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DO LAND USE POLICIES FOLLOW ROAD CONSTRUCTION?

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Do land use policies follow road construction?

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ABSTRACT

We study whether local land use policies are modified in response to enhanced demand for building generated by the construction of a new highway, and examine the extent to which this mediating effect of land use regulations affects building activity. Our analysis focuses on the case of Spain during the last housing boom, 1995-2007. For this period, we assembled a new database with information about new highway segments and details about the modification of the zoning status of land in nearby municipalities. The empirical strategy compares the variation in the amount of developable land before-after the construction of the highway in treated municipalities and in control municipalities with similar pre-treatment traits, this latter group being selected using matching techniques. Our results show that, following the construction of a highway, municipalities converted a huge amount of land from rural to urban uses. The amount of land converted after the construction of the highway was greater: (i) the stronger the demand shock, and (ii) the easier it was to build out, but also (iii) the lower the amount of vacant land to start with, and (iv) the less the opposition expressed by locals. We also show that new highways have an impact on building activity.

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1. Introduction

Land use regulations are a ubiquitous feature of land and housing markets. In the US, urban growth boundaries place limits on the spatial expansion of urban areas (see, e.g., Hannah *et al*., 1993), and zoning ordinances designate permitted uses of land (i.e., open space, agricultural, commercial, industrial, and residential uses) and regulate many other aspects of development (see, e.g., Glickfeld and Levine, 1992)[1]. Other countries similarly employ very detailed systems of land planning[2]. These regulations are justified on the grounds that they prevent the negative external effects associated with the proximity of incompatible land uses (see Moore, 1978). However, in practice, these regulations are also used to prevent new development from interfering with existing residents' interests and to preserve the 'character' of a community. As a result, they also constrain the supply of housing and raise housing costs (e.g., Glaeser and Gyourko, 2003, and Glaeser and Ward, 2006). The net effect of these regulations on welfare is difficult to determine, although there is little evidence of a net positive effect (see McMillen and McDonald, 1993, and Turner *et al*., 2011).

Moreover, some authors even suggest that 'the regulations tend to coincide with, or anticipate, the market solution rather than modify it' (Wallace, 1988, p.307). From this 'zoning follows the market' view, regulations would be unnecessary because the government would provide the same land use pattern as that afforded by the unconstrained market. Such a situation might come about as the private agreements reached by the parties tend to mimic centralized decisions dealing with externalities (see Fischel, 1985). It might also be the case that local governments cater in the main to development-related interests as opposed to those of homeowners (see Molotch, 1976, Solé-Ollé and Viladecans-Marsal, 2012, and Hilber and Robert-Nicoud, 2013) so, eventually, when obliged to modify their planning documents, they tend to take decisions that allow proposed developments to go ahead. Moreover, seen from this perspective, not only are land use regulations meaningless, they are also likely to have a detrimental effect. This is the case, for example, if a government's response to market forces is delayed thereby reducing the supply elasticity of housing and contributing to housing price increases (see Mayer and Somerville, 2000, and Glaeser and Ward, 2006).

[1] These regulations also impose all sorts of requirements on new development: building heights and densities, the location of a building on the lot, the proportions of the types of space on a lot (e.g., how much landscaped space is required), whether or not parking should be provided, etc. Besides the specificities of regulations, red-tape and delays in the permitting process are also a concern (see Gyourko *et al.*, 2008).

[2] See, e.g., Cheshire and Sheppard (2004) and Riera *et al*. (1991) on the UK and Spanish cases, respectively. These policies are mostly the responsibility of local governments, but higher layers of government might also play a role in some countries.

In this paper, we examine whether land use policies do indeed follow market forces by studying whether local governments respond to demand shocks by amending existing planning documents and allowing more land to be developed. More specifically, we study the decisions of Spanish local governments to convert land from rural (i.e., open space, agricultural) to urban uses (i.e., commercial, industrial, and residential) during the last housing boom (i.e., from 1995 to 2007), focusing on a specific kind of demand shock, namely the construction of a highway in the municipality. To do so, we study the effects during that period of the construction of a new highway segment on the growth in the amount of land designated for development, focusing specifically on the timing of these effects. We then analyze whether these effects are heterogeneous, presenting estimates for sub-samples classified in terms of (i) the strength of the demand shock, and (ii) the existence of geographical constraints, but also in terms of (iii) the amount of vacant land at the outset, and (iv) whether locals are favorable/opposed to development. Finally, we study the effect of highway construction on housing market outcomes, including, the growth in developed land and the rise in the number of housing units.

The paper makes several contributions to the literature. First, to the best of our knowledge, no papers have previously analyzed the way in which local governments make planning or zoning decisions following a demand shock. In this paper, we show just how active Spanish local governments (or at least some of them) are following the construction of a highway[3]. Moreover, no papers have compared the overall effect and the timing of a demand shock on both land use decisions and building activity. Here, by comparing the response of land conversion, on the one hand, and land development and housing construction, on the other, we are able to draw relevant conclusions as to whether land planning decisions anticipate market forces and about the time required for this to happen.

Second, no previous papers would appear to have analyzed the interaction between highway construction, a function typically shared between state and federal governments, and land use regulations, a local responsibility in most countries. Clearly, in countries operating this kind of institutional arrangement, the layers of government in charge of funding, planning

[3] Moreover, although some studies have been made of the determinants of land use regulations (e.g., Bates and Santerre, 1994 and 2001; Evenson and Wheaton, 2003; Glaeser *et al*., 2005; Dehring *et al*., 2008; Hilber and Robert-Nicoud, 2013; Sáiz, 2010), all of them draw on a cross-section of data (owing presumably to data limitations), focused most invariably on indicators aggregated at the metro area level (e.g., Hilber and Robert-Nicoud, 2013; Sáiz, 2010). Only a few papers to date have focused on actual local policy decisions (see, e.g., Kahn, 2011; Solé-Ollé and Viladecans-Marsal, 2012 and 2013), thus analyzing the response of policy-makers to local conditions when decisions are made.

and building highways need to be aware of local planning responses when evaluating the effects of a new project.

Third, although there is a sizeable body of literature on the impact of highway construction on local development (e.g., Rephann and Isserman, 1994; Lokshin and Yemtsov, 2005; Chen *et al*., 2009; Mu and van de Walle, 2011)[4], these studies do not consider the possibility that the impact of highways on the local economy might be mediated by the way in which local policies (and in particular, local planning) are drawn up and, as such, by the workings of the local political process. However, one weakness that is recognized by this line in the literature is its lack of attention to the heterogeneity of the effect of roads (see van de Walle, 2009). One of the few papers to deal with this issue is Rephann and Isserman (1994), who find that the effects of the extension of the inter-state highway system in the U.S. are positive only for places in close proximity to a sizeable urban area. A point that we stress in this paper is that we also expect the effect of highways to be greater in locations where the market is larger (i.e., in urban areas), but that the positive effect of new highways might be restricted to an even smaller set of locations (e.g., those where locals are favorable to development).

Fourth, although there is a growing body of literature examining the effects of highways on city growth and urban sprawl (e.g., Duranton *et al*., 2012, Baum-Snow *et al*., 2012, Garcia-López 2012 and Garcia-López *et al.*, 2013), these studies are not concerned with the impact on land occupation and land uses but only on population and employment growth[5]. Yet, one of the problems created by urban sprawl is the enormous consumption of open space[6]. Funderburg *et al*. (2010) study the effects of roads on changes in land use patterns, but in common with the papers cited above, they do not study the impact of road construction on local land use policies, which jointly with the road itself determines urbanization outcomes. Several papers do analyze the effect of land use regulations on housing construction (e.g., Mayer and Somerville, 2000), but none considers the interaction with highway construction.

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[4] The literature on the effects of highways is much older and forms a larger body. The geographical focus has shifted from the national (e.g., Aschauer, 1989; Fernald, 1999) to the regional (e.g., Holtz-Eakin, 1994; Garcia-Milà and McGuire, 1992, Garcia-Milà *et al*., 1996), and then to the local level (e.g., Chandra and Thompson, 2000; Rephann and Isserman, 1994). The volume of literature in the case of Spain is also great (e.g., De la Fuente *et al*., 1995, Mas *et al*., 1996, and Boscá *et al*., 2002, among many others), but most studies draw on regional data (see Holl, 2004, for an exception). Here, we focus on papers examining the effects at a small geographical scale.

[5] Baum-Snow (2007) and Baum-Snow *et al*. (2012) analyze the effect of highway construction on population suburbanization in the US and China, and Garcia-López (2012) and Garcia-López *et al*. (2013) study the same question with Spanish data; Duranton and Turner (2012) focus on the effect on city growth in the US.

[6] See the European Environmental Agency (2006) and Greenpeace (2010) for evidence on this issue for Europe and Spain.

Fifth, we believe there are various reasons why Spanish local governments provide an excellent testing ground for these hypotheses. Periodically, they are required to pass comprehensive land planning documents, specifying which land plots can be developed and which have to remain undeveloped, at least until future amendments are made to the plan. Fortunately, we have been able to access a unique database that measures the impact of these decisions on land conversion. Second, Spanish local governments enjoy almost complete freedom in areas related to town planning. Third, the period analyzed witnessed a demand shock of an extraordinary magnitude, creating extremely high expectations of residential construction growth, which forced local governments to take decisions as to whether to permit this growth (and so modify the planning documents thereby allowing more land to be converted from rural to urban uses) or to remain passive and not permit any additional growth that had not been planned for before the boom.

Sixth, it is our contention that a focus on the demand shocks generated by new highway segments offers certain advantages. Indeed, the construction of such segments is an easily identifiable event that enables us to define quite clearly a treated set of municipalities (those gaining access to a new highway) and a set of controls (those not gaining access). And, although highway location is obviously not exogenous, it is our belief that this problem is much attenuated when we compare the before-after evolution in land use outcomes in treated vs. control municipalities that are similar in terms of certain basic determinants of the geographical allocation of new highway segments (including pre-treatment outcomes and pre-treatment accessibility to a main road). Our empirical methodology builds on the previous literature dedicated to road project evaluation (see van de Walle, 2009, for a survey). In line with many other papers in this tradition we combine a before-after analysis with matching techniques (see Rephann and Isserman, 1994; Chen *et al.*, 2007, Lokshin and Yemtsov, 2005, and Mu and van de Walle, 2011).

Our analysis shows that, following the construction of a new highway segment, the municipalities converted a huge amount of land from rural to urban uses. Moreover, land conversion took place in the first half of the period, coinciding with the initiation of the project. We also confirm that the amount of land converted after the construction of the highway was greater in places with higher demand (i.e., urban areas) and low geographic constraints (i.e., favorable topography). However, land conversion was also greater in places where local residents were more favorable to development (e.g., places with a low percentage of homeowners and commuters) and/or in places where development interests had more influence over the local planning process (e.g., municipalities controlled by right-wing parties and majority governments). We also show that new highways had an impact on real estate outcomes including the amount of land developed and the number of housing units.

The paper is organized as follows. In section 2 we describe the system of land use regulation in Spain and the evolution of our outcome variables during the period of study. In this section we also describe the expansion of the Spanish highway network in recent decades and, especially, during the period of study. Section 3 describes the methodology used in the analysis. Section 4 presents the results. Section 5 concludes.

2. Institutions and data

2.1 Local land use regulations

In Spain, there are more than 8,000 municipalities, although most are small (60% with fewer than 1,000 inhabitants). Municipalities are democratically elected governments with the usual responsibilities for local spending and taxation[7]. One of their main tasks is land use regulation. Here, municipalities are responsible for specifying and implementing zoning regulations, subject to basic legislation enacted by central and regional governments, and subject also to regional oversight[8].

Land use regulations in Spain are controlled by a highly detailed, rigid system (see Riera *et al*., 1991), but they differ little from the zoning regulations operative in various parts of the US. An essential characteristic of the Spanish system is that, although an individual might own the land, the government is empowered to control and implement all processes of urban development. Landowners cannot develop their land without the prior agreement of the local administration. It is not simply that they need a building license: before reaching this step, the government must have declared the land 'developable' and have defined the precise conditions for such development. The main tool that the government uses to achieve this is its urban plan. Municipalities draw up a 'General Plan', which provides a three-way land classification: *developed land*, *developable land* (those areas of the community where future development is allowed), and *non-developable land* (the rest of the territory – agrarian and

[7] Municipalities are multi-purpose governments with responsibilities for the typical range of local public services (including, refuse collection and treatment, water supply, street lighting and paving, parks and recreation, cultural and sports facilities, etc.). See Solé-Ollé (2012) for a detailed description of local public finances in Spain.

[8] The regional government can reject local zoning regulations on the grounds of their interference with regional policies, including, for example, regional infrastructure provision (roads, water pipelines, etc.), regionally protected lands, etc. The general opinion, however, is that during the last boom regional governments were largely ineffective in detaining local development. Thus, while in theory regional governments can stop development invoking regional policy priorities, they are unable to force local governments to accept the quantity or the type of development they seek.

other uses, where the development process is strictly prohibited, at least until a new plan is approved). Figure 1 illustrates how this classification works and how the land uses may change after the amendment of the plan.

[Insert Figure 1]

The 'General Plan' has to be updated from time to time in order to adapt land use regulation to economic and demographic changes. The process of amending the 'General Plan' is quite complex. The plan is drawn up by the government team and then has to be approved by the city council. There are many transparency and participation requirements involving both the opposition and the citizenship. These tasks might take at least an entire term-of-office to be completed. Land uses can also be modified during the implementation of the plan, via what is known as an amendment (or 'Partial') plan. These changes are also subject to binding legal requirements, but tend to be implemented somewhat faster. In any case, success in having the new plan approved and the speed of that process depend on the mayor's strength[9].

