Chapter 12
Do Planning Policies Limit the Expansion of Cities?

Stephen Sheppard

Abstract . . . it is essential . . . that the town should be planned as a whole, and not left to grow up in a chaotic manner as has been the case with all English towns, and more or less with the towns of all countries. A town, like a flower, or a tree, or an animal, should, at each stage of its growth, possess unity, symmetry, completeness, and the effect of growth should never be to destroy that unity, but to give it greater purpose. . ..

– Ebenezer Howard, *Garden Cities of Tomorrow, 1898*

This paper considers whether planning policies, as practiced in the world's cities, have the potential for controlling or limiting the expansion of urban land use. The question is certainly relevant for design of policies to respond to urban sprawl. The analysis does not establish that these constraints are necessarily desirable, but does find some evidence that some aspects of planning regulations can be effective in limiting urban expansion.[1]

Keywords Land use • Remote sensing • Urban planning • Urban sprawl

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1 Introduction

Concern about urban "sprawl" has been present among the popular, policy and academic communities at least since the 1950s.[2] Concern about the levels of urban expansion continues. Urban expansion has become the object of more intense academic investigation as well as a search among policy makers for approaches that will eliminate or reduce the worst external costs associated with urban expansion, while at the same time permitting the economy to experience the improved productivity and other benefits that appear to be associated with urbanization.

While there is debate about the exact levels of external costs associated with urban expansion, the urgency of the concern is not misplaced. Having just passed the watershed mark of having over half of the world's population reside in urban places, the annual rate of growth of the global urban population is about 2 % and about 4 % in the poorest countries. If urban land per person remains constant, this implies a doubling of the "urban footprint" within the next 35 years. In actual fact the growth of incomes will accelerate this process, so that within the next three decades the countries of the world will be called upon to double the population accommodated within the built urban environment. Given that the present stock of structures and other capital that constitutes the built environment required about 3,000 years to accumulate, this is a daunting task. Of particular concern is the prospect that urbanization and urban expansion will proceed with insufficient plans to accommodate the growth and inadequate policies to contain it.

The purpose of this paper is to investigate whether planning policies, as practiced in the world's cities, offer any hope of controlling or limiting the expansion of urban land use associated with cities. The question is certainly relevant for design of policies to respond to urban expansion. If there are no policies that are capable of restricting total urban land use, then the most sensible alternative would seem to be to make ambitious preparations for the doubling of total urban land use within the next 30 years.

This paper is not concerned with whether restriction of total urban land use, if achievable, is desirable. There have been many other papers that considered this question. Cheshire and Sheppard 2002, for example, measure both the costs and benefits of land use regulation in the context of specific British cities. They conclude in that context that, on the margin, constraints appear to be too restrictive so that a modest relaxation of planning constraints would appear to be welfare-improving. Their estimates of the positive value of open space preservation and

[2] The first use of the term to describe urban expansion identified in the Oxford English Dictionary is in August of 1955, when a writer in the *Times* asserted that it was ". . . sad to think that London's great sprawl will inevitably engulf us sooner or later, no matter how many green belts are interposed in the meantime between the colossus and ourselves." Thus apparently from the very beginning there were doubts about the efficacy of planning policy in limiting urban expansion. Earlier usages of the term include that by Frederic Osborn (1946), a disciple of Ebenezer Howard, who attributed suburban sprawl to improved transportation available through "electric traction . . . and the petrol or gasoline motor. . .." Black (1996) attributes the first use to Earle Draper, an urban planner active in several southeastern US cities.

limits on industrial land use suggest that, at least in some contexts, a complete absence of constraint on urban land use would also not be optimal. The paper does not consider all of the many different contexts in which planning policies **might** be effective in limiting urban land use. We simply ask whether, as practiced around the world, they are effective in reducing urban land use.

If planning policies are not effective in limiting total urban land use, it does not follow that planning itself is of no value to cities. Planning departments and "land use planning" policies (however conceived and practiced) can help improve the coherence of urban expansion and make the most effective use possible of public capital investment. These policies might reduce uncertainty about availability and location of roadways and other infrastructure and improve the efficiency of cities. To review the academic literature on this subject, however, is to be confronted repeatedly with assertions that the problem of urban expansion arises because of "inadequate planning" that, if corrected, will lead to denser and more compact cities. Our aim is to simply inquire whether, and to what extent, this is true.

2 The Impacts of Planning Policy

While many popular writers and some academics regard being "unplanned" as the *sine qua non* of urban sprawl, the evidence is at best mixed concerning whether formal planning policies have the effect of constraining the level of urban land use in cities. Studies on the subject tend to fall into (at least) three conceptual categories. There are studies that derive the impact of planning regulations using primarily theoretical arguments or simulation exercises. Second, there are studies whose primary focus is to use theoretical and empirical arguments to evaluate the potential benefits of planning regulations or to explore the interactions between other policies (such as those regarding taxation or public transportation) and land use planning policies. Finally, there are a limited number of empirical studies of the apparent effects of planning policies. It is with this latter group that this paper belongs.

Examples of the first group of studies would include Sheppard (1988), which derives the qualitative impacts on land use and land prices that result from changes in the availability of land for development, including the impact of urban growth boundaries. Turner (2007) provides a model in which the equilibrium density of development may diverge from (be less than) the efficient density and in this way captures a situation that could be properly be called "sprawl". He identifies circumstances when taxes on low density development may be welfare improving.

Burchfield et al. (2006) present an ambitious empirical examination of the causes of urban expansion. While their data are limited to the United States, their approach to analysis is otherwise similar to the one followed in this paper. Unfortunately, they do not directly look at the impact of planning policies. Nechyba and Walsh (2004) present a useful survey of some of the literature on urban sprawl, but unfortunately divert attention from the essential elements of urban sprawl – expanding use of land for urban purposes – and concentrate attention on sorting of different household types within the city. This emphasis on Tiebout sorting is of course interesting in other contexts but has little to do with increased total or per-capita use of land.

One difficulty with understanding and modeling the expected impacts of planning on total urban land use is that "planning" is a complex public function that incorporates aspects of civil engineering and provision of infrastructure, coordination of development activity, provision of public goods, and regulation of development. When a city makes provision for urban growth by obtaining rights-of-way for water and sewer lines or road construction, these activities might be called "planning" and even in some cities undertaken by a planning department, but they do not act to constrain urban land use. Development of "strategic plans" undertaken by planning departments in many countries may help coordinate development patterns and make for more efficient provision of infrastructure, but they don't necessarily limit total urban land use. To better understand this process, we require an abstract framework within which to characterize and present how planning might operate to regulate the expansion of cities.

