Assessing Urban Land Use Regulation in Argentina: Literature Review and Research Strategy

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Abstract

This paper reports the advances made in our research on urban land regulation in Argentina during 2010 and 2011 and describes what we plan to do next. In this research we aim at a better understanding of the determinants and consequences of urban land regulation, based on empirical analysis of Argentinean cities. Exploratory work started in 2009 when we carried out a comprehensive Land Use Regulation and Practices Survey of planning directors in 118 municipalities, generating a comprehensive database for the main urban agglomerations in the country. Subsequently, we extended the survey to cover an additional 331 municipalities and added data on land cover metrics derived from satellite images. Preliminary findings show that 60 percent of the built-up area of the average municipality is located in the urban core and 39 percent in suburban locations. The size of built-up core area increases with city size, reaching 85 percent in the largest cities. Interestingly, built-up areas include a significant amount of open space. In terms of growth patterns, spatially fragmented new development declines monotonically with city size suggesting not only that fragmentation gets filled-up over time but also that most new development occurs as extensions of the build-up core area. Moving forward we plan to examine the links between land cover metrics and regulation and improve the explanatory power of our regulation indicators with new data and weighted zoning measures.

Keywords: urban land use regulation, stringency/flexibility of urban regulation, zoning, urban regulation indicators, Argentina cities, land cover metrics, satellite images

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Introduction

In order to better understand the determinants and consequences of urban land use regulation we analyze the degree of stringency/flexibility of selected regulation indicators. For example, we compare municipalities on how they constraint land use intensity using measures such as floor area ratio (FAR) or minimum lot size. Adding a spatial dimension to the regulation indicators we can determine the extent to which regulation constraints impact the total area of the municipality.

Land use regulation has both direct and indirect economic effects on cities and these effects persist for a long period of time. For example, the interaction of land markets and their regulation helps determine access to a wide range of publicly provided goods and services, affects the consumption of environmental goods, and even impacts on informal land development and on the pattern and the incidence of residential segregation.

Empirical studies can shed light on many of those issues. However, comparable data on regulatory measures for land use across municipalities are scarce. As a result of limited data—even in developed countries—the few theories that have been advanced about determinants and effects of regulation have not been carefully tested. Thus far, international research has barely scratched the surface with respect to the extent and complexity of processes that generate land use regulation and how they affect land markets.

Having improved the availability of data on land use regulation in Argentina, we are now able to address a number of questions, particularly those related to the causes and consequences of land regulations for residential use and the dynamics of informal urban land markets. What we accomplished by compiling the information in a comprehensive urban regulation database for Argentina is certainly unmatched in Latin America.

Our database includes detailed information on local urban land use regulation (2009 and 2011), quantitative metrics for all zoning areas within municipal jurisdictions (2011), and land cover metrics based on satellite images in years circa 1990 and 2000 for 30 urban agglomerates. The preliminary descriptive analysis presented here (and more extensively in Goytia and Pasquini, 2010 and 2012a) suggests interesting insights. For example, we found that restrictiveness in land use regulation varies strongly across municipalities in Argentina, and we are currently examining the determinants of such spatial variation.

Because we expect the community of scholars to help develop methods to test hypotheses linking regulation and land use outcomes more reliably, we have made our database publicly available and indicate in this paper the analytical strategy we plan to develop using these data. Also, in order to support policy making, we have developed a webpage[1] where practitioners can easily consult and analyze the results of the regulation information.

[1] http://www.utdt.edu/ver_contenido.php?id_contenido=8274&id_item_menu=16122

As we move forward, we contemplate two main lines of analysis. First, our next step consists in improving and developing new indices of regulation incidence and practices to measure the regulatory stringency and its enforcement. Having a standardized regulatory index facilitates comparisons at the municipal level as well as at the aggregated metropolitan and state levels.

Second, we plan to use (spatial) econometrics to analyze the characteristics of the municipalities as related to the determinants of regulation and the effect of regulation on the development and spatial fragmentation of the urban footprint. We expect the results of this modelling exercise to help detect the impact of land use regulation on land prices, on informal land and housing development, and on sprawl. Throughout the analysis we expect to identify regulatory patterns that are associated with given land use outcomes.

After briefly reviewing our preliminary findings from the 2010 Regulation and Practices Survey, Section 2 of this paper presents a review of the academic literature on the determinants of land use regulations, mostly but not exclusively for cities in the United States. Section 3 is organized in four parts describing the main steps in our research strategy. The first part reports on the construction of geographically referenced zoning indicators; the second describes land cover metrics that we generated using satellite images; the third part focuses on how we plan to improve regulation indices to measure regulatory stringency/flexibility; and the last part discusses our strategy for empirical econometric analysis of the data provided by the 2011 Survey on Regulation and Practices of Residential Land Use.

The Expansion of the Database and Preliminary Findings

After the first survey of municipal planning directors in Argentina in 2009, we saw the need to expand the sample and improve the questionnaire by adding questions related to regulation enforcement and change. The new survey was carried out from May through September of 2011.[2]

While the 2009 survey covered municipalities within large urban agglomerates, the 2011 sample was extended to include two additional groups of municipalities. First, we added all 41 municipalities with more than 50.000 inhabitants that were not part of the original sample, and second we added 290 municipalities with 20,000 to 50,000 inhabitants. Overall, the 2011 survey covers 190 respondents from jurisdictions representing almost the complete universe of municipalities with a significant level of land use planning in Argentina. According to the 2001 Census, our targeted sample accounts for nearly 80 percent of the total population in Argentina (approximately 60 percent in the Great Buenos Aires region and an additional 20 percent elsewhere). The survey was carried out in partnership with the *Secretaría de Asuntos Municipales* (Municipal Affairs Secretariat—SAM), of the *Ministerio del Interior de la Nación Argentina*. The Secretariat helped us identify key people in land regulation in each municipality permitting us to build a comprehensive list of contacts. In each municipality, our primary contact was the municipal planning director, where none existed we contacted a planning officer specially designated by the mayor to answer the survey.

[2] The survey questionnaire is available at http://www.utdt.edu/Upload/_134159550250122200.pdf

In most cases, respondents answered the survey on line, using a webpage specifically created for the purpose. However, due to technical limitations in some municipalities, the questionnaire and the responses had to be sent using the postal service. To minimize non-response, we contacted respondents directly and followed up mainly by telephone. Because we were particularly interested in ensuring responses from municipalities within urban agglomerates, we devoted significant efforts to these particular jurisdictions. This was especially the case of municipalities within the largest urban agglomerates, including the Great Buenos Aires region, Santa Fe and Cordoba. We achieved a final response rate of 71 percent.

Goytia, Pasquini, and Hagedom (2012a) give a detailed account of the findings from the 2009 survey, some of which are now been used to develop hypothesis regarding the role of regulation in urban land markets. For example, in analyzing infrastructure provision, we found that publicly financed extension of infrastructure is less frequent in municipalities with a large share of vacant land, as well as in less urbanized municipalities. How infrastructure is financed—either publically or privately—seems to impact the share of land occupied by gated communities in rapidly urbanizing jurisdictions suggesting that local governments favor gated communities as a way to ensure private financing for infrastructure. Not surprising, rapidly urbanizing municipalities have the highest incidence of informal land occupation.

Literature Review on Determinants of Land Use Regulation

What type of jurisdiction adopts particular kinds of land use regulations? This is the question addressed in this section which reviews the academic literature on the determinants of land use regulations, mostly but not exclusively for cities in the United States.

The rationale for land use regulation falls into three broad categories. The academic literature cites externalities and fiscal purposes as motives for regulating land use, in particular for zoning and growth controls.[3] The literature also considers a third category—exclusionary purpose—as added-on to the fiscal motive.

Taking into consideration the perspective of welfare economics, the production of regulation is seen as an optimal solution to market failures, correcting for externalities, especially in densely populated places. Therefore, a powerful economic justification for local governments to regulate land use lies on the idea that such regulation is designed largely to manage *externalities* which need some mechanism for dispute resolution. In countries such as Argentina, local governments are delegated a diversified bundle of powers to regulate land use, although some provinces still provide the overall legal land use framework.