Fortunately for our purposes, we enjoyed access to a new dataset that provides information on these land use categories at the municipal level. The information is provided by the Spanish property assessment agency (*Dirección General del Catastro*, Ministerio de Hacienda, http//www.catastro.meh.es) and is derived as a by-product of the assessment process that this agency undertakes on all properties in the country. This database provides information on the amount of *developable land* ('suelo urbanizable'), *developed land* ('suelo construido') and on the number of *housing units* ('unidades urbanas'). Our empirical analysis focuses on the evolution of the amount of *developable land* during the last housing boom, that is, the period that runs from 1995 to 2007. These years cover the whole period of expansion in the Spanish housing market[10]. The main variable of interest is the *increase in developable land* during this period measured relative to developed land at the beginning of the period (i.e., in 1995). This variable is labeled as $\Delta d_{i,t\text{-}t0}$, and computed as $\Delta d_{i,t\text{-}t0} = (D_{i,t} - D_{i,t0})/B_{i,t0}$,

[9] Municipal councils in Spain are elected every four years. After the election, the new council elects a mayor who then decides on the composition of the executive. Due to their agenda-setting powers and to the high level of party discipline, Spanish mayors enjoy great influence, especially when they are governing in majority or with a stable coalition. Highly fragmented councils might hinder the approval of any new regulations (including planning amendments). Majorities backed by landslide electoral victories might likewise find it easier to promote urban expansion, even if voters are opposed to such measures (see Solé-Ollé and Viladecans-Marsal, 2012).

[10] The housing market collapsed in 1992 after a boom that started in the middle of the 1980s. After 1995, housing construction and housing prices started to grow again. The growth accelerated after 2001 and peaked by the end of 2007. This period also coincides with the years for which the database on land use categories is available.

where $D_{i,t0}$ and $D_{i,t}$ are the amounts of developable land at the beginning of the period and at some latter date (i.e., 1999, 2003 or 2007) and $B_{i,t0}$ is the amount of developed land at the beginning of the period. Note that, in terms of the land categories in Figure 1, this variable is the ratio between the purple and orange areas. This variable can be interpreted as the government's planned percentage increase in city size during a given period (see Solé-Ollé and Viladecans-Marsal, 2012 and 2013).

The first row of Table 1 presents the value of this variable for several years during this period. Between 1995 and 1999 the increase in developable land amounted to 28.6% of the amount of land already developed in 1995; this proportion jumped to 73.3% in 2003 and to 113.5% in 2007. The second row of Table 1 presents information about the level of this variable, i.e. the amount of developable land, or the summation of the increase during the period (first row) and the amount of vacant land in 1995 (i.e., the amount of land that had been designated for development but that had not yet been developed). The amount of vacant land is also computed relative to the size of the city in 1995 as $v_{i,t0} = (D_{i,t0} - B_{i,t0})/B_{i,t0}$[11]. In 1995, the amount of vacant land was equivalent to 70.2% of the initial city size. This share rose to 98.9% in 1999, to 145.3% in 2003 and to 183.7% in 2007.

[Insert Table 1]

The other two rows in Table 1 also show the evolution of the two construction outcomes we are able to examine, namely, the growth in the amount of *developed land* and the growth in the number of *housing units*. Regarding this first outcome, note that the amount of developed land (labeled as $\Delta b_{i,t-t0}$ and computed as $\Delta b_{i,t-t0} = (B_{i,t} - B_{i,t0})/B_{i,t0}$) grew by 18.7% during 1995-99, by 45.5% during 1995-2003, and by 51.8% during 1995-2007. The evolution is similar in the case of *housing units*, although the rates of growth are smaller, suggesting that growth has been very land intensive[12].

Note that, since both *developable* and *developed land* have both been measured with respect to the initial size of the city, their evolution can be readily compared. Thus, according to these data, the real growth in city size during this period was quite staggeringly high (approximately 50% growth across the whole period), although it was much lower than

[11] Note that the increase in the amount of vacant land over the period is equal to the increase in developable land (i.e., $\Delta v_{i,t-t0} = ((D_{i,t} - B_{i,t0}) - (D_{i,0} - B_{i,t0}))/B_{i,t0} = (D_{i,t} - D_{i,t0})/B_{i,t0} = \Delta d_{i,t-t0}$).

[12] This means that a large share of land consumption during this period involved a larger amount of land per housing unit and also the greater use of land for other uses, such as business activities, parking lots and infrastructures. According to data obtained from the aerial photographs of the *Corine Land Cover* project (Ministerio de Fomento, 2006), most development between 1987 and 2000 took the form of low-density urban growth (up by 30%) and scattered growth (up by 26%), while the area undergoing compact development increased by a mere 4.1 per cent.

planned city growth (at more than 100%). There are several potential explanations for these differences. First, in places without sufficient vacant land at the outset, the planning documents had to be amended before construction could commence, while the consequent construction projects also required a number of years to reach completion. Planning amendments can take several years to be passed, so that development suffers further lags[13]. Second, it might also be the case that city councils care less about mistakes in forecasting demand than do developers, so (in places where people are favorable to growth) they tend to convert large tracts of land from rural to urban uses, even if there is some risk that the land will not subsequently be developed. Third, although these statistics show that, on average, Spanish municipalities did allow huge amounts of land to be developed, we do not know whether this increase in land supply occurred in places where there was the greatest need for land.

2.3 Highway construction

Over the last three decades, Spain undertook a highly ambitious expansion of its highway network. During the period 1980-2011 more than 10,000 km of new highways were built (see Table 2). Highway construction was especially intense during the 1980s and early 1990s, given the importance attached to it in the socialist party's agenda and also as a result of the arrival of huge amounts of European funds earmarked for this purpose (see Solé-Ollé, 2013). Note, however, that a substantial number of highways were constructed in Spain throughout all the periods analyzed. The period from 2003 to 2007 (the one analyzed here) is the one with the highest number of kilometers of new highways built (i.e., a total of 2,446 km)[14]. However, the percentage growth in the number of kilometers of highways was much lower than that in the earlier periods, due to the fact that the main network had already been completed.

[Insert Table 2]

Figure 2 shows the Spanish highway network in 2000 (in dark blue), the new highway segments built during the periods 2000-2003 (in light blue) and 2003-2007 (in red), and the network of *Main roads* (in grey). This map was drawn using information collected from

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[13] So, in the Spanish case, it could be that construction extended after the start of the housing bust in 2008 due to these lags. Land conversion should in theory have stopped after the start of the crisis although, given the lengthy approval processes of planning amendments, it might also have been the case that some expansionary plans were approved during the housing bust (i.e., after 2007).

[14] The use of a longer period would have given us more highway segments to analyze, but is unfeasible due to lack of data. Recall that land use data is available since 1995. As we will explain latter, we are also going to test whether highways build during 2003-2007 did have some influence on land policies enacted in previous periods (e.g., in 1999-2003 and in 1995-1999), which means that highways built during these periods can not be used for the analysis.

annual official road maps for the years 1999, 2003 and 2007 published by the Ministry of Public Works (http://www.fomento.es). Using GIS software, we created digital vector maps with polylines (highway and other main road segments). Using a layer of municipality boundaries provided by the National Geographic Institute (http://www.ign.es), we were then able to associate new highway segments with municipalities. This is basically how we identified the set of potentially treated municipalities (see next section for more details). During the period 2003-2007, a total of 291 municipalities gained access to a new highway segment, i.e., a new highway segment with ramps was built in the jurisdiction of the municipality. Only 14 of these municipalities did not have access to a *Main road* prior to obtaining highway access. This suggests that having access to the main road network is an important determinant of the decision to build a new highway. We take this into account in our identification strategy (see next section).

[Insert Figure 2]

Some specific traits of the network should be noted. First, overall, the highway network is highly radial, with many highways emanating out from Madrid towards cities in the periphery. As documented elsewhere, this is a traditional characteristic of road building in Spain (see Bel, 2010, and Garcia-López *et al*., 2013). Second, while this radial structure is evident in the 2000 network, it is not the case of new segments built after 2000. The main purpose of highways built during the periods 2000-2003 and 2000-2007 was to improve connectivity between medium-sized cities, and no longer to link medium-sized cities in the periphery with the capital, Madrid. Good examples of such segments are those located on the A-66 highway running North-South parallel to the Portuguese border (the so-called 'Autovía de la Plata') and the A-23 highway in the North-East of Spain, linking Zaragoza and Teruel. These traits have certain implications for the properties of the identification strategy we select for this paper (see next section).

3. Empirical strategy

3.1 Methodological options

One of the most challenging problems faced in evaluating the effects of road construction on economic outcomes is that places that gain access to a new road probably differ from places that do not gain such access. The literature evaluating the effects of road construction has dealt with this problem in different ways (see van de Valle, 2009).

First, some authors argue that comparing the evolution over time of the economic outcome of interest (e.g., firm location, housing construction, etc.) in places that gained vs.

places that failed to gain access to the road (i.e., using 'difference-in-differences' or fixed effects) is sufficient to control for unobserved municipal heterogeneity and for potential problems of simultaneity in economic outcomes and in the location of the new road projects. For example, Holl (2004) uses a fixed-effects Poisson model to study the effect of highway construction on the location of firms in Spain. She argues that fixed effects are appropriate when the simultaneous nature of the outcome (firm location in this case) and highway location is due to particular location-specific characteristics. She explains why this has been the case in Spain by arguing that in many cases the road plans designed by the Spanish government chose to build highways by doubling up the number of lanes of the existing national roads. She notes that places with access to a national road were also more attractive for firm location prior to the construction of the new highway. Fixed effects would also control for topographical traits that might influence the route of the highway (highways tend to avoid, more than national roads, rugged terrain).

Second, other papers complement the use of 'difference-in-difference' methods (DiD) with a more careful selection of the control group. The DiD analysis is based on an implicit assumption: in the absence of the intervention, economic outcomes would have evolved over time similarly in treated and control units (see Blundell and Costa Dias, 2009). Note that this may not be the case in the example discussed above: places with access to a national road might have grown more than places without such access even in the absence of the highway upgrade. A strategy for dealing with this problem involves comparing places where road access has been upgraded (from national road to highway) with places that have access to a national road but which did not get an upgrade. Obviously, even places that already had a national road before the treatment period can be heterogeneous; after all, there must be a reason why the government decided to upgrade one national road and not another, so there is still room for improving the selection of the control group. Many papers use matching techniques to improve this selection. Here the aim is to select a subset of control units that are similar to the treated units in those traits that are a priori expected to influence both the probability of treatment and the evolution of the outcome variable. Rephann and Isserman (1994) adopt this approach, applying a sequential caliper and matching treated and control units using a similarity measure (based on the Mahalanobis distance). Indeed, many papers in this literature adopt this latter approach (see, e.g. Chen *et al.*, 2007, Lokshin and Yemtsov, 2005, Mu and van de Walle, 2011).

The main assumption of matching is the so-called 'conditional independence assumption' or 'unconfoundedness' (see Rosenbaum and Rubin, 1983; Blundell and Costa Dias, 2009; Imbens and Wooldridge, 2009). This basically means that, conditional on observed covariates, no unobserved factors are associated both with the treatment and with potential outcomes. This assumption may be controversial but it is surely more reasonable when matching is used in combination with DiD methods (see Blundell and Costa Dias, 2009), since some of the unobserved covariates might be time-invariant. Moreover, the availability of panel data also facilitates the assessment of the validity of the 'unconfoundedness' assumption (see Imbens and Wooldridge, 2009).

Third, a further possibility is to provide a compelling argument to show that highway location is exogenous. For example, Chandra and Thompson (2000) argue that highway construction is endogenous in urban areas but exogenous in rural areas. Holl (2004) argues that, in the Spanish case, the stated purpose of road plans is to improve the connectivity between Spain's main cities, which means that the decision to build a new highway is probably influenced by the growth prospects of nodal cities, but unaffected by the characteristics of places located in intermediate segments. By using a small geographical unit (e.g., municipalities or highway segments), it would thus be possible to eradicate this problem. However, for this argument to have some validity it must be the case that the units analyzed belong to intermediate highway segments. An inspection of the Spanish highway network (see previous section) suggests that this was probably not the case for most of the segments built during the last three decades. The claim seems to be more valid for the segments built during the period 2003-07, the one analyzed here. An additional problem is that in many cases more than one route might connect two nodal cities; the government chooses between these routes by taking into consideration various technical aspects (e.g., ruggedness and land availability) as well as other differentials (e.g., population size or even political clout). This means that, even in this case, these differences need to be dealt with when selecting the control group.

Fourth, some recent papers deal with the endogeneity issue by seeking an exogenous source of variation in road construction. For example, Baum-Snow (2007) and Duranton and Turner (2012) employ the road network planned many years before and/or information from historical road networks. They claim that the planned/historical road network was designed with purposes in mind that were unrelated to future local growth (e.g., connectivity between major cities, exploration routes). For the Spanish case, Garcia-López (2012) and Garcia-López *et al.* (2013) use historical maps from the eighteenth and nineteenth centuries. They argue that these old road networks were built with the purpose of connecting the capital city, Madrid, with the periphery so as to facilitate military control of the territory and/or to foster nation building (see also Bel, 2010). They document that the modern highway network has the same radial structure and can, thus, be explained in part by the old historical network. The exogeneity of such instruments relies on the various motives underpinning construction in the past, but it can only hold after conditioning for a range of demographic and geographic covariates[15]. In any case, unfortunately, we are not able to use the instruments constructed by Garcia-López *et al*. (2013) in this paper, the reason being the segments we analyze (built during 2003-2007) do not follow the old radial network (see previous section), which means that the instruments are unable to explain satisfactorily the location of the more recent highway projects.

In short, having reviewed these methodological approaches, we conclude that, in our case, the best way to proceed is by seeking to select the best possible control group for our treated municipalities and then to compare the time evolution of the outcome variables for these two groups. The following sections describe how we define the treated and control groups and also how we estimate the effects of highway construction.

3.2. Research design

Sample. Our starting sample includes 1,841 municipalities and reflects the availability of our data. The information on new highway segments covers the whole of Spain (with the exception of the Canary Islands), but the database on land use categories is not available for certain regions (the Basque Country and Navarra) and the information is incomplete for many municipalities (especially for 1995, which is the start year of the database). Moreover, most of the other databases used are restricted to municipalities over 1,000 inhabitants, meaning that the smallest municipalities have been eliminated from our sample. We have also eliminated some municipalities for which we were unable to find information regarding some of the control variables. The eventual database includes virtually all municipalities with more than 5,000 inhabitants and aproximately 50% of those with between 1,000 and 5,000. We believe the final sample to be representative of the population, at least for the municipalities with more than 1,000 residents[16].