Cheshire and Sheppard (2002) consider the impacts of specific types of land use planning in the context of specific small cities in England. The results are derived in the context of a relatively straightforward model of urban land use, which is adapted here to identify expected impacts. There are N households with identical preferences over residential land and a vector q of other goods. A household living distance x from the city center at angle (or direction) θ faces annual transportation costs given by $t(\tau, x, \theta)$. The variable τ represents the cost of inputs to transport production (such as the cost of fuel. We assume that $\frac{\partial t}{\partial \tau} > 0$ and $\frac{\partial t}{\partial x} > 0$. Each household has annual income M from employment in the city and thus has $M - t(\tau, x, \theta)$ to allocate between residential land and other goods.

Let $h(u, r, p)$ be the compensated demand for residential land, which depends on the utility level u, the price of land r and the vector of other goods prices p. Let $r(u, x, \theta, \tau, p, M)$ be the "bid rent" function defined as the price of residential land at each location (x, θ) that allows the household to achieve utility level u given that it has income M, faces prices of other goods p and must pay commuting costs $t(\tau, x, \theta)$. The value of agricultural land is given by R_a. In the absence of planning constraints, urban residential land use extends to a distance of $x_a(\theta)$, defined implicitly by the equality:

$$r(u, x_a(\theta), \theta, \tau, p, M) = R_a \tag{12.1}$$

Clearly, $x_a(\theta)$ depends upon u, τ, p, M and R_a as well as θ. To simplify notation we suppress these additional arguments except where confusion would result.

Planning constraints are represented in a stylized fashion. Policies such as urban growth boundaries and to some extent greenbelts attempt to constrain urban development from taking place beyond a particular distance from the center of the city. Suppose that for every direction θ there is a distance $\chi_2(\rho, \theta)$ that is the maximum distance where consumption of land for residential purposes is permitted. Here ρ is a planning policy parameter, and we assume that $\frac{\partial \chi_2}{\partial \rho} < 0$. This represents urban containment policy. Actual urban residential land use will extend to the distance min $(x_a(\theta), \chi_2(\rho, \theta))$.

Planning policies also might attempt to defend open spaces that are interior to the built-up area of the city. These may be parks, greenways, or even farm land that is not allowed to be developed. To represent such policies, suppose that there is a parameter $0 < \omega \leq 1$ that specifies the share of land that may be privately consumed. If planners want to set aside land for parks, open space or some other form of shared land consumption within the built-up area, they may do so by setting ω to a value less than one. There is also a distance $\chi_1(\theta)$ that represents the innermost extent of residential land use, which depends on the level of commercial activity in the urban center and the land requirements for these non-residential activities.

Equilibrium is determined by a utility level $\hat{u}$ shared by all households having the property that:

$$N = \int_0^{2\pi} \int_{\chi_1(\theta)}^{\min(x_a(\theta),\chi_2(\rho,\theta))} \frac{\omega \cdot x}{h(\hat{u}, r(\hat{u}, x, \theta, \tau, p, M), p)} dxd\theta \tag{12.2}$$

The intuition behind Eq. 12.2 is straightforward. The numerator is the density of land availability at distance x given planning policy ω. The denominator is the local density of land consumption by utility maximizing households. The ratio is the number of households accommodated at location (x, θ). Zero excess demand for land requires that integrating the number of households accommodated at each location over all urban locations must equal the total number of households to be accommodated.

In equilibrium, with each household achieving utility $\hat{u}$ the total amount of land consumed for private residential purposes in the urban area is obviously:

$$T = \int_0^{2\pi} \int_{\chi_1(\theta)}^{\min(x_a(\theta),\chi_2(\rho,\theta))} \omega \cdot x\, dxd\theta \tag{12.3}$$

If $\omega = 1$, $\chi_1(\theta) = \bar{\chi}_1$ and $\min(x_a(\theta), \chi_2(\rho, \theta)) = \bar{\chi}_2$ then Eq. 12.3 reduces to $\pi \cdot \bar{\chi}_2{}^2 - \pi \cdot \bar{\chi}_1{}^2$. In the absence of these restrictions, Eq. 12.3 is used to give a general expression of total urban area.

Within the context of this model, several comparative static properties of the equilibrium are easily established. They are summarized as follows:

	Results	Description
1.	$\frac{\partial T}{\partial N} \geq 0$	Increasing population increases total urban land
2.	$\frac{\partial T}{\partial M} \geq 0$	Increasing household income increases total urban land
3.	$\frac{\partial T}{\partial \tau} \leq 0$	Increasing transport costs decreases total urban land
4.	$\frac{\partial T}{\partial R_a} \leq 0$	Increasing agricultural land value decreases total urban land
5.	$\frac{\partial T}{\partial \rho} \leq 0$	A stricter containment planning policies decreases total urban land
6.	$\frac{\partial T}{\partial \omega} \leq 0$	Increasing internal open space will decrease total urban land

Cheshire and Sheppard did not test whether some observed characteristic or activity of the UK planning system was actually associated with a change in ρ or ω (viewed through the lens of this model). Rather, they assumed that the planning system operated to set *some* level of these constraints. They used the estimated parameters from an almost ideal demand system to simulate the land value outcomes resulting from different values of the parameters, selecting the values $\hat{\omega}$ and $\hat{\rho}$ that provided the best fit to the observed data (pattern of land values and maximum extent of urban development). Using these values they were then able to consider and simulate counter-factual scenarios such as the impact of removing these planning constraints.

In this paper we consider a different question: is there some observable characteristic of planning practice or planning policies that is empirically associated with impacts on total urban land use of the sort suggested in the simple model described above? At the same time, and as a general test of the simple modeling approach itself, it is possible to see if the other predictions of the model concerning the impacts of population, income, transport costs and agricultural land values are supported empirically. If these predictions are generally supported then it might be reasonable to conclude that the model provides a useful framework within which to think about urban land use and land use regulation. We can then inquire what aspects, if any, of planning policies have an impact on the expansion of cities.

Before proceeding to describe the data used and the results obtained, one thing must be noted. It is clear that to test the model described here, we would need either a long and sufficiently varied time series of data for a single city, or a cross section of data from a variety of cities so that we can observe the variation in population, income, planning policies, and other variables that permit us to estimate the impacts. Ideally we would have a well designed panel of observations for a diverse and representative sample of cities. For the most part, such data do not exist. We make use of a unique data resource that provides measurements of total urban land cover obtained using consistent methodologies applied in a sample of cities around the world.

