fewer than 1,000 inhabitants. Hence, our data set includes almost all the municipalities with more than 1,000 inhabitants. This we believe to be sufficiently representative given that they account for about 85% of the total population. Additionally, the year of study was not randomly selected but rather determined by the availability of budgetary data disaggregated by functions and sub-functions. Table 1 provides the definition, source and descriptive statistics of all the variables included in the analysis.

Urban sprawl variables. First, we shall focus on the main variables included in this study, which are those related to urban development patterns. In line with previous studies, we consider urban sprawl to be a low-density growth pattern characterized by the excessive and discontinuous spatial expansion of urban land. However, measuring this phenomenon remains somewhat elusive, with the vast majority of studies employing variants of population density to proxy urban sprawl. But, there is no agreement regarding the right specification for its measurement or its appropriateness as a sprawl measure. First, there is no consensus as to the most suitable variable for capturing density (density of housing units, population or employment), the extent of space over which density should be characterized (total or urbanized area) and the scale at which density should be measured (metropolitan area, municipality or neighbourhood) (see Gordon and Richardson, 1997 and Torrens and Alberti, 2000 for a fuller explanation). Second, as noted in Carruthers and Ulfarsson (2003), density is only part of the picture and, on occasions, it provides a somewhat ambiguous image of the urban form, telling us little about the distribution of residential uses (Galster et al, 2001). Even so, density is the most widely used indicator of sprawl because of its simplicity (Elis-Williams, 1987) and the difficulty of obtaining data for alternative measures (Carruthers and Ulfarsson, 2003).

Table 1. Definition of the variables, Descriptive Statistics and Sources

Definition	*Mean*	*St. Deviation*	*Sources*
Total spending	782.38	381.59	Spanish Ministry of Finance (*Liquidación de Presupuestos de las Entidades Locales*, 2003)
Current spending	516.75	219.36	
Local police	27.63	32.35	
Basic infrastructures and transportation	92.31	125.01	
Community facilities	79.97	69.16	
Housing and community development	123.6	133.76	
Culture and Sports	115.21	102.35	
General administration	127.98	104.71	
Current grants	223.67	99.005	
Capital grants	130.28	150.92	
Urbanized land	261.94	365.04	Property Assessment Office (*Catastro Inmobiliario Urbano. Estadísticas básicas por municipios y de parcelas urbanas*, 2003)
Residential houses	0.5371	0.2417	
% Scattered population	0.0651	0.1321	*Nomenclátor* (National Statistics Institute, 2003)
Population centres	0.002	0.0037	
Population	14583.3	79598.2	*Census of Population and Housing* (National Statistics Institute, 2001)
% Immigrants	0.0592	0.0663	
% Population < 5	0.0452	0.0138	
% Population 5-19	0.1582	0.0311	
% Population > 65	0.2028	0.0731	
% Without studies	0.1454	0.0929	
% Graduates	0.0694	0.0392	
% Unemployed	0.1467	0.1016	
% Old houses (built before 1950)	0.2471	0.1683	
% Second houses	0.1805	0.1549	
Tourists (Tourist index / population)	119.719	455.001	*Anuario Económico "La Caixa"*
Wage	25440.18	2708.62	Spanish Regional Accounts and Quarterly Survey of the Labour Market (National Statistics Office, 2003)
Central city	0.0231	0.2438	Own elaboration
Urban area	101.85	289.59	
Income	8887.76	1744.43	
Tax Share	0.6666	0.2212	Property Assessment Office, National Statistics Office, Spanish Ministry of Finance, and *Anuario Económico "La Caixa"*

Notes: Budgetary variables, wages and income measured in euros; urbanized land measured in square metres. Budgetary variables, urbanized land, residential housing, population centres and income in *per capita* terms.

One of the most common quantifiers is population density itself (Ladd and Yinger, 1989; Ladd, 1992), and this can be combined with alternative measures of sprawl (see Carruthers and Ulfarsson 2002, 2003, 2006; Glaeser and Khan, 2003), so as to provide a more realistic profile of the nature of the urban development. More recently, a number of researchers, aware that existing databases are not suitable for studying the scattered nature of development, have sought to develop more sophisticated methods (see Burchfield et al, 2006). This latest approach is without doubt of great potential, but unfortunately the data available for the Spanish case prevent us from implementing it. Thus, in the present study we employ a density variable, *urbanized land*, in *per capita* terms and measured at the municipal level.

Given that little is known about the exact nature of the relationship between this variable and the costs of providing public services, we adopt a highly flexible approach that allows the data to determine the functional form. Using a *piecewise linear function* (Ladd 1992), the relationship between *per capita* urbanized land and local costs, while controlling for other variables, is estimated as a series of linear connected segments (see Figure 1). The estimated coefficients, labelled β_1 to β_4 in the corresponding figure, indicate the slope of each segment. With a sufficiently large sample, this technique leads to a close approximation of the true functional form. In order to determine the length of each segment (labelled d_1 to d_3), various strategies might be used. In the present study we adopt the method employed by Dahlberg et al. (2006). First, we estimate equation (9) when including the urban sprawl variable (*urbanized land*). The relationship between *per capita* urbanized land and *per capita* current spending, both variables expressed in logs, is shown in Graph A of Figure 2. From the figure it seems that there is a positive and non-linear relationship between both variables in all segments but the first. Next, we estimate equation (9) leaving out the urban sprawl variable. If we have correctly controlled for the other explanatory variables, the remaining residual impact should illustrate the effect of the sprawl variable on the local costs. The relationship between the remaining residuals from equation (9) and the *per capita* urbanized land is presented in Graph B of Figure 2[6]. In general, the graphical analysis suggests a very similar performance. The vast majority of the observations are concentrated in the middle of the diagram, showing a positive relationship between the two variables, while at the extremes of the diagram there are few observations that present any great variability. Thus, two points of inflection can also be identified where the slope of the adjustment line changes (labelled here with the first and third vertical dotted lines). Given the size of the middle segment (which includes the majority of the observations in the sample), we chose to divide it in two (second dotted line). Thus, the *per capita* urbanized land is

[6] We conducted the same analysis for total spending and the four disaggregated spending functions. The graphs obtained show a very similar functional form. For reasons of space, these graphs are not included here.

divided in four segments: less than 75 m^2/pop (*urbanized land*_1), between 75 and 160 (*urbanized land*_2*)*, between 160 and 700 m^2/pop (*urbanized land*_3*)* and more than 700 m^2/pop (*urbanized land*_4)[7].