Treated municipalities. We define our treated units as the municipalities in our sample that gained highway access during the period 2003-07 but which had access to a main road in 2003. Panel (a) in Figure 3 illustrates the selection of treated municipalities in a hypothetical

[15] The main Spanish cities already existed when these road networks were built and these old roads even sought to avoid highly rugged terrain.

[16] Various checks performed suggest that our sample is representative of the whole population. First, we compared our sample with the municipalities for which we have land use information (those used to construct the data for Table 1) and the numbers are not very different. We also compared the variables for which we have information for all municipalities with between 1,000 and 5,000 residents (e.g., population, land area, population of the urban area, ruggedness, etc.) finding no differences. Results are available upon request.

‘local labor market’. Treated municipalities are those represented in violet: both a main road and a new highway cross their jurisdiction. Municipalities represented in blue are not directly treated (i.e., they did not obtain a new highway) but they belong to the same ‘local labor market’ as a municipality gaining highway access, and so they constitute an alternative set of treated municipalities. We use these municipalities to assess whether the effects of highways ‘spill over’ the boundaries of the municipalities directly affected by the highway. Municipalities in green are not treated because of a lack of data.

[Insert Figure 3]

As explained in the previous section, 291 municipalities gained access to a new highway during the period 2003-2007. Of these, 14 did not have access to a main road prior to that period. This suggests that restricting the analysis to the sample with prior access to a main road might make sense: places with and without prior access to a main road might simply not be comparable. Of the remaining 277 municipalities (=291-14), 129 have fewer than 1,000 residents, and 54 have between 1,000 and 5,000 residents, but we did not have access to all the required data for them. This leaves us with 99 municipalities that: (i) gained highway access between 2003-2007, (ii) already had access to a main road in 2003, and (iii) for which we have all the data. Figure 4 illustrates the location of these treated municipalities in the map, highlighting both the relevant highway segment and municipal boundaries.

[Insert Figure 4]

Control municipalities. We define our control units as the municipalities that fulfill three conditions: (i) did not gain highway access between 2003-07, (ii) had access to a main road in 2003 but not to a highway, and (iii) did not belong to the same ‘local labor market’ as any of the treated municipalities. We use the ‘local labor markets’ constructed by Boix and Galletto (2004) based on commuting patterns. In our sample, we have 742 municipalities that already had access to a highway in 2003; these have to be discarded as controls. The remaining 986 municipalities (=1,827 – 742 – 99) did not have highway access in 2007. Of these, 663 did have access to a main road in 2003, and 323 were located in a ‘local labor market’ not containing any of our treated municipalities. These 323 municipalities, therefore, constitute our control group. The exclusion of municipalities not gaining direct access to the highway but belonging to the same ‘local labor market’ as the treated units serves to ensure that the controls are not affected by the treatment[17], since this would bias the estimated effect of the

[17] This is known in the evaluation literature as the SUTVA (Stable Unit Treatment Assumption) and states that “the potential outcome of one unit should be unaffected by the particular assignment of treatment to the other units” (see Cox 1958).

highway on economic outcomes[18]. As explained above, we use these municipalities as an alternative treatment group, allowing for the possibility that the effect of highways extends beyond the boundaries of the municipality obtaining the new highway. In Panel (b) of Figure 3 we illustrate the selection of controls belonging to a hypothetical 'local labor market' (different from that in Panel (a), from which we have selected the treated units). Municipalities depicted in yellow are the controls, because they had access to a main road and did not gain access to a new highway. Municipalities in pink are not used as controls, either because they already had access to a highway before that period or because they do not have access to a main road. Finally, municipalities in green are potential controls, but we have no data for these.

Timing of treatment. As explained above, we have good information regarding the period in which the highways were completed. By comparing 2003 and 2007 road maps, we can determine which municipalities gained highway access during this period. What we do not know, however, is the timing of other important events in the construction of a highway. When did the construction of the highway segment begin? When was the tender for the highway segment awarded? When did the government include an item for this project in its budget? When did a preliminary project for the highway first become available? When was the highway included in a road plan? The timing of these decisions (and not solely the completion of the road) might also be relevant for our analysis, especially if local governments have access to this information and use it to forecast whether a new highway will be accessible in a near future.

Although, we do not have the details of all these steps for all highway segments, we can predict what the average timing is and what should be the appropriate response of a given local government. We know, for example, that the construction of a highway segment of average length (say 10 to 20 km) takes around two years. We also know that the time lag between a decision being taken by the government to include a project in its budget and the start of construction is approximately two years (a period in which the many complications of the tendering process have to be resolved)[19]. Clearly, prior to this four-year period, the

[18] The direction of this bias is unknown, depending as it does on the sign of the spillovers. If, for example, neighboring municipalities also benefit from the highway, comparing municipalities gaining direct access to a highway with other nearby municipalities would bias the coefficient downwards. See, e.g., Boarnet (1997) for evidence on the spillover effect of highway investment.

[19] This information was obtained in conversation with experts in the implementation of highway construction projects. This was followed up by an internet search monitoring the evolution in a number of major highway projects during the period analyzed (i.e., several segments of highways A-66, 'Autovía de La Plata' and A-23 Zaragoza-Teruel). We examined the Memoranda of the Spanish Ministry of Public Works, press information about tenders, etc. Our research showed that the timing

government might already have undertaken some work in relation to the highway segment, including, for example, drafting various projects, conducting environmental evaluations, including proposals in road planning documents, etc. This preliminary period could extend from between one or two years in the case of projects that are added to the political agenda by surprise to decades in the case of projects that lost their initial support because of changes in political priorities or the lack of resources[20].

[Insert Figure 5]

The point we wish to emphasize is that, even if it is true that local government will probably be aware of the project from the outset, the reaction to a new highway only begins when that local government really believes that the construction of the road will go ahead. So, although we expect local governments to act in anticipation of the completion of the road, we consider that this reaction will perhaps only start once the project has been included in the budget and, primarily, once the tendering process is complete. At this juncture, the local government can reasonably expect the highway segment to be built and that it will be completed in a period of around four years. This means that for projects completed during the period 2003-2007 (which in fact coincided with a local term-of-office), it is reasonable to expect that it was the local incumbent during the previous term (i.e., 1999-2003) that actually started to consider the possibility of amending the master plan in order to convert land from rural to urban uses. Figure 5 illustrates the timing of our treatment: the treatment period (labeled *after treatment*) covers the period 1999-2007, and is divided into two sub-periods, 1999-2003 when the project was presumably started, and 2003-2007 which is when we know that the project was completed. The period 1995-1999 is the period *before treatment*: the year 1995 is our initial period, used as the baseline for comparisons of the evolution of the outcome variables and also to measure pre-treatment municipal characteristics; the year 1999 is reserved to perform a validity test, since we do not expect the treatment to have any effect on the outcomes for 1999.

3.3. Matching

By restricting the sample to those municipalities with prior access to a main road we ensure that the treated units (those gaining access to a new highway) and the control units (the remaining municipalities) are more comparable. Note, however, that only a modest fraction

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described here matched well with that of the cases studies. Detailed information is available upon request.

[20] In fact, such delays may also occur (albeit to a lesser extent) in the budgeting phase, thus delaying the tendering process (see Bel, 2010, and Caamaño and Lago, 2012, for evidence on delays in the execution of infrastructure budgets in Spain).

of the municipalities with prior access to a main road gained new access to a highway during the period. This suggests that these municipalities should still differ from those that did not receive the treatment. One possible way of dealing with these differences is to control for other factors that might have a simultaneous effect on highway location and on local land use policies. However, it is well-known that the ability of regression analyses to adjust for differences in observed covariates is severely reduced when the between-group differences in these covariates are substantial (e.g., Rubin, 2001; Imbens and Wooldridge, 2009), as is probably the case here. In this situation, using matching methods to balance the distribution of the covariates of the two subsamples helps reduce the bias of the estimates. The goal is to compare cases where all other causal variables are as similar as possible, so that any difference between cases can be attributed to the treatment (see, e.g., Rosenbaum and Rubin, 1985). Matching is the observational study analog of randomization in ideal experiments (see, Rosenbaum and Rubin, 1983, and Rubin and Thomas, 2000), although less complete as it can only balance the distribution of observed covariates. A further advantage of matching is its complete transparency. The matching algorithm is applied before the estimation of the treatment so as to balance the covariates of the two groups as much as possible. This ensures that the choices made by the researcher at this stage are not contaminated by the knowledge of how the choice of the covariates impacts the results obtained. As Ho *et al*. (2007) note, by using matching researchers are forced to specify a priori the research design they are going to use.

In this paper we use propensity score matching to select a subset of the municipalities with prior access to a main road that are most similar to those gaining access to a new highway. We then adhere to the recommendation of Ho *et al*. (2007) and estimate a parametric model with the data of our final matched sample. Other authors, such as Rubin (2001) and Crump *et al*. (2009), also recommend this procedure, suggesting that the propensity score be used only for systematic sample selection as a precursor to regression estimation (or to more complex parametric methods). In most studies using matching techniques, the analysis performed to obtain the treatment effect is a simple difference in means (or the equivalent to a bivariate regression between the treatment indicator and the outcome, in the parametric case). However, it is well-known that if the matching is not exact, the procedure can be improved by adjusting for covariates. There are several ways of performing this adjustment non-parametrically (Rubin, 2001; Dehejia and Wahba, 1999; Abadie and Imbens, 2006 and 2011), but the obvious way is simply to run a multivariate regression using the matched sample and the covariates employed in the estimation of the propensity score. Ho *et al*. (2007) recommend this procedure and suggest treating the predetermined covariates as fixed, meaning that standard errors and confidence intervals should be computed as in a normal regression framework[21].

Matched sample. We constructed the matched sample using the 'propensity score'. We estimated a logit model, using as the dependent variable a dummy equal to one if the municipality gained access to a new highway during the period 2003-2007 (and zero otherwise) and as regressors variables deemed to have an influence on both the location of the new highway segment and on the conversion of land from rural to urban uses. The 'propensity score' was then computed and control municipalities were matched to their treated counterparts based on presenting a similar 'propensity score'[22]. The method used was the 'nearest neighbor matching with replacement', whereby a given control unit can be matched to more than one treatment unit, which increases the average quality of matching and reduces the bias.

Matching variables. As explained above, the matching strategy builds on the 'unconfoundedness' or 'conditional independence' assumption, requiring that the outcome variable (i.e., land conversion) be independent of treatment (i.e., highway placement) conditional on the 'propensity score'. Hence, implementing the matching procedure requires choosing a set of variables that credibly satisfy this condition. Only variables that simultaneously influence the treatment decision and the outcome variable should be included. Obviously, in order to avoid interference with the treatment, these variables should be measured prior to the treatment; in our case, the variables were measured circa 1995 (see Table A.1 in the Appendix).

The variables used to estimate the logit equation can be classified into the following groups. First, we include a set of demand variables, on the grounds that in places where there is more demand for building we would expect there to be more land conversion and a greater government response in providing the required infrastructure. In this group we include the following variables (see Table A.1 in the Appendix for precise definitions): log(*Urban area population*), *Major urban area* dummy, log(*Population*) and log(*Unemployment*). All these variables have been previously reported to be key determinants of land use decisions (Solé-Ollé and Viladecans-Marsal, 2012) and highway location (Holl, 2011)[23]. Second, we include a

[21] In some types of matching, the parametric analysis might require some adjustment. For instance, when using 'matching with replacement', weights must be used to ensure that the parametric analysis reflects the actual observations (see Ho *et al*., 2005; and Dehejia and Wahba, 1999).
[22] Just six municipalities fell outside the common support. We performed a robustness check by excluding them from the analysis, and the results did not change.
[23] The unemployment variable might also have an impact on highway placement given the high redistributive bias of Spanish infrastructure construction (see Solé-Ollé, 2013).

set of variables measuring the geographical constraints on both development and highway building: log(*Open land*), log(*Area's open land*), log(*Ruggedness*), log(*Area's ruggedness*), and % *Vacant land*. In places with large tracts of open land there is more room for development and mapping out the highway route can also be expected to be easier. Municipalities surrounded by other municipalities with huge amounts of available open land will probably see how both the location of the highway and the new development occur in neighboring municipalities. Places with poor topography are less likely to gain direct access to a highway and are more likely to be less developed. Places with large tracts of vacant land at the outset do not need to convert that much land from rural to urban uses as land is already available for development and, as land is ready to build, the changes of getting highway access are also probably larger.

The list of potential variables to include is longer but, following Ho *et al*. (2007), we opt for a parsimonious specification where all the variables used are statistically significant and help to predict the outcome of interest. The use of this parsimonious specification produced a good balance of covariates and good matches. Nevertheless, we also tried some additional specifications. We added the following demand variables: *Beach* and *Coastal* dummies, *Tourist specialization*[24], and *Employment density* and *Predicted Employment growth*[25]. These variables did not add much explanatory capacity to the model and in none of the cases was the t-statistic greater than one. We also tried a specification whereby we added some variables that might be assumed as being correlated with preferences for/against development. These were %*Homeowners*, %*Commuters*, *Right-wing government* dummy, and *Majority government* dummy. None of these variables had a discernible impact on the probability of gaining highways access, and so were not included in the final specification.

Note also that some of the variables included in the logit are measured at the municipality level, while others are measured at the 'local labor market' level, it not being clear which is the best choice. On the one hand, given that highways constitute network infrastructures it seems to make sense to consider the traits of the surrounding area. On the other hand, the decision might be taken to include all the variables measured at both levels. In some cases, however, this generates too much noise, given the high spatial correlation of the

[24] Improving accessibility to tourist areas (and, hence, to beaches) seems to have been a relevant driver of highway location until the mid-1990s (see Holl, 2004). Note, however, that only a few of the new highway segments built between 2003 and 2007 link up to the coast (Figures 2 and 4).

