ABSTRACT. Does growth management result in lower marginal land consumption rates? The literature offers inconclusive and inconsistent results. This paper uses new data covering all U.S. metropolitan areas and multiple time periods to estimate panel models of effects of growth management on the spatial extent of urban development. Dummy variable estimation misleadingly suggests that growth management increases urban area extent. However, fixed-effect estimates across different growth management regimes find that more highly regulated regions and stronger planning states have lower marginal land consumption rates, while regional containment policies, as measured here, do not appear to reduce the size of urban areas. (JEL R14, R52)

I. INTRODUCTION

Across the United States, some regions and states, concerned to limit “sprawl,” have adopted various efforts to control the outward spatial expansion of urban land development. The suite of policies, programs, incentives, and regulations adopted by regions and states has been called by many names, most often “growth management” or “smart growth.” These interventions into regional land markets, classified as “urban containment programs” by Pendall, Martin, and Fulton (2002) and Nelson and Dawkins (1999), can take the form of strong urban growth boundaries, such as in Portland, or more accommodating urban service area boundaries. Policies can be adopted by a regional entity or mandated by state law. The strength of particular containment policies and implementation vary widely from region to region and state to state, which has made comparison of programs across areas difficult. The empirical literature assessing the impacts of growth management on spatial patterns varies as much as the policies studied, and little consensus exists within the literature as to whether or how these policies impact land markets and land development outcomes.

Approaches to growth management or urban containment have in common, however, a concern to address the perceived problem of excessive conversion of forest, farmlands, and other open lands to lower-density urban or suburban development. Whether this concern arises because of water quality, habitat loss, traffic congestion, aesthetics, or central-city deterioration, the intent of growth management policies is to reallocate low-density development at the urban-rural interface toward higher-density development within or near existing urbanized areas and in areas serviced by urban infrastructure. Do these programs work? While some form of state or regional growth management has been in place for at least 30 years (DeGrove 2005), it is only more recently that evaluation research has measured under what conditions these policies actually reduce the spatial extent of urban land development. Empirical work on this question in the past decade has reached some contradictory conclusions. Some studies have suggested that growth management reduces the outward expansion of urban areas, while other studies have found no statistically significant impacts of growth management on urban area extent. Some studies have even concluded that growth management is associated with increases in the outward expansion of urban areas. This empirical confusion on such an important arena of land policy is partly a result

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of limited data availability, and partly from the application of different statistical methods or models of the process of urban spatial expansion. In this paper, I offer both a conceptual and a methodological framework for investigating the effects of growth management on the spatial extent of urban land, and apply these to a new and more extensive data set covering all U.S. metropolitan areas over a 20-year time period. Even with a richer data set and panel methods, the results do not provide a completely straightforward answer as to the impacts of growth management on urban area size.

Although there have been a lot of different tests of the impacts of growth management, as I argue in Section II, a test derived from a theory of urban land markets entails whether growth management is associated with lower marginal (per capita) land consumption rates over time. How much does the size of the urban area have to expand to add one additional person? Because growth management attempts to restrict the outward spatial extent of land development, additional households must be accommodated at higher densities or lower marginal land consumption. Although the common language within land use studies refers to population density (persons divided by land area), in the rest of this paper I use the term per-capita land consumption (land area divided by persons.) When interpreting regression coefficients, it is less cumbersome to refer to “marginal land consumption” rather than something like “marginal density.”

In this paper, I test the hypothesis that effective growth management should be expected to lower marginal land consumption rates in a region, relative to what land consumption rates would otherwise be in the absence of growth management. The empirical model cannot address the welfare gains or losses from regional growth management, a topic on which there is a growing and diverse literature (Anas, Arnott, and Small 1998; Wassmer and Lascher 2006). There does not yet exist consensus as to how to compute or aggregate the costs and benefits of growth management restrictions, and doing so is beyond the scope of this paper.

II. URBAN LAND MARKETS AND THE SPATIAL EXTENT OF URBAN DEVELOPMENT

In order to assess the claim that growth management reduces the spatial extent of urban areas, it is first necessary to embed the analysis within a standard framework of urban land markets. Within the urban economics field, the bid-rent, monocentric model of urban land markets has dominated for nearly 50 years (Mills 2000; Spivey 2008). With reasonably straightforward comparative statics and assumptions, and with only a limited number of variables, the model generates strong testable predictions about the spatial extent of city area or urban development. Even though city structure is becoming more polycentric, the model continues to hold up empirically quite well (Malpezzi and Guo 2001; Spivey 2008), often explaining over 75% of the variation in city size in a sample of cities (Paulsen 2012). The equilibrium properties and comparative statics of this model were first established by Wheaton (1974) who showed, among other things, how the model could explain the spatial extent of urban development. The model has been extended and estimated econometrically by Brueckner and Fansler (1983), McGrath (2005), Spivey (2008), and Paulsen (2012).

Assuming that employment is centralized in the central business district (CBD), land rents (and therefore lot sizes and development densities) decline with distance to the CBD. At some distance from the CBD, rents in agricultural use exceed rents for urban development, and this point represents the spatial limit or spatial extent of urban development. If this distance from the CBD at which land rents in agriculture equal those in urban development is denoted by $d_1$ and assuming a perfectly circular city with no geographical constraints, the total area of urbanized land development in the city ($L$) is $L = \pi \cdot d_1^2$. Again, the standard model’s comparative statics (Wheaton 1974; Brueckner and Fansler 1983) would predict that the area of urban development is increasing in population and income and decreasing in agricultural land prices and per-mile commuting costs. Empirical implementation involves regressing some
measure of urban land area on population, income, agricultural land price, and transportation cost variables. Recent work shows all but the commuting cost variable hold robustly (Spivey 2008; Paulsen 2012).

