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The Effects of Portland's Urban Growth Boundary on Urban Development Patterns and Commuting

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Summary. This research investigates the effects of Portland's urban growth boundary (UGB) on urban development patterns and mobility. Three different methods are adopted for evaluating Portland's UGB: intermetropolitan comparisons; comparisons inside and outside the UGB; and, statistical analyses utilising regression models. Intermetropolitan comparisons do not support the conclusion that Portland's UGB has been effective in slowing down suburbanisation, enhancing infill development and reducing auto use. A significant level of spillover from the counties in Oregon to Clark County of Washington took place during the 1990s, indicating that the UGB diverted population growth into Clark County. Results from the statistical analyses also support the above findings. The UGB dummy variable was not significant during the 1980s and 1990s, indicating that the UGB had little impact on the location of new housing construction during the 1980s and 1990s. Unlike the UGB, the Clark County dummy variable is significant for both models, supporting the spillover effects of the UGB.

1. Introduction

Since the first US urban growth boundary (UGB) was established in Lexington, Kentucky, in 1958 (Nelson and Duncan, 1995), UGBs have become one of the most popular urban growth management tools. By 1999, more than 100 cities and counties in the US had adopted UGBs and three states, Oregon, Tennessee and Washington, had passed statewide mandates for UGBs (Staley *et al.*, 1999). Oregon adopted growth management legislation in 1973 and Portland's UGB was proposed in 1977 and approved by the state in 1980. The Washington Growth Management Act was passed in 1990 and Clark County, WA, introduced a UGB in 1995 (Bae, 2001).

Perhaps no other city in the US has been mentioned as often as Portland in urban planning literature. Portland's UGB has been in the centre of controversy for the past two decades between the pro-marketeers and government intervention advocates. As an advocate of UGBs, the American Planning Association recommends that UGBs be established

> to promote compact and contiguous development patterns that can be efficiently served by public services and to preserve or protect open space, agricultural land, and environmentally sensitive areas (Ding *et al.*, 1999, p. 53).

On the other hand, Jan Brueckner argues that

> urban growth boundaries can easily yield undesirably draconian outcomes, because they are not directly linked to the underly-

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> ing market failures responsible for sprawl (Brueckner, 2000, p. 170).

In spite of numerous UGB studies, there is no agreement about their effectiveness. Given these differing views, this paper will attempt to evaluate the effects of Portland's UGB on urban development patterns, transport choices and mobility. Specifically, the assessment will focus on whether Portland's UGB: controls sprawl and encourages infill development; curtails automobile usage and promotes public transit ridership; and, maintains mobility.

There is the persisting problem of how to separate the effects of Portland's UGB from autonomous market forces and other land use and growth management policies. Although it is difficult to assess to what extent Portland's UGB has contributed to current urban spatial formation and mobility, it is feasible to evaluate if Portland's UGB has had any influence on urban development patterns. This can be assessed in the following ways: by comparing Portland with other metropolitan regions; by comparing inside and outside the UGB within Portland; and, by statistical analyses.

The remainder of this paper contains six sections. Sections 2 and 3 introduce Portland's UGB and review the previous research. Section 4 compares Portland with other metropolitan regions in the US. In section 5, comparisons are made inside and outside the UGB within Portland. Section 6 introduces the standard least square estimation method to assess if the UGB affected urban spatial formation. Section 7 contains conclusions and suggested policy implications.

2. Portland's Urban Growth Boundary

Metro, the managing body of Portland's UGB, defines the UGB as

> a legal boundary separating urbanizable land from rural land … The boundary controls urban expansion onto farm, forest, and resource lands. At the same time, land, roads, utilities, and other urban services are more efficiently distributed within the urban boundary (Metro, 2002, p. 1).

Under Oregon law, Metro has the responsibility for maintaining a 20-year supply of residential land to accommodate urban activity and growth for the Portland metropolitan area. The Portland UGB covers 24 cities (including the urban portions of Washington, Multnomah and Clackamas counties) that contained 369 square miles with 1.3 million residents in 2000 (see Figure 1).

Three co-ordinated measures are generally used in managing the UGB: phased development inside the UGB; limiting development outside the UGB; and, flexible boundary of the UGB (Daniels, 1999). Phased development is a way to encourage contiguous development inside the boundary by building only on open land that is adjacent to existing development. Local governments in Oregon are required to make public facility plans that ensure that zones inside the UGB will be developed at urban densities. The local government provides an incentive to developers in the permit process by quickly responding (within four months) to a developer's proposed project if the project is going inside the UGB.

Along with phased development inside the UGB, counties in Oregon are given the authority of zoning rural lands for exclusive farm use and forest conservation outside the UGB. As of 1998, about 25 million acres of farm and forest have been zoned for exclusive farm use and timber conservation (Daniels, 1999). In addition, Oregon designated rural residential zones with 3–5 acre minimum lot sizes outside the UGB. The boundaries of the UGB are designed to change over time. The boundary of Portland's UGB has changed about three dozen times as the metropolitan population has increased by 700 000 people since 1979.