[25] In fact, these last two variables had a negative (although not statistically significant) impact on the probability of gaining access to a new highway, and the effect disappeared when controlling for the level of unemployment. In Spain, therefore, it seems the goal of helping lagged regions is granted greater importance than more efficiency-oriented motives in the location of highway projects (see Solé-Ollé, 2013).

variables (the case of unemployment, for example), so we opted to retain only those variables that gave the best performance. (Note that in the case of population, open area, and ruggedness, we included the variables measured at both levels of aggregation)[26].

Finally, we also include a set of political variables. Here, we consider that the main political determinant of the probability of a municipality gaining highway access is the partisan alignment between the mayor and the regional president and/or the central government (see Solé-Ollé and Sorribas-Navarro, 2008). Since during most of the period (1996-2004) the party in power at the central level was the right-wing ‘Partido Popular’ (PP from now on), we included in the equation a set of variables that measures the possible combinations of having a regional president belonging to the PP and a mayor that does or does not belong to this party. Moreover, in the case of the regional government we also allowed for the possibility that the PP had been in control of the region for most of the time or alternatively that the control of the region had swung back and forth from the PP to the PSOE (the left-wing ‘Partido Socialista Obrero Español’). Using a series of F-tests we reduced the number of political variables to just two. The two political categories that actually added some explanatory power to the equation were the interaction between being a regional PP stronghold (i.e., *Core* PP dummy) and having a mayor that did not belong to this party (i.e., *Unaligned mayor* dummy) and the interaction between being in a region that periodically swung from PSOE to PP control or vice-versa (i.e., *Swing* PP dummy) and having a PP mayor (i.e., *Aligned mayor* dummy).

Validation. Using the aforementioned variables we are able to balance the covariates in the two subsamples (see Table A.2 for the results of the logit estimation). We performed several tests to determine whether or not we achieved a good matching. First, we performed a comparison of means between treated and control units in the unmatched and matched samples (see Rosenbaum and Rubin, 1985). These tests are shown in Table A.3 in the Appendix. In the unmatched sample, the treated group (the municipalities gaining highway access) are disproportionately located in major urban areas or in ‘local labor markets’ with larger populations, have more vacant land and less open land (both in the municipality and in

[26] Some papers suggest that in these cases matching could adopt a multilevel approach. The problem with this, however, is that the spatial correlation is quite high for some variables. This means that using two levels (i.e., municipality and ‘local labor market’) does not improve the model’s explanatory capacity. We therefore opted for a more practical solution: selecting the level of each variable that improves the explanatory capacity of the model. Some papers (see, e.g., Arpino and Mealli, 2011) even suggest using fixed effects for higher layers of aggregation (e.g., region, ‘local labor market’). This was not an option in our case, given the reduced number of observations for some of these higher units.

neighboring areas), the terrain is less rugged (also both in the municipality and in the immediate area) and are also more politically appealing. In the matched sample, none of the differences in means between the treated and the control group are statistically significant. Second, we also examined standardized bias both before and after matching; before matching, many variables presented a bias greater than 20%, which is the level above which some authors suggest linear regression coefficients risk being highly biased (see Imbens and Wooldridge, 2009). After matching, all the variables presented a bias below this level and the reduction in % bias was substantial (in the order of between 60 and 90% in most cases)[27]. Third, we also re-estimated the propensity score on the matched sample and compared the pseudo-R2s before and after matching, which were actually 0.360 and 0.029, respectively. LR tests of joint significance of the regressors before and after the matching presented values of 162.12 and 6.54, with p-values of 0.000 and 0.886, respectively. All these tests suggest that matching was quite successful in balancing the sample.

3.4. Estimated equation

We estimate the effect of receiving the treatment during the period that extends from year $t0$ (before treatment) to some year in the future t (after treatment) on the growth in the outcome variable between these two moments in time. The treatment variable is denoted by Δh_i and is a dummy equal to one if municipality i gained access to a new highway during the period, and zero otherwise. The estimation is performed separately with the samples containing each of the two control groups identified in the previous sections: either the municipalities with prior access to a main road, or a subset of these municipalities selected using matching techniques.

Our main outcome variable is the increase in developable land during this period measured relative to developed land at the beginning of the period (see section two). Recall that we denote this variable by $\Delta d_{i,t\text{-}t0}$. We estimate the following equation:

$$\Delta d_{i,t-t0} = \alpha + \beta_1 * \Delta h_i + \mathbf{z}_{i,t0}^{'} \gamma + \varepsilon_{i,t} \qquad (1)$$

where $\mathbf{z}_{i,t0}$ is a vector of municipal characteristics either time-invariant or measured before treatment, and $\varepsilon_{i,t}$ is an error term with the usual properties. The variables included in $\mathbf{z}_{i,0}$ are the same as those used in the selection of the matched sample. The inclusion of these controls is not strictly necessary in the case of the matched sample but, as shown in Abadie and Imbens (2006 and 2011), covariates might help reduce the bias in the estimation if matching is not perfect.

[27] Note also that the average bias was 39.2% before the matching and just 4% after.

The before-after analysis allows us to eliminate any time-invariant factors that may have an influence on the decision to convert land from rural to urban uses and on the decision to build a highway in a given place. Clearly, there might be time-invariant omitted factors which are simultaneously correlated with $\Delta d_{i,t\text{-}t0}$ and Δh_i. We deal with this problem by assuming unconfoundedness given lagged policy outcomes and other pre-treatment variables (see Imbens and Wooldridge, 2009)[28]. So, we include in the $\boldsymbol{z}_{i,0}$ a measure of the percentage of vacant land at the beginning of the period $v_{i,t0}$. Recall from section two that $\Delta d_{i,t\text{-}0} = \Delta v_{i,t0.}$ Vacant land is defined as land that has been classified in the past as developable but that has yet to be developed (see section two). Clearly, the decision to increase the amount of developable land is strongly affected by the amount of developable land already available in the municipality (see Solé-Ollé and Viladecans-Marsal, 2012).

One way of assessing the validity of the unconfoundedness assumption is to estimate the causal effect of the treatment on a variable known to be unaffected by it, typically because its value is determined prior to the treatment itself (see Imbens and Wooldridge, 2009). The most interesting case is to consider the treatment effect on a lagged outcome. If this effect is not zero then the treated observations can be assumed to be distinct from the controls. If, however, the treatment effect is zero, it is more plausible that the unconfoundedness assumption holds. To implement the test, the vector of covariates has to be split in two groups, separating a pseudo-outcome from the other variables. Here, our pseudo-outcome is the increase in developable land from 1995 (the initial period) to 1999 (the year before the beginning of the treatment period). When testing for the treatment effects on the increase in developable land during the period 1995-1999 we also control for pre-treatment covariates, including the amount of vacant land in 1995. The test thus considers the differences in the amount of developable land in 1999 for municipalities that are already similar with respect to their amount of vacant land in 1995. Actually, this test can be implemented together with the estimation of the treatment effects for the period after the treatment. The estimated equation is as follows:

[28] There is some discussion in the literature regarding the advantages and drawbacks of controlling for lagged outcomes in a before-after analysis. Estimating equation (1) without conditioning for lagged outcomes is what a traditional 'difference-in-differences' analysis does. The specification that adds the lagged outcome is referred to as the 'uncounfoundedness-based' approach. Imbens and Wooldrige (2009) conclude that "the 'DiD' approach appears less attractive than the unconfoundedness-based approach in the context of panel data. It is difficult to see how making treated and control units comparable on lagged outcomes will make the causal interpretation of their difference less credible as suggested by the DiD assumptions" (p.68). The use of lagged outcomes in matching analysis is also very common (see Blundell and Costa, 2008).

$$\Delta d_{i,t-t0} = \alpha + \beta_1 * \Delta h_i + \beta_2 * after_t * \Delta h_i + \mathbf{z}_{i,0}^{'} \gamma + \delta_t + \varepsilon_{i,t} \tag{2}$$

Here, we pool three cross-sections of data, corresponding to the periods 1995-1999, 1995-2003, and 1995-2007. The dummy *after* is equal to one for those periods ending in a year in which we expect new highways to have an effect (i.e., 2003 and 2007) and zero for the period 1995-1999, and δ_t are period fixed-effects. A test of whether β_1 is equal to zero allows us to assess the uncounfoundedness assumption: conditional on $z_{i,t0}$, the effect of Δh_i on $\Delta d_{i,1995\text{-}1999}$ should be zero. The parameter β_1 is the treatment effect in which we are interested. In fact, since the effect of the highway might change over time (recall that we do not know for certain whether municipalities are able to anticipate fully the effect of the highway during the term-of-office prior to the completion of the infrastructure), it is convenient to allow for different effects in the two treatment sub-periods (i.e., those ending in 2003 and 2007). This is the equation we estimate to obtain these period-specific effects:

$$\begin{aligned}\Delta d_{i,t-t0} = \alpha + \beta_1 * \Delta h_i + \\ + \beta_2 * started_t * \Delta h_i + \beta_3 * completed_t * \Delta h_i + \mathbf{z}_{i,0}^{'} \gamma + \delta_t + \varepsilon_{i,t}\end{aligned} \tag{3}$$

where *started* is a dummy equal to one for the period ending in 2003 and *completed* is a dummy equal to one for the period ending in 2007. Equations (2) and (3) are estimated by OLS with standard errors clustered at the municipality level.

Finally, in order to allow for heterogeneous effects, equation (2) is re-estimated allowing the treatment to be different in the two different regimes:

$$\begin{aligned}\Delta d_{i,t-t0} = \alpha + \beta_1 * \Delta h_i + \\ + \beta_{21} * d(x_i < \bar{x}) * after_t * \Delta h_i + \beta_{22} * d(x_i \geq \bar{x}) * after_t * \Delta h_i + \mathbf{z}_{i,0}^{'} \gamma + \delta_t + \varepsilon_{i,t}\end{aligned} \tag{4}$$

where $d(x_i < \bar{x})$ and $d(x_i \geq \bar{x})$ are two dummies equal to one if the value of a given variable is lower/higher than a given threshold (usually the median of the distribution)[29]. The variable *x* is also a pre-determined variable but may or may not be one of the variables included in the vector $\mathbf{z}_{i,t0.}$ The interacted variables measure: (i) the strength of the demand shock, (ii) geographical impediments to building, (iii) the amount of vacant land at the outset, and (iv) the preferences of locals for/against development. Many papers have shown that these variables are drivers of decisions regarding land use regulations (see, e.g., Sáiz, 2010, on the

[29]Not all the potential covariates were eventually included in the logit used to estimate the 'propensity score'. Where one of the *x* variables was not included in the $\mathbf{z}_{i,t0.}$ vector, we added the dummy as a control in the estimation. Similarly, a more flexible estimation would involve allowing the β_1 coefficients to vary between the two regimes.

effect of topography, Solé-Ollé and Viladecans, 2012, on the effects of the amount of vacant land, and Kahn, 2011, Hilber and Robert-Nicoud, 2012, and Solé-Ollé and Viladecans, 2012, on the preferences of residents). What is less evident, however, is that these drivers also affect the size of the impact of a highway on land use decisions. In Appendix A we outline a simple theoretical model that is capable of predicting these interaction effects. This model suggests that (under some mild assumptions) the effect of a new highway access on land conversion should be stronger: the stronger is the demand for building in the municipality, the easier it is to build out (e.g., the less rugged is the terrain), the lower the amount of vacant land at the outset, and also the less opposed to development locals are.

4. Results

Main results. Table 3 presents the results obtained when estimating equations (2) and (3). In panel (a) we estimate the *overall effect of new highways* (equation (2)) throughout the whole treatment period (identified via the *after* dummy). In panel (b) we provide more detailed information regarding the *effect of new highways over time* (i.e., *started* and *completed* dummies, which refer to the period 1999-2003 and 2003-2007, respectively). Columns (i) and (ii) report estimates for the sample of municipalities with prior access to a main road. In columns (iii) and (iv) we report estimates using the matched sample. Columns (i) and (iii) report the results without covariates (with just the year fixed effects) and columns (ii) and (iv) add the full set of controls to the equation.

[Insert Table 3 and Figure 6]

The average effects of highway construction throughout the whole treatment period (the coefficient for the interaction between the Δh_i and $after_i$ dummies) are positive and statistically significant. However, the effect is greater when using the matched sample. For example, the results in column (iv) indicate that a municipality gaining access to a new highway experiences an extra increase (i.e., with respect to a similar municipality not obtaining such access) in the amount of developable land of around 89% of the initial size of the city (i.e., of the amount of developed land in 1995). This is, indeed, a particularly large effect, being twice as great as the effect obtained when using the whole sample (see column (ii)). Panel (b) of Table 3 reports the estimated coefficients for the interactions between the Δh_i and the $started_i$ and $completed_i$ dummies and, thus, allows for different effects to occur in the 1999-2003 and 2003-2007 periods. The results in columns (iii) and (iv) (corresponding to the matched sample) suggest that most of the effects occurred during the first municipal term-of-office (period 1999-2003). The estimated treatment effect by 2003 is around 70%, rising to around 100% by 2007. However, a simple test of equality of coefficients (bottom of panel (b)) is unable to reject that these two numbers are equal. The results are qualitatively similar when using the whole sample (columns (i) and (ii)), although here the effect is not statistically significant during the first period. In any case, however, the test of equality of coefficients cannot reject that these two numbers are also equal in this case.

These results are also illustrated in Figure 6. In this figure we plot the evolution of the amount of developable land, which is simply the summation of the starting amount of vacant land (as of 1995) and the (estimated) increase in developable land. The coefficients used to draw this graph are taken from column (iii) of Table 3. The plot shows how the evolution of the amount of developable land in the treated and control municipalities diverged during the periods 1999-2003 and 2003-2007. It is quite clear that there is a differential trend and that this trend does not differ much in the two treatment periods. The graph also emphasizes that the level reached in 2007 is higher than that in 2003; however, the confidence intervals are too wide for us to be able to discard the possibility that these two numbers are equal.