As cities grow in population and/or income, the additional land demand is met partially by increased density in already developed areas and partially by increasing the spatial extent of land development. McMillen (2006) demonstrates that as cities add population, the “density gradient” (envelope of the bid-rent function showing declining density as a function of distance from the CBD) shifts upward, while as income increases the gradient becomes flatter. Both effects would lead to an increase in the spatial extent of urban development outward to some new distance \(d_2\), where \(d_2 > d_1\). New development at the urban-rural interface, which takes place at distances between \(d_1\) and \(d_2\) from the CBD takes place at lower densities (larger lot sizes) than existing development. There continues to be great academic and popular debate as to whether to term this development “sprawl” or the natural outcome of urban land markets.

When states or regions engage in growth management policies to reduce the spatial extent of urban development, they do so based on the belief that the observed shift in urban extent from \(d_1\) to \(d_2\) is larger than socially optimal and that policy to accommodate future populations in a more constrained spatial extent is warranted. In practical terms, growth management is either motivated by the perception that development densities at the urban-rural fringe are excessively low or that excessive amounts of formerly agricultural or forested land are converted to urban development. In terms of the urban model above, this is equivalent to saying that growth management policies are based on the belief that the density gradient is flatter than it should otherwise be. If the spatial extent of urban development is excessive relative to some socially optimal level, then growth management could potentially improve overall regional welfare.

But why might the spatial extent of urban land development be excessive? The two main categories of explanations offered in the literature relate to “market failures” and “policy failures.” Brueckner (2000) defines sprawl as “excessive” spatial expansion, and discusses the three most common market failures in urban development that might cause the size of the urban area to be excessive. First, land prices, particularly at the urban-rural interface, might not reflect the social or environmental costs of loss of open space or working landscapes (forested lands or farmland) or the impacts of development on water quality, habitat, or other natural resources. Growth management that slows conversion of these lands to urban development is therefore one (among many) ways to try to “get prices right” for undeveloped land. As an alternative to stricter forms of growth management, many states and regions (and private land trusts) spend money to preserve lands at the urban-rural interface (Daniels and Lapping 2005).

Second, failure to charge automobile drivers the full marginal cost of their congestion reduces per-mile transportation costs below a socially optimal level. Recently, Langer and Winston (2008) have shown that undercharging for congestion lowers land use density in metropolitan areas, which increases the spatial extent of urban development. Again, alternatives to using growth management to address this problem could include congestion tolling (Brueckner 2000; Mills 2000; Glaeser and Kahn 2004). The third market failure (which could as easily be classified as a policy failure) is that financing infrastructure by means of the property tax means present taxpayers pay some of the costs of new growth. Therefore new growth does not pay its full marginal cost. As an alternative to growth management, infrastructure impact fees have become a popular option in many states and regions (Brueckner 1997; Ihlanfeldt and Shaughnessy 2004).

An alternative framework that gives rise to motivations for regional or state growth management sees excessive spatial development of urban areas as resulting from policy failure. Two main channels of policy failure are discussed in the literature: federal tax expenditures for housing consumption, and local government zoning policies. First, federal tax expenditures for owner-occupied housing include the mortgage interest deduction, exclusion of capital gains taxes on the sale of res-
idences, and no taxes on imputed rent (Schwartz 2010). In a series of papers, Voith and Gyourko have shown that the tax treatment of owner-occupied housing lowers user costs, increases demand for housing, increases consumption of housing relative to other goods, and therefore increases the spatial extent of the urban area (Voith and Gyourko 1998; Voith 2000; Voith and Gyourko 2002).

Growth management policies, obviously, cannot impact federal policy, but they can be directed toward correcting or mitigating the second channel of policy failure in metropolitan development, that of local government zoning. Most metropolitan areas within the United States contain tens if not hundreds of independent municipalities with the ability to affect land use through zoning. Jurisdictions design zoning policies in response to the needs and interests of existing residents and homeowners without consideration of the spillovers of these decisions on other municipalities or the region as a whole (Fischel 1999, 2001, 2004; Levine 2006). The density of land development within a municipality that would otherwise result from the urban bid-rent gradient might be considered too dense for the existing residents, who use the zoning power of the municipality to zone for development densities below market levels. If one community’s zoning results in either less land available for development or lower densities than the market, that land demand is displaced farther out within the metropolitan area. When most or all of the suburban municipalities within a region adopt restrictive zoning, the net effect is to increase the size of the urban area (Fischel 2004; Paulsen 2006).

The empirical literature linking restrictive zoning to sprawl and excessive land development has grown significantly in the last 20 years (Thorson 1997; Fischel 1999; Voith 1999; Pendall 1999; Fischel 2004; Glaeser and Kahn 2004; McDonald 2004; Munneke 2005; Glaeser and Ward 2006; Wu and Cho 2007; Rothwell and Massey 2009).

Whether the excessive spatial extent of urban land development arises from market failures or the structure of local zoning, regional or state growth management policies are aimed to reduce the spatial extent of development and the conversion of lands to urban uses at the urban-rural fringe. The form and particulars of regional growth management policies that have been adopted vary significantly from place to place, and a thorough review of the literature on growth management is beyond the scope of this paper. Excellent histories, evaluations, and critiques of growth management approaches are presented by Daniels and Lapping (2005), Daniels (2009), DeGrove (2005), Howell-Moroney (2008), Ingram et al. (2009), Popper (1988), Weitz (1999), and others. Growth management policies try to mitigate the distortions of urban land markets or of local zoning policies, or both. Although the suites of tools adopted vary from place to place, these often include special tax treatment of or funding for farmland and open-space preservation, environmental protection zoning, agricultural zoning, urban growth boundaries/urban service area boundaries, infrastructure impact fees, and/or adequate public facility ordinances. These policies attempt to affect the spatial extent of urban land development in at least one of four ways: reducing the supply of developable land at the urban fringe, increasing the price of suburban development, redirecting growth away from the fringe toward the center, or requiring higher-density development at the fringe. If growth management is structured to reduce the total overall supply of urban development space, then it has been criticized for displacing growth to other regions or increasing housing costs (Levine 1999; Pendall 1999; Nelson et al. 2002; Quigley and Raphael 2005; Zabel and Paterson 2006; Saiz 2010; Schmidt and Paulsen 2009). However, some forms of regional growth management are designed to provide a mechanism to override local opposition to higher-density growth and force or induce municipalities to accept the level of development that the market might otherwise provide. In this second case, growth management could result in lower marginal land consumption rates without necessarily displacing growth or raising housing prices.