3. Literature Review

There are numerous studies on the effects of UGBs on urban development patterns and housing markets. Since the effects of UGBs

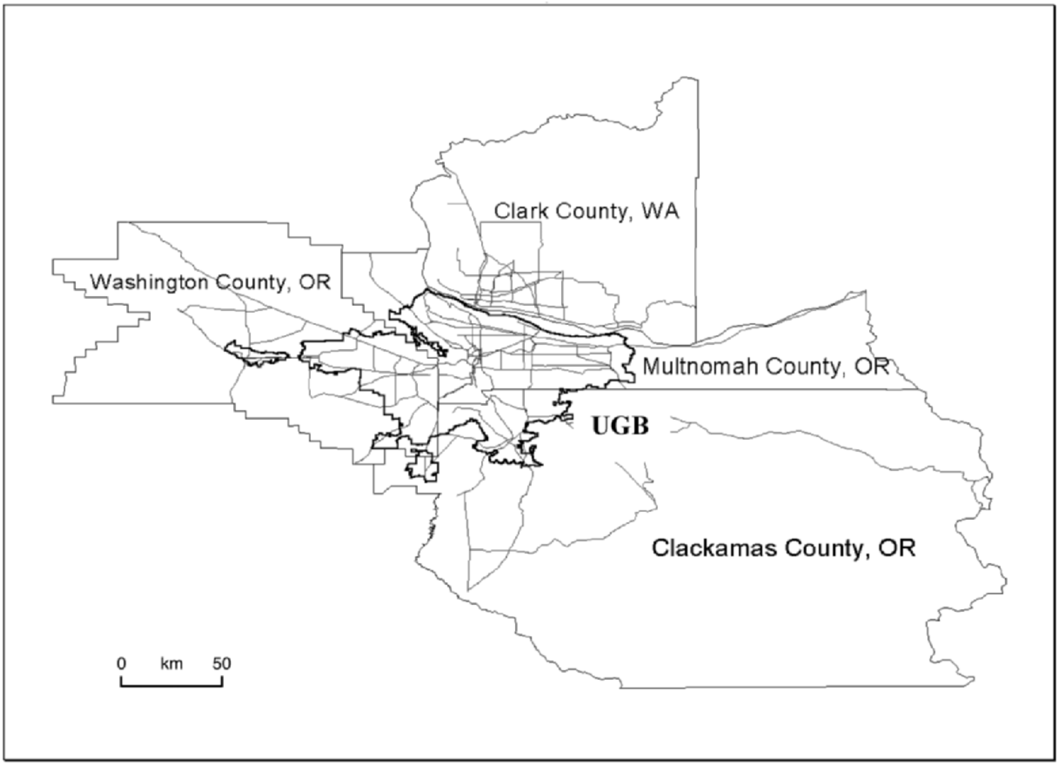

Figure 1. Portland's urban growth boundary.

on land and housing prices are well documented (Knaap, 2000) and beyond the scope of this paper, this review focuses on the effect of UGBs on urban development patterns.

Empirical analyses show contradicting results about the effects of UGBs on urban development patterns. Some argue that Portland's UGB has contributed to controlling urban sprawl and urbanised density increases (Patterson, 1999; Nelson and Moore, 1993; Kline and Alig, 1999), while others insist that Portland's trend of suburbanisation and land use patterns is no better than those of other metropolitan areas (Richardson and Gordon, 2001; Cox, 2001).

Nelson and Moore (1993) analyse residential building permits, residential land divisions and density of residential development inside and outside Portland's UGB between 1985 and 1989. They conclude that most regional development has been directed within the UGB. However, they argue that considerable development continues outside the UGB and that "efficient expansion of the UGB in the future may be jeopardised by low-density development patterns along the boundary" (Nelson and Moore, 1993, p. 302).

One Thousand Friends of Oregon (1991) conduct similar studies in analysing the density of residential development in Portland from 1985 to 1989. They find that actual development densities in multiple-family zones are closer to the planned density, reaching about 90 per cent, whereas those in single-family zones fall short of the planned density level, approaching only 66 per cent.

Kline and Alig (1999) analyse farm and forestland conversion in Oregon and Washington and find that most urban development is concentrated inside the UGB. However, they are unable to provide evidence that the

UGB protected farm and forestland outside the UGB from urban development.

Although these studies conclude that the UGB makes significant contributions to contain urban development inside the UGB, their findings cannot be generalised because of several limitations in their research. They examine building permits and density changes for the three counties on which the UGB is drawn, ignoring Clark County, WA, where growth from the three counties may spill over. Knaap (2000) also argues that if Portland is defined by the UGB, then it has grown by only 1.2 per cent in the past 20 years. However, if all urban footprints are included, then Portland has grown by about 29 per cent. Another limitation of the above studies is the time-span of their research. Two of the studies draw conclusions from data analysis covering the 5 years between 1985 and 1989. Since urban land uses change over a relatively long period of time, a 5-year trend analysis does not represent a long-term trend of urban development.

Richardson and Gordon (2001) compare Portland with Los Angeles and find that suburbanisation and decentralisation in both regions are quite similar. They also examine housing affordability and transit ridership in both regions and conclude that growth management controls have almost no impact.

Bae (2001) analyses cross-border impacts of the UGB between Portland and Clark County, WA. She examines population and employment growth, jobs–housing imbalances and traffic flows for the four counties in the Portland metropolitan region. She concludes that the growth management policies do not stop growth; rather, they merely divert growth into other locations—especially, Clark County, Washington, which has the fastest population growth in the state of Washington.

Cox (2001) compares Portland with Atlanta by analysing 17 variables including population and employment growth, auto use and transit ridership. He concludes that

> Despite its smart growth policies, Portland is not different from other urban areas. Most growth is in peripheral areas, with comparatively little growth in the center (Cox, 2001, p. 21).

Studies arguing that the UGB has little impact on urban development patterns have limitations because of the generalisation in their findings. Even though these studies use recent data, they do not select enough samples to conduct intermetropolitan comparisons. Findings from a comparative analysis of a couple of metropolitan regions do not represent the relative performance of Portland's UGB among other metropolitan regions.

