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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]

Albert Solé-Ollé, Miriam Hortas Rico[c]

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.

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2000

2000/1 - Esteller, A.; Solé, A., "Vertical Income Tax Externalities and Fiscal Interdependence: Evidence from the US"

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2001

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