In the analysis of land use regulation, zoning is the regulatory instrument that has been studied the most by urban economists. Zoning regulates the range of uses (commercial, industrial, residential) to be developed in each area as well as the intensity of each use (density or floor-area-ratio). Zoning aims to promote the general welfare by separating land uses in order to

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[3] Comprehensive reviews of the literature on local land use regulations are available, including on growth control regulations (Fischel, 1990), on land use and zoning (Pogodzinski and Sass, 1991), among others

mitigate negative externalities. This means that zoning is intended to correct for an inefficient market allocation of land when externalities are not internalized.

Some recent studies highlight the confusion between externalities and the exercise of monopoly power by preexisting landowners. This need not be intentional or even conscious, as owners of preexisting dwellings will have financial incentives to search very carefully for external effects in urban land use patterns, so that restrictive regulation (i.e. reducing the land and housing supply) will appear to be welfare enhancing rather than welfare reducing (White, 1975, Hamilton,1978, Fischel, 1980 and 1985, Quigley, 2007).

Restrictive land use regulation and zoning may confer particular benefits to owners of existing real estate properties (homeowners) by reducing the supply of developable land or the number of available dwelling units. When this happens, homeowners see the value of their property increase and thus may have a monetary interest in restricting growth (Quigley, 2007).

A second motivation for zoning and growth control is usually identified as a fiscal one. It is generally argued that the aim of land use regulation is not only to manage externalities, but fiscal reasons are important as well as primary rationale for local authorities to regulate land use. The rationale here is that decentralization confers an additional bundle of responsibilities to local governments for economic development and financing of public goods and services which are significantly affected by patterns of land use. Thus, municipalities take into account the fiscal implications of alternative forms of development when considering regulatory measures that influence the size of the local tax base and the demand for local government services.

Growth controls or zoning may thus act to exclude certain groups of potential residents such as the poor or minorities. Therefore, a third motive that is now considered in the literature on the use of zoning and other land use regulations is an exclusionary purpose aimed to maintain community homogeneity or even to exclude particular population groups. In that respect, although the composition of the tax base is considered, it is the exclusionary aim which prevails. Inhanfeldt (2004) provides a recent review of the evidence on exclusionary land use regulation for suburban communities in US. In his review, he considers whether there is evidence of a desire to exclude poor households or minorities for reasons unrelated to the preservation of the value of local real estate or the local fiscal base, but finds no such evidence. In general, homeowner preservation of real estate value appears as of first importance in motivating exclusionary regulations (Inhanfeldt, 2004). In other words, the evidence analyzed is mostly consistent with the fiscal motive, which reflects both a desire for value preservation (since net fiscal benefits are capitalized into property values) and a desire on the part of homeowners to maximize the net benefits they receive from the local government in the form of services.

This topic is extensively treated from a political economy point of view in the analysis of local government regulation, started with several seminal works such as those by Downs (1957), later followed by Ellickson (1977) and Fischel (1985), among others. Following Ellickson (1977) the theoretical literature in urban economics incorporated explanations for the underlying motives of residents, arguing that the adoption of restrictive land use regulation is for the benefit of the owners of existing real estate in the jurisdiction.

Homeowners are the most sensitive players in local politics, which is not the case at the state or national level. Land use regulation is largely determined by local planning boards and legislative bodies whose members are elected by local residents. In view of that, the dominant political economics view suggests that land use regulation reflects the aspirations of the majority of voters (Fischel 2001, Ortalo-Magné and Prat 2007, and Hilber and Nicaud 2010).

Political economy models provide different explanations for the interest that local homeowners have in exercising political influence to establish urban growth controls by means such as creation of amenities, restriction of the supply of housing and capitalization or strategic interaction with other local governments. Because homeowners cannot diversify their assets adequately, they are motivated to be "home voters," meaning that voting patterns of homeowners (as well as other local political activities) are guided by their concerns about home values (Fischel, 2001).

The "collective property rights approach" to zoning and growth controls was initially formulated by Fischel (1985), in his book, *The Home-voter Hypothesis*. The argument is that the homeowners' prospect of capital gains and losses is the most consistent motivator for local government regulatory activity due to the fact that the great part of the wealth of the residents is tied up in their homes (Fischel, 2001). Land use regulation provides municipal voters the opportunity to claim property rights in their municipality's location advantages and amenities. Not only external effects are internalized but the process also allows for residents to use land use regulation and zoning as devices to maximize the value of their homes. It is in this sense that the home-voter hypothesis is presented as an explanation for local patterns of land use regulation, where residents resist neighborhood change.[4] "Not in my backyard" (NIMBY) attitudes are not confined to potential environmental hazards, but also may manifest opposition to higher-density or low-income housing, which may motivate homeowners to influence land use by mobilizing political power or by voting.

Recall that the group of "home-voters" may be homogenous—a prevalence of homeowners or absentee landowners—or can be very heterogeneous, including renters and a large contingent of informal owners, as observed in most cities in developing countries.
Models of political influence in which special interests may define the outcomes are more likely to prevail as the electorate increases in size and issues become more numerous. For example, Ellickson and Tarlock (1981) reached the conclusion that the land use agenda is more likely to be 'captured' by development interests in the larger, more heterogeneous jurisdiction, or in large and complex places where many renters live. There is less interest in growth controls among low income homeowners residing in poorer suburbs (Ellickson, 1977), or among those living in older and declining suburbs (McDonald and McMillen, 2004). The studies from developed countries indicate that the degree of regulatory restrictiveness might be the greatest in small, homogeneous suburban jurisdictions and least restrictive in large, heterogeneous cities and very rural areas.

One key issue in this type of analysis is the assumption that municipal voters are conscious participants in governance, not merely passive receptors of decisions by government officials. This is an issue that can surely be discussed when considering questions of asymmetric

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[4] In Fischel's view, adopting the home-voter approach strengthens the case for viewing the local property tax as a benefit tax.

information. This view assumes that local voters and their elected officials understand the relationships that link zoning, spending, taxation, and property values (Lenon et. al., 1996) which might not always be the case.

Finally, when we come to the empirical studies, the evidence strongly suggests that 'home-voters' are influential in regulating land use *locally* (e.g. Dehring *et al.* 2008), but this approach has less explanatory power in explaining differences *across metro areas* with respect to regulatory restrictiveness.

Review of Empirical Studies on the Determinants of Land Use Regulations

One relevant issue addressed by empirical studies is how land use regulation (and its restrictiveness) is measured, due to the fact that comparable data on regulatory measures for land use across jurisdictions are not abundant. The empirical studies that evaluate the determinants of land use regulation can be classified in different groups regarding the type of regulation considered and the scope of the analysis (e.g. within metropolitan areas or across metropolitan areas).

Most of these empirical models regress land use indicators on a set of explanatory variables, using isolated regulatory measures or aggregated in overall land use stringency indicators. As a result, there are studies assessing the determinants of a bundle of regulatory measures in the form of a land use stringency index. Another group of studies focuses on explaining the determinants of a single regulatory measure, such as minimum lot size (MLS), zoning or growth controls.

Land use restrictiveness across metropolitan areas (MSA) in the US is usually measured by regulatory indicators, such as the Wharton Residential Urban Land Regulation Index (*WRLURI*) created by Gyourko, Saiz, and Summers (2008), constructed to capture the stringency of residential growth controls, or the *SAKS* measure—created by Saks (2008)—which uses the simple average of six independent measure of land use regulation obtained from surveys conducted during the 1970s and the 1980s.

Classifying empirical research by the scale of analysis, we find studies that measure the stringency of regulation across metropolitan areas, and sometimes across states, and others focused on a single state or city. The first group takes advantage of the substantial variation in regulatory regimes across metropolitan areas to provide evidence of the diversity of local housing markets.[5] Glaeser and Ward (2009)[6]and Hilber and Nicaud (2010) are the two most recent studies using *aggregate* indices—rather than discrete measures of different land use regulations, to capture the overall regulatory environment by running estimations at MSA level.[7]

[5] See for example, Glaeser, Gyourko, and Saks, 2006; Green, Malpezzi, and Mayo, 2005; Gyourko, Saiz, and Summers, 2008; Hwang and Quigley, 2006; Linneman et al., 1990; Mayer and Somerville, 2000; Quigley and Raphael, 2005; Quigley, Raphael, and Rosenthal, 2004; and others reviewed in Quigley and Rosenthal, 2005

[6] The authors use land use regulation data from the Pioneer Institute's Housing Regulation Database for Massachusetts Municipalities in Greater Boston. These data were supplemented with information from the Mass GIS system detailing the minimum lot size requirements throughout the state. Permitting and demographic data come from the Census.