This paper is distinguished from earlier works in several respects. This research employs more dependable methods than other studies to assess the effects of Portland's UGB. Unlike Richardson and Gordon (2001) and Cox (2001) who compared Portland with one or two other metropolitan regions, this paper compares Portland with all other metropolitan regions in the US, controlling for population size. As a result, a more objective evaluation of the effects of the UGB is possible. Furthermore, this paper introduces standard regression models in order to estimate the effects of the UGB on urban development patterns. Data reliability is another advantage of this paper. The recent release of the 2000 census STF3 makes it possible to analyse 20-year trends on various issues from 1980 to 2000, which is a sufficient time-period for measuring the effects of the UGB.

4. How Is Portland Different from Other Metropolitan Regions?

This section compares the Portland PMSA (Primary Metropolitan Statistical Area) with other metropolitan areas for the following variables: urbanised population, urbanised land area, population density in urbanised area, employment in central city, housing unit proportions in the urbanised area, auto and transit users, and mean commuting time. Thirty-two metropolitan regions in the US with populations over one million in 1980 were selected for comparison.

Table 1. Population, land area, and density in the Portland urbanised area, 1980–2000

	1980	1990	2000	Percentage change 1980–2000	Rank (out of 32)
Urbanised population (000s)	1026	1172	1583	54.3	8
Land (square miles)	349	388	474	35.8	9
Density	2940.3	3021.0	3340.0	13.6	15

Source: US Bureau of Census, STF3, 1980, 1990 and 2000.

Table 2. Growth rate and rank for the selected variable in Portland

Variables	Growth rate, 1980–2000 (percentage)	Rank (out of 32)
Employment in central city	70.8	6
Housing units in urbanised area	54.4	16
Auto users	69.9	12
Public transit users	26.1	11
Mean commuting time	14.5	15

Source: US Bureau of Census, STF3, 1980 and 2000.

Table 1 presents changes in Portland's population, land size and density in the urbanised area over the past two decades. Urbanised population and land are good indicators of urbanisation trends. The urbanised population has increased by 54 per cent, while the urbanised land area increased by 36 per cent over the 1980–2000 period. Portland's growth rates are ranked 8th for urbanised population and 9th for urbanised land among 32 metropolitan areas. These findings imply that urbanised land area and population have increased at a faster rate than other metropolitan areas, making Portland one of top 10 fastest-growing metropolitan areas. Population density in the urbanised area has risen by 13.6 per cent, which is about the average of the selected metropolitan areas, ranked at 15th.

Table 2 shows Portland's growth rates and ranks for the variables associated with urban development and mobility over the 1980–2000 period. Employment in the central city of Portland grew by 70.8 per cent during the past 20 years. Portland's employment growth rate in the central city ranked 6th, indicating that Portland's growth rate is much higher than in most other metropolitan areas. Employment in the central city can be used as a measurement to analyse urban form and spatial distribution of employment. Portland's data show that the central city in Portland continues to play a role as the urban employment centre through revitalisation programmes for the central city, unlike many metropolitan areas where the employment share in the central city keeps decreasing. Since the UGB's primary concern is to contain urban residential development within the boundary, it is difficult to find whether or not the UGB affected the growth rate of employment in the central city.

Housing units in the urbanised area have increased by 54 per cent during the past two decades, which is about average of the selected metropolitan areas. Auto users and transit users have increased by 70 per cent and 26 per cent over the 1980–2000 period. Those growth rates are moderately higher than in other metropolitan areas, because Portland stands above average, ranked at 12th and 11th respectively. Mean commuting time in Portland grew by 14.5 per cent over the 20-year period; compared with other metropolitan areas, Portland's growth rate in mean commuting time ranked at 15th, which is about the average.

Table 3. Changes in commuting flow by county between 1980 and 2000 (percentages)

	Place of Work					
Place of residence	Clackamas	Multnomah	Washington	Three Oregon counties	Clark, WA	Total
Clackamas	64	24	154	53	481	54
Multnomah	122	15	123	26	253	28
Washington	261	23	113	85	551	86
Three Oregon counties	85	17	118	47	318	48
Clark, WA	665	89	284	115	101	105
Total	90	22	121	50	112	56

Source: US Bureau of Census, CTPP, 1980 and 2000.

Although intermetropolitan comparisons do not control the factors that might explain differences among metropolitan areas, these comparisons can be instructive for understanding Portland's relative performance in terms of urban development pattern and mobility over the 1980–2000 period. The findings from intermetropolitan comparisons show that Portland does not appear to have experienced less suburbanisation, greater infill development or reduced auto use relative to other metropolitan areas.

5. Urban Development Patterns and Mobility Inside and Outside Portland's UGB

This section focuses the study area on the Portland metropolitan area in order to analyse urban development patterns and commuting inside and outside the UGB. Four major counties of the Portland PMSA (Clackamas, Multnomah and Washington County in Oregon and Clark County in Washington)[1] were selected for this analysis, because most commuting takes place within these selected counties and these counties absorbed almost all of the development over the past 20 years.

Since the UGB boundary crosses over census tract boundaries, it is not easy to obtain census information inside and outside the UGB. This paper takes several steps to obtain census information inside and outside the UGB

(1) Obtain census information by block group[2] for 1980, 1990 and 2000 in order to minimise errors that may occur when splitting a zone into multiple polygons.
(2) Establish block-group boundary maps for 1980, 1990 and 2000, and the UGB boundary map on GIS.[3]
(3) Split block groups into inside and outside the UGB by using GIS spatial analysis tools.
(4) Obtain census information inside and outside the UGB by using the split factors derived from GIS spatial analysis.

