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Expansionary zoning and the strategic behavior of local governments.

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Abstract. This paper analyzes the extent to which local land supply is the result of strategic interaction among nearby local governments. In a setting of limited tax instruments to raise revenues and interjurisdictional competition for mobile residents, municipal authorities are provided with the economic incentives to convert land from rural to urban uses, hence promoting urban growth. Using data on a large sample of Spanish municipalities for the period 2003-2011 and a modified Cournot-style competition model, we report evidence in support of this hypothesis. The results suggest that local incumbents do not make policy decisions in isolation, and reaction functions arise because the mobile tax base reacts to the regulatory measures that modify land uses in each municipality.

Keywords: local land supply, land use conversion, local governments, spatial econometrics, Cournot competition.

JEL codes: C21, H7, R14

INTRODUCTION

A long line of research in economics analyzes the factors that shape local land use regulation. Land regulation can influence the amount, location and shape of urban development, with a non-negligible impact on land rents and housing prices, environmental quality, transportation costs, and even labor markets (Lenon et al., 1996). Many theories have been developed to explain why regulation arises (Gyourko & Molloy, 2015), including: (i) the role of homeowners, owners of vacant land and land developers in the local political process and their incentives to either promote or restrict development, (ii) a limited supply of vacant land, resulting either from topographical constraints or previous development and (iii) zoning policies that reflect the intention of local governments to alter land use and control the amount and quality of residential development in their jurisdiction.

The literature on the causes and consequences of land use regulation is rich. Some recent examples include Evenson & Wheaton (2003), Ihlanfeldt (2004, 2007), Quigley & Rosenthal (2005), Pendall et al. (2006), Glaeser et al. (2006), Gyourko et al. (2008), Glaeser & Ward (2009), Saiz (2010), Hilber & Robert-Nicoud (2013) and Jackson, 2016. While all these papers examine land use regulations in the context of a single community in isolation, a number of papers have also investigated the use of zoning to induce sorting of individuals across communities (see, e.g., Rolleston, 1987; Calabrese et al. 2007). A few empirical papers have expanded this model of regulation to consider population flows across jurisdictions, so that the land use policies in one jurisdiction will affect the decisions in neighboring communities. Brueckner (1995) and Helsley & Strange (1995) are good examples of theoretical papers modeling land use

regulation with strategic interactions among neighboring communities. In particular, these studies model the adoption of growth controls and minimum lot sizes, respectively, to limit urban expansion. Turning to the empirical evidence on these interjurisdictional interdependencies in land use decision-making, Lenon et al. (1996) find that a zoning change in one township often leads neighboring townships to enact similar changes. Nonetheless, Brueckner (1998) is the first one using spatial econometric techniques to provide empirical evidence on the existence of policy interdependencies in the adoption of stringent growth controls. Finally, note that these studies are also related to a recent strand of the literature analyzing how the scale of the political economy process matters for urban growth (see, e.g., Ortalano-Magne & Prat, 2014 or Parkhomenko, 2018).

Thus far, however, research has focused on land use regulation as a tool to limit urban expansion. But, what happens when the population moves freely across jurisdictions that have the ability to set its own land use policy? Under which circumstances would local incumbents utilize land use policy as a tool to compete for new residents? In a Tiebout setting, where middle- and upper-income residents shop among rival nearby locations, local governments will compete to attract those mobile residents to their jurisdictions, as it translates into a broader tax base and higher tax revenues¹. This competition becomes particularly relevant in an environment where local authorities have limited fiscal capacity and a limited set of tax instruments to raise revenues. If this is the case, land use conversion becomes an important source of financing for local governments, as it has the biggest payoff when there is rapid urban growth (Peterson, 2009). To the best of our knowledge, however, no attempts have been made in the literature to analyze spatial interdependencies between competing cities in

the selection of zoning policies aimed at promoting (instead of restricting) residential development.

Thus, in order to further investigate the drivers of local governments' behavior, this paper incorporates the interdependence of land use conversion among neighboring cities by means of reaction functions that show how the decision variable for a given jurisdiction depends on the choices of other jurisdictions. A given city is likely to interact with many competing cities in the housing market, and the challenge is to allow for such interaction in the empirical specification. To motivate the empirical work, we first develop a simple theoretical model, which consists of a modified 2-city Cournot model with minimum production levels, where cities are constrained to offer some fixed quantity of developed land and they can expand by converting land from rural to urban uses. Then, a spatial model is specified to empirically account for such interjurisdictional interdependencies in land use decision-making. The estimation uses data on the amount of land zoned for development in Spain during the period 2003-2011. This variable has been constructed using data that come from a new and unique database that provides detailed information on land use categories at the municipal level (Spanish Property Assessment Agency, Ministry of Economics). In addition, socio-economic, geographical and political factors are included as control variables in the model. The results report a positive and significant interaction coefficient.

The rest of the paper is organized as follows. In the next section, we provide an overview of the institutional setting for land use regulation in Spain. The third section presents a simple theoretical model from which we derive the hypothesis to be tested empirically. In the fourth section, we develop the model and describe the data, while the

main results are presented in the fifth section. Finally, the sixth section concludes.

INTERJURISDICTIONAL COMPETITION FOR MOBILE RESIDENTS

According to the Tiebout model (Tiebout, 1956), individuals are mobile across jurisdictions and choose their location according to their preferences. Middle- and high-income individuals flee from inner city problems (such as noise, pollution, or congestion) and sort themselves in nearby residential locations endowed with positive amenities, such as open space or a pleasant climate, where they can enjoy larger single-family housing units in a safer, greener and more peaceful environment. In the urban economics literature, it has been argued that population growth, along with rising incomes and lower commuting costs, have facilitated this population shift towards the suburban jurisdictions located around the metropolitan area core (i.e., the Central Business District)². In such a setting, suburban local governments can compete to attract those mobile residents to their jurisdictions, which translates into higher tax bases and, therefore, higher tax revenues. They use their well-established power to control land use to promote construction activity by increasing land use conversion from rural to urban uses, while enacting expansionary zoning policies for residential development purposes.

This strategic competition among nearby jurisdictions is theoretically consistent with three different mechanisms: (i) the spillover model, (ii) the resource flow or tax/welfare competition model, and (iii) the yardstick competition model (Brueckner, 2003). In many cases, it is not immediately clear whether substantive spatial dependence stems from one of these models, or a combination of them. The *expenditure spillover model* states that, as local public services can have beneficial or detrimental effects on nearby jurisdictions, an agent (i.e. local government) chooses the level of the

strategic variable observing directly on other agents decisions. The *resource-flow model* rests on the idea that local governments compete with each other for mobile resources. That is, the agents' strategic decisions are affected by the amount of certain resource availability, and because the distribution of such resource depends on the decisions of the rest of the agents, each agent's decision on the strategic variable is indirectly influenced by decisions of all other agents. The *political yardstick competition model* determines that voters use information from other jurisdictions to judge the performance of their own politicians. The reason for this behavior is that voters do not know what level of services can be provided relative to a certain tax level. Since tax rates in nearby communities are easily observed, they can serve as a benchmark. If voters consider relative performance, rational politicians will do the same and mimic their neighbors' decisions.