[7] See also Gyourko *et al.* (2008) and Saiz (2010) on the merits of using MSA aggregates.

However, that this latter group of studies does not examine variation in regulatory regimes within metropolitan areas—a point noted by Ihlanfeldt (2007).

Another group of studies examines determinants of land use regulation in communities or towns in a single state. Among those we find studies by Pollakowski and Wachter (1990), Green (1999), McDonald and McMillan (2004). These studies not only address but actually take advantage of the richness of within-market variation, even though questions arise as to the extent to which their findings can be generalized.

Determinants of Land Use Regulation: Externalities, Fiscal and Exclusionary Motives

Most of the studies that provide evidence on the intended purposes of exclusionary regulations look at the political economy of regulations and can be categorized into two broad types. A first group focus on the motivations behind the adoption of restrictive land use regulation by local jurisdictions (Rolleston, 1987; Bates and Santerre, 1994; Pogodzinski and Sass, 1994), reviewed by Inhanfeldt, 2004. A second group assesses the characteristics of the jurisdictions associated with the adoption of given land use regulations. These studies provide evidence on the types of cities most likely to use a particular regulation or that are likely to have more restrictive land use policies overall, as for example studies by Lenon *et al*. (1996) on zoning; Baldassare and Wilson,1996 and Brueckner (1998); Feiock (2004), and McDonald and McMillan (2004) on growth controls.

To identify the specific motivations behind the adoption of land use regulations, all these studies adopt the same empirical methodology, where a measure of *land use regulation* is regressed on variables that attempt to proxy for each of the different motivations. We have already explained in the previous section the three different potential motivations: (a) externality (desire to mitigate negative externality effects that arise from incompatible land uses), (b) fiscal (the desire of existing residents to maximize the net benefit they receive from the public services/taxes package provided by the local government), and (c) exclusionary motivations (a deliberate desire to exclude lower income and/or minority households from the jurisdiction).

There is certain consensus across studies based on cities and communities in the US, that *fiscal* consideration frequently motivates the more restrictive land use regulations. While the fiscal motive may exclude lower-income and minority households, this is seen as a byproduct and not as the primary objective. The evidence on *exclusionary* motives is mixed across studies that focus on exclusion by income or by race (Inhanfelt, 2004).

However, Bates and Santerre (1994) provide some interesting evidence supporting the exclusionary hypothesis. The authors find that higher central-city poverty relative to suburban poverty reduces the percentage of land zoned residential. Similarly, Rolleston (1987) finds that lower percentage of minority residents relative to surrounding communities increases the restrictiveness of residential zoning

One particularity of the study by Rolleston (1987) is that data on communities in New Jersey, US, are used to analyze the determinants of residential zoning restrictiveness on vacant land. The author uses a weighted index of the restrictiveness of residential zoning which combines indexes of residential use and minimum lot size[8] developed by Cho and Linneman (1993). The index assigns specific weights to the proportion of vacant residential land zoned for particular lot sizes. The restrictiveness index is regressed on externality, fiscal and exclusionary variables. The externality variable is population density in residentially developed land areas. The fiscal variables include the proportion of total tax base derived from non-residential property, local fiscal capacity relative to surrounding communities, and percentage change in local fiscal capacity from 1967–70. The exclusionary variables used are the percentage of local minorities relative to surrounding communities and a measure of local income homogeneity.

Rolleston (1987) concludes that there is enough evidence to support both the fiscal and the exclusionary hypotheses, but the externality motive is not supported by the results. However, the variable selected (population density) is assumed to be the most rudimentary proxy for the externality motivation, and that might be affecting the results. Fiscal variables are generally statistically significant with the expected signs supporting the fiscal motivation for zoning. Finally, the variables measuring the exclusionary motivation yield contrasting results. The percentage minority relative to that of surrounding communities is negative and statistically significant, which is consistent with the exclusionary hypothesis. The expectation is that income-homogeneous communities will adopt more restrictive zoning in order to maintain income uniformity. By construction, higher values of the income homogeneity represent greater income dispersion within the jurisdiction. However, the estimated significant coefficient has an unexpected positive sign.

Bates and Santerre (1994) estimate two simultaneous equations using 1970 data from 132 towns in Connecticut. The first equation explains the minimum lot size requirement (MLSR) placed on vacant residential land, while the second equation explains the fraction of vacant land zoned for residential purposes (FRL).

Bates and Santerre conclude that exclusionary zoning is reflected in residential land use zoning rather than in lot size regulation.[9] Their empirical analysis supports the hypothesis of the *externality motive* as measured by the share of developed land in the community currently used for non-residential purposes (used in the FRL equation) and the average size of residential lots in use (entering the MLSR equation).

The results of this study support the existence of a fiscal motivation, as well. Here, the *fiscal motive* is measured by two variables: the percentage change in the town's population over the prior decade (considering that greater growth imposes increasing public service costs on residents) and non-residential property taxes per capita (considering that residents in a community are likely to zone less land for residential use given relatively high-tax revenue from non-residential uses).

[8] In a way their approach is analogous to that used by Pollakowski and Wachter (1990) and Cho and Linneman (1993).

[9] These authors find a trade-off between the fraction of vacant land zoned for residential use and the average lot size and argue that either device can be used to control growth.

Lastly, the authors measure the *exclusionary motive* by the ratio of poverty in the nearest central city relative to poverty in the community object of the study. The main rationale here is that, for a desire to exclude lower income households to exist, greater relative central-city poverty should be associated with less vacant land allocated to residential use and a larger minimum lot size requirement.

Another study, by Pogodzinski and Sass (1994), uses panel data for 1960–90 from communities in California, US, to estimate a system of equations that treat local fiscal variables, zoning and demographic dynamics of these communities as endogenously determined. The relevance of this study is that regulation is treated as an endogenous decision rather than being exogenously determined.

The dependent variables in these equations are minimum lot size and percentage of land zoned for single-family residential housing. The externality motive is measured by the percentage of dwelling units that are owner-occupied, which is based on the idea that higher quality housing will be built in larger plots, an issue that should provide spillover benefits to existing homeowners. Finally, fiscal and exclusionary motives are measured using community median household income, and the percentage of the community's population that is non-Hispanic White is used to measure only the exclusionary motive.

Results from the first model that uses minimum lot size as dependent variable, an increase in the percentage of owner-occupied dwellings decreases—rather than increases—with minimum plot size, a finding that is contrary to the externality motive. Reflecting either the fiscal or the exclusionary motive, median household income increases with lot size, while an increase in percentage non-Hispanic White is not statistically significant, giving less confidence to the exclusionary motive. In the land use allocation model, higher income reduces the share of single family residential zoning in the total, while percentage non-Hispanic White has the opposite effect. Hence, the results from both equations provide mixed evidence on the exclusionary motive.

Using a wide group of growth controls measures, other than zoning, MacDonald and McMillen (2004) employ factor analysis to describe how the use of particular policy instrument tends to be correlated for 198 suburban jurisdictions of greater Chicago, US. Their data include the number of growth controls used by each city. Factor analysis is then used to generate three different factors which reflect: (a) regulations of quality development; (b) regulation of lower-class development and (c) growth control. Factor scores for each factor are regressed on characteristics describing each city.[10]

The econometric results from this study show the characteristics of communities associated with the different types of regulatory measures. The dependent variables are the three factor scores for

[10]Factor analysis is a standard technique for reducing the dimension of a dataset by producing composite variables , which we called "factors," that represent patterns of covariance that exist in the original dataset (Harmon, 1976; Kim and Mueller, 1978). It expresses each variable x as a linear combination of the K common factors plus a unique component ui. Here, the K factors define a three-dimensional vector space that is a subset of the original 12-dimensional vector space.

the 198 suburbs and separate *probit* analyses computed for each individual regulatory measure. Among the explanatory variables, the location of the community (measured by the distance from the central business district), the population in 1990, median household income and racial composition, and the age of the community (indicated by the proportion of housing built before 1940 and from 1980 to 1990) are part of the model. The dataset also includes overall crime rate in the suburb, proportion of families in poverty in 1990 and unemployment rate in 1990.

