Spatial Determinants of Land Prices in Auckland: Does the Metropolitan Urban Limit Have an Effect?

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Abstract

Land prices within monocentric cities typically decline from the centre to the urban periphery. More complex patterns are observed in polycentric and coastal cities; discrete jumps in value can occur across zoning boundaries. Information on these patterns within Auckland is important to understand: (a) the nature of Auckland's development, including the impact of infrastructure investments; and (b) the effects of regulation in causing discrete land valuation changes. One such regulation in Auckland is the metropolitan urban limit (MUL); we specifically examine whether the existence of this growth limit affects land prices. We do so in the context of a model of all Auckland land values over a twelve-year period, finding a strong zoning boundary effect on land prices.

JEL classification
R14, R38, R52

Keywords
growth limits; zoning restrictions; boundary effects; land value gradients

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1 Introduction

Land values indicate the market value that people ascribe to specific places. These values are affected by demand factors, such as views, amenities and proximity to employment and transport. Modern studies of the impacts of agglomeration in urban centres and of the value of new infrastructure provision use land values to measure the benefits of a certain feature, be it an infrastructure project or spillovers induced by proximity to other firms, markets and workers.

One reason that land value is a particularly useful measure of infrastructure provision, and of local spillovers, is that land is a fixed factor. Other factors (labour and capital) migrate in response to new opportunities and bid up the price of the fixed factor in the area in which those opportunities arise. The bids placed on land reflect the value of the local opportunity.

In studying such effects, one must also understand the nature of land supply, including regulatory restrictions on land use. As an extreme example, gold may be discovered in a certain locality, but the value of land in that locality may remain unchanged if laws prevent extraction of that gold because of environmental reasons.

In urban areas, growth limits and other zoning restrictions fulfil a regulatory role in governing the nature of a city's development. In this study, we examine the impact of a particular set of growth limits: Auckland's Metropolitan Urban Limits (MUL). The MULs are set as part of the Auckland Regional Policy Statement, a planning document that has a statutory basis. Specifically, the MULs are used "to define the boundary of the urban area with the rural part of the region." We analyse whether the MUL in Auckland affects land prices in the city. Specifically we model land prices across the greater Auckland region and test whether land prices exhibit a boundary effect at the limits prescribed by the MUL boundary. If the MUL constitutes a binding constraint on land supply for the city, we would expect land just inside the boundary to be valued more highly than land just outside. We also test whether land just inside the boundary is valued at a premium or discount relative to all other land within the growth boundary.

Growth limits are designed to affect the location and nature of urban expansion. In order to judge the impacts of say an infrastructure project, the nature of zoning restrictions must be understood. For instance, a new transport route may not result in new development if zoning restrictions prevent location of new activities near the route, whereas considerable development may take place in the absence of such restrictions.

Whether growth limits and zoning restrictions have a material effect on land values, at either a localized scale or at a city-wide scale, depends on a number of factors. First, a growth limit may not be binding. If a city's current and prospective expansion is well within the growth limit, no city-wide effect should be experienced and little local effect will be apparent. Second, a growth limit may be circumvented (as reported, for instance, by Pendall (1999) for some cases in the United States). Third, a growth limit may be binding in certain directions but not others. In these cases, the growth limit may have a material localized boundary effect on land values where the constraint binds, but will not necessarily have a major effect on overall city-wide prices.

Growth limits are commonly used as planning tools in many countries. A theoretical rationale that supports the use of growth boundaries arises for cases where traffic congestion is unpriced, so that cities sprawl in an inefficient manner. In the absence of congestion pricing, a growth limit may be a second-best policy to deal with congestion and sprawl (Kanemoto, 1977; Arnott, 1979; Pines and Sadka, 1985). Analyses supporting this approach tend to be based on a monocentric city model. In many cases (including Auckland), however, cities are polycentric. Anas and Rhee (2006, 2007) show that in these 'real world' cities, urban growth boundaries are not generally second-best policy instruments and may have seriously negative welfare consequences (Anas and Rhee, 2006). Indeed, in cities with cross-commuting and faced with congestion, it may be optimal for the city to increase its sprawl. In their model, where the shadow price of land under urban use exceeds the agricultural rent, "*planners should allow the urban area to sprawl more geographically (longer radius and more land) in order* *to reduce aggregate travel cost*" (Anas and Rhee, 2007, p.285; italics in the original).

Even where urban growth boundaries may be an optimal or second-best response to unpriced externalities, their operation may cause negative overall welfare consequences. Knaap and Hopkins (2001) contrast an optimal inventory management approach to urban growth boundaries with actual management approaches. Typically, revisions to urban growth boundaries are made at discrete (pre-chosen) points of time (e.g. twenty years after imposition of a previous boundary). Knapp and Hopkins show that this approach is inflexible in the face of unanticipated economic and demographic developments. Instead, boundaries need to be revised on a continuous basis reacting to the available supply and price of vacant land. In particular, boundaries require expansion once the price of land within the boundary relative to an external benchmark rises past some critical threshold. Their analysis places the issue of discrete boundary effects for land values at centre-stage in analyzing the effects and efficiency of a growth limit.