Figure 1. Piecewise linear function

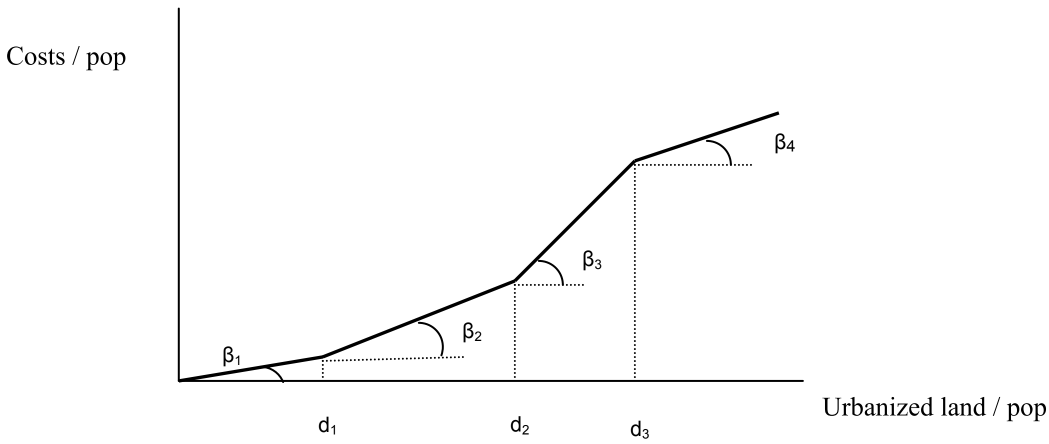
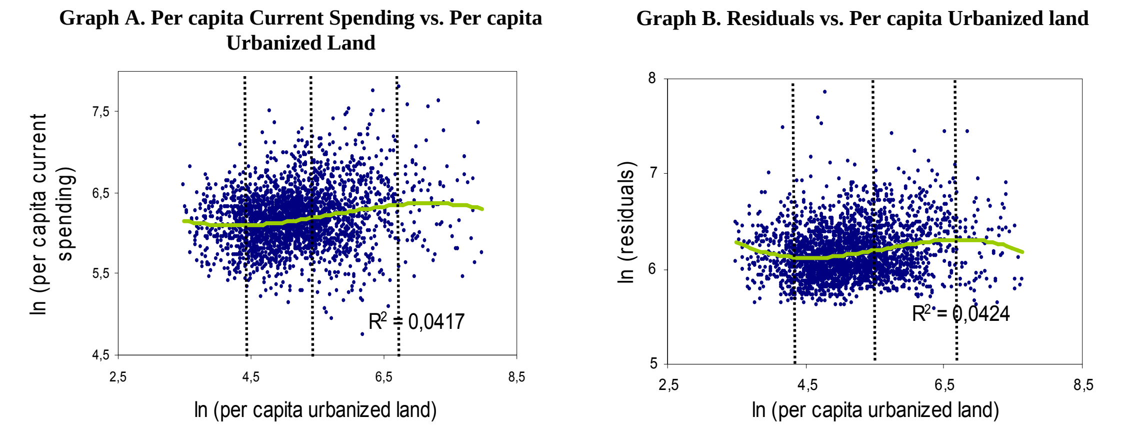


Figure 2. Scatter diagrams

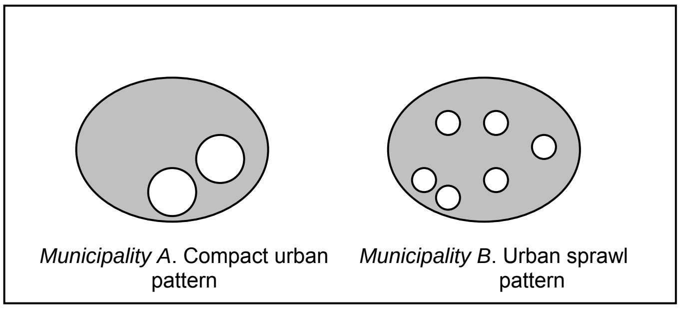


[7] The first segment includes 9% of the municipalities in the sample, the second 40%, the third 45% and the last 6%.

Although density may help to create scale economies for certain public services, it does not, as mentioned above, unilaterally describe the character of urban areas. For example, the spatial extent of the provision area is determinant for many services, since their cost of delivery varies with distance. So, in order to provide a more accurate measurement of the dimension of sprawl, taking into account its spatial dimension, we included additional sprawl variables in the model. Specifically, we added three variables: *residential houses*, *% of scattered population* and number of *population centres*[8], all measured in *per capita* terms. Their inclusion is justified on the following grounds. Suppose that only *urbanized land* is included in the model as a sprawl variable. Obviously, given two municipalities with the same population (both in terms of size and characteristics), the residents in the one with the most *per capita* urbanized land will live in the larger homes. However, little can be said about their spatial distribution, i.e., about the physical form of development. As is shown in Figure 3, a municipality with two apartment buildings (municipality A) and a municipality with six single-family houses (municipality B) will both have the same *per capita* urbanized land.

Figure 3.

Compact urban pattern vs. Urban sprawl pattern



Note: the grey area indicates the total land area of the municipality, while the white area denotes urbanized land.

So, given that *per capita* urbanized land does not capture the full extent of urban sprawl, we included the additional measures of sprawl described above. In this way, the number of *residential houses* identifies whether houses or apartment blocks are the prevalent buildings in the municipality. A predominance of single-family houses, combined with a greater *per capita* urbanized land will be related to a low-density and spatially expansive urban pattern, associated with a higher level of land consumption. Further, the *% of scattered population* and *population centres* will determine the extent to which urban growth is scattered and discontinuous.

[8] The National Statistics Institute defines *population centre* as a group of at least ten buildings which form streets, squares and other urban roads. Hence, *scattered population* refers to those people who live in buildings not included within this concept of a population centre.