This section analyses jobs–housing balance and cross-border commuters between the three counties in Oregon and Clark County, Washington, during the past two decades. For this, origin–destination matrices for 1980 and 2000 were obtained from the census. Table 3 shows growth rates for intercounty commuting flow between 1980 and 2000. There are several findings to note. First, commuters working in Multnomah County, the core county of the region, have increased by only 22 per cent, while commuters working in other counties grew at faster rates, ranging from 50 per cent to 121 per cent. These findings indicate that employment suburbanisation has occurred from Multnomah to the peripheral counties, even though the central city plays a role as the employment centre, as shown in Table 2. Secondly, the number of commuters living in Clark County and working in the three Oregon counties has increased by 115 per cent, while the number of reverse commuters travelling from three Ore-

Table 4. Mode choice of commuters (auto and public transit), 1980–2000 (percentages)

	1980		1990		2000	
	Auto	Public	Auto	Public	Auto	Public
Inside UGB	82.5	10.9	87.2	7.4	85.5	9.0
Outside UGB						
Three Oregon counties	91.7	2.5	94.7	1.5	94.6	2.0
Clark County, Washington	94.2	1.2	94.7	2.2	94.7	2.7
Sub-total	93.1	1.8	94.7	1.9	94.7	2.4
Total (four counties)	85.2	8.6	89.4	5.8	88.3	7.0

Source: US Bureau of Census, STF3, 1980, 1990 and 2000.

gon counties to Clark County has risen by 318 per cent. The cross-border commuters in both directions (Oregon to Washington and Washington to Oregon) have increased significantly during the past two decades. Under this circumstance, it is not appropriate to assess the effects of the UGB solely with three Oregon counties, as done in several previous studies.

Since job suburbanisation and the increase in intercounty commuting are virtually common phenomena in every US metropolitan area over the 1980–2000 period, it is difficult to judge that the Portland area has experienced a worsening jobs–housing imbalance, compared with other metropolitan areas. However, the increase in cross-border commuters is likely to have made commuting distance longer, which undermines the UGB's goal for maintaining mobility.

Table 4 shows the transport mode choices inside and outside the UGB. The share of auto commuters inside the UGB rose from 82.5 per cent to 87.2 per cent in the 1980s and dropped to 85.5 per cent in 2000, while the share using transit went in the opposite direction. On the other hand, the share of auto commuters outside the UGB went up slightly from 93 per cent to 94.7 per cent in the 1980s and did not in the 1990s. Commuters outside the UGB both in the three Oregon counties and Clark County showed a high dependency on autos, ranging from 92 per cent to 95 per cent. A relatively high transit share inside the UGB may be the result of the extensive availability of public transport within the UGB. An interesting finding is that the share of public transit inside the UGB increased from 7.4 per cent to 9.0 per cent during the 1990s. However, it is too early to draw a conclusion that the UGB contributed to the rise of public transit share, because transit shares outside the UGB also increased in the 1990s.

Metro (2002) insists that the UGB will not result in more congestion. Its position is that

> Spread out, or sprawling cities, force most trips into automobiles and cover longer distances and more miles driven. The result is actually more traffic congestion, not less. As the region grows it will be more congested, but Metro is working towards ensuring transportation choices and maintaining mobility (Metro, 2002, p. 2).

However, the results presented in Table 5 are not supportive of this position. Travel times inside the UGB grew faster than those outside the UGB. Mean travel times inside the UGB increased by 2 per cent in the 1980s and, more significantly, by 12 per cent in the 1990s. Combined with the results of the previous analysis, the following factors seem to be responsible for longer commuting time both inside and outside UGB

(1) population and employment suburbanisation which results in longer commuting distances;
(2) an increase in transit share in the 1990s which contributed to longer commuting

Table 5. Mean commuting time (minutes)

	1980	1990	2000	Percentage change 1980–90	Percentage change 1990–2000	Percentage change 1980–2000
Inside UGB	20.59	21.04	23.58	2.2	12.1	14.5
Outside UGB						
Three Oregon counties	25.63	26.12	28.53	1.9	9.2	11.3
Clark County, Washington	21.96	21.19	24.66	− 3.5	16.4	12.3
Sub-total	23.66	23.41	26.21	− 1.1	12.0	10.8
Total (four counties)	21.38	21.72	24.38	1.6	12.2	14.0

Source: US Bureau of Census, STF3, 1980, 1990 and 2000.

Table 6. Share of housing units by year built

	Before 1959	1960–69	1970–79	1980–89	1990–2000	Total
Inside UGB	82.3	74.4	65.2	64.8	60.4	70.2
Outside UGB						
Three Oregon counties	7.5	10.0	14.5	13.7	13.9	11.6
Clark County, Washington	10.2	15.6	20.3	21.5	25.7	18.1
Sub-total	17.7	25.6	34.8	35.2	39.6	29.8
Total number (four counties)	224 902	84 212	153 251	95 794	180 299	738 458

Source: US Bureau of Census, STF3, 2000.

times (public transit has longer travel times than auto because of stopping and waiting); and,

(3) congestion caused by growth of population and non-work activities, and by the bottleneck in the bridges connecting Clark County and the rest of the Portland metropolitan region caused by the increased interactions (Bae (2001) conducted a detailed analysis about traffic congestion on those bridges).

6. Effects of the UGB on Portland's Residential Development Patterns

This section examines the effects of Portland's UGB on urban residential development patterns. Two types of analysis were conducted: analysis of housing units constructed inside and outside the UGB for the past 20 years, and, statistical analysis.

6.1 Analysis of Housing Units by Year Built

Table 6 presents the share of housing units by year built and by location. The shares of housing units inside the UGB have declined over time from 82.3 per cent before 1959 to 60.4 per cent in the 1990s. The shares of housing units outside the UGB in the three Oregon counties have been constant since 1970, but Clark County has experienced a rapid growth in share from 16 per cent in the 1960s to 26 per cent in the 1990s.