III. CURRENT STATE OF EMPIRICAL RESEARCH

There have been six studies in recent years (Carruthers 2002; Anthony 2004; Wassmer
that specifically measure the effect(s) of
growth management on the spatial extent of
urban development, at least indirectly. These
studies are summarized in Table 1, showing
each study’s time period covered, regression
methodology, dependent variable, source of
urban area extent data, sampling frame, how
the study operationalizes the concept of
growth management, whether the study em-
beds the analysis within a urban land market
model (land prices and income), and the main
findings. The papers are arranged chronolog-
cally. Although some of the studies include
other variables and other analyses, I report
here only the results directly related to this
paper: the effect of growth management pol-
cies on the spatial extent of urban develop-
ment. In some of these studies, the spatial ex-
tent of urban development is measured only
indirectly through a measure of urban density.
This review of these previous studies focuses
on methodological differences, how each
study operationalizes growth management,
and the data sources used in order to under-
stand the apparently contradictory results in
the literature.

Methodological Approaches

What is the appropriate form of measure-
ment of the effects of growth management on
criticize much of the earliest work on the ef-
effects of growth management on housing
prices as neglecting endogenous selection into
treatment groups: regions or states may be
more likely to adopt growth management in
the presence of faster rates of land develop-
ment. Saiz (2010) shows that regions with a
greater taste for regulations are more likely to
have more restrictive land development reg-
ulations. Cross-section regressions, therefore,
would likely be unable to determine whether
a coefficient on “growth management” mea-
sures the effects of growth management or
differences in characteristics of regions more
likely to adopt growth management.

Implementation of cross-section regression
estimates (utilizing the notation in Section II
above) of the effects of growth management
have frequently looked like the following:

\[ L = \beta_0 + \beta_1 p + \beta_2 y + \beta_3 r_a + \ldots + \beta_4 \text{Growth Management} + \epsilon, \]

with growth management being operational-
ized either as a dummy variable, a count of
the number of years growth management has
been in place, or some ordinal measure of the
strength of the growth management program.

However, the meaning and interpretation of
the sign and significance of the coefficient
on growth management in this framework is
often misleading. As a dummy variable inter-
cept shifter, does a positive (negative) coeffi-
cient mean that growth management is asso-
ciated with increased (decreased) land
consumption rates? Or, does a positive (neg-
ative) coefficient indicate that regions with
higher (lower) land consumption rates are
more likely to adopt growth management? In
a study of nine states, Howell-Moroney
(2008) demonstrates that regions with faster
relative rates of growth in previous periods
were more likely to adopt growth manage-
ment regimes. Because this is the case, there
are reasons to be careful about the interpre-
tation of the meaning of growth management
variables in models of land consumption.

When selection into treatment groups is en-
dogenous, cross-section regressions with pol-
icy variables cannot measure the marginal ef-
fect of the policy. The coefficient measures
not only the marginal effect of growth man-
agement on land consumption, but also in-
cludes average differences in land consump-
tion rates between regions with and without
growth management. Similarly, statistically
insignificant coefficients should not be inter-
preted to indicate that growth management is
unrelated to land development trends. To
demonstrate this, I conduct simple cross-sec-
tion regressions only on the year 2000 urban
land area extent in my sample of 329 metro-
politan areas. Independent variables were
population, median household income, agri-
cultural land prices, and each of the different
growth management variables described be-
low. All of the measures of growth manage-
ment, except for the state growth management
### TABLE 1
Comparison of Previous Research Studies: Effect of Growth Management on Urbanized Land Area

<table>
<thead>
<tr>
<th>Study</th>
<th>Time Period(s)</th>
<th>Method</th>
<th>Dependent Variable(s)</th>
<th>Land Area Data</th>
<th>Sample</th>
<th>Growth Management</th>
<th>Agricultural Land Prices</th>
<th>Income</th>
<th>Main Finding(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nelson, Dawkins, and Sanchez 2007 (collecting studies by Nelson and others from 1999 onward)</td>
<td>1990–2000</td>
<td>First-difference regression</td>
<td>% change urbanized land density; % change exurbanized land</td>
<td>Classification of Census tracts by density categories</td>
<td>50 largest metropolitan areas</td>
<td>Regional level; Nelson, Dawkins, and Sanchez's measure of &quot;urban containment&quot;</td>
<td>No</td>
<td>No</td>
<td>Strong urban containment reduces urbanized population density; reduces % change in exurbanized land.</td>
</tr>
<tr>
<td>Carruthers 2002</td>
<td>1982, 1987, 1992, 1997</td>
<td>Fixed-effects panel; simultaneous equations (3SLS)</td>
<td>Urbanized land area</td>
<td>National Resources Inventory</td>
<td>283 metropolitan counties = all metropolitan counties in AZ, CA, CO, FL, GA, ID, NV, NM, NC, OR, TN, TX, UT, WA</td>
<td>State level; age of growth management (years) in CA, FL, GA, OR, WA</td>
<td>No</td>
<td>Yes</td>
<td>Only FL variable significant. Positive sign indicates FL program increased urban land area.</td>
</tr>
<tr>
<td>Anthony 2004</td>
<td>1982–1997</td>
<td>First-difference regression</td>
<td>% change in urbanized land density</td>
<td>National Resources Inventory</td>
<td>49 states (excluding AK)</td>
<td>State level; dummy variable and years-in-place for state growth management; state dummies for agricultural protection zoning</td>
<td>No</td>
<td>No</td>
<td>Insignificant results on all growth management variables. Agricultural protection zoning in a state increases urban densities.</td>
</tr>
</tbody>
</table>