A possible concern regarding these results is that they might simply be picking up the fact that places benefiting from highway construction are just different from other locations (i.e., they tended to grow more during the period and they had a higher probability of obtaining highways because of this). Yet, note that the results in Table 3 also provide the information needed to test the 'uncounfoundedness' assumption. The coefficient estimated for Δh_i is not statistically different from zero, suggesting that localities that gained access to a main highway and those that did not grew no differently during the period 1995-1999. Note also that in the matched sample (i.e., columns (iii) and (iv)) treated and control municipalities are identical with respect to their respective amounts of vacant land in 1995 (a fact that is confirmed by the equality of means tests presented in Table A.2 in the Appendix). This means that municipalities that were equal with respect to lagged outcomes (i.e., vacant land in 1995) also experienced growth of a similar magnitude during the following period, which preceded the construction of the highway. This is clearly illustrated in Figure 6 with the amount of developable land in the two groups virtually overlapping during the pre-treatment period (1995 and 1999) and diverging in the treatment period (2003 and 2007). Yet, it should be noted that the pre-treatment period was not one of complete inactivity as regards land use policies. In both groups there was a substantial amount of land being converted from rural to urban uses (see also Table 1 in section 2) and in the case of the control group the trend in the amount of developable land was virtually the same before and after 1999.

Interaction effects. Table 4 shows the results of the estimation of equation (4) –i.e., when we allow the effect to differ between groups of municipalities. The aim of this analysis is to test whether highways have a larger impact on land use policies in certain municipalities than they do in others. In Appendix A we illustrate this possibility by means of a simple theoretical model. Our model predicts that the impact of the highway will be greater in places facing larger demand shocks. In order to test this hypothesis we split our sample in two: municipalities located in urban areas with urban population over/below the median. We chose *Urban area population* (in fact, it is the population in the 'local labour market') as this is one of the variables with most explanatory power in the logit and also because it is statistically significant in the land conversion equation (although these results are not shown here for reasons of space). The model also predicts that the effects of the highway will decrease the more difficult it is to build. Here we use two variables: terrain *Ruggedness* (see Sáiz, 2010) and the availability of *Open space* (note that both variables presented a statistically significant impact both in the treatment and in the land conversion equations). In these two cases we also split the sample in two: values of each variable above/below the median. Likewise, the model predicts that the increase in the amount of developable land from a base period will be lower, the greater the amount of vacant land that is available at the outset. Once again, vacant land is a significant determinant of land conversion (see also Solé-Ollé and Viladecans, 2012) and was included in the final logit specification. Additionally, we split the sample into municipalities with high and low values of a further two variables plausibly correlated with the preferences of local residents in favor of/opposed to development: %*Homeowners* and %*Commuters*. Both groups are assumed to be opposed to development, homeowners because they believe development will depress the value of their property (see, e.g, Fischel, 2001, Ortalo-Magne and Prat, 2011, Dehring *et al*., 2008; Hilber and Robert-Nicoud, 2013) and commuters because they work outside the community and so do not benefit from improved job prospects in town. Finally, the model also predicts that the effect of a highway on land conversion will be greater the more pro-growth is the ideology of the local government and/or the higher is the influence wielded by developers (see Solé-Ollé and Viladecans, 2012 and 2013). To take these predictions into account, we also split our sample into municipalities controlled by right-wing vs. left-wing governments (i.e., the interacting variable is the *Right-wing* dummy, see Table A.1 for a complete definition) and also into municipalities governed by a majority government (i.e., *Majority* dummy) vs. municipalities governed by a coalition or minority government. We expect right-wing and majority mayors to be more responsive to the enhanced demand for building created by a new highway and, therefore, to convert more land from rural to urban uses.

[Insert Table 4]

The results in Table 4 confirm most of these predictions. Panel (a) reports the results when the sample was split according to demand and supply variables, and panel (b) reports the results when it was split in relation to preferences for or against development. In each column we report the coefficient estimated for each of the regimes, with *High* and *Low* in most cases indicating whether the variable is above/below the sample median. However, when the variable used to split the sample is a dummy (i.e., Right-wing or Majority), *High* and *Low* indicate whether the dummy is equal to one or zero, respectively. At the bottom of the panel we report, for each of the variables, a test of the equality of coefficients in the two regimes. The results show, first, that the effect of a highway on land conversion was restricted mainly to the sample of municipalities located in the most populated areas. In this case the treatment effect was approximately 100% of the initial city size vs. just 23% in the case of municipalities located in less dense 'local labor markets'. Moreover, the difference between the two regimes was statistically significant, and the coefficient of the low populated areas was not statistically different from zero. This result is consistent with findings in the literature that also show that the positive effects of highways are only recorded in areas that are in close proximity to urban areas (see, e.g., Rephann and Isserman, 1994). Second, the results also show that the effects of a new highway are restricted to municipalities with a substantial amount of open land and whose topography is favorable. In this last case, for example, the treatment effect in rugged areas is approximately 50% of the initial size of the city, while in places with a more favorable topography the effect is around 120% of the initial city size. The two coefficients are statistically different from each other at the 95% level. Third, the effect of the highway on land conversion is statistically zero in places with a high amount of vacant land at the outset. In such places there was no need to designate more land for development, since there was already sufficient land classified in this category in 1995. By contrast, in places with little vacant land the effect of the new highway was around 100% of the initial city size and statistically significant at the 95% level. These results suggest that, as expected, the effect of the construction of a new highway on land use policies is restricted to places with high demand and good topography, and where the supply of developable land was restricted before the demand shock.

In the first two columns of panel (b) we show how the effect of a new highway is also greater in places with a low proportion of homeowners and commuters. This impact is much more apparent in the case of commuters: in places with few commuters, the treatment effect was around 110% of the initial city size, while in places with a high proportion of commuters the effect was around 36%. Both coefficients are statistically significant (although the second one only at the 90% level), while the difference between the two coefficients is also significant (also at the 90% level). The difference between places with a low and a high percentage of homeowners is smaller and not statistically significant. Finally, in the last two columns of panel (b) we show the estimated coefficients for right-wing vs. left-wing governments and for majority vs. other types of government. The results are striking in both cases: the effect of a new highway on land conversion is much greater if the municipality is run by a right-wing mayor: 120% vs. 50%. Both coefficients are statistically significant, as is the difference between the two (at the 90% level). The difference is even greater in the case of majority governments: the treatment effect in this case is 130% (vs. 34% for a coalition or minority government). The difference between these two coefficients is statistically significant at the 99% level. The results suggest, therefore, that the preferences of the local community matter. Land use policies will follow highway construction to a lesser extent in places where the residents disapprove of development (i.e., municipalities with a large proportion of homeowners and/or commuters), in places where the mayor belongs to a party known to have an ideology that does not favor development (i.e., where the mayor belongs to a left-wing party), or where the mayor is more constrained by electoral considerations (i.e., the mayor governs without a majority).

Admittedly, however, these heterogeneous results need to be treated with extreme caution. Even if we had identified a causal effect in each of the subsamples, it would be difficult to attribute a causal difference in the treatment effect solely to the variable used in splitting the sample. Any of these variables might be correlated with other factors that have not been taken into account, and some of these factors have also been used for splitting the sample. For example, municipalities in urban areas also have less open space available and are places built on less rugged terrain. This means that it is difficult to determine which of these three variables is driving the results – it might be just one of them, two or all of them. A similar situation arises with the initial amount of vacant land available and the right-wing dummy, which are also positively correlated. To dissipate some of these doubts we might stress that the correlations between all the variables used to split the sample are quite low, most being less than 10%. The largest correlation coefficients are around 20% (precisely in the two examples cited above). In order to check whether this might be a problem for our results we re-estimated each of the interaction regressions adding as extra interactions those between $\Delta h_i * after_i$ and the other interacted variables that presented the strongest correlation with the one under analysis (e.g., in the case of vacant land, the right-wing dummy, and vice versa). In all cases, the results regarding the interaction effect for the original variable did not change greatly[30]. This suggests that the results shown in Table 4 are substantive and not driven by the omission of other variables that are also interacting with the treatment.

Building activity. The response of Spanish municipalities to the building of a new segment of highway, with the conversion of vast tracts of land from rural to urban uses, seems remarkable both in terms of quantity and speed. However, it remains unclear as to whether the response ultimately had an impact on real estate outcomes. Primarily, we are not in a position to determine whether the municipalities that expand their developable land most can accurately forecast demand for building in the municipality. It might be that they designate greater amounts of land for development in the hope that construction will occur at some point in the future if the land is available to be built upon. Therefore, it is important that we consider the effects of the construction of a new highway on real estate outcomes, including, for example, the amount of developed land and the number of housing units built. These considerations are undertaken in Table 5. Panel (a) presents the treatment effect over the whole *after* period and panel (b) differentiates between sub-periods. Columns (i) and (ii) present the results for the increase in the amount of *Developed land* and columns (iii) and (iv) for the increase in the number of *Housing units*. Columns (i) and (iii) use the whole sample (controls being municipalities with prior access to a main road) and columns (ii) and (iv) use the matched sample.

[Insert Table 5]

The results show that gaining access to a new highway also has an effect on the two specific real estate outcomes considered. The average treatment effect is 52% in the case of developed land. This means that, while a new highway provokes an 89% expansion of the 'potential' size of the city (i.e., the increase in the amount of developable land), the real expansion of the city was much lower[31]. This divergence can probably be attributed to time lags in the development process: as many municipalities did not dispose of sufficient vacant land at the beginning of the period (recall that these are precisely the ones that converted most land), they need time (in fact, one term-of-office) to modify the planning documents to permit more development to be undertaken. Although a number of development projects had already been started in the first period, others had to wait until the second term to be initiated and then several years were needed before these projects were completed. Panel (b) of Table 5

[30] For reasons of space, the results are not shown in the paper, but are available upon request. We also add to the equation interactions between the x's and Δh_i and also with the year fixed effects. The results were also qualitatively unchanged.

[31] Recall that we can compare those two variables precisely because they have been measured with respect to the same denominator, the initial amount of developed land.

confirms this intuition. In this case, the coefficient for the second period (on the interaction between Δh_i and $completed_i$) is much higher than that for the first period (on the interaction between Δh_i and $started_i$). Moreover, the coefficient for the first period is not statistically significant and the equality of the two coefficients can be rejected at the 90% level (see column (ii)). Note that this result differs from that obtained in the case of developable land in Table 3: in that case we were unable to reject the hypothesis that the increase in the amount of developable land occurred mainly in the first period.

This impression is confirmed when we consider the growth in the number of housing units. Here the point estimate for the first period is not only statistically insignificant but it is nearly zero. The effect in the second period is much higher: the new highway caused the housing stock to grow by 13%. Note that this effect is much lower than that for the amount of developable land. As explained in section two, this might be due to the fact that the type of development experienced in Spain during these years was extremely land-intensive. Vast tracts of land were allocated to commercial and industrial uses and employed for the construction of parking lots and the housing of infrastructure. Likewise, residential density fell considerably. Unfortunately, the data currently available do not allow us to investigate these possibilities in any further detail.

[Insert Figures 7 & 8]

Figures 7 and 8 show the evolution of the amount of developed land and of the number of housing units over the period for the treated and control municipalities. If we compare them with Figure 6 (which did the same for the amount of developable land), these two figures clearly show that, while the evolution of treated and control units began to diverge after 1999, the difference between the two groups was not substantial before 2007.

Spillover effects. The above results show that the impact of a new highway access on a municipality in which the highway segment is built can be substantial. However, as the spatial area of such a municipality is quite small, it would be reasonable to expect that a new highway would also have an impact on neighboring municipalities. In this section we examine the effects of the highway on municipalities belonging to the same 'local labor market' as that of the municipality gaining direct access to the highway. We use the same sample, and the treated and control units are unchanged. However, we are concerned with a different outcome: for each of the municipalities in the sample therefore we define a new variable, namely, the value of the outcome (i.e., the increase in the amount of developable land) in the other municipalities belonging to the same 'local labor market'. In Table 6 we show the results for all three outcome variables when focusing on the rest of the municipalities in the 'local labor market' as well as the results for the whole area. Columns (i) and (ii) show the results for developable land. Column (ii) indicates that the size of the treatment effect on these other municipalities is much smaller (i.e., 17% of the initial size of the city) than that on the municipality gaining direct access to the highway (89%, see Table 3). A further difference becomes apparent – the effect is also more clearly split between the two sub-periods. The increase in the amount of developable land is around 14% by 2003 and 27% by 2007. The hypothesis that these two coefficients are equal can be rejected at the 90% level. In the case of developed land, the effect in the neighboring municipalities is also smaller than in the central municipality (i.e., 19% vs. 61% in 2007). The timing of the effect is unchanged: development occurred mainly in the second sub-period.

[Insert Table 6]

In the case of housing units, however, the effect is greater in the neighboring municipalities (i.e., 17% vs. 13% in 2007). This might be attributed to the tendency for industrial and commercial land uses (which we suspect represent a very large percentage of the increase in land consumption over the period) to concentrate near the highway, while residential development is more evenly distributed in space tending perhaps to avoid the places where other land uses concentrate. Unfortunately, a lack of detailed information about land uses mans this claim cannot be assessed.

All in all, the conclusion that can be derived from the analysis is that the construction of a new highway segment has a huge impact on the municipalities gaining direct access to it. This effect, moreover, extends to other municipalities in the same 'local labor market', but the effect diminishes with distance from the highway.

5. Conclusion

In this paper we have analyzed whether Spanish local governments modify their land use policies in response to an increase in demand for building generated by a new highway. Our results show that this is the case, at least during the period 1999-2007. The increase in the amount of land designated for development during this period was twice as high in municipalities gaining access to a new highway than it was in other municipalities. The results also show that this effect occurred during the early years, coinciding with the initiation of the highway project. This suggests that municipalities are able to anticipate the effects of a highway on housing demand, so ensuring that there will be sufficient land to start the projected developments at a later date. The impact of the highways also extended to real estate outcomes including, for example, the amount of developed land and the number of housing units. The impact on these two outcomes was smaller than it was for the developable land, and occurred mostly during the second half of the period. We interpret this as being due to the lengthy process of converting land from rural to urban uses, which usually takes a whole term-of-office. In municipalities without sufficient vacant land at the outset, development projects have to wait until the planning documents have been modified. This interpretation is reinforced by a number of additional results indicating that the municipalities with little vacant land initially are those that convert most land from rural to urban uses. Overall, these results suggest that, while local land use policies appear to adapt to market forces quite rapidly, the time required to amend planning documents and implement the changes may contribute to delays in the completion of development projects. However, without access to municipal-level housing price data we are not really in a position to assess whether this has been a particular problem in Spain.