3 The Data

The data we analyze provide a measure of the total urban land cover in 120 cities around the world, at two points in time about a decade apart. The cities included in our sample represent a random sample of all urban places in the planet having metro area population in excess of 100,000 persons. The sample is stratified to ensure representation of cities by broad income group, size class, and global region. Thus we have a representative sample in the sense that the proportion of the global urban population that lives in small cities in low-income countries in Latin America (for example) is similar to the proportion of population in our total sample who lives in small cities in low-income Latin American cities. The location of cities, along with indicators of size and income category, is illustrated in Fig. 12.1.

For each of these cities, we bring together three types of data: satellite images that were analyzed to measure the total urban land cover in each city, detailed local data collected by field researchers who visited each city, mostly in 2005–2006, and national level data for the country in which each city is located collected from World Development Indicators and from other global data sources.

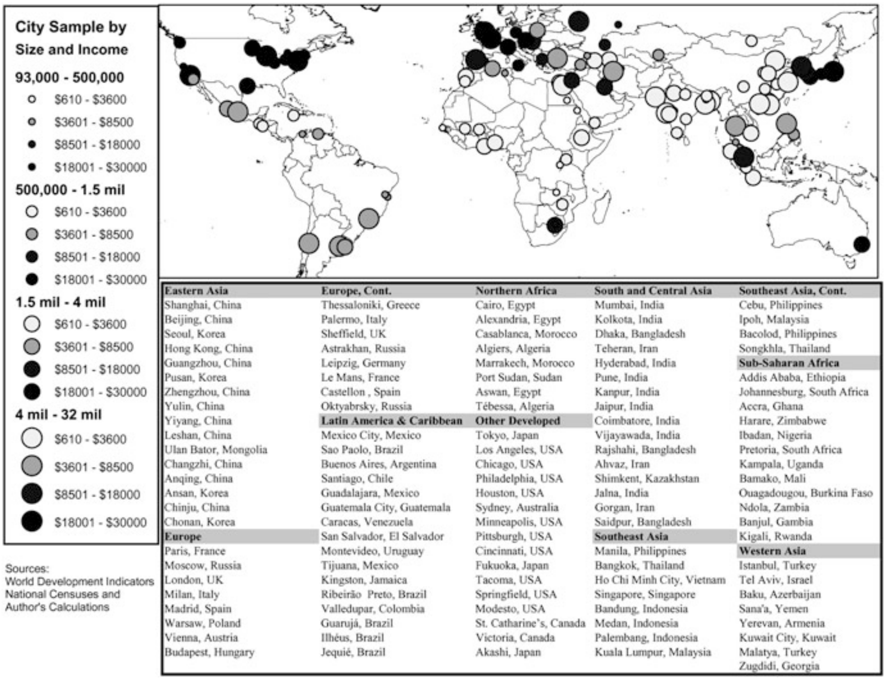

Fig. 12.1 Distribution of global urban sample

We obtained Landsat TM or ETM[3] satellite images for two points in time, approximately 10 years apart. The earliest images are from 1984, and on average the first images are from autumn of 1989. The latest images are from late 2002, and on average the second images are from fall of 1990. Thus on average, the two images are about 11 years apart. These satellite images are divided into pixels that correspond to an area on the surface that is 28.5 m^2. For each pixel the image provides 6 or 7 brightness levels of light, three in the visual spectrum and three in the infrared region. These brightness levels are used to “classify” the image. This means that an analytical procedure is used to sort pixels into categories corresponding to an estimate of conditions on the surface. The classification scheme used was simple and sorted pixels into three categories: urban cover, non-urban cover, and water. A supervised, three-pass cluster analysis procedure was used for each image. Pixel-level analysis and comparison with ground photographs taken by the field researchers indicates that pixels are correctly classified in between 85 % and 90 % of the cases. The concern in this analysis is with the aggregate urban land cover for the entire urban area. In a typical city, there will be well over a million pixels so that on average we expect the accuracy of measurement of total urban land use to be very high.

[3] The TM or Thematic Mapper instrument was included in Landsats 4 and 5 and so potentially provide data from late 1982 through 2007. The ETM or Enhanced Thematic Mapper instrument is on Landsat 7 and so provides data beginning in late 1999.

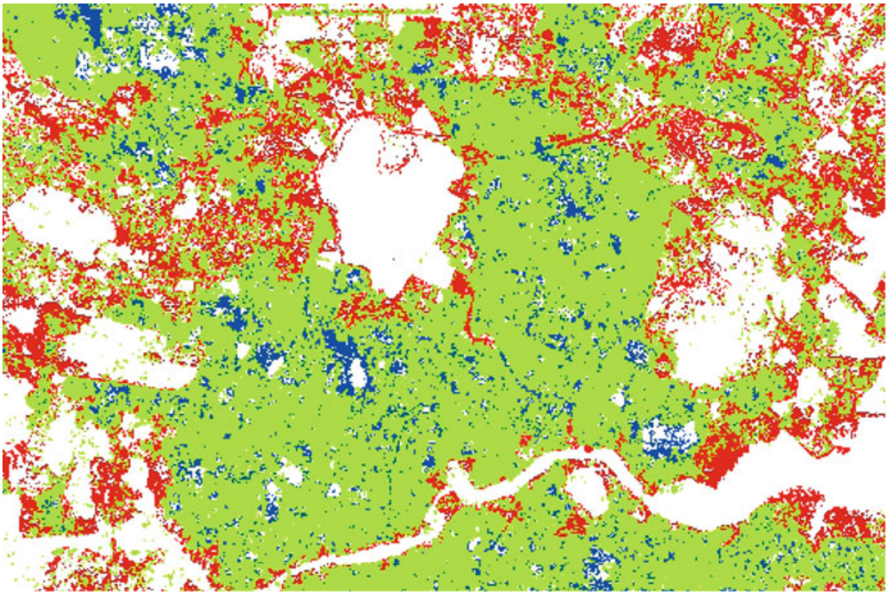

Fig. 12.2 Classification of urban land cover in Hyderabad, India

The final outcome is an image similar to that presented in Fig. 12.2. This image actually combines two classifications. One for November 1989, shown in green, and one for October 2001, combining all colors. The areas marked in red are represent new urban development at the periphery, while the areas in blue represent new urban development that is surrounded by areas that were developed in 1989. The area of each type of land use is recorded and this provides our measure of total urban land cover for each city and each date.