*(table continued on following page)*
<table>
<thead>
<tr>
<th>Study</th>
<th>Time Period(s)</th>
<th>Method</th>
<th>Land Use</th>
<th>Land Use</th>
<th>Land Use</th>
<th>Land Use</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wassmer 2006</td>
<td>2000</td>
<td>Cross-section regression</td>
<td>Urbanized land area</td>
<td>Size of Census-designated &quot;urbanized area&quot;</td>
<td>Yes</td>
<td>Yes</td>
<td>Regional containment and state growth management policies reduce the size of urban areas. Each year in effect increases reduction in land area.</td>
</tr>
<tr>
<td>Yin and Sun 2007</td>
<td>1990–2000</td>
<td>First-difference regression</td>
<td>% change in population densities</td>
<td>Classification of Census tracts by density categories</td>
<td>No</td>
<td>Yes</td>
<td>Dummy variable measuring state program is positive and significant for urban densities. Agricultural protection zoning in a state reduced urban densities.</td>
</tr>
</tbody>
</table>

TABLE 1
Comparison of Previous Research Studies: Effect of Growth Management on Urbanized Land Area (continued)
dummy variable, were statistically insignificant in these cross-section models.1 The positive coefficient on state growth management I find in this exercise is the same as has been reported previously in the literature. As discussed below, this measure of growth management is both statistically and conceptually problematic.

Because of the difficulty in obtaining all of the variables necessary to estimate the relationship between growth management and land consumption over multiple time periods, some have instead estimated first-difference models of the equation above. Writing $\Delta$ to indicate the change from time $t_1$ to $t_2$, the estimated form would then be

$$
\Delta L = \beta_0 + \beta_1 \Delta p + \beta_2 \Delta y + \beta_3 \Delta r_o + \ldots + \beta_4 \text{Growth Management} + \varepsilon.
$$

If this is the case, what is the interpretation and meaning of the coefficient $\beta_4$, where

$$
\beta_4 = \frac{\partial \mathbb{E}(\Delta y|\Delta x_1 \ldots \Delta x_n)}{\partial x_4}.
$$

and $x_4$ is the variable for growth management? A negative coefficient does not indicate that growth management reduced urbanized land area, nor does it indicate that areas with growth management had lower marginal rates of land consumption relative to non-growth-managed areas during the time period. Rather, it indicates that moving from a non-growth-management region to a growth management area is expected to lead to a smaller change in the average change of land area. Theory does not necessarily tell us what to expect about the change in the average change. If, for example, a fast-growing region shows a slowing down of growth rates, this would be consistent with a negative coefficient in a first-difference model.

Carruthers (2002) and Howell-Moroney (2007) point out that the proper test of the effect of growth management on urban land area extent is a positive coefficient on the Florida dummy variable, which is interpreted that growth management increased the spatial extent of developed land. He attributes this result to the design of Florida’s program, particularly the requirement of “concurrency”—infrastructure availability prior to development approval. Concurrency requirements might force growth to the urban fringe where infrastructure capacity (particularly roads and sewer/water) is in more plentiful supply, and therefore the perverse incentives involved in this form of growth management might actually contribute to sprawl.

Howell-Moroney (2007) also critiques many of the previous studies for not utilizing a panel framework. He limits his analysis to only those nine states classified as growth management states and classifies growth management regimes as weak, moderate, and strong. In the regression on urban land area and under both dummy variable specification and “years of growth management” specification, he finds that only the coefficient on “strong” growth management is statistically significant and negatively related to land consumption rates.

**Measurement of Growth Management**

There are three main sources of data used to operationalize the concept of growth management in previous research. I use each of those three sources in this paper, with an additional new source, and this permits direct testing of the different measures to see which ones better fit the data and provide more information in explaining impacts on land development. The first approach to operationalize growth management, seen in five out of the six studies summarized in Table 1, is to

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1 These regressions are not reported for the sake of brevity but are available from the author upon request.
use a state-level measure, even when the unit of observation is the county, metropolitan area, or urbanized area. These studies focus on state-level measures because state policies constrain and empower local and regional decision making over land use. Local governments or regions may not be able to exercise urban containment policies or urban growth boundaries unless authorized or enabled by their respective state laws and planning systems. Local governments or regions may operate growth management policies only because they are required to by state law. Operationally, as shown in Table 1, state policy has been measured as either a dummy variable (whether the state has the growth management policy in place for a particular time or not) or a variable measuring the number of years a policy has been in place. The years-in-place measure is based on the belief that there could be a delay between policy adoption and binding impacts on land market outcomes. Two studies (by Howell-Moroney 2007 and Yin and Sun 2007) expand upon this concept by classifying growth management states by intensity (weak, moderate, strong) or according to some rank-order index.