One of the main conclusions from McDonald and McMillan study is that their findings strongly confirm Fischel's hypothesis that suburban development controls are used to benefit homeowners. Another important finding is that larger suburbs tend to make greater use of nearly all forms of development controls, suggesting economies of scale in the formulation and implementation of regulations. Regression results for each individual regulatory measure show consistent positive effect of population size on the use of any policy or combination of policies.

The determinants for the propensity to use growth controls is greater, the greater is distance from the CBD and if the suburb is located in the highest-growing county in the metropolitan area.

In the 1970s and 1980s, the propensity to use growth controls is found to be lower in suburbs with larger minority populations (both Black and Hispanic) and in suburbs with higher crime rates. The size of the community is not a determinant of the propensity to use growth controls.

The propensity to have regulation restricting lower-class development is positively related to population size and with suburbs having higher crime rate and lower income.

The propensity to regulate quality development is positively related to the population size and median household income. The effect of the size of the suburb suggests that larger communities have more resources to develop this type of regulation.

McDonald and McMillan (2004) present another set of econometric results in their analysis of the determinants of zoning complexity, using as dependent variable the number of zoning categories—single-family residential, multifamily residential, commercial and other land uses. Here, the presumption is that the number of zoning categories related to a particular land use is an indicator of the level of complexity and detail in regulating that particular use. They argue that small suburbs often have very simple zoning ordinances while zoning complexity increases with the size of the community.

The authors first examine the complexity of zoning by considering each of the five zoning types in isolation and estimate Poisson models of land use zoning category counts for each of the five uses. The complexity of zoning in all five categories have a strongly positive correlation with population size of the suburb while higher-income communities have more complex zoning for single-family housing units.

The factor analysis of the zoning complexity data shows that there are linkages across uses and that the level of zoning complexity is associated with population size. These results lead the authors to suggest that decisions by communities to choose particular combinations of zoning categories are usually contingent upon the nature of the perceived needs. Jurisdictions with higher incomes and newer housing tend to have a more complex combination of zoning for residential and commercial uses. Poorer communities tend to have more complex zoning for multifamily apartment housing and commercial uses. The latter may reflect lower housing costs in multifamily buildings as well as expansion of commercial establishments.

On the whole, the econometric results tend to confirm the hypothesis that suburban growth controls are used to benefit homeowners. However, the results are consistent with a broader set of homeowner interests than perhaps has previously been recognized as they suggest the presence of economies of scale in growth control policy. In other words, the smaller suburbs may simply not be able to afford a large panoply of land use policies. Also those jurisdictions with lower incomes, larger minority populations and greater poverty rates have more interest in promoting growth rather than containing growth.

These results points to several interesting issues in the academic literature on regulatory restrictions in municipalities within and outside metropolitan areas. According to Fischel (2004), land use regulation originates in larger cities and then spreads quickly to the suburbs and surrounding towns as the city grows. Rudel (1989) provides evidence on the timing and restrictiveness of zoning being tied to the distance from the central city, while Gyourko *et al.* (2008) find that municipalities within MSAs tend to be more highly regulated than their counterparts outside MSAs. Another relevant conclusion in the same vein comes from a group of studies reviewed by Baldassare and Wilson (1996), showing that growth controls are favored when residents feel that their community is being overwhelmed by rapid urban growth occurring in surrounding jurisdictions.

Another empirical contribution, by Hilber and Nicaud (2010), identify the origins of cross-sectional variation in land use regulation across metropolitan areas in US, rather than within a single MSA. The authors follow a political economy approach to assess the *causal* effect of residential development on the overall regulatory restrictiveness at the MSA level. Like Glaeser and Ward (2009), the authors use *aggregate* indices, rather than measures of different types of land use regulation, to capture the overall regulatory environment. Estimations are run at MSA level.[11] Both *WRLURI* and *SAKS* indexes are scaled to have a mean of 0 and a standard deviation of 1.

Hilber and Nicaud (2010) use data from 1992 to explore the causal effect of the share of developed residential land on regulatory restrictiveness around 2005. They test the hypothesis that more developed places are more regulated. The study takes into consideration the endogenety of residential development relative to the regulatory environment, using an exogenous source of variation of urban development to identify its effect on regulation. To do that they use two sets of instruments: natural amenities and topography and explain their choice of instruments by arguing that locations with desirable amenities and areas with plain terrain are generally those that are more developed since the average conversion costs are lower.

The methodological strategy for identification of these effects is based on three complementary explanations of the measure of land use restrictiveness, similar to those already reviewed above.

[11] See also Gyourko *et al.* (2008) and Saiz (2010) on the merits of using MSA aggregates.

These are regressed on a nested model of variables that proxy for (i) the welfare economics hypothesis, (ii) Fischel's 'home voter' hypothesis, and (iii) the 'influential landowner' hypothesis, running OLS and instrumental variables regressions.

As already noted, the welfare economics explanation for land use suggests that regulation corrects externalities (market failures). So, in Hilber and Nicaud (2010) study, population density in the developed residential area is used as proxy for the intensity of these market failures. The motivation for doing so is based on urban economic theory predicting that externalities conductive to agglomeration economies—and higher urban costs—are sensitive to distance and therefore, denser places generate more non-market interactions and pecuniary externalities, which are both conductive to urban growth (e.g. knowledge spillovers, labor market matching) as well as to urban costs (e.g. noise or congestion).

Secondly, the 'home voter' hypothesis*,* which argues that places with a higher home ownership rate can be expected to be more regulated, is also tested. The 'influential landowner' hypothesis (the political influence of owners of developed land relative to the influence of owners of undeveloped land) is captured in the model by the share of developed residential land in an MSA (*SDL)*. The 'developable residential land area' is the total land area minus the surface area that is covered by 'non-developable' land uses.

The authors include additional controls for other alternative explanations. For example, the share *of Democratic Party votes in the State* presidential elections, suggests that regulatory restrictiveness may be driven by political ideology, while average *household wage* controls for the possibility that regulatory restrictiveness is driven by income sorting. Finally, *regional dummies* are included to capture all other region-specific unobservable characteristics.

Preliminary findings are encouraging in support of the influential landowner hypothesis since only the influential landowner variable has the expected sign and is statistically significant. Turning attention to the controls, MSAs in Democrat-voting states are more regulated, possibly reflecting the behavior of liberal voters who, in the US, tend to be ideologically more sympathetic to regulation than conservative voters. This result is robust to the addition of an interaction term (between *share democratic votes* and *average income*), suggesting that lower and upper income Democrats do not hold significantly different views on regulations. *Region dummies* reveal that broad geographic patterns emerge, with the West being the most regulated region and the Midwest (the omitted category) the least regulated.

<u>Endogenety Issues and Specifications in Empirical Models of Land Use Regulation</u>

As we have already noted, the relevance of the Hilber and Nicaud (2010) study lies on how endogenety concerns are tackled in the identification strategy. In particular, the study considers one important limitation of the OLS estimates for some key explanatory variables if endogenously determined such as *SDL,* implying that the estimation of the coefficient for the landowner hypothesis will be downwards biased in case regulation works as an impediment to growth. The issue is addressed by instrumenting for *SDL* using a set of exogenous variations that are not directly correlated with the regulatory measure *WRLURI*. The identification assumption is that places endowed with *desirable amenities and located on plain terrain* are developed earlier, attract more residents over time and, as a result, are more developed.[12] According to Glaeser et al. (2005), who find that the 'regulatory tax' is highest in Manhattan and in the San Francisco Bay area (exceeding 50 percent of house value), but find no evidence of high property tax in places such as Pittsburgh or Detroit.[13] Hilber and Nicaud (2010) suggest in their model that the most desirable places should indirectly be the most regulated.

The share of *plain terrain* is a supply factor, used as an instrument for *SDL,* considering that it is simpler and cheaper to convert open land into developed land in plain terrain. Finally, one last instrument *historical population density in 1880* captures all the unobserved and time-invariant amenity and cost factors which are not included in the previous set of instruments. It also captures historic amenity and cost factors that were important a long time ago in starting the dynamic development process of city growth.