Figures 2–5 show the spatial distribution of housing units constructed during the 1960s, 1970s, 1980s and 1990s. Approximately 75 per cent of new housing units in the 1960s were constructed inside the UGB. Clark County, Washington, accommodated 15 per cent of the new housing units built in the same period. The Portland metropolitan region experienced rapid population (hous-

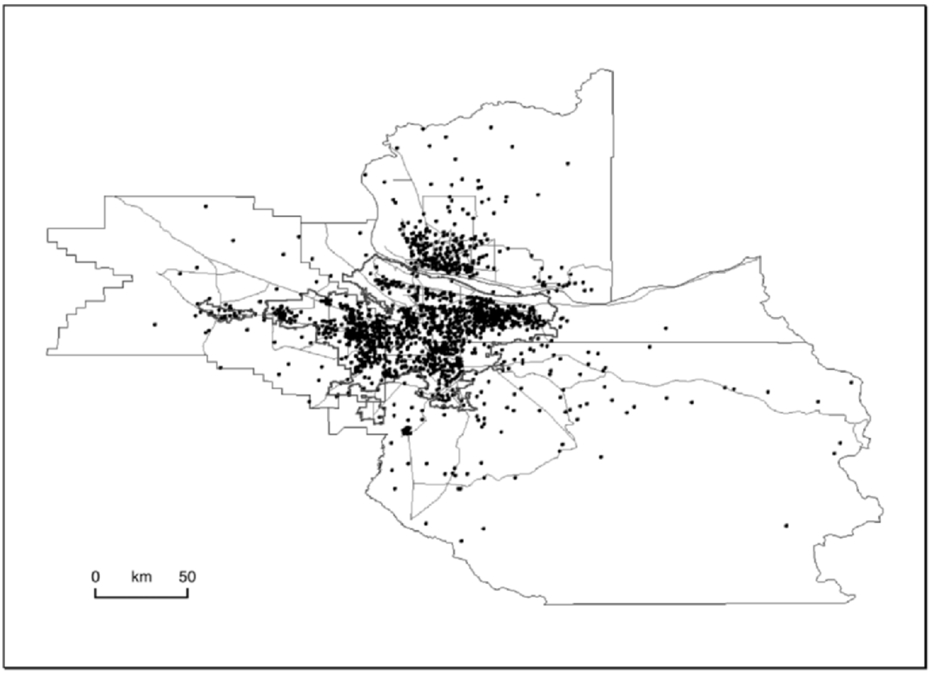

Figure 2. Housing units built, 1960–69. *Key*: 1 dot represents 50 housing units.

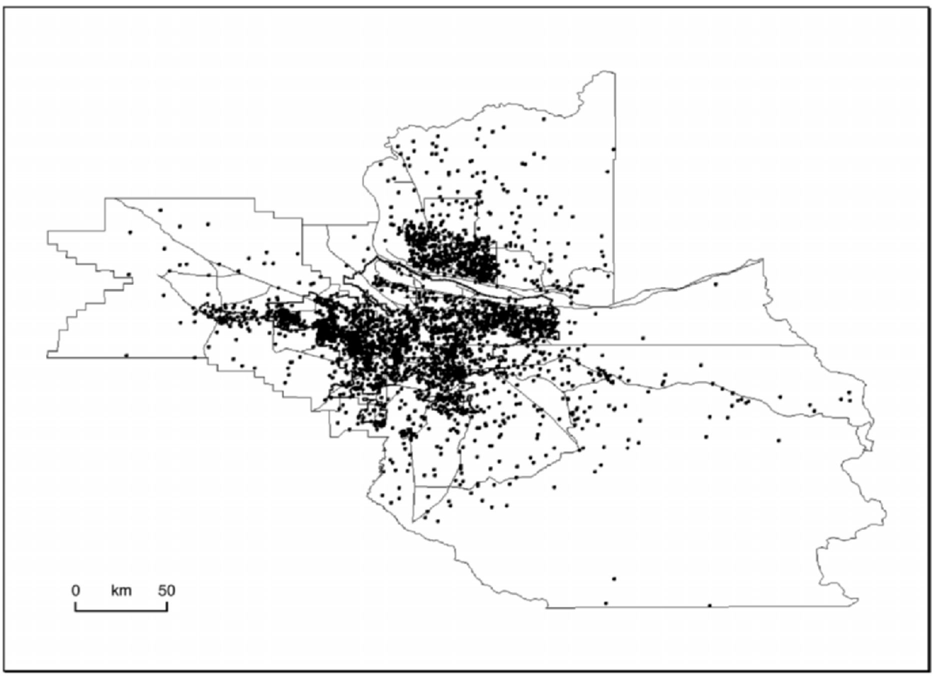

Figure 3. Housing units built, 1970–79. *Key*: 1 dot represents 50 housing units.

ing) growth during the 1970s, which resulted in doubling the number of new housing units constructed during the 1960s. As shown in Figure 3, significant population suburbanisation started to take place towards Clark County as well as to the south-east in the 1970s. Total housing units constructed during 1980s declined by almost 60 000 units,