In our context, a local government does not care directly about the amount of converted land levels of other local governments but about the amount of residents that can be attracted to its jurisdiction. Accordingly, the strategic-interaction theoretical framework that best describes our model is the *resource-flow* explanation. The distribution of residents among jurisdictions is affected by the converted land choices of all local governments. Therefore, each local government is indirectly affected by other neighboring local governments' decisions. According to the tax (or welfare) competition theory, a tax (welfare) reaction function arises because the tax base is mobile and reacts to local tax rate (welfare) differentials. This procedure results in an inefficient race to the bottom of tax rates (welfare programs). In our setting, the mobile tax base reacts to the regulatory measures that modify land uses in the municipality. The result is an excess of land devoted to urban development.

There are various reasons why Spanish local governments provide an excellent testing ground for these ideas. First, land use policy is basically a local responsibility. Second, land use conversion from rural to urban uses is a profitable activity for municipal authorities, as recently shown in Hortas-Rico (2014). As a result, local governments use land to implement regional competition and easily pursue extra revenues that help to finance public goods' provision. Next, we present some institutional details about our case study area, Spain.

How does the land use conversion work in Spain?

Since the first Land Use Act was passed in 1956, the Spanish urban planning scene has been affected by numerous legislative reforms. The Land Use Act of 1956 introduced public intervention in land use decision-making as a remedy for real estate speculation. In the same vein, the Land Use Act of 1975 led to the decentralization of urban planning to regional and local governments, hence adapting from pre-democratic bodies to the new political and territorial circumstances emanating from the Constitution of 1978. According to this law, the central government would establish the land use regulation benchmark (regarding the protection of areas designated non-developable), which would be complemented by laws enacted by regional (basic spatial planning guidelines) and local governments (detailed physical planning). In practice, local authorities enjoyed considerable freedom in determining a municipality's urban planning and ended up controlling the supply of urban land for real estate development. The high political fragmentation (more than 8,000 municipalities), along with a lack of regional coordination, led to an intense urban development activity. As a result, the

traditional compact city model was replaced with randomly spread out suburban development. In 1990, a new Land Use Act was passed with the objective of designing new urban planning strategies for containing urban sprawl while helping to revive urban centers. The constant increase in housing prices observed during the 1990s motivated a new Land Use Act, which was passed in 1998. This new law led to the liberalization of land use because an increase in land supply was expected to reduce housing prices (Fernández, 2008; Bilbao et al., 2006; Roca & Burns, 2000). Nonetheless, the elevated prices that housing reached in Spain prior to the collapse of the housing market in 2007 demonstrate the failure of this public policy, which has profited speculating developers by giving them more land on which to build while not enhancing sustainability (González-Pérez, 2007).

In light of the above, one can conclude that the explosive urbanization process experienced in Spain from the mid-1990s to the end of 2000s was fueled by the rapid conversion of land from undevelopable rural status to open-for-development status, a process facilitated by local governments. In Spain, land is either public or privately owned³. Nonetheless, the unique characteristic of the planning system in Spain is that, although an individual might own the land, the local government is empowered to control and implement all the procedures for urban development. Landowners cannot develop their land without the prior consent of the local administration, which must declare the land developable and must precisely define the conditions for such development.

The local land use planning is instrumented via General, Partial and Special Land Use Plans. A local government's General Plan classifies the municipality's land

into non-developable rural land and open-for-development urban land, which can be either developable (vacant land) or developed (built-up land); it also establishes the organizational structure of the territory (system of communications) and the system of open spaces and community services. A Partial Plan is a more detailed planning document for land use conversion from developable to developed land. The Partial Plan follows the guidelines depicted by the General Plan (develops it into new urban areas; regulates the portions of municipal land to be developed) and specifies land zoning (residential, commercial and industrial uses of development), reserves of green areas and public equipment, streets, and the maximum floor area ratio for each dwelling, among other factors. A Special Plan is required whenever land is converted from non-developable rural land to open-for-development land.

What are the benefits of land use conversion?

In Spain, as in many other countries, the local provision of public services is financed primarily from local taxes, user fees and the non-earmarked grants that local governments receive from upper tiers of government. Nonetheless, the limited management capacity of local authorities to obtain and handle resources means that many municipalities face financial difficulties when trying to meet their expenditure needs. Thus, a number of local governments maintain the investment levels required to satisfy their residents' demand by relying either on immediate financing derived from urban growth or on transfers from the regional or central government. In a recent empirical study, Hortas-Rico (2014) provides evidence in this regard. Using data for 4,000 Spanish municipalities for the period 1994–2005, the author finds that the fiscal benefits to municipalities due to new development appear to exceed its costs. In

particular, new development (i) increases demand for new infrastructure, which is covered in the main by intergovernmental grants and, to a lesser extent, by revenues linked to the real estate cycle; and (ii) leads to a short-term current surplus, as the increase in current revenues offsets the increase in current expenditures due to public service provision for new developments.

Land use conversion and expansionary zoning are considered as a key source of local government fiscal revenue⁴. The reasons are manifold. First, as aforementioned, vacant land is not ready for development until it is included in a Partial Plan. In other words, urbanization requires prior approval of a Partial Plan to be attached to the General Plan. In doing so, urban developers are under the obligation to hand over a portion of newly developed land to the municipality. In particular, owners of developable land must cede the land needed for public roads, green areas and public facilities free of charge, as well as land corresponding to the 15% of the total built-up floor space authorized (or the equivalent in monetary terms). This land will be incorporated into municipal assets as public land, and the local authority would be able to sell this stock of land for the general public interest and use those revenues to meet their residents' demand for public goods and services. Second, the local government also receives revenues from taxes levied on construction activity, including construction taxes, building permits and taxes on land value improvements. Third, local tax revenues also increase because of the property tax, the main source of funding at the local level. This tax is assessed in proportion to housing values, and varies according to the class of property (residential, commercial, industrial and vacant) and the location of the asset (i.e., tax rates vary across jurisdictions). Note that the property tax rate is higher for urban than rural land uses, even if the land is not developed yet. Clearly, this becomes

an economic incentive for local governments to convert land from rural to urban uses, even without a clear intention of development. Fourth, local governments also benefit from grants received from upper tiers of government. Approximately 70 percent of these transfers come in the form of a formula-based block grant allocated by the central government. This grant is allocated through a population-based formula, with weights increasing at specific population thresholds. Hence, local governments could benefit from attracting new residents, as higher population counts could lead to higher per capita transfers to a given municipality. Also note that, according to the Spanish grant system, a proportion of capital transfers are dependent on the municipality's infrastructure deficit, which, in turn, is usually induced by urban growth (Hortas-Rico, 2014). Finally, the expropriation of rural land is not a common practice, but it could be implemented for a purpose deemed to be in the general interest. A problem arises when this expropriated land is converted to urban uses and then sold to private developers at a higher price.