Dependent variables. As explained above, the Spanish municipal sector is characterized by a high degree of fragmentation, with an extremely large number of municipalities with very small populations, resources and management capacity. Therefore, the responsibilities assumed by local governments are distributed according to the size of their populations, as is established by basic law. Specifically, public provision is compulsory for all municipalities in services such as trash collection, street cleaning services, water supply, sewer system and street lighting, among others. Municipalities with a population greater than 5,000 inhabitants, additionally, have to provide parks, public libraries, and solid waste treatment. Municipalities with a population greater than 20,000 have to provide local police and social services. Finally, municipalities with a population higher than 50,000 inhabitants also have to provide public transport and environmental protection. Further, the law provides that local governments can offer additional services to those cited above, as well as complementing the services provided by other levels of government, in areas such as education, culture, housing, health and environmental protection, in order to satisfy the demands of their residents.

In the present study we focus on those local competences that we consider to be most directly influenced by a low-density and spatially expansive urban development pattern: infrastructures and other facilities (such as sewerage, water supply or street paving and lighting, cultural and sports facilities, public parks), and certain local services (police protection, street cleaning, trash collection). In so doing, we analyse the six expenditure functions of the municipal budget that include these competences (*Basic infrastructure and transportation, Community facilities, Local police, Housing and community development, Culture and sports,* and *General administration*), which represent about 70% of total local spending[9], as well as total (*Total*) and current local spending (*Current*). In all cases, spending is measured in *per capita* terms. Unfortunately, the expenditure functions we consider do not correspond exactly with those analysed in previous studies, primarily in the U.S. (see Carruthers and Ulfarsson, 2003, 2006). The reason for this is that the structure of the municipal sector in Spain differs from that in the U.S. The two systems do not share the same municipal competences nor do they have the same expenditure composition in terms of the proportion each function represents in terms of total spending. For instance, U.S. empirical studies analyse education, which is perhaps the most important part of U.S. local spending, while in Spain it is not a sole municipal responsibility. Besides, spending on local police is lower in the Spanish case, unlike spending on housing, which is higher.

[9] The structure of the Spanish municipal budget in 2003 was as follows (percentage of total spending in parentheses): Public Debt (6.6%), General Services (13.2%), Local Police and Public Safety (7.2%), Social Promotion and Protection (10.35%), Economic Regulation (4.7%), Transfers to Public Administration (0.7%), Basic Infrastructures, Transport and Communication (9%) and Production of Social Public Goods (48.15%). This last function includes Health (1.13%), Educational Services (4.1), Housing (17.33%), Community Facilities (12.2%) and Culture (11.61%).

Control variables. Returning to equation (9), local public spending depends on both cost and demand factors. The first group of cost factors is related, as outlined above, to the urban development pattern. Additionally, we can identify cost factors other than urban sprawl, such as population, responsibilities, harshness of the environment, spillovers and input costs. In order to account for the effect of these cost factors, we include three groups of control variables in the model (demographic, social and economic cost variables). Finally, four fiscal capacity indicators account for the effect of resources on the demand for local public services[10].

First, we briefly describe the demographic cost variables. Generally, in previous studies population has been introduced as the only demographic cost factor –it being identified with the potential service users. Here, we consider an alternative approach that places resident population in one of several groups, in which they are considered as potential users presenting special needs (Solé-Ollé, 2001). Thus, we include the following variables: total population (*population*), the share of the population below the age of five (*% population*<5), between five and nineteen years old (*% population* 5-19) and older than sixty-five (*% population*>65), as well as the shares of the population without studies (*% without studies*) and those that have graduated (*% graduated*). In principle, we would expect the coefficients of these variables to be positive, so that the greater the number of potential users presenting special needs, the greater the local costs should be. Additionally, as previously mentioned, in Spain the level of responsibilities of each municipality varies with population size[11]. Consequently, the more responsibilities the municipality assumes, the higher the local public spending should be[12]. To account for this effect we add three dummies representing the different levels of responsibility (*responsibility*_1, *responsibility*_2, *responsibility*_3)[13]. These variables equal 1 if a municipality has more than 5,000, 20,000 or 50,000 inhabitants, respectively.

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[10] Given that these control variables are not the main objective of this present study, they are discussed here only in brief. See Ladd and Yinger (1989), Ladd (1992) and Solé-Ollé (2001) for a review of arguments that justify their inclusion in the local spending model.

[11] See the previous section on *Dependent Variables* for a more detailed explanation.

[12] However, many local governments tend to provide services even without any established official responsibility, but rather in response to residents' demands. Thus, the relationship between the level of responsibility and local spending might not be as evident as it might at first seem (Solé-Ollé and Bosch, 2005).

[13] These dummies are included in the *Total* and *Current* spending equations. In the four spending functions considered, dummies are not included with the exception of the *Local Police* equation, since this responsibility is compulsory for municipalities with a population higher than 20,000. The services included in the other five functions are either compulsory for all municipalities or non compulsory for any municipality, so dummies are not needed.

Second, we briefly describe the social cost factors. This group of variables controls for the effect of the harshness of the environment on local costs. Specifically the variables included are the share of residents that are immigrants (*% immigrants*), the share of residents that are unemployed (*% unemployed*) and the share of houses built before 1950 (*% old housing*). On the one hand, the first two variables are a measure of disadvantaged residents (Ladd and Yinger, 1989). Given that some services, such as health or social services, are mainly provided to this group of people, a municipality with more disadvantaged residents will spend more than other municipalities in providing the same level of these services. On the other hand, old housing is a measure of the age and, thus, of the quality of the infrastructure. Besides, this variable can provide information about the percentage of residents that live in deteriorated housing. The coefficients of the variables included are expected to affect local public spending positively, according to the results obtained in previous analyses (Solé-Ollé, 2001, Solé-Ollé and Bosch, 2005).

Third, we briefly describe the economic cost factors. To account for input costs, we include a wage variable (*wage*), measured as the ratio between total wages and salaries paid and the number of workers. Given that wage data is not available at the municipal level, we have used provincial information. We expect a positive impact of wages on costs, since the higher the salary in the private sector, the higher the salary should be in the public sector in order to attract workers.