The states commonly identified as having a state growth management program across all studies include Florida, Hawaii, Maine, Maryland, New Jersey, Oregon, Rhode Island, Vermont, and Washington. Carruthers (2002), Anthony (2004), and Yin and Sun (2007) include California and Georgia, while Wassmer (2006) does not. Howell-Moroney (2007) includes Georgia, but not California. The diversity across studies in the definition of growth management is indicative of the lack of clear consensus as to which types of state-specific institutions count as growth management. It is also important to point out that states might have growth management policies officially, while implementation and enforcement can vary significantly. While an in-depth institutional analysis of each state’s program is beyond the scope of this paper (see, for example, the detailed history of each state by DeGrove 2005), whether to include or exclude particular states is an empirical question. I estimated all of the regressions in this paper both with and without California and Georgia and tested whether their inclusion/exclusion alters the estimated relationship between growth management and land consumption. I find that the inclusion/exclusion of California and Georgia does not significantly affect the overall fit of the model, does not change other coefficients significantly, and only slightly alters the coefficients on state growth management programs. For this reason, this paper includes California and Georgia as growth management states.

At the state level, I also include an alternative measurement of growth management that has not been used in previous empirical work. The Institute for Business and Home Safety, in conjunction with the American Planning Association and the American Institute of Certified Planners conducts a survey and characterization of “State Land-Use and Natural Hazards Planning Laws.” Based on expert evaluation they classify states on the “strength of state planning role” in managing growth and supervising local planning. Their threefold classification is “weak,” “significant,” or “substantial.” The list of states coded as “substantial” includes California, Florida, Hawaii, Maryland, New Jersey, Oregon, Rhode Island, and Washington. The middle category (“significant”) includes those previously classified as growth management (such as Maine, Vermont, and Georgia) but also includes states such as Wisconsin, which mandates local comprehensive plan consistency, has strong agricultural protection zoning, and enables urban service/sewer-service area limits. As with any categorization, of course, this expert judgment is not perfect because states commonly thought of as more

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2 Available at ofb.ibhs.org/page?pageId = state_land_use.  
3 “A weak role would be that played by a state whose planning enabling legislation is basically permissive, that is, simply authorizing local governments to plan without requiring them to do so or providing extensive guidance for the purpose. A significant role would go further in either requiring some types of local governments to plan, being more detailed in its specifications of required elements, or otherwise taking a more active role in determining the content and process of local planning. A substantial role would be that of a state government mandating comprehensive plans by local government and providing detailed guidance on the content of those plans. The last category primarily includes those states that have taken the lead in enacting various kinds of state growth management legislation.” Source: ofb.ibhs.org/page?pageId = state_land_use.
permissive to development (e.g., Nevada and Arizona) are classified as “significant.” Nevertheless, this categorization represents some level of professional consensus as to relative state policy environments.

A second main source of measurement of growth management is at the regional (not state) level and is based on the survey and plan-coding analysis of Nelson and others (Nelson 1999; Nelson and Dawkins 1999; Dawkins and Nelson 2002; Nelson et al. 2002; Nelson, Sanchez, and Dawkins 2004; Nelson, Dawkins, and Sanchez 2007). The authors developed their inventory based on a survey of metropolitan planning organizations, and through reading and assessing plans. Their data measure whether a region had some form of “urban containment” policy in place, and the year the policy was instituted. Nelson, Dawkins, and Sanchez (2007) use this data to develop a fourfold typology of urban containment based on whether it is strong or weak and whether it accommodates or restricts growth.

Wassmer (2006) utilizes this regional data in his study of urban containment policies on the spatial extent of urbanized areas, using year 2000 U.S. Census data. He uses the data to indicate whether any containment policy is in place and also utilizes the data on whether the urban containment policy within a region is nonlocal. Nonlocal containment means that more than just one city (or the entire region) is affected by growth management. Containment policies that impact only one city in a region are unlikely to significantly alter aggregate land development outcomes for the region as a whole. In this present study, I follow Wassmer and count as regional containment regimes only those that are nonlocal based on the data presented by Nelson and Dawkins (1999).

A third type of data used does not measure growth management policies directly, but rather measures the overall restrictiveness of a region’s regulatory system for developable land for new residential development. The first line of research in this area is represented by the separate works of Pendall and Malpezzi (and others) (Malpezzi 1996; Pendall 1999; Pendall 2000; Green and Malpezzi 2003; Green, Malpezzi, and Mayo 2005). These researchers undertook studies of and surveys of jurisdictions in the largest metropolitan areas and constructed indices to measure zoning and permitting restrictions across a number of dimensions. However, it is important to note that the overall restrictiveness of the regulatory regime in a region is not the same thing as growth management and may, in fact, be the opposite of what is intended by growth management. If nearly all of the communities within a region adopt restrictive zoning, that region would score high on the regulation index, but this is not the same thing as having regional growth management. For example, of the eight regions with the highest score on the Wharton restrictions index data described below (score > 1), only one of them is classified as having a regional containment program, and only three have a state growth management system in place. Overall restrictiveness of land regulations within a region may, as above, reflect the cumulative zoning policies of municipalities and not overall regional growth management. In fact, the second most restrictive metropolitan region in the Wharton Index is Boston, where each local community engages in restrictive zoning and there is no regional growth management at all (Glaeser and Ward 2006).

More recently, two updated sources of information about zoning and other supply restrictions in major metropolitan areas have been developed, independently, by Pendall and scholars at the Wharton School (Pendall, Puentes, and Martin 2006; Gyourko, Saiz, and Summers 2008; Saiz 2010). Pendall’s work updates his 1999-era survey and covers the 50 largest metropolitan areas. Factor scores are reported separately for policies or restrictions in the areas of zoning, containment, infrastructure, growth control, and affordable housing. Likewise, the Wharton Residential Land Use Regulatory Index (WRLURI) (also called the Wharton Regulation Index) is a weighted index of 11 subindices measuring supply restrictions, density restrictions, approval delays, and additional measures of state-court decisions regarding land use and developer property rights (Gyourko, Saiz, and Summers 2008). Saiz (2010) reports the values of the WRLURI for the largest 95 metropolitan areas in his study of housing supply,
and it is this measure that I use in the empirical work below for 94 metropolitan areas. The index ranges from −1.24 to 1.89, with higher numbers indicating a greater degree of restrictiveness, and the index is designed to center around zero.