THEORETICAL FRAMEWORK

In order to investigate the interjurisdictional interdependencies in land use decision-making consider, for simplicity, a metropolitan area containing just two cities, 1 and 2. Urban land in each city (q_1 and q_2 , respectively) is owned privately and can be either developed or developable. The existing stock of developed land is given by \bar{q}_1 and \bar{q}_2 . The amount of developable land (s_1 and s_2) is not fixed and depends on each city's decision on land use conversion from non-developable rural uses to open-for-development urban uses.

$$q = q_1 + q_2 = \bar{q}_1 + s_1 + \bar{q}_2 + s_2 \quad (1)$$

The inverse demand function of urban land is then defined as $p = D(q)$, where p is the land value. The model assumes that both cities border each other and are very close substitutes, so that land in both cities are perfect substitutes and the land price is equal across the two cities⁵. In addition, each local government provides public services (z) proportionally to population, with a congestion parameter $\alpha=1$:

$$z_1 = \alpha(\bar{q}_1 + s_1) \quad (2)$$

$$z_2 = \alpha(\bar{q}_2 + s_2) \quad (3)$$

The objective function of the local government is the fiscal surplus, which is defined as the difference between tax revenues (with t_1 and t_2 denoting the tax rates) and the costs of providing the public service z .

Suppose that local governments only levy a tax on land value in each community, so that tax revenues in city 1 are

$$t_1 \cdot (\bar{q}_1 + s_1) \cdot p = t_1 \cdot (\bar{q}_1 + s_1) \cdot D(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) \quad (4)$$

Also assume that the cost of providing z_1 is a function of the city's urban land and a vector X_1 of city characteristics⁶, such that

$$c(z_1; X_1) = c(\bar{q}_1 + s_1; X_1) \quad (5)$$

with $c_{z_1}' > 0$ and $c_{z_1 z_1}'' > 0$.

In addition, the local government of each jurisdiction adopts a Cournot-Nash strategy, choosing its level of tax rate and public good provision treating all other jurisdictions' choices of tax rates and public good provision as given. Then, the local government's fiscal surplus in city 1 is given by the following expression⁷:

$$\pi_1 = t_1 \cdot (\bar{q}_1 + s_1) \cdot D(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) - c(\bar{q}_1 + s_1; X_1) \quad (6)$$

The city chooses s_1 , the amount of land to be developed, to maximize (6), subject to

$$q_1 \geq \bar{q}_1 \quad (7)$$

Differentiating expression (6) with respect to s_1 , and assuming that the condition given by expression (7) is not binding, the first-order condition for the choice of s_1 is

$$\begin{aligned} \frac{\partial \pi_1}{\partial s_1} \equiv \theta_1 &= (t_1) \cdot D(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) + t_1(\bar{q}_1 + s_1) \cdot D_{s_1}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) \\ &\quad - c_{s_1}'(\bar{q}_1 + s_1; X_1) = 0 \end{aligned} \quad (8)$$

And the second-order condition is

$$\begin{aligned} \frac{\partial \theta_1}{\partial s_1} &= (2t_1) \cdot D_{s_1}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) + t_1(\bar{q}_1 + s_1) \cdot D_{s_1 s_1}''(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) \\ &\quad - c_{s_1 s_1}''(\bar{q}_1 + s_1; X_1) < 0 \end{aligned} \quad (9)$$

Because s_2 appears in $D(\bar{q}_1 + s_1 + \bar{q}_2 + s_2)$ and $D_{s_1}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2)$, the choice of s_1 depends on s_2 , and the effect of s_2 will be given by

$$\frac{\partial \theta_1}{\partial s_1} ds_1 + \frac{\partial \theta_1}{\partial s_2} ds_2 = 0 \quad (10)$$

$$\frac{ds_1}{ds_2} = -\frac{\partial \theta_1}{\partial s_2} / \frac{\partial \theta_1}{\partial s_1} = -\frac{t_1(D_{s_2}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) + (\bar{q}_1 + s_1) \cdot D_{s_1 s_2}''(\bar{q}_1 + s_1 + \bar{q}_2 + s_2))}{t_1[2D_{s_1}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) + (\bar{q}_1 + s_1) \cdot D_{s_1 s_1}''(\bar{q}_1 + s_1 + \bar{q}_2 + s_2)] - c_{s_1 s_1}''(\bar{q}_1 + s_1; X_1)} \quad (11)$$

where $\frac{ds_1}{ds_2} \geq 0$, which means that the reaction function of city 1 can have either slope.

According to the existing literature (see Bulow et al., 1986), a positive slope of this reaction function suggests that nearby municipalities are strategic complements (as they reinforce each other), while a negative slope means that they could be considered as strategic substitutes (as they offset one another). Since the strategic complementarity/substitution among adjacent municipalities is related to the curvature of the demand for housing⁸, Equation (11) is also a statement about the theoretical characteristics of the demand curve. Usually, a negative slope of the reaction function is due to the fact that demand functions are generally downward sloping. However, a sufficiently convex demand function could lead to a reaction function with a positive slope. In that case, if demand is coming at an extensive margin (i.e. attracting new residents *à la* Tiebout), the slope of the inverse demand function could be driven by the income or household preferences distribution⁹. Finally, also note that a “non-result” of zero implies that the characteristics of demand are such that the behavior of one municipality has no effect on its neighbors, suggesting perhaps that there is approximately perfect competition with each municipality too small to affect others.

If we want to impose a positive slope for expression (11) it is required that:

$$D_{s_1 s_2}''(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) < -D_{s_2}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) / (\bar{q}_1 + s_1) \quad (12)$$

As there is no estimate in the literature that allows us to make this assumption, it becomes an empirical question. Thus, if the estimated parameter is positive the empirics will confirm that this condition holds and, therefore, that the land-use decisions of adjacent municipalities can be considered as strategic complements¹⁰.

EMPIRICAL ANALYSIS

Econometric strategy

The model developed in the previous Section suggests that city 1's supply of developable land depends on the amount of development s_2 chosen by the competing city 2. Empirically, however, the interaction phenomenon is not that simple. A given city is likely to interact with many competing cities in a regional housing market, and the challenge is to allow for such interaction in the empirical specification. Spatial econometrics provides an ideal tool kit to address the strategic behavior on land use conversion. In the empirical literature on strategic interaction among local governments, endogenous interaction effects are theoretically consistent with the situation where taxation and expenditures on public services interact with taxation and expenditures on public services in nearby jurisdictions (Brueckner, 2003). Most papers rely on the spatial lag specification (SAR), which is theoretically consistent with alternative sources of strategic interaction. As explained in Section 2, the *resource flow mechanism* is the strategic -interaction theoretical framework that best describes our model. Thus, we rely on theory and define a SAR model as our baseline specification to empirically confirm the existence of strategic interaction effects among nearby jurisdictions and whether

they relate to the *resource-flow mechanism*. Two different modeling strategies can be adopted to test the existence of governments' interdependencies interactions. On the one hand, the *specific-to-general approach* estimates a non-spatial linear regression model and then tests whether the model needs to be extended with spatial interaction effects (Elhorst, 2010). On the other hand, the *general-to-specific-approach* starts estimating a general model including the spatial lags of the dependent variable, the independent variables and the residuals, and then tests if any of them is not significant. Mur & Angulo (2009) carry a simulation exercise to identify the correct model specification and determine that under all standard assumptions both strategies produce hardly distinguishable results. However, the *general-to-specific* approach produces better results when distortions, such as non-normality in the errors or heteroskedasticity with a spatial pattern, are introduced into the data generation process (DGP). On the other hand, the impact of endogeneity on the explanatory variables seems to be more acute in the *general-to-specific* approach.