Our results also show that the reaction of Spanish local governments to the housing demand shock created by a new highway is highly heterogeneous. It appears that only those municipalities located in a large enough ‘local labor market’ opt to increase the amount of developable land to any substantial degree. This might simply be because the housing demand shock that we have assumed does not actually manifest itself in the more rural areas; these local councils might not perceive that the highway will increase building activity that much and so they take no immediate steps to modify the existing planning document. This conclusion is further strengthened by the fact that the impact of a new highway on land development and housing construction is much lower in less urbanized areas. Places with a shortage of open spaces and with a very rugged topography also seem to react less to the opening up of a highway section. As discussed, these results are in line with the literature. However, we offer some novel results and some findings that are often overlooked: for example, local government reaction to a new highway (as well as its eventual impact on real estate outcomes) is also much less evident in places where the locals (residents or their political representatives) are opposed to development. More specifically, we find that places with a high proportion of homeowners and commuters tend to convert less land from rural to urban uses following the construction of a highway. By contrast, municipalities with a right-wing mayor (an ideology that has been documented as being favorable to development in Spain) and with a majority government (which can afford to cater more to developers’ than to voters’ interests) increase the land designated for development much more than is the case of other municipalities gaining access to a new highway.

Overall, our study depicts a fairly mixed scene. On the one hand, market forces had an enormous influence over the use of land, this despite the fact that Spain’s land use regulations are strongly interventionist. The huge increase in the amount of land designated for development during the last housing boom, especially in places experiencing an above average shock (i.e., in places gaining access to a highway), is clear evidence that these regulations did not represent a complete impediment to development at the aggregate level. On the other hand, however, the need to adapt these regulations to the new conditions may have led to some delays in the development process. Moreover, in certain places the regulations might have prevented the eventual materialization of development projects generated by the new highway. As described, this might have occurred in places where residents and/or political representatives were openly opposed to growth and/or the political process was less permeable to the pressures of development lobbies. Both the delays and the prohibitions on new development might have impacted on the evolution of housing prices in Spain; however, this claim is very difficult to verify due to the lack of data. Yet, were this to have been the case, we might conclude that the highway construction boom experienced in Spain during recent decades could also have contributed to fuel the boom in housing prices.

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Tables and figures

Table 1:
Evolution of land use policy outcomes in Spain, 1995-2007

	1995	1999	2003	2007
Δ *Developable land*$_{t,1995}$ /*Developed land*$_{1995}$	--.--	0.286	0.733	1.135
Developable land$_{t}$ /*Developed land*$_{1995}$	0.702	0.989	1.453	1.837
Δ*Developed land*$_{t,1995}$ /*Developed land*$_{1995}$	--.--	0.187	0.455	0.518
Δ*Housing units*$_{t,1995}$ /*Housing units*$_{1995}$	--.--	0.087	0.202	0.387

Note: Municipalities of the Basque Country and Navarra not included. Source: *Estadísticas Catastrales* (several years), Dirección General del Catastro, Ministerio de Hacienda (http://www. catastro. meh.es/).

Table 2:
Evolution of the Spanish highway network, 1980-2011

	Km at the end of the period	*Km of new highways*	*% Increase*
1980-1990	5,520	2,222	67.34
1990-1995	7,950	2,430	44.02
1995-2000	10,292	2,342	29.45
2000-2003	11,582	1,290	12.53
2003-2007	14,028	2,446	21.12
2007-2011	16,322	2,294	16.35

Source: Anuario Estadístico (several years). Ministerio de Fomento (www.fomento.es).

Table 3:
Effects of new highways on land use policies

	Dep. var.: increase in Developable land ($\Delta d_{i,t\text{-}t0}$).			
	Main road		*Main road + Matching*	
	(i)	(ii)	(iii)	(iv)
(a) *Overall effect of new highways*				
Δh_i	0.191	-0.079	-0.049	0.046
	(0.239)	(0.244)	(0.289)	(0.279)
$\Delta h_i{*}after_t$	0.517	0.437	0.669	0.886
	(0.292)*	(0.184)**	(0.268)**	(0.293)***
Adjusted R^2	0.081	0.182	0.095	0.214
(b) *Effect of new highways over time*				
$\Delta h_i{*}\ started_t$	0.417	0.337	0.715	0.717
	(0.338)	(0.244)	(0.377)*	(0.338)**
$\Delta h_i{*}completed_t$	0.617	0.538	1.054	1.056
	(0.329)*	(0.245)**	(0.386)***	(0.322)***
$started_t = completed_t$	0.200	0.201	0.349	0.339
(*F-test p-value*)	(0.335)	(0.319)	(0.536)	(0.328)
Adjusted R^2	0.081	0.174	0.096	0.214
Time fixed effects	YES	YES	YES	YES
Control variables	NO	YES	NO	YES
Obs.	1266 = 422 × 3		462 = 154 × 3	

Notes: (1) $\Delta d_{i,t\text{-}t0}$= outcome variable, i.e. increase in the amount of developable land, as a proportion of initial amount of build-out land. (2) Main road = municipalities included in the control group are those with prior access to a Main road; Main road + Matching = municipalities included in control group are selected via matching from those with prior access to a Main road; (3) Δh_i = treated units, i.e. municipalities gaining access to a new highway during the period. (4) $after_t$: Dummy identifying the treatment periods. (5) Estimation method: OLS estimation in columns (i) and (ii) and weighted least squares in columns (iii) and (iv). (6) Control variables: variables used in the estimation of the 'propensity score' (see Tables A.1 and A.2 in the Annex). (7) Values in parentheses are standard errors; ***, ** & * indicate that the coefficient is statistically significant at the 1%, 5% and 10% levels; standard errors clustered at the municipality level.

Table 4:
Heterogeneous effects of new highways on land use policies

	Dep. var.: increase in Developable land ($\Delta d_{i,t\text{-}t0}$).			
	(a) *Demand and supply*			
	Urban area population	*Rugged-ness*	*% Vacant land*	*% Open land*
	(i)	(ii)	(iii)	(iv)
$\Delta h_i * after_t *$ (Dummy= *Low*)	0.231	1.237	1.014	0.306
	(0.320)	(0.506)***	(0.397)**	(0.415)
$\Delta h_i * after_t *$ (Dummy= *High*)	1.071	0.529	0.280	0.954
	(0.406)**	(0.289)*	(0.262)	(0.456)**
High - Low	0.840	-0.707	-0.915	0.647
(*F-test p-value*)	(0.383)**	(0.506)**	(0.557)*	(0.576)
Adjusted R^2	0.325	0.342	0.295	0.305
	(b) *Preferences for/against development*			
	% Home-owners	*% Com-muters*	*Right-wing mayor*	*Majority government*
	(v)	(vi)	(vii)	(viii)
$\Delta h_i * after_t *$ (Dummy= *Low*)	1.032	1.160	0.503	0.341
	(0.504)**	(0.477)**	(0.262)*	(0.167)*
$\Delta h_i * after_t *$ (Dummy= *High*)	0.653	0.361	1.215	1.302
	(0.303)**	(0.174)*	(0.478)***	(0.439)***
High - Low	-0.377	-0.865	0.711	0.965
(*F-test p-value*)	(0.574)	(0.447)*	(0.387)*	(0.373)***
Adjusted R^2	0.325	0.334	0.341	0.345

Notes: (1) Control group = *Main road + Matching*; all estimations include the same control variables as in Tables 1 and 2. (2) Overall effect of new highways; we only report the coefficient of the interaction between $\Delta h_i * after_t$ and the dummies defining each regime. (3) Low/High: in columns (i) to (vi) dummy equal to one if the interaction variable is higher than the median; in columns (vii) and (viii) High is a dummy equal to one if there is a *Right-wing mayor* and a *Majority government*, respectively, and equal to zero if there is a *Left-wing mayor* or a *Coalition/ Minority government* otherwise.

Table 5:
Effects of new highways on building activity

	Dep. var.: increase in Developed land ($\Delta b_{i,t-t0}$).		*Dep. var.: increase in Housing units* ($\Delta u_{i,t-t0}$).	
	(i)	(ii)	(iii)	(iv)
(a) *Overall effect of new highways*				
Δh_i	-0.131	-0.015	-0.061	-0.030
	(0.104)	(0.245)	(0.031)**	(0.201)
$\Delta h_i * after_t$	0.326	0.523	0.126	0.090
	(0.255)	(0.308)*	(0.039)***	(0.044)**
Adjusted R^2	0.146	0.219	0.250	0.258
(b) *Effect of new highways over time*				
$\Delta h_i * started_t$	0.164	0.376	0.079	0.051
	(0.239)	(0.295)	(0.034)**	(0.040)
$\Delta h_i * completed_t$	0.490	0.612	0.173	0.130
	(0.222)**	(0.241)**	(0.034)**	(0.062)**
$started_t = completed_t$	0.326	0.236	0.093	0.079
(*F-test p-value*)	(0.239)	(0.198)*	(0.072)	(0.049)*
Adjusted R^2	0.147	0.218	0.253	0.259
Time fixed effects	YES	YES	YES	YES
Control variables	YES	YES	YES	YES
Obs.	1266	462	1266	462

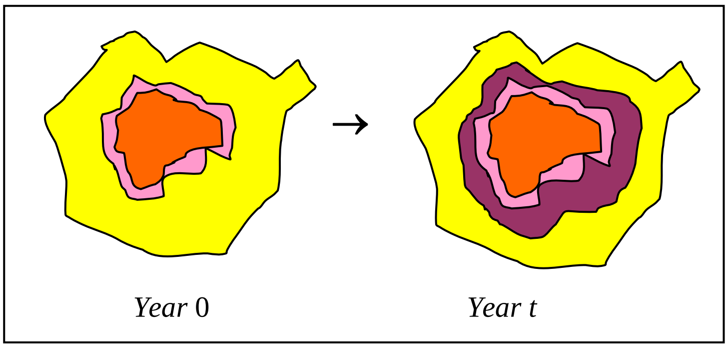
Notes: (1) Control group: *Main road* in columns (i) and (iii), and *Main road + Matching* in columns (ii) and (iv). (2) Effects in municipalities gaining access to a new highway. (3) See Table 3.

Table 6:
Spillover effects of new highways

	Dep. var.: increase in Developable land ($\Delta d_{i,t\text{-}t0}$).		*Dep. var.: increase in Housing units* ($\Delta b_{i,t\text{-}t0}$).		*Dep. var.: increase in Housing units* ($\Delta u_{i,t\text{-}t0}$).	
	Whole area	*Rest of Area*	*Whole area*	*Rest of area*	*Whole area*	*Rest of area*
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
(a) *Overall effect of new highways*						
Δh_i	0.024 (0.209)	0.038 (0.224)	-0.072 (0.108)	-0.035 (0.244)	0.023 (0.178)	0.010 (0.126)
Δh_i*$after_t$	0.273 (0.104)**	0.167 (0.073)**	0.165 (0.072)**	0.104 (0.062)*	0.112 (0.057)**	0.148 (0.066)**
Adjusted R^2	0.247	0.254	0.200	0.212	0.291	0.288
(b) *Effect of new highways over time*						
Δh_i* $started_t$	0.174 (0.098)*	0.137 (0.074)*	0.096 (0.060)*	0.064 (0.052)	0.063 (0.033)*	0.086 (0.066)
Δh_i*$completed_t$	0.410 (0.236)**	0.275 (0.137)***	0.258 (0.121)**	0.186 (0.086)**	0.135 (0.057)**	0.172 (0.076)**
$started_t$ - $completed_t$ (*F-test p-value*)	0.236 (0.140)*	0.139 (0.063)*	0.161 (0.090)*	0.121 (0.063)*	0.072 (0.062)*	0.086 (0.034)*
Adjusted R^2	0.253	0.218	0.209	0.218	0.361	0.351

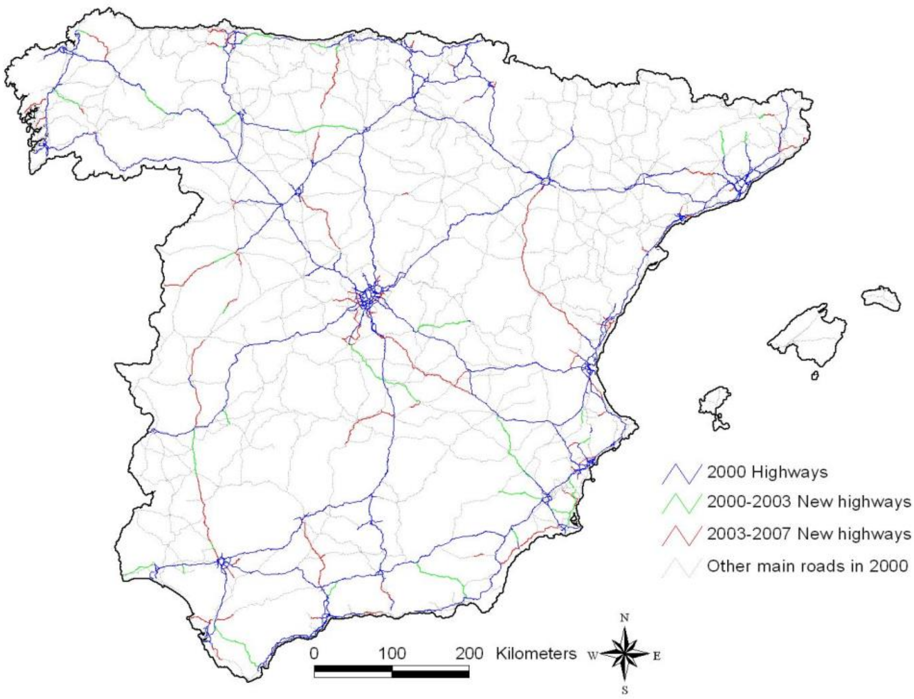
Notes: (1) Control group: *Main road + Matching* estimation; all estimations include time fixed effects and the same control variables as in column (iv) of Tables 1 and 2. (2) Whole area: average effect over all municipalities belonging to the same Local Labor Market as that gaining access to the new highway; Rest of area: average effect over the municipalities belonging to the same Local Labor Market, excluding the one/s obtaining access to the highway. (3) See Table 3.