The effect of spillovers on local public spending is measured through two dummies. First, a dummy that is equal to 1 if the municipality is a central city (*central city*), defined as provincial capitals or municipalities with a population higher than 100,000. Second, a dummy that is equal to 1 if the municipality belongs to an urban area (*urban area*), that is, if the municipality is located less than 35 kilometres from a central city. We assume that such municipalities have to bear higher costs derived from the greater mobility generated in these areas. Nevertheless, in these cases spillovers might increase also as the population surrounding these particular municipalities increases (Solé-Ollé and Bosch, 2005; Solé-Ollé, 2006). To account for this effect, these two variables are multiplied by the ratio between the population of the rest of the urban area and the population of the municipality (*central city × surrounding population*, and *urban area × surrounding population*). Additionally, we include a further two variables that account for those non-residents that can be considered potential users of local public services: the share of second homes in each municipality (*% second homes*) and the number of tourists *per capita* (*tourists*). In line with previous findings, we can expect a positive effect of these variables on *per capita* local spending (Solé-Ollé and Bosch, 2005).

Finally, the last group of control variables includes three variables that account for the effect of resources on the demand for local public services. The first variable is a measure of *per capita* income (*income*), whose coefficient (parameter β in equation (9)) is the income elasticity of demand. The second variable included is the *tax share*, defined as the tax bill of the representative resident divided by the *per capita* tax revenues of the municipality. Its coefficient refers to the price elasticity (parameter α in equation (9)) [14]. The tax bill includes two taxes, the property tax and the vehicle tax[15], and is computed as follows. On the one hand, we calculate the sum of the property tax per urban unit, which is multiplied by the average number of residential urban units *per capita* of the sample. On the other hand, we obtain the sum of the vehicle tax per vehicle and we multiply it by the average number of vehicles *per capita* in the sample. Then, we add both and divide them by the *per capita* tax revenues of the municipality. A negative coefficient of the income elasticity of demand and a positive coefficient of the price elasticity are expected.

Finally, in order to account for the transfers received by each municipality we include two per capita variables: *Current transfers* and *Capital transfers*. Both variables, according to the specification in equation (9), are divided by income and multiplied by the tax share. Transfers received by municipalities from upper tiers of government are expected to influence local spending positively.

3.3 Results

The *per capita* local public spending function, specified in equation (9), is estimated using the ordinary least squares approach. The results of *per capita* current spending are shown in Table 2. We performed four estimations using the same model (equation (9)), the only difference being the sprawl variable included each time. Thus, in Column (1) we introduced *urbanized land* per capita. In Column (2) we introduced *urbanized land*, as well as the other three sprawl measures: *residential houses*, *% of scattered population* and the number of *population centres.* In order to disaggregate the total effect of the *per capita* urbanized land in several segments, in Column (3) we included as our sprawl measure the *piecewise linear function* (see section 3.2.a): *urbanized land*_1 (< 75 m^2 / pop), *urbanized land*_2 (75 - 160 m^2/ pop), u*rbanized land*_3 (160 - 700 m^2/ pop), and *urbanized land*_4 (> 700 m^2/ pop). Finally, in Column (4), we introduced the variables of Column (3) along with the other three sprawl measures.

[14] Both income and tax share refer to the representative resident. Given that we are not able to obtain data regarding the representative voter, we have used the data for the average voter.

[15] Note that the business tax has not been included in the tax bill on the grounds that the average voter is not likely to be a business owner.

Table 2. Effects of urban sprawl on local current spending in Spain.
Cross-section for the year 2003. Sample of 2,500 municipalities (1)

	(1)	(2)	(3)	(4)
(i) *Urban development patterns*				
Urbanized land	0.0578 (6.12)***	0.0625 (6.67)***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.0896 (2.45) **	0.1456 (4.00) ***
Urbanized land_2 (75 - 160)	--	--	0.0904 (3.42) ***	0.0738 (2.85) ***
Urbanized land_3 (160 - 700)	--	--	0.0182 (0.99)	0.0311 (1.71) *
Urbanized land_4 (>7 00)	--	--	0.1402 (3.37) ***	0.1281 (3.15) ***
Residential houses	--	0.0878 (3.52)***	--	0.0879 (3.46) ***
% Scattered population	--	0.0032 (1.34)	--	0.0027 (1.12)
Population centres	--	-0.0554 (-10.62)***	--	-0.0551 (-10.51) ***
(ii) *Demographic, social and economic cost factors*				
Population	0.0187 (1.57)	0.0014 (0.12)	0.0186 (1.54)	-0.0002 (-0.02)
Responsibilities_1 (5,000 - 20,000)	0.0716 (3.78) ***	0.0685 (3.66) ***	0.0721 (3.79) ***	0.0672 (3.59) ***
Responsibilities _2 (20,000 - 50,000)	0.0829 (2.60) ***	0.0603 (1.93) **	0.0831 (2.61) ***	0.0583 (1.88) *
Responsibilities _3 (> 50,000)	0.1071 (2.28) **	0.0491 (1.06)	01112 (2.38) **	0.0514 (1.12)
% Population (< 5)	0.2125 (6.80) ***	0.1251 (3.91) ***	0.2049 (6.55) ***	0.1187 (3.70) ***
% Population (5-19)	0.0900 (1.64)	-0.0035 (-0.06)	0.0882 (1.58)	-0.0084 (-0.15)
% Population (> 65)	0.0158 (0.45)	-0.0686 (-1.90) *	0.0081 (0.23)	-0.0774 (-2.12) **
% Without studies	0.0062 (0.58)	0.0036 (0.35)	0.0034 (0.32)	0.0015 (0.14)
% Graduates	0.0421 (2.62) ***	0.0308 (2.00) **	0.0405 (2.51) **	0.0282 (1.82) *
% Unemployed	0.0003 (0.02)	-0.0096 (-0.73)	0.0001 (0.01)	-0.0090 (-0.69)
% Immigrants	0.0253 (3.73) ***	0.0239 (3.69) ***	0.0242 (3.60) ***	0.0231 (3.59) ***
% Old houses	-0.0041 (-0.50)	0.0077 (0.94)	-0.0040 (-0.48)	0.0081 (0.97)
% Second houses	0.0135 (2.72) ***	0.012 3 (2.44) **	0.0138 (2.75) ***	0.0125 (2.45) **
Tourists	0.0037 (3.07) ***	0.0048 (4.02) ***	0.0036 (3.00) ***	0.0047 (3.92) ***
Wage	0.1498 (2.33) **	0.1242 (1.93) *	0.1598 (2.45) **	0.1395 (2.16) **
Central city	-0.0057 (-0.43)	0.0020 (0.18)	-0.0041 (-0.29)	0.0036 (0.29)
Urban area	0.00001 (0.48)	0.00003 (1.26)	0.00001 (0.64)	0.00004 (1.37)
(iii) *Fiscal capacity indicators*				
Income	0.7455 (14.18) ***	0.6833 (13.34) ***	0.7516 (14.37) ***	0.6907 (13.53) ***
Tax share	-0.4581 (-18.49) ***	-0.4486 (-16.80) ***	-0.4650 (-18.39) ***	-0.4545 (-16.71) ***
Current transfers	0.1570 (18.27) ***	0.1588 (18.31) ***	0.1578 (18.23) ***	0.1600 (18.27) ***
Capital transfers	0.0238 (4.60) ***	0.0225 (4.44) ***	0.0237 (4.60) ***	0.0224 (4.42) ***
R^2	0.5351	0.5616	0.5370	0.5633
F statistic (zero slopes)	114.63 ***	111.17 ***	101.90 ***	100.06 ***