Specification diagnostics determined the existence of heteroscedasticity and the absence of normal distributed disturbances¹¹. Therefore, we implement the *general-to-specific* approach and estimate the model through spatial heteroscedastic consistent procedures (HAC)¹². This approach starts estimating a general model including the spatial lags of the dependent variable, the independent variables and the residuals and tests if any of them is not significant. The extended model reads as

$$\begin{aligned}
 \mathbf{y} &= \alpha \tau_N + \rho \mathbf{W} \mathbf{y} + \mathbf{X} \boldsymbol{\beta} + \mathbf{W} \mathbf{X} \boldsymbol{\gamma} + \boldsymbol{\epsilon} \\
 \boldsymbol{\epsilon} &= \lambda \mathbf{W} \boldsymbol{\epsilon} + \boldsymbol{\varphi}
 \end{aligned}
 \tag{13}$$

where \mathbf{y} represents the N -dimensional vector consisting of one observation on the dependent variable for every unit in the sample ($i = 1, \dots, N$), $\mathbf{\tau}_N$ is an $N \times 1$ vector of ones associated with the constant term parameter α , \mathbf{X} denotes an $N \times K$ matrix of explanatory variables, with associated (fixed but unknown) parameters $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ contained in a $K \times 1$ vector, respectively. $\boldsymbol{\epsilon}$ is a vector of first-order autocorrelated disturbance terms and $\boldsymbol{\varphi} = (\varphi_1, \dots, \varphi_N)'$ is a vector of independently identically distributed (i.i.d.) disturbance terms with zero mean and non-constant variance σ_i^2 , while λ is the spatial autocorrelation coefficient. \mathbf{W} is a $N \times N$ matrix of known constants describing the spatial arrangement of the municipalities in the sample, where the diagonal elements are set to zero by assumption because no municipality can be viewed as its own neighbor. The variable $\mathbf{W}\mathbf{y}$ denotes the endogenous interaction effects among the dependent variables (i.e. the spatial lag), $\mathbf{W}\mathbf{X}$ the exogenous interaction effects among the independent variables, and $\mathbf{W}\boldsymbol{\epsilon}$ the interaction effects among the disturbance terms of the different spatial units. Finally, ρ is the coefficient that measures the intensity of interaction between location pairs. As noted in the previous section, cities that border each other are supposed to be perfect substitutes, so that the strength of the reaction function will depend on distance. We mainly expect to observe spatial interaction between neighboring municipalities therefore binary queen contiguity matrix becomes appropriate to capture the phenomenon. Nonetheless, alternative distance-based spatial weight matrices are considered in order to provide some insights into how this substitutability and therefore interdependence declines with distance.

Manski (1993) notes that at least one interaction effect must be excluded because otherwise the parameters are unidentified. When a global spillover specification

can be theoretically justified for the process, as we hypothesized in our *resource flow* theoretical model, we should estimate the SDM which assumes $\lambda = \mathbf{0}$ (Lesage, 2014). Given that the estimations are based on the general method of moments and the structuring of the GS2SLS (and equivalent heteroskedastic version), it makes it effectively impossible to fit a SDM¹³, so the most general model that can be estimated to test the significance of our parameter of interest (ρ) is the SAC model, where $\gamma = \mathbf{0}$ ¹⁴.

The spatial HAC estimator is robust against possible misspecification of the disturbances and allows for (unknown) forms of heteroskedasticity and correlation across spatial units¹⁵. Hence, we estimate the SAC model through the GS2SLS estimation method assuming that the disturbance vector is generated by a very general process (Piras, 2010):

$$\mathbf{y} = \alpha \tau_N + \rho W \mathbf{y} + X \beta + \varepsilon ; \quad \varepsilon = R \theta$$

(14)

where θ is a vector of innovations and R is a $N \times N$ non-stochastic matrix the elements of which are not known¹⁶.

Data

The empirical analysis conducted here is based on a sample of 2,543 Spanish municipalities for the period 2003-2011. The data sample is restricted to almost all municipalities above 1,000 inhabitants due to the lack of socio-economic and political

data for those localities below this threshold¹⁷. Note that the Spanish municipal sector is characterized by a high degree of fragmentation, with an extremely large number of municipalities with very small populations, extension, resources and management capacity. In particular, 60% of the approximately 8,100 existing municipalities have fewer than 1,000 inhabitants and represent just 3.6% of the total population. As shown in Table 1, a comparison of our sample with the universe of Spanish municipalities in 2003 indicates that large municipalities are overrepresented in the sample. The mean population of the sample was 13,304 in 2003, whereas the mean population of all municipalities was 5,271. However, the sample does not differ significantly from other municipalities in terms of economic characteristics (per capita income, employment and unemployment rate). In addition, the municipalities included in the sample account for about 96.4 and 96.6 percent of the total population and employment, respectively. Thus, we believe the final sample to be reasonably representative of the whole population, at least for the municipalities with more than 1,000 residents.

[insert Table 1 around here]

As for the time period covered, the analysis covers two terms-of-office, i.e. 2003-2007 and 2008-2011, because of the existing lapse of time between the zoning decision is made, the land is converted from undevelopable to open-for-development status, and then finally developed. In doing so, the dependent variable can be precisely matched to the particular government responsible for the policy at that time. In addition, it is important to note that, in Spain, as in the rest of Europe, the annual rate of change in land-cover type (from undevelopable rural status to open-for-development status) peaked during the 1990s and continued until the housing market collapsed in 2007.

Indeed, 30 percent of the artificial surfaces in existence today were created during the 1990s and the beginning of the 2000s (EEA, 2006), and most of them took the form of residential development (EEA, 2006, 2010).