To summarize, there are a number of ways to operationalize the concept of growth management in this paper. I utilize two different state-level measures: whether the state had a growth management program in place during the time period in question, and a threefold classification of the strength of the state planning role (weak, significant, substantial). Second, I utilize the measurement of regionwide containment as used by Wassmer (2006) and developed by Nelson and Dawkins (1999). Third, I utilize the WRLURI for a subset of 94 metropolitan regions for which it is reported.

IV. OTHER DATA

The dependent variable of interest is a measure of the spatial extent of urbanized land development over time. Until recently, researchers interested in this question have been hampered by inadequate data or data limited to one time period. The main sources of data used have been either the National Resources Inventory (NRI) sample of land use points, satellite-derived land cover data, or data from the Census-designated “urban” areas. Because the NRI data are based on ground samples, sampling errors for smaller metropolitan regions can be quite large. The NRI data have been used in studies of growth management by Carruthers (2002) and Anthony (2004), as shown in Table 1, with differing conclusions. Because of concerns about the accuracy of NRI estimates, other researchers have used Census data. Census data, however, are limited in that classification of areas as “urban” differs with each decadal census, making historical comparisons problematic or impossible. McGrath (2005), studying spatial expansion of urbanized land area, uses a special Census report that consistently estimates the size of the urbanized area, but only for the 33 largest metropolitan areas for the time period 1950–1990. Wassmer (2006), in his study of growth management, uses the size of Census “urbanized areas” for the United States in 2000. Nelson, Dawkins, and Sanchez (2007) and Yin and Sun (2007) instead classify census tracts into density categories, with tracts above a density threshold being considered urban.

For this research, I use a new temporally consistent and spatially consistent data set that contains measurements of the size of urbanized areas for all U.S. metropolitan areas for the years 1980, 1990, and 2000 (Paulsen 2012). This data set was developed using 1980, 1990, and 2000 census data in historically consistent boundaries and applies the Census’s 2000 definition of “urban” consistently and retroactively to previous time periods. This measure of the extent of urban development is thus consistent over time and across metropolitan areas covering the continental United States. Because this data set covers more than two time periods, panel methods can be utilized.

The dependent variable for each of the regressions reported below is the amount of urbanized land area within each metropolitan area, in square miles, for each time period. I use the boundaries of Metropolitan Statistical Areas (MSAs) and Primary Metropolitan Statistical Areas (PMSAs), as defined in the year 2000, as the unit of analysis. The data cover all 329 metropolitan areas in the continental United States.

In previous empirical work measuring the spatial extent of urban land (Brueckner and Fansler 1983; McGrath 2005; Wassmer 2006; Spivey 2008; Paulsen 2012), independent variables included population, income, and agricultural land prices. Most studies either omit transportation cost variables or find them to be statistically insignificant. Actual per-mile commuting cost variables are not available for all years and all metropolitan areas, so proxies are traditionally used, which turn out to be inadequate. Wassmer (2006) and Paulsen (2012) discuss the empirical difficulties of transportation cost variables and why each decides not to include those variables in their analysis.

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4 The numerical difference in metropolitan areas is that Saiz (2010) uses New England County Metropolitan Areas in New England, while I use Metropolitan Statistical Areas.
### TABLE 2
Panel Results: All Four Growth Management Variables

<table>
<thead>
<tr>
<th>State Growth Management Program</th>
<th>Regional Urban Containment</th>
<th>Strength State Planning</th>
<th>Wharton Index (WRLURI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban population</td>
<td>0.0003129 (0.000)**</td>
<td>0.0003128 (0.000)**</td>
<td>0.0002459 (0.000)**</td>
</tr>
<tr>
<td>Median household income</td>
<td>0.0018263 (0.000)**</td>
<td>0.0018802 (0.000)**</td>
<td>0.0069247 (0.000)**</td>
</tr>
<tr>
<td>Value of agricultural land (per acre)</td>
<td>−0.0005097 (0.673)</td>
<td>−0.0002238 (0.844)</td>
<td>−0.014954 (0.000)**</td>
</tr>
<tr>
<td>State growth management program</td>
<td>9.30880 (0.000)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonlocal urban containment program</td>
<td></td>
<td>7.56095 (0.000)**</td>
<td></td>
</tr>
<tr>
<td>State planning strength is significant (dummy)</td>
<td></td>
<td>9.52812 (0.000)**</td>
<td></td>
</tr>
<tr>
<td>State planning strength is substantial (dummy)</td>
<td></td>
<td>11.9771 (0.038)*</td>
<td></td>
</tr>
<tr>
<td>Wharton Index</td>
<td>−9.24204 (0.211)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>−32.295 (0.079)</td>
<td>−35.045 (0.042)*</td>
<td>−154.091 (0.000)**</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.695 (0.694)</td>
<td>0.764 (0.000)**</td>
<td>0.702 (0.056)*</td>
</tr>
<tr>
<td>Fixed effects?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of observations</td>
<td>987</td>
<td>987</td>
<td>987</td>
</tr>
<tr>
<td>Number of groups</td>
<td>329</td>
<td>329</td>
<td>329</td>
</tr>
</tbody>
</table>

Note: Dependent variable: urbanized land area in square miles. *-Values are in parentheses. WRLURI, Wharton Residential Land Use Regulatory Index.

* Significant at 5%; ** significant at 1%.

not the metropolitan area population as whole. Income is median household income for the metropolitan area for each time period (1980–2000), expressed in 1999 dollars. Agricultural land prices for each metropolitan area for each time period are calculated as a weighted-average (weighted by each county’s share of metropolitan land area) of county agricultural land values from the pentennial Censuses of Agriculture, and also expressed in 1999 dollars.