Figure 1:
Land use categories in Spain



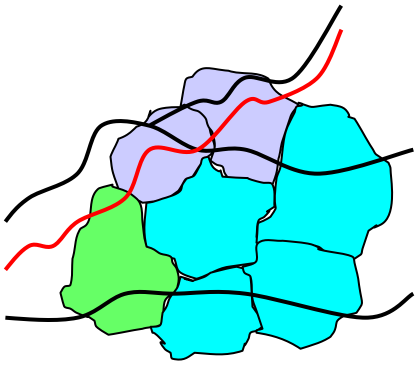
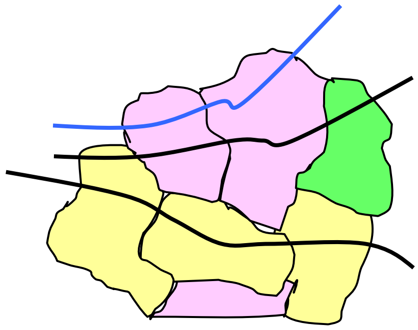
Notes: *Yellow*: 'Non-developable' land (i.e., rural uses or protected land); *Orange*: 'Developed' land; *Pink*: 'Developable' land in *Year* 0 (and also in *Year t*); *Purple:* Developable land in year t but not in year 0 (i.e., amount of land converted from rural to urban uses between *Year* 0 and *Year* t).

Figure 2:
Spanish highway network in 2000 *and segments built in* 2000-03 *and* 2003-07



Source: Official road maps published by the Ministry of Public Works (http://www.fomento.es) and authors' own mapping using GIS software.

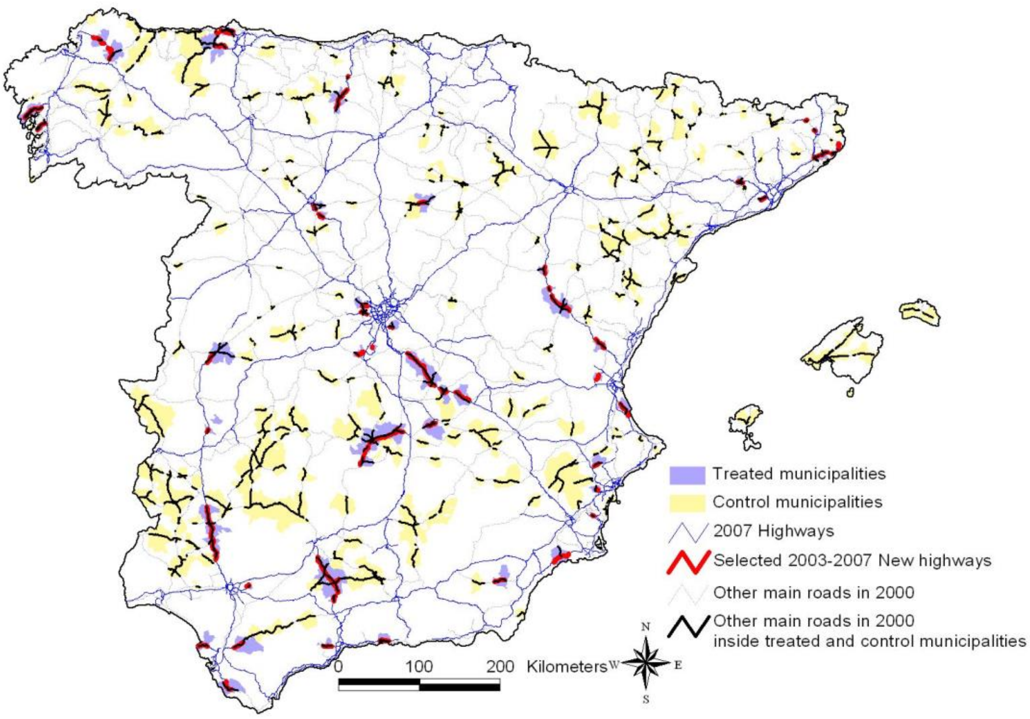
Figure 3:
Selection of treated and control municipalities

a) *Potentially treated* (‘local labor market A’)	b) *Potential controls* (‘local labor market B’)
	

Blue line: Old highway / *Red line*: New highway / *Black line*: Main road
Violet areas: Treated =New highway + Main road
Blue areas: ‘Local labor market’ treatment
Yellow areas: Controls =No old highway + Main road
Pink areas: Potential controls but Old highway or No main road
Green areas: Potentially treated or controls but no data

Source: Authors’ own ellaboration.

Figure 4:
Treated and control municipalities in the map



Source: (1) Official road maps published by the Ministry of Public Works (http://www.fomento.es) and authors’ own mapping using GIS software; (2) We use a layer of municipality boundaries provided by the National Geographic Institute (http://www.ign.es) to match highway segments with municipalities.

Figure 5:
Timing of the treatment

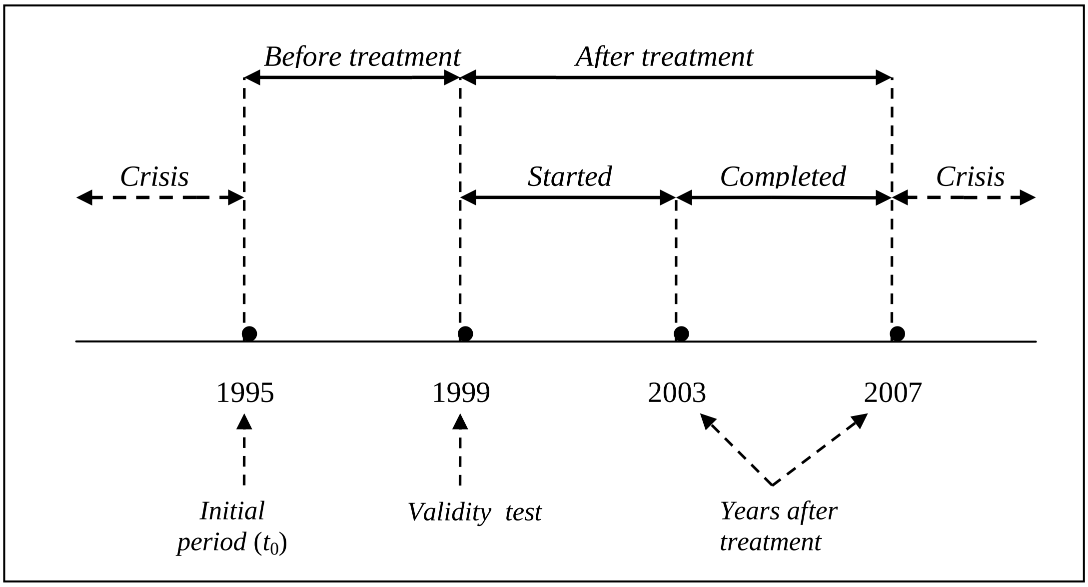
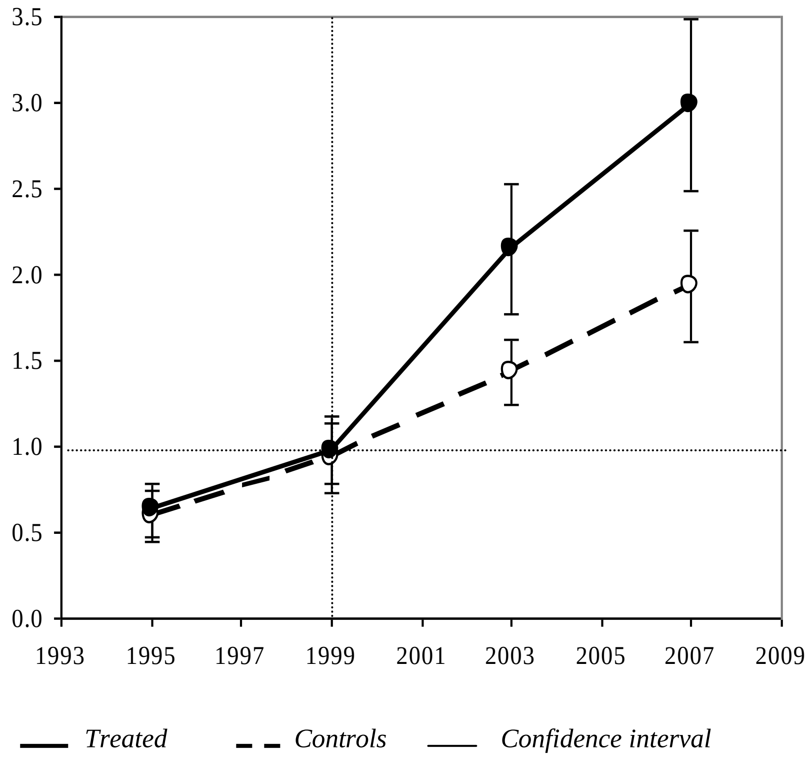
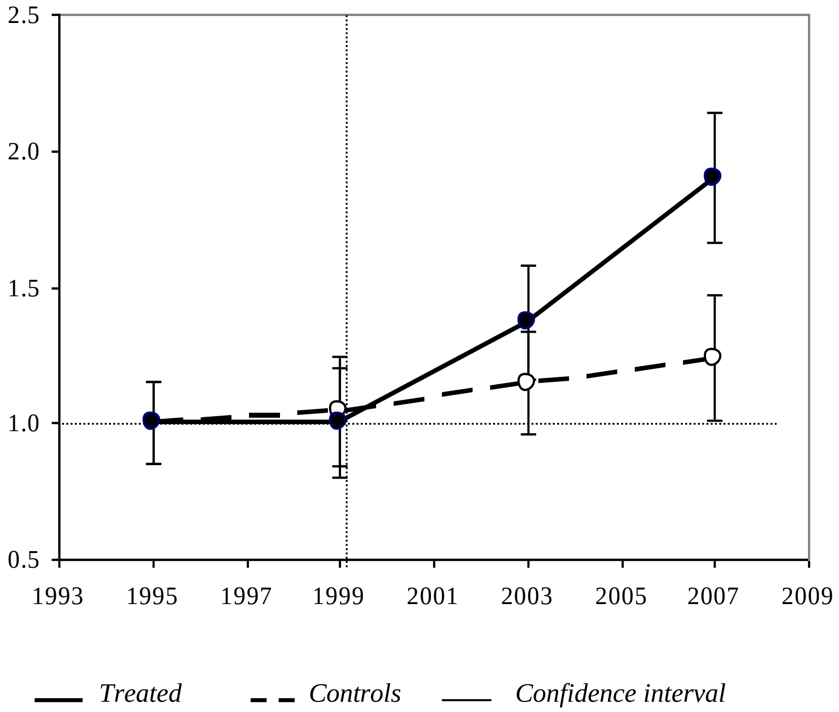


Figure 6:
Evolution of developable land ($d_{i,t}$) in Treated and Control municipalities



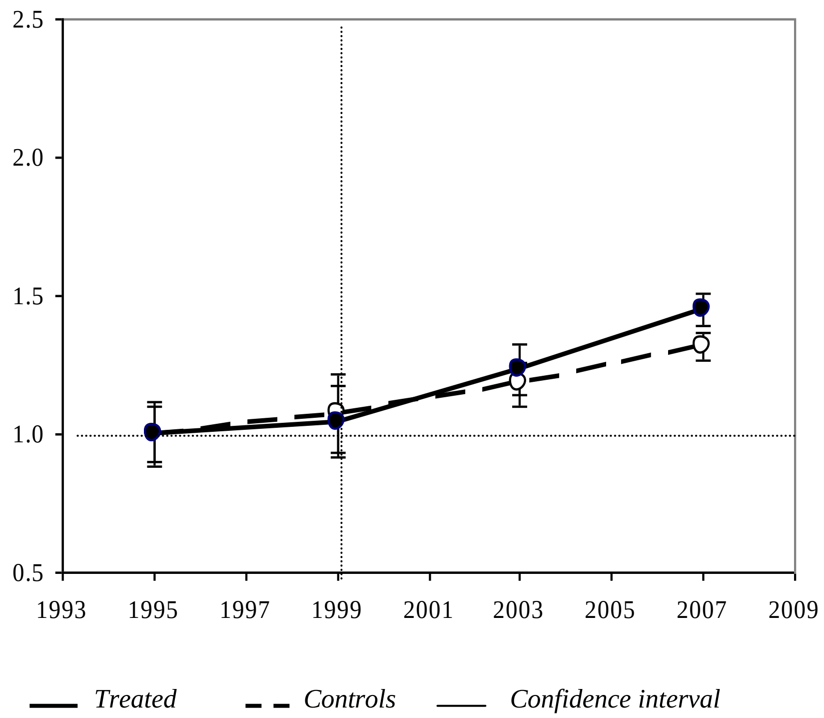
Notes: (1) Effects in municipalities with a new highway access. Coefficients estimated by *Diff-in-diff + Matching.*

Figure 7:
Evolution of developed land ($b_{i,t}$) in Treated and Control municipalities



Notes: (1) See Figure 6.

Figure 8:
Evolution of housing units ($u_{i,t}$) in Treated and Control municipalities



Notes: (1) See Figure 6.

Appendix A:

Modeling the effect of road improvements on land-use decisions

In this section we use a simple model, adapted from Solé-Ollé and Viladecans-Marsal (2012), to predict the effect of road improvements on land-use policies. We pay special attention to the effect of interactions between road improvements and resident's preferences for/against development and other policy drivers as, e.g., demand shocks and construction costs.