Instrumenting for these variables TSLS estimator, the Limited Information Maximum Likelihood (LIML) estimator or the Jackknife (JIVE) estimator are alternatively used. The results confirm the presence of a downward bias in the OLS specification and reinforce the influential landowner hypothesis by showing a positive, statistically significant and larger than the OLS coefficient for *SDL.*

Another caveat leads to endogenizing the population density variable. Land use regulation (e.g. minimum lot size restrictions) affect population density differently suggesting reversed causation and biased estimates. Therefore, the *share of plain terrian* in an MSA and the *historical MSA-level population density from 1880* are used as instruments for density, while regression results are analogous to the previous ones.

Finally, total amount of open land (independent of whether the land is developable or not) in an MSA or the amount of open land in an MSA per capita are used as additional tests for the effect of *SDL* on regulation not to be driven by preferences for open space or conservationist motives. Again, the results provide strong support for the influential landowner hypothesis.

<u>Spatial Data in Empirical Studies</u>

It is important to stress that available information from satellite images and GIS data now constitute additional sources of information to complement the analysis of the determinants of land use regulation. For example, the amount of developable land has been introduced in recent studies in different ways. Saiz (2010) builds a measure of developable land for each MSA in the US and regresses WRLURI on this measure. His findings suggest that cities with a relatively small share of developable land are more regulated. Emphasizing political economy mechanisms, Hilber and Nicaud (2010) complement this study by creating a measure of

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[12] Amenity characteristics (e.g. *average temperatures in January and a major border with a coastline)* are used as instruments for *SDL* since they relate to demand factors (e.g. ceteris paribus, people prefer to live in nice places) and are not directly related to regulatory restrictiveness. However, while *January temperatures* should not have a direct and systematic influence on a broad index of residential land use regulations, *valuable ocean coasts* might require some kind of state or federal protection in the form of regulation.

[13] Glaeser et a. (2005) report on the 'regulatory tax' measure for metropolitan areas in the US.

developed land (SDL) that has developable land at the denominator, in order to understand how the fraction of land *actually developed* influences regulation.

Sprawl studies have benefited as well for the availability of new data. The issue of amenities is associated to sprawl. Burchfield et al. (2006) find that cities with better natural amenities sprawl more than others—likely because of minimum lot size restrictions that reduce the capital-to-land ratio. Hilber attributes this phenomenon to endogenous land use constraints as locations with more desirable amenities are more developed and more regulated.

The literature reviewed here provides a strong motivation for our study. Given the scarcity of evidence on these issues in developing countries, the analysis of the determinants of zoning and other types of land use regulation in Argentina are certainly warranted.

<u>How Flexible Are the Regulations and How They Are Enforced</u>

Municipalities adopt regulation that also impacts new construction. While the bulk of these regulations make new development more difficult, some regulatory rules—like those that are made more flexible to accommodate more density or FAR—can promote or facilitate development. New development is promoted when the rules regulating residential development are made more flexible, for example, by allowing reductions in minimum lot size or by increasing the FAR, among others. Changes in zonings and other land use restrictions are easier to make in municipalities where there is no formal law or land use plan. In other words, jurisdictions with a loose normative environment can quickly adopt more flexible or stringent regulations when a desirable or an unwanted project is proposed. Like Glaeser and Ward (2009), Hilber and Nicoud (2010) use a simple categorical variable that takes on a value of one if the town has passed a regulation that exceeds prior development standards. Later, those categorical variables are added-up in an overall regulatory barriers index (similar to Quigley and Raphael, 2005). This metric aims to capture the overall flexibility of the regulatory environment in a given jurisdiction, while avoiding the loss of statistical clarity associated with looking at the effects of three (or more) regulations simultaneously.

One relevant issue that ought to be considered in the study of urban land use regulation is whether what is actually done may vary from what appears to be allowed in the regulatory framework. There are several reasons for this type of concern. First, variances can be granted that waive certain regulations for specific projects, an issue that we try to capture in the section of our survey that looks at levels of flexibility in the regulation. For example, lack of a comprehensive land use plan or code for urban land use, may confer the greatest flexibility in managing land use especially in jurisdictions where land use is managed exclusively by municipal ordinances.

Second, what is planned as a permissible use may be made infeasible given the regulatory details, or impracticable, as appears to be the case for some types of multi-family housing in certain jurisdictions in the Province of Buenos Aires. Third, some municipalities enforce "policies" that have not been formally enacted, and thus make such "policies" it difficult to track by researchers. Such is the case of mechanisms used to address land invasions at the local government level, that are added on to regularization programs governed at the national and provincial level. For example, several jurisdictions promote relocation of informal settlement residents or intercede for the acquisition of private land, while others let private disputes be resolved in the courts or by private negotiations between the parties affected. All these processes are not codified in local laws or ordinances and we try to capture them in our survey with questions on implementation practices. Fourth, outdated regulations that are still in the books may no longer be enforced. Finally, regulations may be ambiguous or vague—and often are—so interpretation of the same written language can vary within and across municipalities. While most databases on land use regulation are coded according to the official letter of the law, our survey data opens up new analytical possibilities as it has been designed to capture these issues.

The following sections describe our research strategy in its various stages.

Research Strategy

This section describes the main steps in our research strategy. The first part reports on the construction of geographically referenced zoning indicators; the second describes land cover metrics that we generated using satellite images; the third part focuses on how we plan to improve regulation indices to measure regulatory stringency/flexibility; and the last part discusses our strategy for empirical econometric analysis of the data provided by the 2011 Survey on Regulation and Practices of Residential Land Use.

Construction of Geographically Referenced Zoning Indicators

The municipal zoning maps obtained from the 2011 survey are the base for the spatial metrics required to refine the analysis of regulatory data. Specifically, the municipal zoning maps processed with GIS allow us to weight the spatial area where specific regulations apply, such as zoning. The spatial dimension is essential to measure the area of incidence of the regulatory constraint in relation to the total area of the jurisdiction. In other words, the zoning map images (bitmap—BMP) were processed using GIS (Arc Map software 9.3) to geographically refer the land use zones in each municipality.

Preliminary analysis of the zoning maps provides some interesting insights:

- Zoning for residential use is approximately 62 percent of the non-rural zoned area in the average municipality. But there is a high degree of dispersion across municipalities as to the share of residential zone in the total zoned area. For low- and medium-density residential zones, the standard deviation varies between 25 and 27 percent across municipalities.

- The area zoned for residential use of all kinds is 10 percent larger in municipalities where most of the territory is being urbanized, compared to those that are largely rural.This is driven primarily by a significant increase in medium and mixed-use residential area in the mostly urbanized municipalities that have nearly twice as much area zoned residential, compared to the average largely rural municipality.

- Zoning for gated communities is only 3 percent of the total non-rural zoned area, on average. However, there are a few surprising exceptions where the gated community zone covers as much as 80 percent of the urban area. As noted earlier, the area zoned for gated communities tends to be larger in municipalities where most of the territory is being urbanized

Generating Land Cover Metrics Using Satellite Images

The use of land cover metrics is essential for the development of our empirical analysis of urban land use regulation. With these metrics we can determine characteristics of the urban spatial structure and how it changes over time. For instance, we can determine the degree of developed and developable land in a given municipality, and properly assess its population densities.

We follow Angel, Civco and Parent (2010) in their methodology to classify satellite images pixels and in their construction of land cover metrics (see appendix 1). We have images for 30 urban agglomerates in Argentina (140 municipal jurisdictions) for years circa 1990 and 2001. These images, once processed and rendered as land cover metrics, are very useful in the analysis of urban development during that period.

The metrics derived from the satellite images reflect several aspects of spatial urban growth patterns, namely: the built-up area, the urbanized area, the urban footprint, population density, new development, buildable land, openness index, compactness of the urbanized area and the urban footprint, and compactness of open space, both in the urbanized area and in peripheral areas. The definition of these metrics is given in Goytia, C. and R. Pasquini, 2012b.

Preliminary analysis of land cover metrics shows:

- The built-up area in the average municipality is approximately 54 percent within the urban core area, approximately 36 percent in suburban areas, and 10 percent rural areas.

- The size of the built-up urban core increases with population. For example, in municipalities with population above 300,000 inhabitants, the average built-up core area covers 85 percent of the territory, while in municipalities with 152,000 to 300,000 inhabitants the built-up core area is only 70 percent of the total area.