### V. ESTIMATION AND RESULTS

The estimation strategy proceeds as follows. In Table 2, I present panel regression estimates utilizing the four different measures of growth management described above. Because the first two presented (state growth management and regional containment dummies) have policies that vary over time, I am able to estimate these using a fixed-effects panel model. The dummy variable measures whether there was a state growth management program or regional containment regime in place for the year of the observation (1980, 1990, or 2000). For example, if a region or state adopted growth management or regional containment in 1986, it would be classified as being in place for that decade.
A second problem that requires careful explanation is that some metropolitan areas (43 out of 329, or 13%) cross state boundaries. Therefore, the assignment to a particular state for purposes of state-level variables could potentially introduce errors into the analysis of state-level variables. As far as I am aware, only Wassmer (2006) describes how robustness checks were used to test whether this assignment introduces problems into the analysis. As a robustness check on this assignment problem, I first assign the metropolitan region to the first state listed in the official Census metropolitan area name. The state listed first in the Census name is the state of the first-listed central city. After estimating each model, I then assign the metropolitan region to the second state listed, and rerun the regressions, testing for any significant differences in coefficients, error levels, or goodness-of-fit measures. No significant differences are found, so the results in Table 2 represent the assignment of multistate metropolitan regions to the first-listed state. Wassmer (2006) addresses this problem by including a dummy variable to indicate multistate areas, and finds this variable to be statistically insignificant.

For the first two columns of results (state growth management and regional containment), the panels are estimated with metropolitan fixed effects, and with Driscoll-Kraay (Driscoll and Kraay 1998) standard errors, robust to cross section and temporal dependence. Hausman and Breusch-Pagan tests strongly support the use of fixed-effects estimators. For the last two columns (strength of state planning and the Wharton Index) fixed-effects estimators cannot be used because these data exist for only one time period and do not vary over time.

Across all four specifications, the standard urban model variables show the predicted signs: urban land area extent increases with increased population and increased income. The value of agricultural land is significant only in the random-effects models, and the negative sign is as predicted that increases in agricultural land values would be associated with less spatial expansion of urban areas.

The growth management coefficients in this specification are intercept shifters, and the results for state growth management programs and regional containment show significant and positive coefficients. Positive coefficients in this specification have been seen before in the literature and have sometimes been interpreted as evidence against the idea that growth management regimes reduce the outward expansion of urban areas. In this framework, it appears that state growth management programs and regional containment programs are associated with increases in urban area extent, all else being equal. The coefficients on the strength of the state planning variables have a similar interpretation: compared to “weak” state planning states, stronger state planning states have increases in urban area extent. The coefficient on the Wharton Index for the region is statistically insignificant.

I utilize the Davidson and McKinnon (1981) J-test to test which (if any) of these four approaches better fits the data. The J-test involves comparing two nonnested regression models. The first null hypothesis is that Model 1 is statistically preferable to Model 2, and the second null hypothesis is that Model 2 is preferable to Model 1. Both hypotheses could be rejected, neither rejected, or just one rejected. When both are rejected, this ambiguous result means that the test cannot identify which is the most preferable model. I test each of the four models against each other individually. Whenever the model with the state growth management dummy variable is tested in the J-test against any of the other three models, the unambiguous result is that the other model is always preferred to the state growth management dummy model. For all of the other models tested, the results are ambiguous, as the null hypothesis for both models is not rejected.

The fact that the state growth management dummy variable model compares poorly to the other models suggests that continued utilization of that variable or approach is unlikely to be informative in understanding the relationship of growth management and urban area extent. Its poor performance compared to these other three approaches might also provide insight as to why its inclusion in previous research has yielded inconsistent and inconclusive results.
TABLE 3
Fixed-Effects Panels: Containment, State Planning Role, Wharton Index

<table>
<thead>
<tr>
<th></th>
<th>Regional Urban Containment</th>
<th>Strength of State Planning Role</th>
<th>WRLURI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Below Median</td>
</tr>
<tr>
<td>Urban population</td>
<td>0.0002905 (0.000)**</td>
<td>0.0003346 (0.000)**</td>
<td>0.0003566 (0.000)**</td>
</tr>
<tr>
<td>Median household income</td>
<td>0.0022112 (0.000)**</td>
<td>0.0003913 (0.402)</td>
<td>0.001124 (0.000)**</td>
</tr>
<tr>
<td>Value of agricultural land (per acre)</td>
<td>−0.0004424 (0.722)</td>
<td>−0.0016168 (0.273)</td>
<td>−0.0002258 (0.802)</td>
</tr>
<tr>
<td>Constant</td>
<td>−35.815 (0.071)</td>
<td>21.782 (0.031)*</td>
<td>263.433 (0.000)**</td>
</tr>
<tr>
<td>Within $R^2$</td>
<td>0.651</td>
<td>0.734</td>
<td>0.868</td>
</tr>
<tr>
<td>Number of observations</td>
<td>890</td>
<td>97</td>
<td>138</td>
</tr>
<tr>
<td>Number of groups</td>
<td>321</td>
<td>52</td>
<td>46</td>
</tr>
</tbody>
</table>

Note: p-Values are in parentheses. WRLURI, Wharton Residential Land Use Regulatory Index.
* Significant at 5%; ** significant at 1%.

As has been argued above, testing growth management policies as a dummy-variable intercept shifter is only an indirect test of the effect of growth management on urban area expansion. A more direct test proposed here is to compare the coefficient on population across growth management and non-growth-management regimes. If growth management reduces marginal land consumption, the coefficient on population in the model would be expected to be lower for growth management versus non-growth-management areas. I first implement this by using a Chow test (for structural stability), where the growth management dummy variable is used both separately and in interaction terms with all the other variables. The Chow test is that the dummy and all interaction terms are jointly significant, which would mean that a separate model for each “regime” (growth management vs. non-growth-management) can be estimated and that differences in coefficients between different regimes are statistically significant.