For every city, field researchers were hired to collect data on local population and housing conditions, the nature of local planning systems and planning institutions, local house prices and conditions, the extent and conditions of housing located in informal or squatter settlements, local housing finance, and local transportation and travel conditions. Each field researcher was provided with survey forms to complete and instructions, and were selected based on familiarity with the local city and conditions. For our analysis, we rely on the data collected concerning the nature of local planning and land use regulation. These data include information on the total staff employed in the planning department, the amount of time expected to obtain permission to convert land from rural to urban use. The amount of time expected to obtain permission to subdivide land already approved for urban use, and the number of compulsory demolitions of structures within the past year due to non-compliance with planning regulations. Field researchers met with varying degrees of cooperation from local planning authorities, and some data were not available for some cities.

Data on income, cost of motor fuel, prices, exchange rates, and other national level variables available in World Development Indicators are combined. These include, where required, estimates of real value added per hectare of land under cultivation (as a proxy for the value of agricultural land). We make use of the indices of

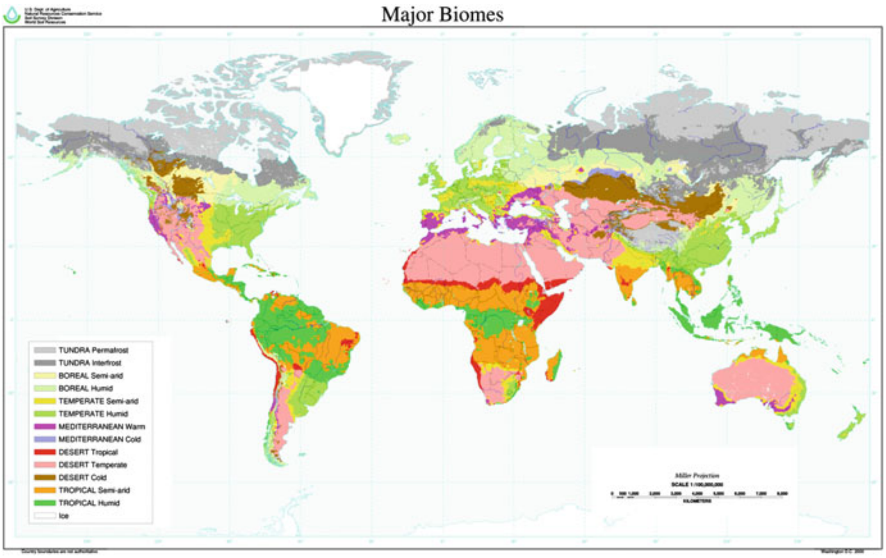

Fig. 12.3 Map illustrating biomes used as instruments

ethnic, religious and linguistic "fractionalization" discussed in Alesina et al. (2003). The location of the center of each urban area was determined (the centroid of the measured urban land cover) and used to determine latitude and longitude. These locations were combined with data on "biomes" – a classification of soil type and prevailing climate conditions – and these agri-climate indicators were used in the analysis. The global distribution of biomes is illustrated in Fig. 12.3.

Population data from national censuses was used for subareas within each city. These varied in size, and for some cities (Paris, Johannesburg, all US cities) the areas were small (similar to census tracts) but for other cities (for example, Accra and Cairo) the subareas for which population data were available were relatively large, and often extended well outside the built up area of the city. When the jurisdictions were completely covered by the available satellite imagery, we included the entire jurisdiction. If the image did not cover the entire jurisdiction, we estimated the population that would be expected to be within the image area by assuming an exponential population density function. We also assumed constant rates of change in population between the two censuses nearest our image dates, and interpolated (or extrapolated) the population to the date of the satellite image.[4] Table 12.1 presents descriptive statistics for all of the variables used in the analysis.

[4] This explains why the smallest city in our sample is listed as having a population in the earlier time period of less than 100,000. While all of our urban areas had 1990 populations of 100,000 for the metropolitan region, this was not quite true once we had truncated some sub areas to account for portions not covered by the satellite image and adjusted for the satellite image date.

Table 12.1 Descriptive statistics

Variable	μ	σ	Min	Max	Obs
Total urban land (KM^2)	402.81	635.11	8.92	4,268	240
Total population	3,363,025	4,459,765	93,040.91	27,200,000	240
Per capita income (2000 USD)	9,914.08	9,916.7	609.88	35,354	240
Agricultural land rent	3,347.65	12,569.78	68.84	150,542.9	240
Cost of motor fuel	0.62	0.36	0.02	1.56	240
Demolition orders	193.74	1,180.94	0	10,000	154
Planning staff	128.89	284.69	0	1,600	178
Planning staff per 100K	4.61	8.05	0	63.72	178
Delay convert rural to urban	13.8	44.48	1	416	182
Delay to subdivide land	5.68	8.78	0.08	75	206
Regional indicators					
East Asia	0.13	0.34	0	1	240
Europe	0.13	0.34	0	1	240
Latin America	0.13	0.34	0	1	240
North Africa	0.07	0.25	0	1	240
South-central Asia	0.13	0.34	0	1	240
Southeast Asia	0.1	0.3	0	1	240
Subsaharan Africa	0.1	0.3	0	1	240
West Asia	0.07	0.25	0	1	240
Other developed (excluded)	0.13	0.34	0	1	240
Instrumental variables					
Shallow groundwater	0.24	0.43	0	1	240
Boreal semi-arid	0.01	0.09	0	1	240
Boreal humid	0.02	0.13	0	1	240
Temperate semi-arid	0.16	0.37	0	1	240
Temperate humid	0.26	0.44	0	1	240
Mediterranean warm	0.11	0.31	0	1	240
Desert tropical	0.03	0.16	0	1	240
Desert temperate	0.08	0.28	0	1	240
Desert cold	0.02	0.13	0	1	240
Tropical semi-arid	0.19	0.39	0	1	240
Tropical humid	0.12	0.32	0	1	240
Latitude	22.98	21.85	−34.89	55.75	240
Longitude	30	73.61	−122.44	151.21	240
Maximum slope	25.96	14.96	4.16	78	240
Ethnic fractionalize	0.38	0.23	0	0.93	240
Language fractionalize	0.35	0.3	0	0.92	240
Religion fractionalize	0.46	0.25	0	0.86	240
Other variables					
Change in area	115.21	126.09	3.19	549.66	240
Change in pop	584,872.9	964,112	−898,817.5	4,916,813	240
Pct change in percap GDP	0.02	0.03	−0.08	0.09	240