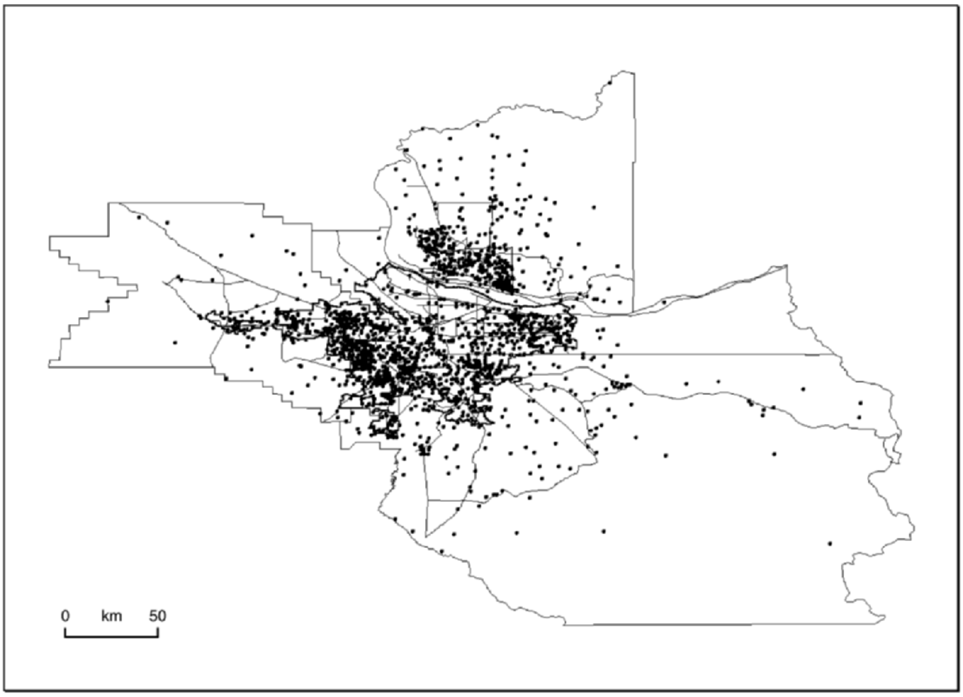

Figure 4. Housing units built, 1980–89. *Key*: 1 dot represents 50 housing units.

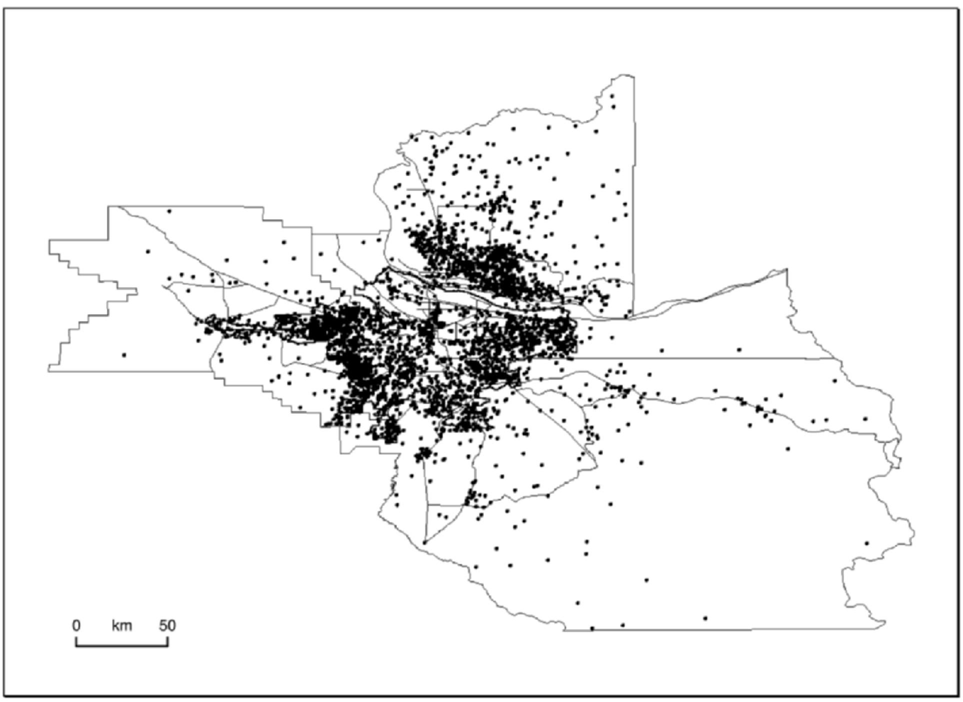

Figure 5. Housing units built, 1990–2000. *Key*: 1 dot represents 50 housing units.

due to the economic downturn. However, the spatial distribution of the 1980s housing is similar to that of the 1970s. Portland experienced a housing construction boom in the

1990s. Nearly twice as many housing units were constructed in the 1990s as were built in the 1980s. Of the new housing units, 40 per cent were constructed outside the UGB. Clark County alone absorbed about two-thirds of these units. Visual illustration of the housing distribution clearly shows that population suburbanisation began in the 1970s and that a significant amount of the new housing constructed during 1980s and 1990s is located beyond the UGB. However, the visual presentation is not a convincing method to test whether or not the UGB affected Portland's residential development patterns, because it is purely descriptive without statistical controls.

6.2 Statistical Analysis

We build a housing supply model in order to examine what factors affect the location of new housing construction. From the housing supply model, we try to test whether or not the UGB influences urban residential development patterns, after controlling other variables affecting housing supply such as housing value, household income, accessibility and location factors. We build a standard regression model where housing units constructed by census-block group are a function of the housing market, neighbourhood and location, and accessibility variables.[4]

Housing market variables include median household income and mean housing value.[5] Housing value and household income are good indicators when developers select development sites. Since new housing units constructed (or supplied) over the past 10 years are regarded as a dependent variable, it is assumed that developers are likely to provide more housing units in a good community (higher income and housing value). Therefore, the signs of those variables are expected to be positive. The model uses lag variables for housing value and household income, which are measured at the beginning year of the 10-year period, because it is rational to argue that the housing value and household income of a community where developers want to invest are available prior to investment decisions.