In the model, the local incumbent takes into account the preferences of the two main stakeholder groups of land-use policies (Glaeser *et al.*, 2005, Hilber and Robert-Nicoud, 2010), namely voters (assumed to oppose development) and developers (assumed to be pro-development). The local incumbent weights both the amount of political rents he will get in the present and the effect of his decision on the probability of re-election. Rents are higher the more land is allowed to be developed, since the developer's profits increase the more land they are allowed to build on, and so do their contributions to the politicians. The probability of re-election is reduced when more land is allowed to be developed because we assume that the representative voter bears some costs from development[32]. The problem for the local incumbent can be stated as:

$$\Delta d = argmax\ R(\Delta d, S(\Delta h, \Delta k), c, v) + p(V(\Delta d, \Delta h, a))\rho T \qquad \text{(A.1)}$$

Where R are political rents, which depend on: (i) the amount of new land allowed to be developed (i.e. converted from rural to urban uses), Δd, (ii) the (forecasted) shock in the demand for land in the community, S, which in turn depends on whether the municipality got access to a new highway, Δh, and on other exogenous demand factors, Δk, (iii) construction costs (e.g., terrain ruggedness), c, and (iv) the amount of vacant land at the beginning of the period, v (i.e. land which was considered developable by a past government decision, but that has not been yet developed). We assume that rents are higher the more land is converted, $\partial R/\partial(\Delta d)>0$ and the higher the demand, $\partial R/\partial S)>0$. We justify these assumptions in two steps: (i) developers' lobby willingness to contribute should increase with profits, and (ii) developer's profits are higher the more land can be build out and the higher the prices the buildings command, and both variables are supposed to grow with S, which responds positively to Δh and Δk: $\partial S/\partial(\Delta h)>0$ and $\partial S/\partial(\Delta k)>0$. We also assume that rents are lower the more costly is to build ($\partial R/\partial c<0$) and the lower the amount of vacant land ($\partial R/\partial v<0$). If there is still land where the developers can build, there is no need to waste resources trying to force the conversion of more land. Finally, we assume $\partial^2 R/\partial(\Delta d)\partial S>0$, $\partial^2 R/\partial(\Delta d)\partial c<0$, and $\partial^2 R/\partial(\Delta d)\partial v<0$, meaning that marginal political rents increase with land demand and decrease with construction costs and vacant land[33].

The second part of expression (1) denotes the expected utility of holding office in the future, and is the product of the probability of re-election, p, the discount factor, ρ, and the future exogenous return of being a politician, T. The probability of re-election depends on the the utility of the representative voter during the term, V (i.e., $\partial p/\partial V>0$), which we assume negatively depends on the amount of development allowed, Δd (i.e., $\partial V/\partial(\Delta d)<0$), and positively on the improved highway access, Δh (i.e., $\partial V/\partial(\Delta h)>0$), and on a set o preference shifters, a (i.e., $\partial V/\partial a)<0$), measuring the disamenity effects of new development. Here we

[32] The average homeownership rate in our sample is 92%, with a minimum of 60%, meaning the median voter is always a homeowner. Despite of this, renters could still have some influence on land policies, something that we take into account in the empirical analysis.

[33] The micro-foundations of the behavior we are describing here can be provided by a traditional model of 'urban growth controls' (see, e.g. Brueckner, 1999, and Brueckner and Lai, 1996).

also assume $\partial^2 V)/\partial(\Delta d)\partial a<0)$, meaning that the marginal effects of development are more negative in places where the residents are more opposed to growth, and $\partial^2 V/\partial(\Delta d)\partial(\Delta h)=0$, which means that the construction of the new highway does not affect the marginal effect of development on utility[34]. In order to ease interpretation, the probability of re-election can be expressed as a linear function of the utility change. To do this, we shall assume that the voter will vote for the incumbent if $V+\eta \geq \sigma_{i,}$ where η is the average popularity of the incumbent and σ_i is the reservation utility level of the voter. To make the problem tractable, we assume η is distributed uniformly on the support $[-1/2\psi, 1/2\psi]$. The higher the value of ψ, the higher the density of swing voters, the more competitive is the election. The reservation utility σ_i is assumed to have a zero mean and to be uniformly distributed on the support [-1/2, 1/2]. Given these assumption, the probability of re-election is just: $p=1/2 - \psi V$. After plugging this into (1), we are able to obtain the FOC with respect to Δd:

$$\Gamma = \frac{\partial R(\Delta d, S(\Delta h, \Delta k), c, v)}{\partial(\Delta d)} + \psi \frac{\partial V(\Delta d, \Delta h, a)}{\partial(\Delta d)} \rho T = 0 \tag{A.2}$$

This expression says that, in the margin, the incumbent chooses the amount of new land to develop so as to equate the value of additional rents and the loss in utility derived from not being re-elected. Note that the weight on voter's welfare rises (and the weight put on rents obtained when satisfying lobby's interests decreases) with the degree of political competition, a measured by the proportion of swing voters, ψ.

The effect of the highway improvement on the amount of new land allowed to be developed can be expressed as:

$$\frac{\partial(\Delta d)}{\partial(\Delta h)} = -\frac{\partial^2 R(\Delta d, S(\Delta h, \Delta k), a, v)}{\partial(\Delta d)\partial(\Delta h)} \frac{1}{\Lambda} > 0 \tag{A.3}$$

Since $\Lambda=\partial\Gamma/\partial(\Delta d)<0$ from the SOC and $\partial^2 R/\partial(\Delta d)\partial S>0$ and $\partial S/\partial(\Delta h)>0$ by assumption. This result says that we expect the new highway access will have a positive effect on the amount of new land allowed to be developed.

Now, we can show that this effect is expected to be milder in places where residents are opposed to development (i.e., high a) and in places where developers have less (relative) influence over local politicians (i.e., high ψ):

$$\frac{\partial^2(\Delta d)}{\partial(\Delta h)\partial a} = \frac{\partial\Gamma}{\partial(\Delta h)} \frac{1}{\Lambda^2} \frac{\partial^2 V(\Delta d, \Delta h, a)}{\partial(\Delta d)\partial a} \psi\rho T < 0 \tag{A.4a}$$

$$\frac{\partial^2(\Delta d)}{\partial(\Delta h)\partial \psi} = \frac{\partial\Gamma}{\partial(\Delta h)} \frac{1}{\Lambda^2} \frac{\partial V(\Delta d, \Delta h, a)}{\partial(\Delta d)} \rho T < 0 \tag{A.4b}$$

Since $\partial\Gamma/\partial(\Delta h)>0$ and $\partial^2 V/\partial(\Delta d)\partial a$ and $\partial V/\partial(\Delta d)$ are negative by assumption. It is also straightforward to show (proofs are omitted but are available upon request) that the effect of roads is lower where it is difficult to build (i.e., high c) and stronger in places experiencing high demand shocks (i.e., high Δk) or with a low amount of vacant land to start with (i.e., low v), i.e., that and $\partial^2(\Delta d)/\partial(\Delta h)\partial c<0$, $\partial^2(\Delta d)/\partial(\Delta h)\partial\Delta k>0$ and $\partial^2(\Delta d)/\partial(\Delta h)\partial v<0$.

[34] This is an assumption also made in the traditional 'urban growth control' literature, which use linear specifications to model the relationship between amount of development and utility. This assumption helps a lot in simplifying the equations and getting more clear-cut predictions.

Appendix B: Additional tables

Table A.1:
Variable definitions and data sources

	Definition	*Sources*
Δ*h*	Dummy equal to one if a new highway segment located in the jurisdiction of the municipality was completed during the period 2003-2007	Road maps from Ministerio de Fomento (several years) and authors' own maps
Δ*Developable land*	[(Developed land + Vacant land, year *t*) – (Developed land + Vacant land, year 1995) / Developed land, year 1995	DCG, Dirección General del Catastro (several years): "Estadísticas catastrales", http://www.catastro.meh.es / esp/estadisticas1.asp#menu1. (Developed land = 'superficie edificada', Vacant land = 'superficie de solares', Housing units = 'unidades urbanas')
Δ*Developed land*	[(Developed land, year *t*) – (Developed land, year 1995) / Developed land, year 1995	
Δ*Housing units*	[(Housing units, year *t*) – (Housing units, year 1995) / Housing units, year 1995	
Vacant land	[Vacant land, year 1995) / Developed land, year 1995]	
Open Land	[Total land area of the municipality - Developed land, year 1995/ Developed land, year 1995]	INE (www.ine.es) & DCG, Dirección General del Catastro (several years)
Area's Open Land	[Total land area of the municipalities belonging to the same 'local labor market' - Developed land in these municipalities, year 1995/ Developed land in the se municipalities, year 1995]	'Local labor markets' as defined in Boix and Galletto (2004) based on commuter patterns
Ruggedness	Municipal average value of the terrain ruggedness index developed by Riley *et al.* (1999).	Spanish 200-meter digital elevation model (http://www.ign.es/ign/layoutIn /modeloDigitalTerreno.do).
Area's ruggedness	Average values for each area.	'Local labor markets' as defined in Boix and Galletto (2004) based on commuter patterns
Urban area population	Resident population in the municipalities belonging to the same 'local labor market' in 1996	INE (www.ine.es), Census of Population (several years)
Major urban area	Dummy equal to one if municipality belonged to a major urban area as of 1996	'Local labor markets' as defined in Boix and Galletto (2004) based on commuter patterns
Population	Resident population in 1996	
Population growth	Growth in resident population between 1991 and 1996 (in %)	Major urban areas as defined by the AUDES project on the basis of geographical continuity (see www. audes.es),
Unemployment	(Unemployed population in 1996/ Resident population over 16 and under 65 years in 1996)	
Commuters	[Commuters in 2001/ Resident population in 2001]	
Homeowners	[Houses occupied by owner in 1991/ Houses in 1991]	
Core PP region	Regional government (i.e., Autonomous Community) controlled by the Partido Popular (PP) during the whole period 1995-2007	Ministerio del Interior, *Base Histórica de Resultados Electorales*, http://www.elecciones.mir.es/MIR/jsp /resultados index.htm.
Swing PP region	Regional government controlled by the PP during some part of the period 1995-2007	& El País (2003): 'Anuario Estadístico'
Aligned mayor	Dummy = 1 if the mayor and the regional president belong to the same party	
Right-wing	Dummy equal to one if the mayor belongs to a party classified as right-wing (e.g., PP, CiU, etc.). See Solé-Ollé and Viladecans (2013)	
Majority	Dummy equal to one if the party of the mayor holds the majority of seats in the local council	

Table A.2: *Propensity score estimation*

Variables	*Coeff.* (*s.e.*)
log(*Urban area population*)	0.646 (0.107)***
Dummy = *Major urban area*	1.394 (0.437)***
log(*Population*)	0.173 (0.120)
% *Population growth*	0.835 (0.675)
log(*Unemployed*)	0.721 (0.330)**
% Vacant land	0.479 (0.265)*
log(*Open land*)	0.269 (0.203)
log(*Area's open land*)	-0.375 (0.241)
log(*Ruggedness*)	-0.869 (0.278)***
log(*Area's ruggedness*)	0.599 (0.437)
Dummy = *Core* PP *region* × *Unaligned mayor*	1.514 (0.629)**
Dummy = *Swing* PP *region* × *Aligned mayor*	0.807 (0.359)**
Constant	-6.997 (0.544)***
Obs.	420
Pseudo R^2	0.360
LR-χ^2	162.68 (0.000)

Table A.3:
Balance tests: Unmatched vs. Matched sample

	Sample	Mean Treated	Mean Controls	t-test t	t-test p-value	% bias	% ∇ |bias|
log(*Urban area's population*)	*Unmatched*	12.157	9.683	12.01	(0.000)***	115.3	
	Matched	11.207	11.498	0.15	(0.877)	-17.2	67.0
Dummy = *Major urban area*	*Unmatched*	0.388	0.057	9.10	(0.000)***	85.8	
	Matched	0.253	0.262	-0.18	(0.857)	10.1	88.3
log(*Population*)	*Unmatched*	8.801	8.831	4.70	(0.000)***	52.1	
	Matched	8.873	8.941	-0.94	(0.346)	-17.2	67.0
% *Population growth*	*Unmatched*	0.031	0.169	-1.66	(0.097)	-23.4	
	Matched	0.037	0.038	-0.01	(0.994)	-0.0	75.8
log(*Unemployed*)	*Unmatched*	-3.362	-3.449	1.44	(0.152)	17.4	
	Matched	-3.373	-3.387	4.2	(0.813)	4.2	99.4
% *Vacant land*	*Unmatched*	0.693	0.560	2.00	(0.046)**	22.3	
	Matched	0.629	0.592	1.33	(0.184)	15.8	29.2
log(*Open land*)	*Unmatched*	4.188	4.697	-3.29	(0.001)***	-37.6	
	Matched	4.413	4.417	1.04	(0.969)	0.6	98.5
log(*Area's open land*)	*Unmatched*	3.975	4.684	-5.26	(0.000)***	-60.8	
	Matched	4.245	4.200	0.25	(0.801)	3.7	93.2
log(*Ruggedness*)	*Unmatched*	3.479	3.928	-4.91	(0.000)***	-31.2	
	Matched	3.588	3.624	-0.15	(0.882)	-12.6	59.6
log(*Area's ruggedness*)	*Unmatched*	3.479	3.926	-4.88	(0.000)***	-52.3	
	Matched	3.502	3.607	-0.02	(0.841)	-2.9	94.5
Dummy = *Core* PP *region* × *Unaligned mayor*	*Unmatched*	0.153	0.067	2.64	(0.009)***	27.6	
	Matched	0.089	0.112	-0.52	(0.601)	-8.0	70.9
Dummy = *Swing* PP *region* × *Aligned mayor*	*Unmatched*	0.265	0.109	3.89	(0.000)***	40.9	
	Matched	0.266	0.235	0.36	(0.717)	6.5	84.0
Pseudo-R^2	*Unmatched*	0.360					
	Matched	0.029					
LR-χ^2	*Unmatched*	162.12 (0.000)					
	Matched	6.54 (0.886)					
Median Bias	*Unmatched*	39.2					
	Matched	4.0					