Notes: Ordinary least squares results. t statistics are shown in brackets. * Significantly different from zero at the 90 percent level; ** Significantly different from zero at the 95 percent level; *** Significantly different from zero at the 99 percent level.

The econometric specification implemented enables us to identify the specific impact of sprawl on spending, since we are able to isolate the effects of other municipal characteristics by introducing a set of control variables. In other words, we are now in a position to compare municipalities with the same characteristics in order to see if those with higher levels of sprawl have to bear higher local service provision costs. Our results indicate that *urbanized land* has a positive and significant impact on local costs - when included in the model by itself (Column 1) and also when interacting with the other three sprawl measures (Column 2) - with a coefficient around 0.06. Given that the variables are expressed in logarithms, the estimated parameters can be interpreted as the price elasticity. Then, a 1% increase in urbanized land increases local public spending by around 0.06%. However, given that the price elasticity is lower than one, the impact of sprawl on costs is greater than the impact on spending. That is, the increase in provision costs is greater than the increase in the level of public services provided. So, once the coefficient has been identified[16], a 1% increase in urbanized land increases local public spending by around 0.11%. From Columns (2) and (4) we can observe that the estimated coefficients of *residential houses* are positive, significant and of a very similar magnitude. So, if we compare two municipalities with the same characteristics and the same *per capita* urbanized land, the one presenting the more scattered distribution of housing will have to bear higher local service provision costs. However, the number of *population centres* has a negative and significant impact on local costs, showing that the higher the number of population centres, the lower public spending will be. The results obtained for this variable can be understood as follows. In a municipality with several population centres (for instance the main population centre and a number of housing developments) the local government will not respond to their demands equally. Quite the opposite, in those population centres mainly comprising second homes, the local authority will provide as few public services as possible, leading to a reduction in public spending. This occurs as second-home owners are usually non residents who are, therefore, unable to use their voting rights to control the mayor's performance in that jurisdiction[17]. Finally, the *% of scattered population* coefficient is positive but not statistically significant.

As can be seen in Column (3), when *urbanized land* is divided in four segments[18] (*piecewise linear function*), all the segments with the exception of the third are statistically significant, albeit that the coefficients present different magnitudes. The coefficients of the first, second and fourth segments are positive and significant, with the slope (and, therefore, the marginal impact on local costs) of the fourth being higher than those of the other two. Thus, we can infer that in a municipality where *urbanized land* ranges between 75 and 160 m^2/pop (median urban sprawl), a 1% increase in this variable leads to a 0.17% increase in costs, while this impact increases up

[16] As discussed in section 3.1, although the parameters cannot be interpreted as their direct effect on costs, the log-linear specification allows us to identify them simply by dividing by (α+1).

[17] Typically politicians seek to maximize the number of votes they obtain by satisfying their residents' preferences. In this context, a politician would have no incentive to respond to the public service demands of non residents.

[18] See Figure 4 for a graphical analysis.

to 0.26% when *urbanized land* is higher than 700 m^2/pop (high urban sprawl). The estimation results in Column (4) show that when the main urban variable interacts with the other three measures of sprawl, the four coefficients of the piecewise linear function become positive and significant. The greater impact of *per capita* urbanized land on costs occurs in both at the highest and lowest population densities (first and last segment, respectively). That is, this variable has a notable impact on costs in compact municipalities, as well as in those municipalities that have already undergone considerable urban sprawl and which continue to spread out. Finally, the magnitude and sign of the other three sprawl measures are the same as in Column (2).

If we now consider the control variables of the model, we see first of all that the price elasticity, identified as the estimated coefficient of the *tax share*, is around -0.45, and that the income elasticity of demand, identified as the coefficient of per capita *Income*, takes a value of 0.75. The magnitude and sign of both coefficients are in accordance with previously published results in the literature. Second, the estimated coefficient of transfers is positive and significant, and can be interpreted as follows. An additional euro of *current transfers* leads to an increase in spending fifteen times higher than that produced by one euro of income, or twice as much in the case of *capital transfers*, suggesting a strong 'flypaper effect' (se also Solé-Ollé, 2001) Third, as expected, the *responsibilities* coefficients are positive and significant, unlike the *population* coefficient, which is positive but not statistically significant. A higher level of responsibilities associated with a larger population leads to an increase in the provision costs of local public services. The share of population younger than five (*% population < 5*), the share of graduate population (*% graduated*), as well as the share of residents that are immigrants (*% immigrants*) have a positive impact on local spending, as indicated by their positive and significant coefficients. The elderly (*% population >65*) present a negative and significant coefficient in two of the four specifications. Unemployed residents (*% unemployed*) and those without studies (*% without studies*), and the share of old housing (*% old housing*) do not have a statistically significant effect on current spending. The two variables that account for spillover effects, *central city* and *urban area*, do not have a statistically significant effect, either. According to the coefficients of the *% of* s*econd houses* and the number of *Tourists*, the non-residents considered as potential users have a positive impact on local costs. Finally, *wages*, in line with the theory, lead to greater costs.