Hence, the strategic behavior of local governments in land use decision-making can be examined by estimating the regression equation given by expression (14), where \mathbf{y} represents the vector consisting of observations of the additional amount of land assigned for new development (that is, the amount of land involved in the zoning process of converting the land use designation from undevelopable rural status to the open-for-development status) for every municipality in the sample between the years 2003 and 2011. Following previous empirical literature (see, e.g., Solé-Ollé & Viladecans, 2013 and García-López et al., 2015), this variable has been computed as the ratio of the previous built-up area. As stated above, the variable $\mathbf{W}\mathbf{y}$ denotes the endogenous interaction effects among the dependent variables, and the coefficient on this competing variable, ρ , measures the strength of the dependence between municipality pairs. This autoregressive parameter indicates how a given city responds to the level of land use conversion in nearby jurisdictions, creating the slope of its reaction function. A non-zero coefficient indicates that these choices are interdependent across cities, and strategic interaction occurs, whereas a zero coefficient means that strategic interaction is not present. In such situations, one city's urban land choice is unaffected by the choices of neighbors. \mathbf{X} denotes a matrix of observed municipality characteristics in the initial year expected to influence differences in the amount of land converted from rural to urban uses, with associated parameters β . Definitions, data sources and expected effects are provided in Table 2. The choice of the control variables that fill out matrix \mathbf{X} is based on the existing literature (see, e.g., Brueckner, 1998; Hilber & Robert-

Nicoud, 2013; Solé-Ollé & Viladecans, 2013). It includes, on the one hand, the vacant land in each municipality, defined as the amount of land assigned for development that remains vacant at the beginning of the period of study as a proportion of previous built-up land (*vacant land*). X also includes other control variables, measuring either the effect of the demand pressures, residents' preferences or the disamenity effects of growth. This set includes measures of local socio-economic factors (*population size, % Aged 25-40, per capita income, homeownership rate, blight*); variables that account for the amenity factors deemed important for location decisions (*%open land, % forests, road accessibility – proxied by the variables vehicles per household, distance to roads and road density -, and a coast dummy*); and two variables related to the political ideology of the local incumbent and his/her preferences for development (*dleft, dmajority*). Local employment shares by fine industry (*%manufacturing, %agriculture, %energy, %construction, %retail, %other services*) and local population shares by region of origin (*%EUmigrants, %non-EUmigrants*) are also included so as to account for possible labor demand shocks -driven by industry expansion or contraction-, and migration shocks -driven by pre-existing settlements patterns-, respectively. In addition, as suggested by Burchfield et al. (2006), we also account for the fact that natural barriers can either constrain (*elevation range, water bodies*) or promote urban development (*terrain ruggedness index, inland water*). Finally, regional (i.e. Autonomous Communities) fixed effects¹⁸ and a dummy variable that accounts for the fact that a municipality is a suburb within a given metropolitan area have also been included (*dSuburb*)¹⁹. Note that all the control variables are taken in the initial year in order to minimize the potential problems caused by reverse causality.

[insert Table 2 around here]

MAIN RESULTS

Non-spatial linear regression parameters provide consistent estimates of the marginal impacts of explanatory variables on the dependent variable, which are identified with the partial derivative of the dependent variable relative to the explanatory variable. However, models containing spatial lags of the dependent variable require special interpretation of the parameters, as spatial regression models expand the information set to include information from neighboring observations. In such cases, the total derivative would be the combined effect of all dependent variable changes in the simultaneous equilibrium, as a change in the explanatory variable for a single jurisdiction can potentially affect the dependent variable in all other jurisdictions (*spillover effects*). This impact includes the effect of feedback loops, where observation i affects observation j and observation j also affects observation i , as well as longer paths that might go from observation i to j to k and back to i (LeSage & Peace, 2009). Thus, the spatial lag model estimate of β obtained after spatially filtering the dependent variable is a consistent estimate of the direct or marginal impact of \mathbf{X} on \mathbf{y} in the equilibrium for the system. The estimation results for the model given by expression (14) are presented in Table 3. Columns (1) to (4) present the estimated coefficients, direct, indirect and total impacts of the GS2SLS estimation of the SAC model, assuming a general process for the residuals²⁰. The estimated coefficients and total impacts presented here are just informative but, for the remainder of the paper, only the post-estimation summary measures of the so-called direct and indirect impacts of the SAC model (Columns (2) and (3)) will be discussed.

Before continuing with the discussion of the results in Table 3, it is worth

mentioning that our spatial approach is subject to standard specification error-generated biases in estimated coefficients that could get reflected in the spatial correlation coefficients²¹. These specification issues include (i) the form of the spatial weight matrix, (ii) the usual concern about appropriate explanatory variables (inclusion of irrelevant variables, omission of relevant variables, measurement errors), and (iii) questions regarding which of the alternative spatial regression models best describes the data (LeSage & Pace, 2009). The methodology implemented here is able to address some of these problems, while others might persist, affecting the quality of the estimates. First, the strong point of our spatial specification is that it accounts for spatial dependence²², whose omission could lead to biased and inconsistent estimates (LeSage & Pace, 2009). Second, the motivation for applying a spatial econometric model is driven by formal theoretical concerns, as the reaction function found in Section 3 provides the theoretical basis for a spatial autoregressive specification. Another relevant source of model uncertainty in spatial econometrics is the spatial weights matrix. Given that this is a relevant issue in spatial econometric modeling, a set of alternative specifications of W s have also been considered. Nonetheless, our methodology does not correct for the potential negative effect of endogeneity caused by reverse causal relationships or measurement errors. To minimize the potential problems caused by reverse causality the explanatory variables are taken in the initial year of the analysis. On the other hand, to deal with the effect of measurement errors and outliers, the estimation method implemented here allows for heteroscedasticity in the residuals.

The most important finding from Table 3 is that the estimated interaction coefficient (ρ) is positive and statistically significant at well over a 99 percent confidence level, and occurs with a magnitude of approximately 0.35 regardless of

which estimation method or model specification is considered. This finding provides evidence of spatial interaction in the land use conversion decisions between neighboring municipalities. A local government's decision on the additional amount of land assigned for new development is positively influenced by the decisions of neighboring jurisdictions, with other causal factors remaining constant. In addition to being positive, the interaction coefficient is less than 1, indicating that an increase in the neighbors' decision variable elicits a smaller increase in a given city's decision variable. In particular, a 1% increase in neighboring developable urban land is associated with a 0.35% increase in own developable urban land. This result could suggest that local incumbents do not make land use policy decisions in isolation, but rather imitate nearby local incumbents when selecting zoning policies aimed at promoting residential development, so that they can attract new residents to their jurisdictions, hence increasing tax bases and local revenues. Our finding relates to the literature on interjurisdictional interdependencies of jurisdictional choice on policies that restrict land supply. These strategic interactions were first integrated into a model on growth controls by Brueckner (1995) and Helsley & Strange (1995). Nonetheless, their spatial pattern was first modeled in Brueckner (1998). He showed that cities in California tended to impose more stringent growth controls when neighboring cities were doing so. Lenon, Chattopadhyay & Heffley (1996) also find that minimum lot sizes in Connecticut townships are larger when lot sizes in neighboring townships are larger.

According to our theoretical predictions, the spatial interdependence is expected to decrease as the distance across municipalities increases. To prove that interdependence declines with distance we estimated the model using alternative distance-based weighting matrices: inverse distance, square inverse distance and k-

nearest neighbors and higher order neighbors. The inverse distance spatial weight matrix and the square inverse distance matrix connect every municipality in the sample giving smaller weight to municipalities that are separated by larger distances. As expected, the estimated interaction parameters are smaller than the one obtained when the model is estimated using a contiguity-based weight matrix (0.38 and 0.32 respectively vs 0.47). In order to take account of differences in the densities of municipal entities we also estimated the model with several $k=3, 4, 5, 6$ nearest neighbors weighting matrices. The spatial dependence parameter is always statistically significant different from zero but declines around one fourth in absolute value from the one obtained with a queen contiguity-based weight matrix specification (from 0.35 to around 0.11)²³. These results show an estimated interaction coefficient that is positive and statistically significant but with a lower magnitude depending on the W considered. Overall, these findings confirm that (i) spatial interdependence exists and (ii) the strength of the reaction function decreases with distance.