Neighbourhood variables are population density, number of existing housing stock (for 1990 model housing units constructed before 1980, and for 2000 model housing units constructed before 1990), proportion of multiple housing units and proportion of housing units inside the urbanised area. Population density is included for examining the level of inner-city residential development. We expect a negative sign for population density because developers are likely to build new housing in areas with a low population density. The existing housing stock can be regarded as a proxy variable representing residential development patterns: contiguous (or infill) or leapfrog development. It is assumed that new housing tends to be constructed in a zone with a large existing housing stock that is likely to have extensive infrastructure and diverse public facilities. If leapfrog development prevails, the existing housing stock variable will have a negative sign. The model also includes the proportion of multiple housing units and proportion of housing units inside the urbanised area for each block group for analysing new housing construction patterns associated with housing type (single- or multiple-family housing) and with community type (urbanised or rural area). It is expected that new housing is likely to be constructed in a community with a high proportion of single-family housing and with a high proportion of housing units inside urbanised area, because those communities have locational advantages such as amenities and easy access to public services.

The model has two accessibility variables: average commuting time and distance from the CBD. Average commuting time can be regarded as accessibility to employment, while distance from the CBD can be used as a measurement for population suburbanisation. The model also includes two important dummy variables to estimate the effects of the UGB and cross-border impacts: UGB and Clark County dummy variables. Table 7 represents the description of variables. The sub-

Table 7. Description of variables

Variable	Description
LN_Hstock_{t-1}	Natural log of the existing housing stock at year $t-1$
LN_Popden_{t-1}	Natural log of population density at year $t-1$
Mid_Income_{t-1}	Median household income at year $t-1$
$Mean\_Val_{t-1}$	Mean housing value at year $t-1$
Mean_Time	Mean commuting time
Dist_CBD	Distance from CBD
Multi_HS_r	Ratio of multiple housing to total
Ur_HS_r	Proportion of housing units located in urban area to total
UGB_Dummy	UGB dummy (1 if within UGB, 0 otherwise)
WA_Dummy	Washington State dummy (1 if within Washington, 0 otherwise)

Table 8. Regression analysis, 1980–90 ($N = 1143$)

Variable	Estimate	*T*-value	Probability
Intercept	− 6.2769	− 13.17	0.0001
LN_Hstock_{t-1}	0.7066	16.45	0.0001
LN_Popden_{t-1}	− 0.0698	− 2.45	0.0144
Mid_Income_{t-1}	6.E-05	5.37	0.0001
$Mean\_Val_{t-1}$	0.0164	5.64	0.0001
Mean_Time	0.0527	3.86	0.0001
Dist_CBD	4.6020	7.92	0.0001
Multi_HS_r	1.9742	9.42	0.0001
Ur_HS_r	0.5058	2.61	0.0093
UGB Dummy	0.0817	0.52	0.6034
WA Dummy	0.8215	4.75	0.0001
$R^2 = 0.434$			

script *t*-1 indicates the beginning year of the model. For the 1990 model, *t*-1 refers to 1980.

Tables 8 and 9 report runs of the standard regression model for 1990 and 2000. As expected, both median household income and mean housing value are positively related to new housing units built. These variables have the expected sign and are statistically significant for both the 1990 and 2000 models. Population density negatively affects new housing construction, while the existing housing stock is positively related to new housing provision. New housing is more likely to be constructed in a zone with a lower population density and with a larger housing stock. This result implies that new housing construction took place in the suburban area (low population density), but not by means of leapfrogging residential development.

Another important finding is that the distance from the CBD and mean commuting time are positively related to new housing construction and statistically significant for both models. This indicates that more housing units are constructed as the zone locates farther away from the CBD, which supports the previous argument on population suburbanisation (Table 1). This also supports the finding that more housing units are built in the suburban area, where commuters have longer travel times, than in the central city (Table 5).

The proportion of multiple housing units and proportion of housing units inside the urbanised area are both positively related with new housing construction and are statis-

Table 9. Regression analysis, 1990–2000 ($N = 1225$)

Variable	Estimate	T-value	Probability
Intercept	− 1.3118	− 2.27	0.0235
LN_Hstock_{t-1}	0.3023	6.17	0.0001
LN_Popden_{t-1}	0.3668	− 9.2	0.0001
Mid_Income_{t-1}	2.E-05	2.76	0.0058
$Mean\_Val_{t-1}$	8.E-06	4.41	0.0001
Mean_Time	0.0404	3.59	0.0003
Dist_CBD	5.5319	10.1	0.0001
Multi_HS_r	1.8528	8.88	0.0001
Ur_HS_r	2.1609	10.62	0.0001
UGB Dummy	0.2106	1.48	0.1387
WA Dummy	1.0165	6.93	0.0001
$R^2 = 0.412$			

tically significant for both models. This suggests that new housing is more likely to be built inside the urbanised area and in a zone with more multiple housing. This finding can be interpreted as an indication that the UGB encouraged compact development. However, the positive relation between new housing construction and the proportion of multiple housing units seems to be affected not by the UGB, but by the spatial distribution of multiple housing in Portland. According to the census, about 24.5 per cent in 1990 and 24.1 per cent in 2000 of total multiple housing units were located outside the UGB in Portland. A similar interpretation can be applied to the positive relation between the proportion of housing units inside the urbanised area and new housing construction. Census data revealed that 19.0 per cent in 1990 and 23.4 per cent in 2000 of total housing units inside the urbanised area were located outside the UGB.

The most important result from this analysis is that the UGB dummy variable is not statistically significant for both the 1990 and the 2000 models, implying that the UGB had no impact on the location of new housing construction. Unlike the UGB, the Clark County dummy variable is significant for both models. Those results suggest that Portland's UGB had little influence on determining the location of new housing construction, while Clark County attracted a significant amount of new housing construction during the past 20 years. More importantly, these results suggest that the UGB diverted Oregon's housing growth to Clark County, since the regression model controlled housing market, neighbourhood and accessibility variables.