Therefore, the sign and the magnitude of estimated coefficients, as well as the explanatory capacity of the model (around 55%), are consistent with the results obtained in previous analyses of the determinants of local public spending in the Spanish case (Solé-Ollé, 2001;

Solé-Ollé and Bosch, 2005). These findings allow us to validate the empirical model used here, giving us confidence in the robustness of the results we obtained for the urban sprawl variables.

In Table 3 we show the estimation results of the urban sprawl variables for *Total spending* and the six expenditure functions[19]. In general, the results obtained for *Total spending* are analogous to those for *Current spending* (which have been explained above). We should stress, however, that here the *% of scattered population* coefficient is positive and significant. Besides, the estimation results for the control variables are very similar in all cases (that is, for total and current spending, and the five spending functions), with the exception of the *Basic infrastructures and transportation* function.

If we now consider the sprawl variables of the six spending functions, we can see in Columns (1) and (2) that the coefficient of *urbanized land* is positive and significant for all functions apart from *Housing and community development,* where it is not statistically significant. On the basis of these results, we can infer that urban development patterns have a different impact on local costs, depending on the type of public service under consideration. Thus, after identification, a 1% increase in *urbanized land* increases *Basic infrastructure and transportation* costs by 0.28%, *Community facilities* costs by 0.11%, *Local police* costs by 0.10%, *Housing and community development* costs by 0.08%, *Culture and sports* costs by 0.17% and *General administration* costs by 0.12%. This provides evidence of the additional local costs generated by the extension of roads to new housing developments. The same is true of police protection, trash collection and street cleaning services, among others. A greater degree of population dispersion undermines the use of scale economies, leading to increased costs.

Our estimation results for the other three sprawl measures are shown in Columns (2) and (4). The coefficient of *residential housing* is positive and statistically significant only in the case of two expenditure functions: *Housing and community development* and *Local police*. The number of *population centres* has a negative effect in all the expenditure functions apart from *Basic infrastructures and transportation*, where it is positive. This might indicate that the extension of roads and other infrastructure to new housing developments has a positive impact on costs, since they represent a great investment when providing a service to a relatively small number of residents. It is also important to highlight the positive and significant coefficient of the *% of scattered population* in two expenditure functions: *Community facilities* and *Local police*. In other words, municipalities with a more scattered population have to deal with higher costs as

[19] Estimation results for the control variables of the model are not included in this paper. However, they can be requested from the authors by email.

regards police protection and local services such as street cleaning, trash collection and water supply.

The piecewise linear coefficients, shown in Columns (2) and (4), are very similar for the various spending functions but differ slightly from those obtained in the total and current spending specifications. Thus, we can infer that the functional form of *urbanized land* has also changed slightly (see Figure 4). Specifically, in all the spending functions, apart from *Basic infrastructures and transportation* and *General administration*, the segment that now remains statistically significant is the last one (> 700 m^2 / pop). Therefore, the impact of a lower population density on these four spending functions increases in the municipalities presenting the highest levels of urban sprawl in contrast to those with the lowest levels. In such cases, the effect of an additional 1% of *per capita* urbanized land increases costs by between 0.33 and 0.85%. The expenditure function in *Culture and Sports* also presents a positive and significant coefficient in the second segment. The results for *Basic infrastructures and transportation* and *General administration* show that the only segment with a significant coefficient is the third (160 - 700 m^2 / pop). Thus, at this level of urban sprawl the increase in costs (0.06%) is mainly due to road construction (0.04%) and administration (0.017%) costs. Besides, these results might indicate that increases in *per capita* current spending in the first segment (per capita urbanized land lower than 75 m^2/pop) are due to services other than those included in the functions already analysed.

Table 3. Effects of urban sprawl on total spending and six expenditure functions in Spain. Cross-section for the year 2003. Sample of 2,500 municipalities. (1)

	(1)	(2)	(3)	(4)
		(i) *Total spending*		
Urbanized land	0.0564 (5.49) ***	0.0617 (6.00) ***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.0815 (1.86) *	0.1207 (2.66) ***
Urbanized land_2 (75 - 160)	--	--	0.0875 (3.04) ***	0.0788 (2.76)***
Urbanized land_3 (160 - 700)	--	--	0.0150 (0.76)	0.0268 (1.35)
Urbanized land_4 (>7 00)	--	--	0.1495 (3.02) ***	0.1393 (2.91) ***
Residential houses	--	0.0457 (1.56)	--	0.0459 (1.53)
% Scattered population	--	0.0058 (2.19) **	--	0.0054 (2.02) **
Population centres	--	-0.0485 (-8.73) ***	--	-0.0480 (-8.62) ***
		(ii) *Community facilities*		
Urbanized land	0.0643 (2.59) ***	0.0669 (2.67) ***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.1182 (1.28)	0.1030 (0.69)
Urbanized land_2 (75 - 160)	--	--	-0.0742 (-0.91)	-0.0597 (-0.73)
Urbanized land_3 (160 - 700)	--	--	0.0537 (1.06)	0.0581 (1.14)
Urbanized land_4 (>7 00)	--	--	0.2866 (3.17) ***	0.2696 (3.02) ***
Residential houses	--	0.0533 (0.97)	--	0.0531 (0.96)
% Scattered population	--	0.0209 (2.75) ***	--	0.0193 (2.52) **
Population centres	--	-0.0372 (-2.23) **	--	-0.0353 (-2.11) **
		(iii) *Basic infrastructures and transport*		
Urbanized land	0.1234 (2.73) ***	0.1228 (2.67) ***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.3472 (1.50)	0.2549 (1.08)
Urbanized land_2 (75 - 160)	--	--	-0.2503 (-1.60)	-0.2187 (-1.40)
Urbanized land_3 (160 - 700)	--	--	0.2337 (2.64) ***	0.2223 (2.51) **
Urbanized land_4 (>7 00)	--	--	0.1888 (0.94)	0.2154 (1.05)
Residential houses	--	-0.2094 (-2.73) **	--	-0.2118 (-2.75) ***
% Scattered population	--	0.0115 (0.89)	--	0.0094 (0.94)
Population centres	--	0.0542 (1.95) **	--	0.0532 (1.92) *
		(iv) *Housing and community development*		
Urbanized land	0.0339 (1.24)	0.0388 (1.41)	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	-0.1201 (-0.76)	-0.0562 (-0.35)
Urbanized land_2 (75 - 160)	--	--	0.1058 (1.11)	0.0925 (0.97)
Urbanized land_3 (160 - 700)	--	--	-0.0816 (-1.45)	-0.0690 (-1.22)
Urbanized land_4 (>7 00)	--	--	0.4103 (4.61) ***	0.3880 (4.36) ***
Residential houses	--	0.1618 (2.44) **	--	0.1616 (2.40) **
% Scattered population	--	0.0053 (0.63)	--	0.0053 (0.62)
Population centres	--	-0.0694 (-3.99) ***	--	-0.0651 (-3.73) ***