We now consider the impact of the control variables. In general, all variables considered here have the expected sign and are consistent with a priori expectations derived from urban economics theory, although a few of them turn out to be not statistically significant. Several interesting findings arise from the results. First, the *vacant land* in each municipality has a negative and significant total impact on the amount of additional land assigned for new development. The argument here is that if a lot of land assigned for development remains undeveloped, there will be no immediate need to alter regulations assigning more land for development (Solé-Ollé & Viladecans, 2013). Second, the effect of demand increases and employment shocks are proxied here with a set of local socio-economic variables. The results show that the *income* variable

plays an important role in explaining local land use conversion. In particular, richer jurisdictions tend to exhibit decreasing land use conversion rates, as the coefficient for the direct impact is negative and statistically significant. This result is in line with the literature, as richer communities tend to avoid additional urban development in their neighborhoods (McDonald & McMillen, 2004). The *homeownership rate* variable has a negative effect, as suggested by Fischel's (2001) homevoter hypothesis, although it is not statistically significant. We also find that all the different employment shares (but energy industry and other services) have a clearly positive and significant impact, suggesting that labor demand shocks increase the demand for housing and, therefore, the additional land assigned for new development. The positive and statistically significant indirect impact of some of these employment shares reflects the presence of employment spillover effects in neighboring jurisdictions. Third, we consider the amenity factors deemed important for location decisions. As expected, there is a more intense land use conversion activity in those locations with better road accessibility, which will ultimately translate into higher urban development, as shown by the positive coefficient of the *road density* variable. In the same vein, the higher the number of *vehicles per household*, the higher the local land supply. This result is in line with a growing body of the literature that has focused on the influence of transportation system improvements and availability of roads on the demand for urban growth (Baum-Snow, 2007; García-López, 2012). In addition, the amount of *open land* is also crucial in explaining land use conversion rates because, if there is a shortage of open land –either because the town grew a lot in the past, or it has a small jurisdiction –, the government might opt to preserve scarce open space or postpone development decisions until a later date (Solé-Ollé & Viladecans, 2013). As expected, this variable exhibits a positive effect on land supply (with both a direct and an indirect impact). Fourth, we test the

hypothesis that natural barriers can either promote or constrain development, as suggested by Burchfield et al. (2006). As expected, there is less land use conversion whenever mountains are present (measured here with the *elevation range*) as they make development more costly, hence limiting urban expansion. The expected negative effect of this variable provides compelling evidence that physical geography influences urban development. In contrast, small terrain irregularities (*terrain ruggedness index*) have the opposite effect, as hillsides where development is more costly alternate with flat portions where development is less costly. On the other hand, the presence of aquifers (*inland waters*) is positively correlated to land supply, as it lowers the cost of obtaining household water, hence facilitating urban development; whereas land is undevelopable whenever *water bodies* (such as wetlands and oceans) are present and, therefore, urban development is contained and land use conversion useless (Burchfield et al., 2006). The significance of the indirect impact for these two variables is due to the fact that the dimension of these phenomena exceeds the administrative boundaries of the municipalities, hence generating spillover effects across jurisdictions. Fifth, the results show that local land supply is higher in the *suburbs* of the metropolitan areas. These locations are, in fact, the ones experiencing higher demand pressures for additional suburban growth (EEA, 2006). Last, but not least, the political factors turn out to be determinant in the process of land use conversion. The *left government dummy*, included in the model to account for the influence of politics on land use decision-making, has a negative and significant effect, indicating that locations that belong to a left party experience less land use conversion devoted to urban development than those where a right-wing party is present, all else equal. This result is consistent with previous empirical studies where cities controlled by right-wing parties allow more land to be developed than similar cities controlled by the left, thus promoting more urban

development (Kahn, 2011; Solé-Ollé & Viladecans, 2013).

[insert Table 3 around here]

CONCLUDING REMARKS

A long line of research in economics analyzes the factors that shape local zoning and land use regulations, as these regulations can influence the amount, location and shape of urban development and even affect land rents, housing prices, environmental quality, transportation costs, and labor markets. Thus far, however, theoretical and empirical research has focused on zoning and land use regulations as tools to limit urban expansion, whereas no attempts have been made in the literature to analyze spatial interdependencies between competing cities in the selection of zoning policies aimed at promoting (instead of restricting) residential development. Understanding the mechanisms through which local governments' decisions and their interactions with nearby and upper-tier governments is key for two reasons. First, to increase the knowledge about the performance of local governments in the economy. And second, to shed light on the role that the institutional setting plays in land use conversion, urban development patterns and, thus, the shape of cities.

In a Tiebout setting, where middle- and upper-income residents, shop among rival nearby locations, local governments will compete to attract those mobile residents to their jurisdictions, as it translates to broader tax bases and higher tax revenues. This competition becomes particularly relevant in an environment where local authorities have limited fiscal capacity and a limited set of tax instruments to raise revenues. This

being the case, land use conversion for residential uses becomes an important source of financing for local governments, as land-based financing has the biggest payoff where there is rapid urban growth.

In order to further investigate the drivers of local governments behavior, this paper incorporates the interdependence of land use conversion among neighboring cities by means of reaction functions. A simple Cournot-style competition model over urban land expansion has been derived and then tested empirically with data on more than 2,000 Spanish municipalities for the period 2003-2011. The empirical evidence supports the main hypothesis derived from the theoretical model, as we find a positive and significant effect of the interaction coefficient. Thus, despite the strong substitutability between nearby municipalities, our findings suggest that they are strategic complements, where greater development in one seems to be met with greater development in its neighbors.

Overall, the results presented here suggest that local authorities need to be aware of the social and economic implications of their land use decision-making. A system for financing municipal budgets that heavily relies on volatile revenues linked to the real estate cycle, fueled by laws on land use that create the undesired incentives for excessive land use conversion, has numerous perils and affects the efficient provision of public goods and services. This being the case, a policy reform regarding the design of the local finance system and restructuring of grants received from upper tiers of governments is required in order to limit urban development. This revised local finance system should not be linked to the real estate cycle and, at the same time, it should also take into account the benefits lost by local governments when committed to sustainable

urban development, while creating the proper incentives for promoting environmental and health benefits to local communities.

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NOTES

¹ That is, more revenues linked to land use conversion (user fees and land sales) and construction activity (such as planning permissions, construction taxes or taxes on land value improvements), as well as the impact on the property tax, the main source of tax revenues on a local scale. Note that the local government is not considered here as a benevolent incumbent acting in the public interest but treated as a self-interested strategic player that attempts to maximize its own utility in the form of maximized net revenues.

² The location of suburban development within an urban area is perhaps one of the most important particularities of many Southern European cities, compared to the North American urban context. Existing empirical evidence highlights the importance of the existing urban fabric in the suburban development processes of Southern European cities, where proximity to the metropolitan urban core is crucial.