In a study of this kind, it is desirable to address the issues of multicollinearity and heteroscedasticity. A standard collinearity diagnosis (Belsey *et al.*, 1980) generated condition indices of 34.8 in 1990 and 48.2 in the 2000 model, implying no multicollinearity problem. In addition, the variance inflation factor (VIF) is computed for each variable in order to check multicollinearity (Table 10). As a rule of thumb, for standardised data, a VIF > 10 indicates harmful collinearity (Kennedy, 1985). None of variables in the regression model has a multicollinearity problem, since the VIFs range from 1.2 to 3.3 for both models. This study also tests for heteroscedasticity by applying the Breushch–Pagan (BP) test (Wooldridge, 2000, pp. 266–270). The null hypothesis of no heteroscedasticity is accepted for both standard regression models.

7. Conclusions

This paper presents several analyses to answer various questions about Portland's UGB that have been debated at great length: did Portland's UGB control sprawl, curtail

Table 10. Variance inflation factors (VIF), by variable

Variable name	1990 model	2000 model
LN_Hstock_{t-1}	1.205	1.618
LN_Popden_{t-1}	2.000	2.538
Mid_Income_{t-1}	2.762	3.300
$Mean\_Val_{t-1}$	2.564	2.849
Mean_Time	1.684	1.629
Dist_CBD	2.481	2.294
Multi_HS_r	1.255	1.511
Ur_Hs_r	2.500	2.410
UGB Dummy	2.874	2.865
WA Dummy	2.083	2.045

automobile usage and maintain mobility? The analysed data suggest that Portland's UGB has not been successful in these efforts. From the intermetropolitan comparisons, Portland ranked as the 8th and 9th fastest-growing metropolitan area among 32 metropolitan areas in terms of urbanised population and land area. When considering that Portland ranked 15th in terms of population density increase in the urbanised area, these results undermine the belief that Portland's UGB controlled urban sprawl and enhanced compact development. Additionally, the positive relationship found in the regression analysis between the distance from the CBD and new housing construction supports the view that Portland experienced substantial population suburbanisation over the 1980–2000 period. It is difficult to find evidence to suggest that Portland's UGB enhanced public transit usage reduced auto users. Although the growth rate for transit users is moderately higher than in other metropolitan areas, ranked at 11th, auto users have also increased at a faster rate than in other regions, ranked at 12th.

Surprisingly and interestingly, the UGB dummy variable is not statistically significant, while the Clark County dummy variable is significant. These results indicate that Portland's UGB has had little effect on drawing new residential development into the UGB, but significant impact on diverting new growth into Clark County, Washington, the only county in the Portland PMSA not included in the UGB.

The results from this paper can trigger interesting policy discussions on urban growth management. Although it is problematic to find detailed evidence on why Portland's UGB did not bring about the intended results, the following arguments can be made. First, and most importantly, Clark County played a role as a safety valve for growth outside the UGB. As shown in Table 6, new housing construction grew much faster in Clark County than in the other three counties in the Portland PMSA over the 1980–2000 period. The unique situation of Portland's UGB raises an interesting issue about the growth management policy of a metropolitan area that crosses state borders. In the case of Portland, Oregon, this portion of the Portland metropolitan area introduced the UGB in 1979, while Clark County in Washington State introduced a UGB in 1995, after the Washington Growth Management Act had been passed in 1990. Clearly, bi-state co-operation is required for an effective UGB policy, so the two state UGB policies should be consistent and compatible with each other.

The second argument on why Portland's UGB did not work effectively is related to the measures in managing the UGB. Measures encouraging phased development inside the UGB are not strong enough to make the UGB a binding constraint. In addition, the boundary must be expanded periodically to accommodate 20 years of growth. A good example of a strong growth control policy is Seoul's Greenbelt. Seoul's Greenbelt was been designated in the Seoul metropolitan area in 1976 and has remained in place for nearly 30 years, allowing no development within the Greenbelt. Although the Greenbelt remains intact due to the banning of private development, achieving its primary goals, a tight greenbelt policy in a rapidly growing metropolitan area such as Seoul has some adverse effects: inner-city densification and leapfrog development (Bae and Jun, 2003). So a tight UGB policy can encourage compact development, but restrictive land use regulation like Seoul's Greenbelt is both constitutionally impossible and politically beyond reality in the US.

This paper initiates an active discussion on the effects of Portland's UGB and should not be understood as an attempt to provide a conclusive end to the Portland UGB controversy. Diverse analyses are required to study the overall effect of the UGB. Micro-level analysis, such as studying development patterns on a street or corridor within the UGB or analysing land use changes outside the UGB from agricultural and environmentally sensitive lands into urban land uses, would further contribute to an informed discussion analysing the effects of Portland's UGB. Discussion arising from this paper should spur these analyses and further study of UGB impact.

Notes

1. These four counties had 93.3 per cent of total population of Portland PMSA in 2000.
2. Block, of course, is the smallest geographical unit available in the census. However, it is not possible to obtain block-level boundary maps for 1980, 1990 and 2000 for the study area.
3. During the past two decades, the UGB has changed almost three dozen times. Most changes were about 20 acres or less. The most significant increase has occurred in 1998 and 1999 by addition of about 4000 acres, which is a 1.5 per cent increase of the total UGB. The UGB boundary map released by the Metro in 2000 was used for this analysis because it is almost impossible to accommodate all the boundary changes into the analysis and, even though major changes were incorporated, it is not expected to affect significantly the analysis results.
4. Since census information is aggregated data, it is not possible to build a behavioural model, which considers both consumer housing choices and developer site choices.
5. The model uses mean housing value instead of median housing value because there is no information about median housing value in the 1980 census.

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