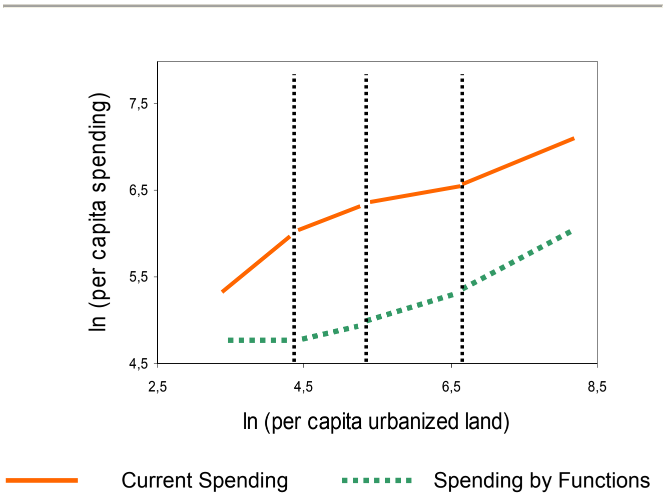
Table 3. (continued)

Variables	(1)	(2)	(3)	(4)
		(v) *Local police*		
Urbanized land	0 .0841 (2.28) **	0.0913 (2.47) **	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.0548 (0.36)	0.1367 (0.83)
Urbanized land_2 (75 - 160)	--	--	0.0317 (0.27)	0.0483 (0.42)
Urbanized land_3 (160 - 700)	--	--	0.0432 (0.53)	0.0512 (0.64)
Urbanized land_4 (>7 00)	--	--	0.3591 (2.21) **	0.3079 (1.93) *
Residential houses	--	0.3582 (3.10) ***	--	0.3568 (3.07) ***
% Scattered population	--	0.0291 (2.66) ***	--	0.0282 (2.55) **
Population centres	--	-0.1428 (-6.06) ***	--	-0.1414 (-5.95) ***
		(vi) *General administration*		
Urbanized land	0.0629 (3.43) ***	0.0724 (3.92) ***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	0.0392 (0.35)	0.1149 (1.02)
Urbanized land_2 (75 - 160)	--	--	0.0537 (0.82)	0.0390 (0.60)
Urbanized land_3 (160 - 700)	--	--	0.0725 (2.09) **	0.0912 (2.61) ***
Urbanized land_4 (>7 00)	--	--	0.0501 (0.70)	0.0395 (0.55)
Residential houses	--	0.0012 (0.03)	--	-0.0015 (-0.04)
% Scattered population	--	0.0001 (0.02)	--	0.0016 (0.03)
Population centres	--	-0.0596 (-5.02) ***	--	-0.0603 (-5.02) ***
		(vii) *Culture and sports*		
Urbanized land	0 .0671 (3.18) ***	0.0793 (3.72) ***	--	--
Piecewise linear function:				
Urbanized land_1 (< 75)	--	--	-0.0142 (-0.14)	0.0932 (0.84)
Urbanized land_2 (75 - 160)	--	--	0.2991 (4.32) ***	0.2798 (4.03) ***
Urbanized land_3 (160 - 700)	--	--	-0.0496 (-1.19)	-0.0264 (-0.62)
Urbanized land_4 (>7 00)	--	--	0.1879 (2.28) **	0.1712 (2.11) **
Residential houses	--	0.0499 (0.73)	--	0.0521 (0.75)
% Scattered population	--	-0.0015 (-0.23)	--	-0.0007 (-0.12)
Population centres	--	-0.0807 (-6.04) ***	--	-0.0794 (-5.93) ***

Notes: Ordinary least squares results. t statistics are shown in brackets. * Significantly different from zero at the 90 percent level; ** Significantly different from zero at the 95 percent level; *** Significantly different from zero at the 99 percent level.

Figure 4.

Piecewise linear function. Comparison between current spending and six disaggregated measures of public spending



Overall we can establish that these six expenditure functions account for about 81% of the total increase in costs due to urban sprawl[20]. In particular, a 1% increase in *urbanized land* raises costs by 0.11%. Twelve per cent of this increase (0.013%) is due to an increase in *Community facilities* costs, 21% to an increase in *Basic infrastructures and transportation* (0.023%), 13% to an increase in *Housing and community development* (0.014%), 6% to an increase in *Local police* (0.007%), 17% to an increase in *Culture and sports* (0.019%) and 12% to an increase in *General administration* (0.014%). In addition, the analysis of the third and last segments of the *piecewise linear function* shows that at this level of urban sprawl approximately all the increase in costs (due to urban sprawl) is attributable to the cost increases in the local services considered in this study.

Finally, we can employ this estimated impact of sprawl on local costs to simulate the situation in Spain over recent years e.g., the period 1995-2005. As shown in section 3.1, *per capita* costs depend on the level of outcome, a group of environmental cost factors and urban sprawl (see equation (3)). Assuming that both the quality of public services (q) and the environmental costs factors (z) have remained almost constant over this period, we can compute the increase in local costs that is basically attributable to urban sprawl ($f(d)$) starting from the following expression:

$$\frac{1}{N}\sum_i c_i^t = \bar{q}\cdot\frac{1}{N}\sum_i f(d_i^t)\cdot\bar{z} \qquad (10)$$

[20] This percentage has been computed from the coefficients, after identification, in Column (1) of Tables 2 and 3.