- The index of openness shows that a typical urban neighborhood consists of approximately equal parts of built-up land and open space. A similar pattern is seen in the urban edge indicator that measures spatial fragmentation at the individual building scale (30 by 30 meters). In both cases however, there is a standard deviation of 0.2 in the edge and openness indices suggesting significant variability with respect to fragmentation across municipalities.

- All fragmentation indicators display maximum values (highest probability of adjacency with open space) in the smallest municipalities with population between 11,500 and 50,000 inhabitants. As the size of the municipality increases, fragmentation decreases monotonically with population.

- New developments in the period 1990–2001 are predominantly *extensions* of the urban footprint. On average, extensions account for 61 percent of all new developments in that period, 29 percent consists of *infill,* and *leapfrog* developments represent only 10 percent of all new developments.

- There is a homogeneous tendency towards less spatial fragmentation in the urban growth pattern as measured by all the indicators considered, over time and across municipalities. In other words, fragmentation indicators for the year 2011 suggest less fragmentation than in 1990 across all the scales of analysis considered and most municipalities.

For more details on the descriptive results the reader is asked to consult Goytia and Pasquini, 2012b.

Development of Second-Generation Regulation Indices

Our next step is to improve the regulation indices that we already have by adding data on new regulations and implementation practices. These second-generation indices also introduce weighted zoning metrics. The improved indices will help determine the degree of stringency in the application of zoning changes, infrastructure provision, and policies regulating access to land. The development of standardized regulatory indices facilitates comparison across municipalities and also permits aggregate analysis at the metropolitan and state levels.

Our original regulation indicators (Goytia and Pasquini, 2010) follow the approach taken in developed countries studies, as for example Gyourko, Saiz, and Summers (2006). However, we soon found out that their approach was not readily transferable to the reality of land use in developing countries such as Argentina. This is so particularly for the following reasons. In developing countries (i) land use regulation law and what is actually applied varies widely; (ii) permissible land use may prove infeasible; (iii) land use policies may not be legally enacted but rather ad hoc initiatives by the local government; (iv) old regulations remain in the books although they are no longer enforced; (v) regulations may be ambiguous, subject to many interpretations; and (vi) informal settlements are common in cities of developing countries but not so elsewhere.

Clearly there is a need to adapt the analytical methods of prior studies and construct new indicators taking into account issues germane to developing countries, such the existence of informal markets and the level of regulation enforcement (Goytia and Pasquini, 2010). The database we currently have is appropriate to address these issues. For example, we can begin to explain variations in the provision of urban infrastructure and access to land depending on the presence of redistributive elements in the municipal regulatory framework. We can also relate infrastructure provision to differences in local fiscal policies.

Goytia and Pasquini (2010) describe the methodology for the creation of thematic indicators that we used in the past. The same methodology is used as basis for developing the improved indicators, which comprise (appendix 2):

i. Land Use Plan and Regulation Existence Indicator (LPI),
ii. Zoning and Residential Projects Approval Processes Indicator (ZRPI),
iii. Building Restrictions Indicator (BRI),
iv. Infrastructure Provision Indicator (IPI),
v. Access to Land Regulation Indicator (ALRI),
vi. Municipal Fiscal Indicator (MFI), and
vii. Project Approval Costs Indicator (ACI).

Note that some of our indicators now incorporate the reported degree of application or enforcement of the specific measures set forth in the regulation. This dimension differentiates between the incidence of a regulation and the degree it is practiced or enforced. Planning directors who answered our survey are very knowledgeable about these distinctions.

A second aspect that we are particularly interested in analyzing is the relation between zoning and building parameters. Our data cover detailed measures for each land use zone category in each of the municipalities in the sample. The recently developed GIS-based metrics of land use zoning allow us to weight building parameters by zone area, thus providing a more relevant measure of the overall degree of stringency of these parameters for the entire zoned territory of a municipality.

We plan to devote a specific paper describing the methodology used to build the improved indicators. The methodology shall comprise regression and principal components techniques, and several robustness checks. The expected results will allow the ranking of municipalities with respect to land regulation stringency along with a set of geo-referenced illustrations.

Land Use Regulation and Municipal Characteristics

Once the new regulation indices are defined, we will approach the analysis of the determinant causes and consequences of regulation. The preliminary methodology to address this question is discussed in this section.

In identifying the factors that determine the production of regulation (i.e. the economics behind regulation) one aspect that we consider important is the link between land use regulation and tenure informality. With the results from our 2011 Regulation and Practices Survey, plus municipal demographic and socioeconomic data, and the geographic and land cover data, we plan to explore this issue by estimating a (spatial corrected) cross-section econometric model. Specifically, we will examine the role of segregation, income inequality, and key variables such as the share of vacant land in the analysis of the links between urban land use regulation and informality.

The key variables to be explained in the empirical analysis are selected from the regulation indicators listed above. This means that we will focus on the study of proxies of regulation stringency, such as our Zoning and Residential Projects Approval Indicator (ZRAI) or the GIS-corrected Building Parameters Indicator across municipalities. Our analysis will also examine specific regulation indicators such as the Infrastructure Provision (IPI).

For example, in the analysis of informality several issues are considered. The existence of vacant land (**pvacantland** in the equations below) or open space, as measured in our land cover metrics, for example, is a necessary condition for the development of new informal settlements (*villa, asentamiento—s*lum). In other words, we need to incorporate—among others—a measure of the developable land that is vacant as a control variable in the analysis of the relationship between regulation and informality.

Explanatory Variables and Econometric Specification

Following the theoretical model developed by Hilber and Robert-Nicoud (2009), we select three variables to be considered in the empirical analysis, explain the hypothesis behind them, and describe their empirical use. These are:

- *Political Power of Homeowners (proxy for the share of developed land (SDL)*: Here the hypothesis is that homeowners will tend to avoid new developments, and their effect on regulation will be stronger the stronger is their political power. Using a similar approach to that of Hilber and Robert Nicoud (2009), we incorporate measures of developed land (as a share of total developable land) as proxies of political power of homeowners. In our case, this variable is measured on the basis of satellite and topographic imagery.

  $$PoliticalPowerofHomeowners \cong (Developedland)/$$

  $$(developableland) = (Footpr\,\mathrm{int}\,builtuparea)/$$

  Note that by definition the share of land that is not built is vacant. As a second approach we use estimations by planning professionals of how much vacant land there is in the jurisdiction.

- *Ratio of homeownership (RHO).* This ratio is another measure the power of homeowners. It is a proxy built using census data indicating the percentage of households that declare to be owners of the dwelling and the land they occupy.

- *Population density* (PD) is a necessary control, notably for regulations used to correct externalities arising from agglomeration. In Argentina, the traditional measures of density are averages based on the ratio of total population and total area of a department (*partido*), the limits of which are well known. However, these limits do not necessarily coincide with the actual limits of the jurisdiction that produces the regulation. Furthermore, the overall administrative area of a municipality is not a particularly good denominator for measuring urban density for several reasons. First, the limits of municipal jurisdictions in Argentina are not clear since many provinces set special areas (or "Ejidos ") as part of the area of municipal jurisdictions. The resulting limits are not useful because they can be changed by fiat through incorporating new areas into the city limits causing density to change overnight. Second, administrative limits can be much larger than the built-up area of the city, usually leading to under-estimation of density (Wolman et al, 2005). Hence, in this study, we do not use the administrative area of the municipality to calculate average density. Instead, we create measures with criteria that are common to all jurisdictions. The area corresponding to the city footprint is the measure we use to define and calculate average urban density.

$$Population\ Density = \frac{Population}{Total\ Footprint\ Area}$$

- *Additional socioeconomic controls*: Moving forward from the identification strategy used to study regulation in developing countries, we consider the role of informality in the theoretical and empirical approach. In contrast with developed countries, where informal land markets are not prevalent, in developing countries households with informal land tenure might influence the political agenda of municipalities—but only in some cases, not always. This happens because the population of informal settlements generally comprises a large share of migrants, both national and international, which might not be local voters. Thus we will need to control for additional variables that might affect the production of regulation. To control for the relative wealth of the jurisdiction, we will use proxies such as the average number of years of education of the resident population and the percentage of population lacking material resources as measured by a deprivation index (*Índice de Privación Material*). We will also incorporate measures of inequality and urban segregation since, theoretically, these processes are linked to the production of exclusionary regulation. Our approach will consider these variables as possible reverse causation.