A hypothesized structural break for the regional containment variable is between those regions with and without regional containment. For the strength of state planning variable, the data are divided into the three categories available (weak, significant, substantial). For the WRLURI variable, I hypothesize a break at the median based on how the index was constructed. Each Chow test was statistically significant (regional containment: $X^2 = 3,378$, $p < 0.00$; strength of state planning role: $X^2 = 24,269$, $p < 0.00$; WRLURI: $X^2 = 1,680$, $p < 0.00$). This means that separate fixed-effects panels for each growth management regime can be estimated and that differences between coefficients are statistically significant. These results are reported in Table 3.

The first two columns of Table 3 show results for the regional (“nonlocal”) urban containment variable. The coefficient on population, which represents the expected urban land area increase associated with adding an additional urban resident in a decade, is higher in regions with containment than in regions without containment. Expressing these coefficients in more easily understood square foot terms, the marginal land consumption per decade in regions with urban containment is 9,328 ft$^2$ of urban land area, while adding one person to a region without containment would lead to an additional 8,098 ft$^2$ of additional urban land area, a difference of 1,229 ft$^2$, or 15%. Recall that this variable is constructed
so that regions are classified as having containment in place only for the decades when it was active. Therefore, differences in coefficients are unlikely to reflect adoption of containment policies in higher marginal-land consumption areas.

Therefore, when estimated in a fixed-effects panel framework across regimes, the results seem straightforward: regional containment policies, at least as measured in this data set and whatever else might be their benefits, do not appear to reduce marginal land consumption rates relative to unconstrained regions. However, these data do not allow us to necessarily conclude that regional containment policies actually increase marginal land consumption rates, because there is the possibility that unobserved heterogeneity between adopters and nonadopters of regional containment programs could still be related to marginal land consumption rates. Secondly, it may be the case that there are significant variations across regions in the strength of containment policies.

In contrast to the results on regional containment policies, the results shown in the middle three columns on the strength of the state planning role give modest support to the idea that strong planning at a state level can reduce marginal land consumption. Comparing the population coefficients between “weak” and “substantial” states shows that, all else being equal, adding one additional person to an area within a strong planning state is likely to lead to a smaller expansion of urban area than in weak planning states (7,103 ft² per capita vs. 9,077 ft², a difference of 1,973 ft², or 21% lower). However, these results are complicated by the fact that the population coefficient for the middle category is higher than for either the strong or weak category. Moving from a state that has only a significant state role to a state with a substantial role is associated with a reduction in marginal land consumption rates, but moving from a weak state to a significant state is associated with increased marginal land consumption rates. It is possible that this ambiguous result derives from how the data were constructed and the difficulty involved in categorizing a number of states into a middle category. States classified in this middle category include Arizona, Connecticut, Delaware, Georgia, Idaho, Maine, Nevada, South Carolina, Tennessee, Utah, Vermont, Wisconsin, and Wyoming. There is quite a wide range of state-level policies regarding growth and development within this category. A plausible alternative, therefore, is to eliminate this category from consideration and examine only the differences between weak and strong states.

The last two columns in Table 3 represent panels of metropolitan regions above and below the median WRLURI score. Here the results are consistent with the hypothesized relationship between land use restrictions and land consumption, and show that more highly regulated places have lower marginal land consumption rates than do lesser-regulated places. Because the Wharton Index measures the overall restrictions on land development within a region, these data provide some evidence that stronger regulation of land development can reduce the size of the urban area for a given population level.

VI. DISCUSSION AND CONCLUSIONS

In this paper, I have argued that a more accurate test of the effects of growth management policies on the spatial extent of urban development is shown in marginal land consumption rates. The evidence and methods presented here, while contributing to the methodological study of land policy impacts, provides partial support for the idea that growth management can be effective in constraining “sprawl.” This research has shown that statewide growth management systems are not associated with reductions in marginal land consumption, but that this variable or measurement itself should no longer be used to measure changes in land use outcomes. The mere presence of any regional containment policy has likewise been shown not to be associated with reduced urban area extent. Further research should examine whether regional containment policies are implemented in a strong enough fashion to really alter the spatial extent of urban development.

The fact that marginal land consumption rates are lower in states with a strong state planning role or in regions with more restrictive land use regulations does, however, pro-
vide some support for growth management and planning efforts to constrain the outward expansion of urbanized land area. These findings are consistent with Howell-Moroney’s (2008) argument that only the strongest forms of state growth management are able to reduce the pace of land development. Because reducing or slowing the conversion of land to urban development has emerged as an important policy goal adopted by many states and regions across the country, the evidence presented here is partially supportive of the effectiveness of strong growth management regimes.

However, the results that moderately regulated places have higher marginal land consumption rates than weakly regulated or strongly managed places can also be instructive for policy design. Modest growth management regimes or modest regional containment efforts may not be effective at reducing land consumption. I have argued above that regions and states vary considerably among each other in terms of the policy approaches undertaken and the strength of implementation. It is likely the case that this institutional variability is poorly captured in existing metrics and variables of growth management policies, suggesting the need for further research. The particulars of institutional design matter a great deal in shaping urban land markets, and classifying policy differences with dichotomous variables may obscure institutional variety.

There is a final caution in the interpretation of these results because this research does not provide evaluation of the welfare implications of regional or state growth management programs. The most commonly cited critique of growth management programs is that, by reducing the supply of land for development, these programs might increase housing prices, resulting in a reduced housing affordability or exacerbated racial segregation (Dawkins and Nelson 2002; Nelson et al. 2002; Downs 2004; Landis 2006; Rothwell and Massey 2009). As more states and regions consider adopting growth management policies these potential trade-offs and distributional questions will no doubt increase in importance.

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References