Where i indicates municipality, t year, and N is the number of municipalities. Hence, we can simulate the average increase in costs due to the impact of sprawl between 1995 and 2005 for each spending category (C_j) by computing the following ratio:

$$C_j = \frac{\frac{1}{N}\sum_i c_i^{2005}}{\frac{1}{N}\sum_i c_i^{1995}} = \frac{\frac{1}{N}\bar{q}\cdot\sum_i f(d_i^{2005})\cdot\bar{z}}{\frac{1}{N}\bar{q}\cdot\sum_i f(d_i^{1995})\cdot\bar{z}} = \frac{\frac{1}{N}\sum_i urbanized\ land_i^{2005\left(\frac{\hat{\beta}_j}{\hat{\alpha}_j+1}\right)}}{\frac{1}{N}\sum_i urbanized\ land_i^{1995\left(\frac{\hat{\beta}_j}{\hat{\alpha}_j+1}\right)}} \quad (11)$$

where $\hat{\beta}_j / \hat{\alpha}_j + 1$ is the estimated coefficient of urbanized land once correctly identified (obtained from Tables 2 and 3), i denotes the municipality, j denotes the expenditure category and N the sample size[21]. Our results indicate that between 1995 and 2005 *per capita* local costs have increased on average by 2.3% due to the impact of urban sprawl. In particular, sprawl has increased community facility costs by 2.3%, infrastructure costs by 7%, housing and local police costs by 2%, administrative costs by 2.7% and culture costs by 3.7%. However, there exists a high degree of dispersion among the sample, given that the increase in costs ranges from 1% up to 80%. More specifically, in 4% of the municipalities analysed the impact on costs is above 10%. The municipalities in which urban sprawl has had the most marked impact on budget levels are mainly those that presented a *per capita* urbanized land below the average level for 1995 and which faced a higher growth rate in terms of the amount of land developed in the period under analysis.

4. Conclusions

Urban development patterns have undergone notable changes in Spain in recent years with the adoption of the spatially expansive and scattered urban growth model of urban sprawl. One of the main consequences of this phenomenon is widely thought to be the increasing costs of providing local public services.

Given that previous empirical analyses designed to test this hypothesis are scarce –and where they do exist they focus primarily on the U.S. case–, we believe that this study of the situation in Spain can make a significant contribution to the existing literature. Here, we have examined the influence of urban sprawl on total and current spending, as well as on the six measures of

[21] Note that for this simulation exercise we have used a much larger sample than before, given that the only variable required, *urbanized land,* is available for 7,300 of the existing 8,100 municipalities.

spending which we consider likely to be most affected by urban sprawl (*Community facilities, Basic infrastructures and transportation, Housing and community development, Local police, Culture and sports*, and *General administration*). In so doing, we have estimated eight expenditure equations with the data from 2,500 municipalities for the year 2003. Urban development patterns were first measured in terms of *urbanized land*, i.e., a measure of the amount of *per capita* built-up area within each municipality. We should stress that our data were available at the local level, that is at the very level where political decisions concerning the public services analysed here are taken. In order to account for the potentially nonlinear relationship between this variable and local costs, we assumed a *piecewise linear function*. In addition to this measure, three other variables were included in the model in an attempt at providing a more accurate measurement of the scale of urban sprawl: *residential houses*, *% of scattered population, population centres.* Finally, we included a group of control variables so as to distinguish the effects of urban sprawl on local costs from those of other cost and demand factors. In this way, once we had controlled for a set of municipal characteristics, we were then able to determine the specific impact of sprawl on costs. Our estimation results for the control variables proved to be very similar to those obtained in previous analyses, indicating the robustness of our empirical model and, more specifically, of our urban sprawl results.

In general, our estimation results indicate that low-density developments led to greater provision costs in all the spending categories considered, with the exception of *Housing*. By adopting the *piecewise linear function* assumption we were able to disaggregate this total effect, revealing that the impact on total costs accelerated at very low and very high levels of sprawl, i.e., in those locations where *per capita* urbanized land was less than 75 (compact pattern) or greater than 700 m^2/pop (urban sprawl pattern). Further, the impact of urban sprawl on the provision costs of the public services considered here was particularly marked at high levels of sprawl (*per capita* urbanized land between 160 and 700, and greater than 700 m^2/pop). These results suggest that in municipalities with a spatially expansive urban development pattern, the provision costs of public services increase initially as a result of increasing road construction costs and rising general administration costs, and then, if the urban sprawl advances further, costs continue to rise as a result of higher costs in providing community facilities, housing, local police and culture. In those municipalities with very low levels of urban sprawl (<75 m^2 / pop), the increase in local costs was due to public services other than those analysed here. The other three measures of sprawl serve to reinforce our results. The *% of scattered population* coefficient was positive and significant in *Total Spending, Community facilities* and *Local police*, and the *residential houses* coefficient in *Housing and community development* and *Local police*. *Population centres* had a negative impact on costs, except in the case of *Basic infrastructures and transportation*, where it was positive. This negative sign might indicate that local governments tend to pay scant regard to the public service demands emanating from the housing developments of non residents, given that they are unable to exert any political control over the mayor. Moreover, the simulation carried out for the period 1995-2005 showed the average increase in local costs attributable to urban sprawl to be quite low (around 2.3%) and, therefore, easily met by the local governments. However, in those municipalities where the amount of urbanized land was below the 1995 average but where urban sprawl was considerable during the period, the increase in costs was markedly higher (above 10%).

Thus, in this paper we have provided evidence of the nonlinear impact of urban sprawl on the costs of providing local public services. Further, more spatially expansive urban development patterns undermine the use of scale economies in the provision of certain public services, such as trash collection, street cleaning and public transport. The extension of basic infrastructures over longer distances to reach a relatively small number of residents leads to an inefficient increase in local costs. This increase should not perhaps be seen as a problem since it results from the specific new urban development pattern desired by the residents. In this sense, the fulfilment of their preferences might justify the higher rates of taxation needed to subsidise these increased costs. However, problems arise when new developers fail to internalise the full costs that they generate, leaving the local government to pay for them (i.e., the municipal authorities raise the taxes of all residents in the jurisdiction and ask for higher transfers from the upper tiers of government).

Finally, we should emphasise that this study simply provides evidence of the existence of higher provision costs of several local services due to urban sprawl. Hence, further research into the impact of sprawl on local revenues is needed so as to determine more accurately the net fiscal impact of this phenomenon on municipal budgets.

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