³ According to data provided by the Spanish Property Assessment Office, the 24% of non-developed urban land was publicly owned in 2011. In big cities such as Madrid or Barcelona, this proportion increased up to 40%. In addition, the 20% of non-developable land was also owned by the public sector (average over all urban areas in Spain).

⁴ See, for instance, Lichtenberg & Ding (2009), Lin & Yi (2011) and Ye & Wu (2014).

⁵ As it is commonly argued in the urban economics literature, in spatial equilibrium the land values across cities are expected to capitalize differences in city characteristics (such as amenities, tax differentials, or differences in public service provision), hence increasing tax returns on that urban land. Nonetheless, the simple theoretical model presented here abstracts from this possibility and considers equal land prices across jurisdictions.

⁶ As long as undeveloped land is not exclusively located at the urban fringe of the municipality, as it is the case in Spain, the size of undeveloped land parcels and their geographical location can have an impact on the costs of providing public services, especially for those services based on networks.

⁷ Note that here we are assuming a constant quality of government services i.e. investment level per unit of population. As suggested by one of the referees this assumption has several implications. Local governments might increase services' quality when the city size increases and provision becomes

cheaper. As a result, better quality of services would capitalize into land values and increase tax returns on that land.

⁸ See Berry & Pakes (2003) for a further explanation.

⁹ We thank one anonymous referee for suggesting this explanation. Indeed, convexity implies that every new increment downward in price results in larger increment to demand than the last. The slope of the inverse demand curve might be driven by income distribution. If there are more households earning 60,000 than 70,000 euros, and more households earning 50,000 than 60,000 euros and so on, then downward price adjustments will open the city to new buyers at an increasing rate (that is, $D''(q) > 0$). Similarly, the slope of the inverse demand curve could be related to the distribution of household preferences because price reductions might determine that more people will decide to live in the suburbs as lower land prices compensate their increasing commuting costs.

¹⁰ We derived the model strategic equilibrium to test if in equilibrium s_1 depends on X_2 as suggested by one anonymous referee. The condition that needs to be satisfied in order for both cities to have no reason to change their level of developable land unless something else changes is $D''(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) > \frac{D_{s_2}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2) - D_{s_1}'(\bar{q}_1 + s_1 + \bar{q}_2 + s_2)}{\bar{q}_2 - \bar{q}_1}$. However, the strategic equilibrium does not provide additional information to the one obtained in city 1's reaction function, as s_1 does not depend on X_2 . Therefore, from a theoretical point of view, there is no reason for estimating a spatial-X or Spatial Durbin Model.

¹¹ The Kiefer-Salmon test ($KS = 0.543$, $p\text{-value} < 2.2e-16$) determines that OLS residuals are not normal and the Koenker Baset test ($BP = 97.4217$, $df = 20$, $p\text{-value} = 3.63e-12$) confirms the presence of heteroskedasticity. Arrainz *et al.* (2010) provides simulation evidence that when the innovations are heteroskedastic, ML produces inconsistent estimates.

¹² The *specific-to-general approach* has also been tested, yielding to similar results. We estimated the model implementing the 2SLS estimation method correcting for heteroskedasticity with two different robustness corrections: a white consistent estimator and a Generalized Least Square estimator of the variance-covariance matrix. Changes in the estimated variance covariance matrix did not lead to large changes in the direct and indirect effects.

¹³ Even if one tries (using higher lags by hand), the results are typically numerically unstable.

¹⁴ Nevertheless, we estimate the SDM through ML and the Likelihood Ratio test statistics point towards a SAR specification. In addition, virtually all the lagged control variables were not significant, indicating

that other city characteristics that might make places more or less likely to imitate or compete for new development were not relevant. These results are available upon request to the authors.

¹⁵ Nonetheless, even if we assume such a general specification for the disturbance process we still have to be concerned about possible misspecifications (e.g., due to an incorrect specification of the weights matrices).

¹⁶ We test the robustness of the model specification to different Kernel functions, and also compare the coefficients significance to the results obtained with the robust estimator to those obtained under the non-robust standard errors.

¹⁷ The municipalities belonging to the regions of the Basque Country and Navarre have been excluded because these regions are not covered by the National Property Assessment Office dataset.

¹⁸ Alternatively, we have also considered metropolitan area fixed effects as defined in Boix et al. (2012). The estimation results are virtually the same, with the exception of the employment shares by fine industry and the local population shares by region of origin. On the one hand, the employment shares loose significance due to the fact that the metropolitan fixed effects capture local labor markets. On the other hand, the non-EU migration variable becomes significant, probably because the spatial patterns of migration are better captured by the broader regional dummies. The results are available upon request to the authors.

¹⁹ We closely follow the methodology proposed by Boix et al. (2012) to classify functional metropolitan areas, according to which one can identify 62 urban areas. Then, all municipalities within a metropolitan area that are not the central city are considered as suburbs.

²⁰ The S2SLS estimation results are not presented here but available upon request to the authors. This approach gives virtually the same results than those reported in Table 2 but with some (usually small) differences in precision.

²¹ See Halleck-Vega & Elhorst (2015) for a discussion.

²² Spatial dependence can arise from interactions among spatial units, either because nearby jurisdictions directly affect each other (spatial lag dependence), because they are affected by the same unobserved factors (spatial error dependence) or because some of the variables used in the empirical models might be measured with error, as the scale at which they are measured may not match the scale of the underlying spatial process (spatial heterogeneity).

²³ To prove that interdependency significantly decays with distance we also estimated the model with higher order neighbors spatial weight matrices and with distance threshold spatial weight matrices. Nonetheless, the irregular shape of municipalities, their small average size and the existence of empty holes in the map with no data makes it difficult to identify the relevant thresholds and the interpretation of the results. In order to save space, these results are not presented here but available upon request to the authors.

Table 1. Comparison of the sample with the universe of Spanish municipalities, 2003.

<i>Selected characteristics</i>	<i>Sample</i>	<i>Total municipalities</i>
Average population	13,304	5,271
Average income	11,659	11,969
Employment	15,776,536	16,326,310
Unemployment rate	14%	12%

Source: Spanish National Institute of Statistics.