Econometric Specification

Summing up, an equation similar to the following one will be estimated:

$$\mathbf{I_j(u)} = \boldsymbol{\beta_1}(\mathbf{u}) * \mathbf{SDL_j} + \boldsymbol{\beta_2}(\mathbf{u}) * \mathbf{RHO_j} + \boldsymbol{\beta_3}(\mathbf{u}) * \mathbf{PD_j} + \sum_{\mathbf{h}} \boldsymbol{\beta_h}(\mathbf{u}) * socioec_{control_j}^{\mathbf{h}}$$

Where *I* stands for an indicator measuring the degree of stringency of regulation in jurisdiction *j*, and will be chosen among the indicators listed in the previous section. The notation $\beta_{\mathbf{k}}(\mathbf{u})$ indicates that the parameter k describes a relationship around location u and is specific to that location. The model is estimated using a Geographically Weighted Regression (GWR).[14]

As is standard in GWR, the estimator will take the form:

$$\hat{\beta}(\mathbf{u}) = [(\mathbf{X}]^T W(u)X)^{-1} \mathbf{X}^T W(u) I$$

Where W(u) is a square matrix of weights relative to the position of u in the study area. The W(u) matrix contains the geographical weights in its leading diagonal and 0 in its off diagonal elements. Notice in particular that in this case the weights themselves need to be computed on the basis of a kernel with a flexible bandwidth. For Argentinean municipalities, the sample points are far from being regularly spaced but are somewhat clustered in the study area, so it is desirable to allow the kernel to accommodate this irregularity by increasing its size when the sample points are sparser and decreasing its size when the sample points are denser.

[14] Charlton M. and Fortheringham S. (2009).

Regulation Externalities of Neighboring Municipalities Extension

Another factor that will be considered is the possible interaction of neighboring municipalities in the production of regulation. For example, exclusionary policies towards lower income groups enacted in one jurisdiction might be externalized in neighbor jurisdictions. This dimension might be particularly important, for example in the case of the analysis of the Access to Land Elements Regulation Indicator (ALRI) or in the case of Infrastructure Provision (IPI).[15] In the analysis of IPI the coverage of infrastructure provision should also be incorporated as control.[16]

Summing up, we expect to estimate a model similar to the following:

$$\mathbf{I_j(u)} = \boldsymbol{\beta_1}(\mathbf{u}) * \mathbf{SDL_j} + \boldsymbol{\beta_2}(\mathbf{u}) * \mathbf{RHO_j} + \boldsymbol{\beta_3}(\mathbf{u}) * \mathbf{PD_j} + \sum_{\mathbf{h}} \boldsymbol{\beta_h}(\mathbf{u}) * socioec_{control}{}_j^h + \sum_{\mathbf{h_2}} \boldsymbol{\beta_{h2}}(\mathbf{u}) * \mathbf{I_j^{h_1}} \qquad (2)$$

The components of equation (2) have been already explained above, with the exception of the forth term $(\Sigma_\downarrow(h_\downarrow 2)$ 【$\beta_\downarrow h2\ (u) *$】 $I_\downarrow j^\uparrow(h_\downarrow 1\ )$ which represents the regulation indicators in h_2 the neighboring jurisdictions and is expected to display a significant coefficient if there are externalities in place.

[15] As mentioned in Goytia, et al. (2012a), the provision of infrastructure has been considered in the literature as an indirect exclusionary (inclusionary) policy.

[16] These variables will be particularly important in analyzing the regulation related to infrastructure provision as well as the financing mechanisms for the provision of infrastructure used in each municipality.

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Appendix 1. Definitions of Urban Growth Analysis Metrics

BUILT-UP AREA

Built-up Area	Impervious surface pixels as identified from Landsat imagery
Urban	Built-up pixels for which the land within a 564 meter radius is 50 - 100% built-up
Suburban	Built-up pixels for which the land within a 564 meter radius is 10 - 50% built-up
Rural	Built-up pixels for which the land within a 564 meter radius is 0 - 10% built-up

URBANIZED AREA

Urbanized Open Space	Non-built-up, non-water pixels for which the land within a 564 meter radius is 50 - 100% built-up
Captured Urbanized Open Space	Non-built-up, non-water pixels that are completely enclosed by Urban, Suburban, and Urbanized Open Space pixels and have a contiguous patch size of less than 200 hectares.
Urbanized Area	Urban, Suburban, Urbanized Open Space, and Captured Open Space pixels
Rural Open Space	Non-built-up, non-water pixels not classified as Urbanized Open Space or Captured Urbanized Open Space

URBAN FOOTPRINT

Peripheral Open Space	Non-built-up, non-water pixels that are within 100 meters of Urban and Suburban built-up pixels
Captured Peripheral Open Space	Non-built-up, non-water pixels that are completely enclosed by Urban, Suburban, and Peripheral Open Space pixels and have a contiguous patch size of less than 200 hectares.
Urban Footprint	Urban, Suburban, Peripheral Open Space, and Captured Open Space pixels
Rural Open Space	Non-built-up, non-water pixels not classified as Urbanized Open Space or Captured Open Space
Exterior Fringe Open Space	Non-built-up, non-water pixels that are within 100 meters of Rural Open Space.

POPULATION DENSITY

Built-up Area Density	Population density of the built-up area
Urbanized Area Density	Population density of the urbanized area
Urban Footprint Density	Population density of the urban footprint

NEW DEVELOPMENT

Total	Built-up pixels existing in T2 but not T1
Infill	New development that is within the T1 urbanized open space or captured open space
Extension	New development that intersects the T1 urban footprint
Leapfrog	New development that does not intersect the T1 urban footprint

BUILDABLE LAND

Circle Radius	The radius of the Buildable Area circle - a circle with a total area 4 times that of the Urban Footprint
Buildable land index	The fraction of land within the Buildable Area circle that is not water and does not have a slope > 15%

OPENNESS

Edge Index	The fraction of built-up pixels that are cardinally adjacent (4 nearest neighbors) to at least on open space pixel.
Openness Index	The average percent of non-urban land within a 564 meter radius of all built-up pixels

COMPACTNESS OF URBANIZED AREA / URBAN FOOTPRINT -

All metrics normalized using the Equal Area Circle unless otherwise stated

Cohesion Index	The average distance between all pairs of pixels in the shape
Cohesion Squared Index	The average distance-squared between all pairs of pixels in the shape (points farther out have more weight)
Exchange Index	The fraction of the area that is contained within the Equal Area Circle (a circle with area equal to the Urbanized area / urban footprint)
Net Exchange Index	The fraction of the area that is contained within the Net Equal Area Circle (a circle with a buildable area -- non-water, slope <15% -- equal to the Urbanized area / urban footprint)
Spin Index	The moment of inertia of the shape
Depth Index	The average depth of the shape
Girth Index	The radius of the largest circle that can be inscribed within the shape

COMPACTNESS OF URBANIZED OPEN SPACE / PERIPHERAL OPEN SPACE/ PERIPHERAL OPEN SPACE

Urbanized OS Proximity Index	Average distance to urbanized OS/average distance of urbanized OS EAC
Urbanized OS Proximity Index (2)	Average distance to urbanized OS/average distance of urbanized area EAC

Appendix 2: Regulation (Stringency/Flexibility) Indicators

This appendix presents the purpose and description of the land use indicators that we developed thus far and that will be used as basis for a new set of improved indicators.[17]

Land Use Plan and Regulation Indicator (LPI)

The aim here is to capture the extent in which a plan for the use of land exists and whether it has been formally established in the legal and regulatory framework. At both the provincial and the municipal level, two indicators (provincial and municipal) reflect the existence of land use plans and whether these have been enacted as laws or decrees (at the provincial level) or as regulatory ordinances at the municipal level (e.g. *ordenanzas*, urban planning codes). These indicators take the value of one in the case a plan for the use of land exists and it has already been incorporated in the respective legal or regulatory framework; one-half in the case the plan exists but it hasn't been promulgated, and zero otherwise.

$$provincial, municipal = \begin{cases} 1 \quad \textit{if} \ \textbf{exists and it has already been incorporated in the respective legal or regulatory framework} \\ \frac{1}{2} \quad \textbf{exists but it hasn't been promulgated} \\ \mathbf{0} \ otherwise \end{cases}$$

$$LPI = STD[provincial + municipal]$$

Zoning and Residential Projects Approval Processes Indicator (ZRPI)

This indicator aims to capture the involvement of different governmental authorities and community organizations in the approval of residential projects. The indicator considers separately the approval of projects that require zoning changes and regular projects that do not require zoning changes.