4 Results

All models reported in this paper have been estimated using all available observations as a cross section data set with standard errors clustered for each city. In addition to population, income, transportation input cost, agricultural land values, and several measures of the level of land use planning, regional fixed effects are included to capture systematic influences of a cultural, economic, or technological nature that might cause all cities in a region to be similarly large or compact. In all cases, we estimate a model that is linear in the logarithms so that the equation to be estimated is:

$$\begin{aligned}\ln(UrbanArea) = \beta_0 + \beta_1 \ln Pop + \beta_2 \ln Income + \beta_3 \ln AgriRent \\ + \beta_4 \ln FuelCost + \beta_5 \ln Planning + \beta_6 EastAsia + \ldots \\ + \beta_1 3 WestAsia + \in\end{aligned} \tag{12.4}$$

A central econometric difficulty for analysis of these data concerns the endogeneity of several of the variables that are used to explain total urban land area. Consider income, for example. Suppose that a city has drawn a large positive ε for urban area so that it has a large amount of urban land cover. This urban land cover consists of built structures, roadways, and other types of physical capital so what we are really saying is that the city has an unusually large stock of physical capital. If this capital is productive, then it might work to increase incomes in the city so that measured income in the urban area will not be fixed, nor random but independent of the model error ε.

Whether failing to account for endogeneity of land use regulation biases the resulting analysis towards finding policies to be effective or finding them to be ineffective depends on the mechanism of endogeneity that is thought to hold. Formally, of course, the direction and magnitude of the bias depends on the structure of the covariance between the error in total urban footprint and the independent variables. An intuitive understanding of the difficulty can be developed by considering a couple of alternative cases. Cities that face high levels of population and income growth will, as a result of these factors, tend to experience high rates of urban expansion. If, in response to this, such cities adopt land use regulation in an effort to constrain urban expansion, the regulations might be partly effective but not fully. As a result cities with a higher probability of adopting growth controls will also exhibit urban expansion and the analysis may be biased towards finding anti-sprawl policies ineffective. Alternatively, it might be that land use regulation emerges primarily to serve the economic interests of existing land owners who seek, for example, to block construction of new housing so as to increase the value of their own property. Cities that are experiencing limited population growth or economic stagnation would tend to have stagnating or declining property values as well. If property owners control land use regulatory authorities in such cities, they might push for even more stringent controls as a way of defending property values against countervailing market forces. In this case we would be biased towards finding exaggerated impacts of land use controls.

We consider five different indicators of the level of planning activity. The number of compulsory demolitions of structures within the past year due to non-compliance with planning regulations, the total number of staff in the planning department, the total number of staff per 100,000 persons in the urban area, the delay (in months) to get permission to subdivide a parcel of urban land, and the delay to convert land from rural to urban use. There are other more conventional measures of the restrictiveness of planning regulations in cities, but some of these are rarely if ever applied in developing country cities (urban growth boundaries) or are difficult to measure (although work to complete these measures is in progress). The five variables considered in this paper have the advantage of being readily understood and reported by a relatively large share of planning offices in the sample of cities.

We endeavor to deal with the endogeneity problem using an instrumental variables approach. Before presenting those estimates it is worth examining, if only for comparison, the results estimated using a conventional OLS approach. Tables 12.2 and 12.3 present these results. In the first column of results estimates are presented for a model with no planning variables, followed by a model that includes compulsory demolitions, then planning staff, then planning staff per 100,000 population, then both delay variables, and finally the delay in converting rural to urban land. This last variable is of obvious relevance to urban expansion, since it is such conversion that is the very essence of urban sprawl. On the other hand, increasing or decreasing the delay might do little to affect the total urban land use in a city.

Table 12.2 presents several results that are of interest. First, note that the impacts of population, income, agricultural land value and transport costs are all of the correct sign and except in two cases all are statistically significant. They are also of magnitudes that are generally plausible. For example the impact of population is consistently slightly larger than 0.8 implying that doubling the population of the urban area increases total urban land use by slightly more than 80 %. This implies that as cities grow, the get larger but also get more dense. Other impacts are also of reasonable magnitudes.

The impact of planning variables is consistently small and never significant. Either planning has minimal impact on urban land use, or these variables are not good proxies for planning restrictiveness, or endogeneity of the sort discussed above is making it difficult to detect.

Before moving to consider the instrumental variables estimates, we note from Table 12.3 that the regional fixed effects are rarely significant. The excluded case is “Other Developed” country cities, which includes cities in the United States, Australia, Canada and Japan. It is not surprising that relative to these the European or South-central Asian cities tend to be smaller, although the effect is not always significant. It is worth noting that sub-Saharan African or West Asian cities tend to be larger (or not significantly different from) cities in the default category.

We need the instruments to be uncorrelated with random error in the total urban land use variable, but capable (as a group) of providing reasonable estimates of the endogenous variables. The instrumental variable strategy we employ uses four broad groups of variables as instruments for the potentially endogenous variables in the model. These are the biome in which the city is located (a rough indicator of the soil type, rainfall and climate factors), the location and topography (latitude,

Table 12.2 OLS estimates

Variable	No plan	Demolition orders	Planning staff	Plan staff per 100 K	Rural and subdiv delay	Rural delay
Population	0.8126***	0.8535***	0.8629***	0.8489***	0.8264***	0.8310***
σ	0.031	0.036	0.037	0.035	0.040	0.038
Income	0.5204***	0.7521***	0.6898***	0.6522***	0.6167***	0.6261***
σ	0.064	0.088	0.092	0.092	0.072	0.065
Agri-rent	−0.2268***	−0.2367***	−0.2903***	−0.2974***	−0.2479***	−0.2550***
σ	0.041	0.044	0.041	0.044	0.037	0.037
Fuel cost	−0.1453**	−0.1473**	−0.0516	−0.0496	−0.1750***	−0.1729***
σ	0.065	0.069	0.092	0.091	0.060	0.062
Rural-urban delay					−0.0155	−0.0209
σ					0.044	0.042
Subdivide delay					−0.0306	
σ					0.043	
Planning staff				−0.0079		
σ				0.026		
Planning staff per 100k			−0.0102			
σ			0.028			
Demolition orders		−0.0147				
σ		0.042				
Constant	−9.1926***	−12.1353***	−11.1391***	−10.5339	−10.1804***	−10.3290***
σ	0.740	0.987	0.959	1.050	0.958	0.873
F	88.8400***	84.3300***	101.2800***	101.1300***	72.2400***	83.8400***
R^2	0.839	0.873	0.875	0.873	0.862	0.870
Root MSE	0.52	0.49	0.49	0.48	0.48	0.48
Observations	240	154	178	174	176	182

*significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent

Table 12.3 OLS estimates of regional fixed effects

Variable	No plan	Demolition orders	Planning staff	Plan staff per 100 K	Rural and subdiv delay	Rural delay
East Asia	−0.1384	0.7348**	0.2995	0.2249	−0.0277	0.0251
σ	0.208	0.323	0.282	0.277	0.248	0.226
Europe	−0.3305**	−0.2024	−0.2508	−0.2726*	−0.3134*	−0.3210**
σ	0.137	0.156	0.155	0.157	0.160	0.158
Latin America	−0.3618**	−0.0680	−0.1146	−0.1668	−0.1263	−0.1013
σ	0.180	0.249	0.164	0.167	0.170	0.160
North Africa	−0.4464	−0.0552	0.1384	0.0570	−0.3153	−0.3001
σ	0.293	0.392	0.358	0.355	0.238	0.227
South Central Asia	−0.6620***	−0.0018	−0.1846	−0.2361	−0.4196**	−0.4210**
σ	0.208	0.298	0.265	0.260	0.210	0.190
Southeast Asia	−0.4608*	−0.2504	−0.2492	−0.3624	−0.3733*	−0.3346*
σ	0.240	0.229	0.237	0.244	0.192	0.187
Subsaharan Africa	0.0999	0.7644***	0.4964	0.3669	0.2634	0.2934
σ	0.199	0.285	0.300	0.316	0.242	0.209
West Asia	0.0646	0.5369***	0.5454**	0.4780*	0.2629	0.2989
σ	0.211	0.197	0.258	0.263	0.264	0.259

*significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent

longitude, presence of a shallow groundwater aquifer and slope of the steepest area developed in the earlier of our two image dates), and measures of the ethnic, linguistic and religious diversity of the national population using the same measures of "fractionalization" that were used in Alesina et al. (2003). These latter measures are included because of their plausible exogeneity to the process of urban land use, and their likely usefulness in capturing aspects of land use regulation and policy. Finally, the regional indicator variables that are included in the model are taken as exogenous and can therefore also serve as instruments for the endogenous (or potentially endogenous) variables.

Initially, consider the success of the instruments in the first stage equations. These are presented in Table 12.4. While a great many of the individual variables are not statistically significant, this is of minimal concern. Each equation has a set of variables that do seem to play a role and permit a reasonable forecast of the main variables.

It is worth noting that the biome variables play an important role in the Agricultural Rent model, as expected. The fractionalization variables play important roles for several variables, particularly the model for rural land conversion delays. This model also performs generally well with one of the higher levels of explanatory power and lower mean square errors.

Tables 12.5 and 12.6 present the instrumental variables estimates using these instruments and estimating the model described above. All IV estimates were obtained using the GMM procedure that is part of STATA's **ivreg2** procedure. Table 12.5 shows again that the estimated impact of population, income, agricultural land values, and transport costs are of the expected sign, a reasonable magnitude, and generally statistically significant, although in these estimates there is a bit less stability across various forms of the models. The impact of fuel

Table 12.4 First stage estimates

	Pop	Income	Agrent	Fuel	Demolish	Plan staff	Staff per C	Sub delay	Rur delay
East Asia	0.1703	−1.4938***	−0.4812	−0.2824*	1.5827**	−1.1344	−0.000070**	−0.9963**	−1.2744**
σ	0.738	0.131	0.409	0.168	0.702	1.046	0.00003	0.490	0.644
Europe	0.2375	0.1789	−0.1043	0.7133***	−1.0115*	1.6665*	0.000094***	0.4842	0.7347
σ	0.626	0.151	0.341	0.151	0.600	0.876	0.00003	0.527	0.658
Latin America	−0.0742	−1.1633***	1.4175***	−0.1227	1.5192	2.3477	0.000154**	0.3382	−0.7498
σ	0.848	0.308	0.438	0.298	1.157	1.538	0.00008	0.711	0.654
North Africa	−0.0527	−1.2682***	1.4921**	0.0631	4.8075***	1.3697	0.000052	0.5217	0.3503
σ	0.884	0.329	0.606	0.402	1.215	1.315	0.00005	0.862	0.694
S-Central Asia	0.0809	−1.2850***	0.4415	−0.2536	2.2873***	0.0062	0.000019	−0.3923	−0.0180
σ	0.753	0.246	0.446	0.330	0.850	1.199	0.00004	0.605	0.559
SE Asia	0.3088	−0.3635	1.7179***	−0.5940*	0.9770	0.2048	0.000039	0.0094	0.5019
σ	0.918	0.344	0.651	10.315	1.178	1.643	0.00004	0.659	0.719
Subsaharan Africa	−0.7685	−1.7587***	0.4633	−0.0910	2.1676**	2.3021	0.000202*	−0.0785	−0.8684*
σ	0.769	0.328	0.412	0.346	0.916	1.437	0.00012	0.559	0.452
West Asia	0.3525	−0.7246	1.8457**	0.5143*	−1.7522	0.9895	0.000013	−0.9983	0.6208
σ	0.844	0.438	0.713	0.274	1.267	1.524	0.00005	0.835	0.720
Shallow GWater	−0.2788	−0.0745	0.0115	0.0265	−0.7381**	−0.9342*	−0.000040	0.2671	−0.3082
σ	0.289	0.118	0.220	0.120	0.324	0.481	0.00003	0.243	0.233
Boreal humid	0.4243	−0.0496	−0.1725	−0.1620	0.6613***	−1.5319***	0.000025	−1.2183	1.0206
σ	1.864	0.360	0.508	0.371	0.187	0.428	0.00002	1.530	0.626
Temp semi-arid	0.8021	0.2968	1.7117***	0.3453	0.9636	0.2606	0.000025	0.1720	0.7542
σ	0.665	0.356	0.544	0.312	0.725	1.273	0.00005	1.039	0.711
Temp humid	1.2577*	0.7664*	1.9244***	0.3426	−0.0627	2.2475	0.000091*	0.5633	1.7837**
σ	0.661	0.389	0.593	0.316	0.652	1.399	0.00005	1.068	0.850
Medit warm	0.9587	0.5445	2.0557***	0.2406	−0.2138	1.9765	0.000081*	0.7407	2.3643***
σ	0.688	0.392	0.573	0.324	0.556	1.287	0.00005	1.029	0.814
Desert tropical	−0.8095	−0.1946	1.4797**	0.5435	−0.7943	0.5087	0.000065	−1.0810	−0.0080