Table 2: Definitions, data sources and expected effects of the variables

Variable	Definition	Source	
Dependent variable			
Δ Urban Land	[(Developable land 2011 + Built-up land 2011) - (Developable land 2003 + Built-up land 2003)] / Built-up land 2003	Property Assessment Office	
Control variables			Expected effect
Vacant land	[Developable land 2003 / Built-up land 2003]	Property Assessment Office	-
Income	Personal income in euros, 2003 (in logs)	Spanish Tax Administration and own calculations.	-
Homeownership rate	[Houses occupied by owner 2001 / Houses 2001]	Census of Population and Housing. Spanish National Institute of Statistics.	-
Employed in manufacturing	[Employed in manufacturing in 2001 / Employment 2001]		+
Employed in agriculture	[Employed in agriculture in 2001 / Employment 2001]		+
Employed in construction	[Employed in construction in 2001 / Employment 2001]		+
Employed in energy industry	[Employed in energy industry in 2001 / Employment 2001]		+
Employed in retail	[Employed in retail in 2001 / Employment 2001]		+
Employed in other services	[Employed in other services in 2001 / Employment 2001]		+
Population	Total resident population in 2003 (in logs)		+
Aged 25-45	[Population between 25 and 45 years old in 2003 / Total resident population in 2003]		+
Migrants_EU	[Migrant population from EU countries in 2003 / Total resident population in 2003]		+
Migrants_nonEU	[Migrant population from non-EU countries in 2003 / Total resident population in 2003]		+
Open Land	[(Total land area of the municipality - Built-up land 2003) / Built-up land 2003]	Corine Land Cover	+
Forest	[Forest and agricultural area (including vineyards, rice fields, fruit trees plantations, olive groves, etc) / Total land area]		+
dCoast	Dummy=1 if the municipality is a coastal location, 0 otherwise.		-
Road density (km/pop)	[Kilometers of roads (main and secondary roads 2000) / Total resident population in 2000]		+
Distance to road (km)	Distance from municipality centroid to the nearest main or secondary road (logs)		-
Vehicles per household	Average number of vehicles per household in 2001 (logs)		+
Blight	[Houses with problems related to noise, dirty, pollution or lack of green space, as of 2001 / Houses in 2001]		-
Terrain ruggedness index (km)	Municipal average value of the terrain ruggedness index developed by Riley <i>et al.</i> (1999), calculated on the 200-meter elevation grid to give a summary statistic of differences in meters of elevation between points 200-meters apart.	National Geographic Institute and GIS (own calculations).	+
Elevation range (km)	Elevation range for each municipality		-
Water bodies	[Wetlands and oceans' area / Total land area]		-
Inland water	[Inland waters / Total land area]		+
dSuburb	Dummy=1 if the municipality belongs to a metropolitan area but it is not the central city, 0 otherwise.	Boix <i>et al.</i> (2012)	+
dLeft	Dummy =1 if the major belongs to a left party during the 2003-2007 term, 0 otherwise. Parties on the left are: PSOE, PCE, IC, and several left regionalist parties.	Spanish Ministry of Home Affairs. Municipal elections in 2003.	-
dMajority	Dummy =1 if the party of the major has a majority of seats in the local council, 0 otherwise.		+

Notes: physical geography variables and other relevant distance measurements have been calculated using Geographical Information Systems (GIS). All data are at the level of the municipality.

Table 3: Estimation results

	SAC GS2SLS (general form for disturbance process)					Summary statistics			
	(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Estimated parameters		Direct impacts	Indirect impacts	Total impacts	Mean	Std dev.	Min.	Max.
<i>Spatial dependence:</i>									
Rho	0.3457***	(0.091)							
Lambda	--								
<i>Control variables:</i>									
Vacant land	-0.1621	(0.161)	-0.1677	-0.0802	-0.2479*	0.638	0.613	0	7.876
Income (logs)	-1.2377***	(0.489)	-1.2798***	-0.6121	-1.8919**	9.308	0.188	8.836	10.188
Homeownership rate	-0.7762	(0.731)	-0.8027	-0.3839	-1.1865	0.837	0.077	0.213	0.988
Employed in manufacturing	3.6498***	(1.207)	3.7739***	1.8051*	5.5790***	0.183	0.115	0.007	0.691
Employed in agriculture	2.4524***	(1.153)	2.5358**	1.2129	3.7487**	0.154	0.138	0.002	0.741
Employed in construction	4.5693***	(1.342)	4.7246***	2.2599*	6.9845***	0.156	0.063	0.037	0.552
Employed in energy industry	5.2054	(3.408)	5.3824	2.5745	7.9570	0.007	0.011	0.000	0.202
Employed in retail	2.4815**	(1.410)	2.5659*	1.2273	3.7933*	0.191	0.053	0.057	0.509
Employed in other services	1.5876	(1.225)	1.6417	0.7852	2.4269	0.297	0.095	0.071	0.692
Population (logs)	0.0173	(0.055)	0.0179	0.0085	0.0265	8.404	1.148	6.909	14.945
Pop. aged 25-45	2.4614	(2.054)	2.5451	1.2173	3.7624	0.229	0.034	0.113	0.381
EU migrants	0.1132	(1.348)	0.1171	0.0560	0.1731	0.027	0.042	0.000	0.491
Non-EU migrants	2.5262	(2.839)	2.6121	1.2494	3.8616	0.019	0.025	0.000	0.246
Open Land	0.0015***	(0.000)	0.0016***	0.0008**	0.0024***	181.53	263.92	0.469	643.51
Forest	-0.1802	(0.214)	-0.1863	-0.0891	-0.2754	0.365	0.277	0.000	0.966
dCoast	-0.0443	(0.221)	-0.0458	-0.0219	-0.0677	0.183	0.387	0	1
Road density (km/pop)	6.4439**	(3.231)	6.6629**	3.1870	9.8500*	0.004	0.012	0.000	0.160
Distance to road (logs)	-0.0144	(0.034)	-0.0149	-0.0071	-0.0220	1.228	1.292	-8.956	4.020
Vehicles per household (logs)	1.6053***	(0.473)	1.6599***	0.7939*	2.4539***	0.985	0.224	0.420	1.890
Blight	1.1743	(0.917)	1.2142	0.5808	1.7950	0.068	0.067	0.000	0.673
Terrain ruggedness index (km)	4.1092	(8.580)	4.2489	2.0323	6.2813	0.006	0.008	0.000	0.064
Elevation range (km)	-0.3631**	(0.212)	-0.3754*	-0.1796	-0.5550	0.476	0.339	0.000	2.218
Inland water	7.1806***	(2.653)	7.4247***	3.5513*	10.9761***	0.003	0.024	0.000	0.566
Water bodies	-0.0557***	(0.018)	-0.0576***	-0.0276**	-0.0852***	1.036	3.365	0.000	58.848
dSuburb	0.2679***	(0.113)	0.2770**	0.1325	0.4095**	0.483	0.499	0	1
dLeft	-0.3047***	(0.100)	-0.3150***	-0.1507*	-0.4657***	0.561	0.496	0	1
dMajority	0.0454	(0.095)	0.0469	0.0224	0.0694	0.625	0.483	0	1
Constant	7.3697	(4.556)							

The dependent variable is the % increase in developable land over the two terms-of-office (2003-2011), with a mean value of 0.8052. The mean values of population and income per capita are 13,304 inhabitants and 11,349 euros, respectively. The estimation includes fixed effects by region (Autonomous Communities). Column (1) reports the GS2SLS results with Spatial HAC standard errors for the specification with spatial lag and spatial error dependence (assuming a very general form for the disturbance process). The corresponding direct, indirect and total impacts are reported in Columns (2), (3) and (4). Numbers in brackets report heteroskedastic-consistent standard errors (HAC standard errors in Column (1)). ***, ** and * indicate that the coefficient is statistically significant at the 1 %, 5 % and 10 % levels, respectively.