The *Zoning Change Approval Indicator (ZAI)* was adapted from Gyourko, Saiz, and Summers (2006) and reflects the degree of difficulty faced by a project to obtain a approval for zoning change. Our survey asked which authorities are involved in approving zoning changes. The organizations listed are: i) The executive power at the municipal or communal level, ii) The Planning Commission, iii) The Zoning Board or Council, iv) The Local (Municipal) Council, v) Provincial level governmental officials, and vi) The Environmental Evaluation Committee. The index adds the value of 1 for each organization involved. Finally, the indicator also adds a value of 1 if residential projects requiring zoning changes must be presented, debated or approved in local assemblies (public hearings) or at meetings with the community, and equals zero otherwise.

ZAI = STD (executive + planningcom + zoningcouncil + localcouncil + provgovofficials + envcomitte + Localassembly)

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[17] Definition as in the paper by Goytia and Pasquini (2010).

The Regular Project Approval Indicator (RPAI) is analogous to the previous indicator. It considers the authorities involved in the approval of projects which do not require changes in zoning, but considers a different list of authorities: i) Planning Commission, ii) Local Council/ local officials, iii) Environmental Revision, iv) Design Revision Office (e.g. cadastre office) and iv) Other authority reported. The index adds one for each authority involved.

$$RPI = STD(planningcomm + loccouncil + envrevision + designrevision + other)$$

The Zoning Change Approval Indicator (ZAI) and the Regular Project Approval Indicator (RPAI) are combined in a single indicator by averaging the value of both indicators. That is, we give equal weight to the two dimensions of the indicator when we build the Zoning and Residential Projects Approval Processes Indicator (ZRPI):

$$ZRPI = \frac{ZAI + RPI}{2}$$

Building Restrictions Indicator (BRI)

The following concepts are related with restrictions in the supply of residential buildings, and then summarized in an aggregate indicator. These are: i) Lot size restriction; ii) Maximum Land Use and iii) Maximum Total Building.

First, our survey asked whether there is a minimum residential lot size restriction and the size of the requirement in case it exists. The indicator will take a higher value for a larger minimum lot size, indicating a higher restriction to the access to land. The indicator considers minimum size lot restrictions in low and high densities areas separately, and adds both dimensions in the aggregate indicator.

Second, the indicator also incorporates the existence of Maximum Land Use and Maximum Total Building Restrictions, and the perception reported by specialists of these as actually being active restrictions for new residential developments in the jurisdiction.

These restrictions are combined in the Building Restrictions Indicator (BRI) as follows:

$$BRI = STD(STD(lotsizehigh * dlotsizehigh) + STD(lotsizelow * dlotsizelow) + STD(landuseopinion * dmaxlanduse) + STD(totbuildopinion * dmaxtotbuild))$$

Where $dlotsize_{high}$ is a dummy variable that takes the value of one if a minimum lot restriction is part of the municipality land use regulation; $lotsize_{high}$ is the size of the minimum lot size restriction in high density areas; $dlotsize_{low}$ and $lotsize_{low}$ are the analogous variables for low densities areas; *dmaxlanduse* and *dmaxtotbuild* are dummy variables taking the value of one if a maximum land use restriction or maximum building restrictions are in place; *landuseopinion* and *totbuildopinion* are subjective variables that range from 1 to 5, and take on a higher value reflecting the degree to which the respondent believes that these are active restrictions for the supply of residential buildings.

Infrastructure Provision (IPI)

In this indicator we consider how basic infrastructure and public services are provided in suburban areas or in areas lacking one or more of these services.

We consider two major issues. First, we ask if the municipality has defined an urban perimeter where it guarantees the provision of basic services to new residential developments. We define a sub-indicator that, for those municipalities that have defined a perimeter, adds one for each service that is guaranteed. The "Urban Perimeter Infrastructure Provision (UPIP)" sub-indicator is defined as:

$$UPIP = STD\ (upelectricity + upsewerage + upwater + upgax + uppavement + upsidewalk + upstretlig\ htingposts)$$

Where up_x is a dummy variable that stands for the provision of service x within the urban perimeter.

The second issue is how infrastructure is financed in those areas that lack complete access to basic services. We consider here if the municipality and the firms providing public services finance the service extension to these areas. If neither the municipality nor the respective public service firm provides finance, then the cost is completely born by the developers or new users. Two sub-indicators (IPMUN and IPPUBSERV) are constructed in other to capture the role of the municipality and the public services firms respectively:

$$IPPUBSERV = STD\ (pubservfirm_{electricity} + pubservfirm_{sewerage} + pubservfirm_{water} + pubservfirm_{gas} + pubservfirm_{pavement} + pubservfirm_{streetlig\ htingposts})$$

Where $munfin_x$ is a dummy variable that stands for the municipality financing the extension of the service x and $pubservfirm_x$ the analogous for the respective public service firm.
Finally the three sub-indicators are added in the Infrastructure Provision Indicator (IPI). A higher value for this indicator is expected to reflect a more active role of the municipality in the provision of infrastructure.

$$IPI = STD(UPIP + IPMUN + IPPUBSERV)$$

Access to Land Regulation Indicator (ALRI)

This is a measure of the presence of redistributive and access to land related elements in the regulation of the use of land. The index adds one for each of the following elements incorporated in the regulation: i) Recovery of the added value (appreciation) of land, ii) Obligatory use of the urban land, iii) Regularization of occupied land (e.g., establishing that occupied land, after a certain period of time, and if there is no opposition, might be regularized in favor of the occupant), iv) Building permits reserved for social projects., v) Obligatory donation of land for social projects, vi) Obligatory donation of land for public equipment (e.g., schools, green areas), vii) Possibility that the municipality may acquire land for social purposes, viii) Fiscal incentives for zones that are desirable to be developed.

ALRI = STD(AddedValueRecovery + ObligatoryuseUrbanLand + Regularizationoccupiedland + Socialprojectsreserve + LandDonation + LandDonatioPubEquipement + LandMunicipality + FiscalIncentives)

Municipality Fiscal Indicator (MFI)

This indicator aims to reflect the power of the municipality in obtaining local resources. The following aspects are incorporated: i) The total tax collection per capita, which is aimed to reflect the available economic resources for the municipality; ii) In relation to the effectiveness in tax collection, we analyze the effective tax revenue as a measure of total tax billing. This measure is expected to reflect the efficiency of the municipality in its tax collecting function; iii) We incorporate two other measures related to the registration of buildings for fiscal purposes. First, we analyze a subjective dummy variable taking the value of one if respondents consider that the building registry or cadastre (i.e., *catastro*) has been recently updated. Second, an objective measure accounts if the updating has been made in the last two years. These data comprise the Municipality Fiscal Indicator (MFI):

MFI = STD(taxcollectioncapability) + STD(taxperhhcapita) + STD(dudpdateregistry)+ STD(drecentudpdated)

Projects Approval Costs Indicator (ACI)

This indicator seeks to reflect the costs related to registration procedures for residential projects. It considers time and monetary costs.

Approval time (AT) is a measure of the average time the revision of a project takes between presentation and approval. This is a subjective indicator, since there are low chances that respondents have a precise estimation of the average delay. We asked separately the average time for single-unit and multiple-units residential building projects. The AT variable is then defined as the average time for the two procedures.

$$AT = \left(\frac{ATsingleunits + ATmultipleunits}{2}\right)$$

The survey also asked the monetary value that is charged for a property title registration. In practice, many buyers of land or buildings do not have formal land tenure because they avoid the costs related to registration. We incorporate this cost as a relevant cost in our comparative analysis. A dummy variable takes the value of one in the case the municipality charges for property registration an amount above a threshold to be determined in the sample (e.g., the 66^{th} percentile in the sample).

$$ACI = STD(AT) + STD(AMC)$$