(continued)

Table 12.4 (continued)

	Pop	Income	Agrent	Fuel	Demolish	Plan staff	Staff per C	Sub delay	Rur delay
σ	0.807	0.561	0.649	0.421	1.127	1.293	0.00005	1.204	1.073
Desert temperate	0.5416	0.2901	1.2933*	−0.1430	1.2253**	0.1029	0.000035	−0.1711	0.2088
σ	0.681	0.412	0.706	0.371	0.598	0.904	0.00003	0.995	0.630
Desert cold	1.1485	1.1533***	0.6288	−0.2629	−0.1890	1.3508	−0.000002	0.0411	1.4549
σ	1.205	0.395	1.266	0.797	1.476	1.605	0.00005	1.029	0.934
Trop. Semi-arid	1.1280	−0.1581	1.6571***	0.4457	−0.3052	0.6773	0.000023	−0.3780	1.1722
σ	0.698	0.420	0.568	0.354	0.706	1.361	0.00005	1.081	0.759
Trop. humid	0.3076	0.2360	2.0796***	0.7686**	−2.0399**	1.0218	0.000045	−0.5374	−0.5628
σ	0.884	0.454	0.648	0.349	0.967	1.452	0.00005	1.114	0.880
Latitude	−0.0093	−0.0052	0.0233***	−0.0065	0.0036	0.0234	0.000002**	0.0089	−0.0197**
σ	0.011	0.004	0.007	0.004	0.012	0.020	0.00000	0.008	0.008
Longitude	0.0015	−0.0062***	0.0032	−0.0016	0.0102*	0.0126*	0.000001*	0.0014	0.0034
σ	0.005	0.001	0.002	0.001	0.006	0.007	0.00000	0.003	0.003
Slope	−0.0474	0.2522***	0.2008	−0.0455	1.1745***	0.0827	0.000018	0.0094	−0.2460
σ	0.205	0.093	0.133	0.097	0.390	0.369	0.00002	0.211	0.192
Ethnic frac.	0.0625	−0.3021***	−0.3817***	−0.4465***	1.1057***	0.4051	0.000014	0.1511	0.6184***
σ	0.229	0.101	0.136	0.094	0.384	0.392	0.000001	0.245	0.196
Language frac.	−0.0890	0.0727	−0.1560	0.2011**	−0.6573**	−0.1517	0.000001	0.0088	−0.4490**
σ	0.190	0.088	0.130	0.077	0.302	0.372	0.00001	0.226	0.187
Religion frac.	−0.0244	0.0583	0.3036***	−0.0025	−0.0463	0.2046	0.000015	−0.1561	−0.3527*
σ	0.120	0.069	0.100	0.065	0.250	0.217	0.00001	0.132	0.112
Constant	13.0244***	8.4599***	2.92066***	−0.09455*	−2.9319**	1.1559	−0.000122	0.9239	1.6519
σ	0.973	0.482	0.766	0.520	1.329	2.019	0.00010	1.248	1.045
R^2	0.145	0.809	0.637	0.388	0.692	0.238	0.35620	0.392	0.592
Obs	240	240	240	240	178	178	178	206	182

*** *significant at 1 %*, ** *significant at 5 %*, * *significant at 10 %*

Table 12.5 Instrumental variable estimates

Variable	No plan	Demolition orders	Planning staff	Plan staff per 100 K	Rural and subdiv delay	Rural delay
Population	0.6495***	0.7598***	0.8133***	0.7468***	0.9212***	0.8865***
σ	1.35	0.070	0.088	0.109	0.111	0.100
Income	0.5505***	0.6121***	0.3330**	0.4297***	0.5499***	0.6041***
σ	0.125	0.124	0.150	0.162	0.139	0.107
Agri-rent	−0.2755***	−0.2043***	−0.3149***	−0.2950***	−0.4309***	−0.3558***
σ	0.083	0.080	0.108	0.104	0.129	0.103
Fuel cost	−0.2813	−0.3985**	−0.2966	−0.3431	−0.0782	−0.2822
σ	0.188	0.168	0.233	0.230	0.271	0.194
Rural–urban delay					−0.2852**	−0.1335**
σ					0.116	0.067
Subdivide delay					0.3117*	
σ					0.175	
Planning staff				0.0127		
σ				0.081		
Planning staff per 100k			0.0476			
σ			0.076			
Demolition orders		0.0006				
σ		0.058				
Constant	−6.8255***	−9.7041***	−6.7306***	−6.9815***	−9.4717***	−10.0035***
σ	1.839	1.291	1.652	1.952	2.284	1.937
Anderson LR statistic	25.06**	27.34***	19.37*	23.73**	13.43	24.77**
Hansen J	14.46	14.77	11.67	10.58	9.39	11.36
x2 Endogeneity test	20.13***	3.69	11.32**	11.2**	16.72**	15.5***
F-statistic	16.92***	29.18***	32.52***	22.56***	29.87***	33.2***
Centered R^2	0.8	0.85	0.83	0.83	0.77	0.85
Uncentered R^2	0.99	0.99	0.99	0.99	0.99	0.99
Root MSE	0.56	0.51	0.53	0.54	0.59	0.5
Observations	240	154	174	178	176	182

*significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent

Table 12.6 Regional fixed effects for IV models

Variable	No plan	Demolition orders	Planning staff	Plan staff per 100 K	Rural and subdiv delay	Rural delay
East Asia	−0.1473	0.1972	−0.4921	−0.3033	−0.1239	−0.2176
σ	0.360	0.473	0.422	0.453	0.377	0.305
Europe	−0.3369	−0.0868	−0.3827	−0.2605	−0.4910*	−0.2748
σ	0.213	0.159	0.268	0.276	0.284	0.222
Latin America	−0.4015	−0.2162	−0.6659***	−0.5147*	−0.2107	−0.1945
σ	0.265	0.255	0.244	0.275	0.281	0.235
North Africa	−0.6444	−0.6575	−1.0012**	−0.7975	−0.3032	−0.3625
σ	0.398	0.584	0.502	0.531	0.508	0.406
South Central Asia	−0.8055**	−0.6267	−1.2529***	−1.0841**	−0.5737	−0.7493**
σ	0.353	0.428	0.386	0.423	0.410	0.294
Southeast Asia	−0.4239	−0.4929	−1.1610***	−0.8579*	−0.2158	−0.4443
σ	0.396	0.379	0.419	0.465	0.529	0.378
Subsaharan Africa	−0.0266	0.2546	−0.7759	−0.4320	−0.0243	0.0765
σ	0.356	0.370	0.491	0.530	0.421	0.313
West Asia	−0.0595	0.1946	−0.1565	−0.0129	0.3226	0.2502
σ	0.324	0.308	0.357	0.404	0.385	0.354

*significant at 10 per cent, ** significant at 5 per cent, * significant at 1 per cent

cost is estimated with considerably less precision, and it may be that we need a broader measure of the costs of travel than the cost of gasoline, or that our instruments are just weak for this variable.

Is it really necessary to estimate these relationships using an instrumental variables approach? While income, population and planning policies all might be endogenous in principle, perhaps in practice the relationships are so weak that a more standard estimation procedure would be acceptable (and produce lower variance parameter estimates). We test this possibility using a statistic described more fully in Baum et al. (2007). The test is presented in the row in Table 12.5 labeled "χ^2 Endogeneity test." This test statistic is distributed χ^2 under the null that the variables representing population, income, agricultural rent, fuel costs and the planning variables are exogenous. As can be seen from the table this is rejected at the 95 % level or better for all cases except the case of using demolition orders as the measure of planning restrictiveness. It seems reasonable to conclude from this that there is an endogeneity problem in these data that must be addressed.

If an IV approach is required, one might be concerned that the instruments we have chosen are relevant to the task of modeling the endogenous variables. Even though the first stage estimates, presented in Table 12.4, appeared to perform reasonably well, the canonical correlation between the instrumental variables and the endogenous variables might generally be very low. The Anderson likelihood ratio statistic is designed to test exactly this concern. This statistic is based on a null hypothesis that the smallest canonical correlation between the instruments and endogenous covariates is zero and that the regressors are normally distributed. Failure to reject the null suggests concern about the relevance of the instruments. Table 12.5 indicates that all of the models reject the null at the 90 % level or better except the model that includes both the time delay in subdivision and the time delay in obtaining permission to develop rural land.

Finally, we might have established that an IV approach is necessary due to endogeneity, and identified a set of instrumental variables that are sufficiently closely correlated with the endogenous variables to be judged relevant, but we could still face the difficulty that the instruments themselves are not independent of the error term in the model. To provide a test of this concern we consider Hansen's J statistic test. This statistic is asymptotically distributed χ^2 under the null hypothesis of validity of the overidentifying restrictions in the model. These will fail if the instruments are endogenous or belong in the model directly. While the power of this test may be somewhat low in our modest sized samples (the distributional properties are established asymptotically), examination of the row in Table 12.5 that contains the Hansen J statistic shows that none of the tests reject the null hypothesis. To this extent, we suggest at least provisional acceptance of the proposition that there is endogeneity present that must be dealt with, that the instruments we use are relevant, and that they are sufficiently independent of the model error to provide a valid estimate. This is particularly true for the models that use total planning staff, planning staff per capita, and the delay in getting permission to develop rural land.

The demolition and staffing variables to indicate land use planning activities are again not statistically significant nor correctly signed. The situation is different for the indicators of planning delay, and in particular for the time delay in converting rural to urban land. This variable is significant (at the 95 % level) and correctly signed. This might provide a reasonable indicator of planning restrictiveness that can be collected and compared across cities globally. The estimates presented here indicate that a doubling of the delay (say from 6 to 12 months) would be associated in the data with about a 13 % reduction in total urban land use, *ceteris paribus*.

5 Conclusion

We conclude by drawing attention to three central points. First the simple model presented above generates comparative static predictions that are generally supported in the data. The impacts of population, income, and agricultural land values are clearly supported. The impact of transport cost (as represented by the price of motor fuel) is a bit less clear, but is generally supported. The impacts of those planning activities that result in delays in the conversion of land from rural to urban uses is associated with an impact that is statistically significant and correctly signed. The impact of internal open space preservation is possibly supported, although our measure of delay in conversion of rural to urban land is perhaps less clearly capturing this aspect of planning policy.

A second point to make is that our results seem to support the suggestion that some, if not all, aspects of planning are capable of constraining expanding land use in cities. It is impossible to say in general whether such constraint is welfare improving or reducing. Other investigations suggest it can be either.

Table 12.7 Impact of a one standard deviation change

	One σ %	% Urban land
Population	132.61 %	111.09 %
Income	100.03 %	59.32 %
Ag land value	375.48 %	−142.42 %
Fuel cost	57.63 %	−16.44 %
Rural to urban	322.38 %	−47.03 %

Finally, what about the relative power of these policies? They might be capable of constraining urban land use but so weak relative to the forces that are causing cities to expand that they are of little consequences. Table 12.7 presents some information on this issue by considering the percentage impact on total urban land use of a one standard deviation increase in the variable (measuring the standard deviation across our sample of cities).

	Result	Description	Confirmed
1.	$\frac{\partial T}{\partial N} \geq 0$	Increasing population increases total urban land	Yes
2.	$\frac{\partial T}{\partial M} \geq 0$	Increasing household income increases total urban land	Yes
3.	$\frac{\partial T}{\partial \tau} \leq 0$	Increasing transport costs decreases total urban land	Yes, weakly
4.	$\frac{\partial T}{\partial R_a} \leq 0$	Increasing agricultural land value decreases total urban land	Yes
5.	$\frac{\partial T}{\partial \rho} \leq 0$	A stricter containment planning policies decreases total urban land	Yes, for delay
6.	$\frac{\partial T}{\partial \omega} \leq 0$	Increasing internal open space will decrease total urban land	Possibly

The analysis suggests that while planning policies, and delay in land conversion in particular, are not the most powerful of impacts (that role is reserved, perhaps surprisingly, for the value of agricultural land, followed by population increase itself) it is of a comparable order of magnitude as the impact of income, and it might be reasonable to expect that some form of land use regulation policies could play a role in limiting urban expansion if it is determined that such constraint is desirable.

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