Considerable evidence now exists in the United States that urban growth boundaries can have major effects on patterns and dynamics of new housing supply across cities (Malpezzi, 1996; Ryan et al, 2004; Pendall et al, 2006). These impacts may be accompanied by major land price effects. In summarizing the results of a number of studies from California (Dowall, 1979; Dowall and Landis, 1982; Landis, 1986), where growth boundaries have been in use since the 1960s, Anthony (2003) reports a consistent finding that growth limits result in higher housing prices. Downs (1992) found that in San Diego County, the median sale price of existing houses rose by 54% within three years of the imposition of a growth boundary. Katz and Rosen (1987), Schwartz et al (1981) and Zorn et al (1986) have found similar effects. More recently, a significant body of work by Glaeser, Gyourko and associates finds that land use regulation, including growth controls, has had major effects on city house prices in the United States.

Literature on empirical effects of growth limits in Auckland and/or New Zealand is sparse. Grimes et al (2007) find that new residential building in Auckland is prevalent just inside the MUL boundaries, contrasting with a lack of similar activity on the outward side of the boundary. This provides prima facie evidence that the boundary has been effective in containing residential development in and around Auckland.

One study of the impact of the MUL is referred to by the Auckland Regional Growth Forum (1999) [ARGF], conducted shortly after formal adoption of the MUL in 1998. That report sought to understand the impact that the MUL has had on land and house prices, as well as to examine the historical use of growth limits in Auckland and how they fit with relevant planning legislation (the Resource Management Act). The study notes that MULs have been used for the past fifty years in Auckland, so their use under the 1998 Regional Growth Strategy is not new. In earlier years, the prime motivation for their use was to avoid inefficient and expensive provision of urban infrastructure but "in more recent times the emphasis has switched to protection of the environment in the area outside the MUL" (ARGF, p.4).

The study reported modelling work on the impact of the MUL on land prices. It found that for areas near the MUL, land inside the boundary was worth more than land outside; the ratio of inside land value to outside land values across all parts of the MUL was greater than unity and reached 3.9 for one part of the boundary (North Shore City) in 1996. These results are consistent with the MUL constraining effective land supply for urban purposes, causing a step change in the return to land inside the boundary relative to the (mainly agricultural) return earned by land just outside the boundary.

In interpreting this result, the ARGF noted that reasons for this result could also include topography, greater provision of infrastructure (e.g. sewerage) for land inside the MUL and high amenity value for land just inside the MUL due to residents pricing in easy access to the countryside. The report suggested that this latter factor "could push up land prices near the MUL relative to other parts of the urban area that don't have such good access to the countryside" (p.3). The study found some evidence of higher amenity values within the MUL in some locations, but not in others.

The underlying research on which the Auckland Regional Growth Forum report was based has not been published. It is therefore unclear how the results were derived and whether the interpretation published in the Regional Growth Forum report is a consistent reflection of the underlying research findings. In addition, several more years of data are now available with which to evaluate the effect of the MUL on Auckland land prices. The current study conducts an analysis of these effects. It does so within the context of a model of wider Auckland land values. This model assists in understanding not only the MUL impact, but also the impact on land values of distances from various key nodes (including the CBD), distance from the coast, differential effects across local authorities and types of land (e.g. rural versus other). In some estimates, we control for the impact of social variables such as population density, incomes and levels of relative deprivation which in turn will reflect amenity effects referred to be the ARGF. By controlling for a wide range of factors that may otherwise affect land values, we are able to identify the impacts of the MUL boundaries on land prices around Auckland.

The paper proceeds as follows. Section 2 describes our methodology, followed by a brief description of our data (section 3). Results are presented in section 4, using a number of specifications and estimation techniques. Conclusions are contained in section 5.

2 Methodology

The emphasis of our study is on the effects of the metropolitan urban limits (MUL) on Auckland land prices. We examine the boundary effects of the MUL within the context of a model of land prices across Auckland. Specifically, we model the per hectare land value of each meshblock in the greater Auckland region, comprising the seven territorial local authorities (TAs): Rodney, North Shore, Waitakere, Auckland City, Manukau, Papakura and Franklin. A meshblock is the smallest area used to collect and present statistics by Statistics New Zealand. The size of a meshblock depends primarily on the number of people and type of area covered. Meshblocks in rural areas generally have a population of around 60 people, while in urban areas a meshblock is roughly the size of a city block and contains approximately 110 people (source: Statistics New Zealand).

We denote the per hectare land value in meshblock j at time t as LMB_{jt}. For all our estimates, we deflate LMB_{jt} by land prices in other major North Island cities (LWH_t), where the latter is proxied by the average of the per hectare land price in each of the next two largest North Island cities, Wellington and Hamilton. In our baseline model, the relative land value [$\ln(LMB_{jt}/LWH_t)$] is modelled as a function of distance from the coast, distance from the CBD, distance from other key nodes, TA effects, impacts of being inside or outside the MUL, plus a 'rural' variable. An extended model also includes the influence of social variables (income, relative deprivation and population density).

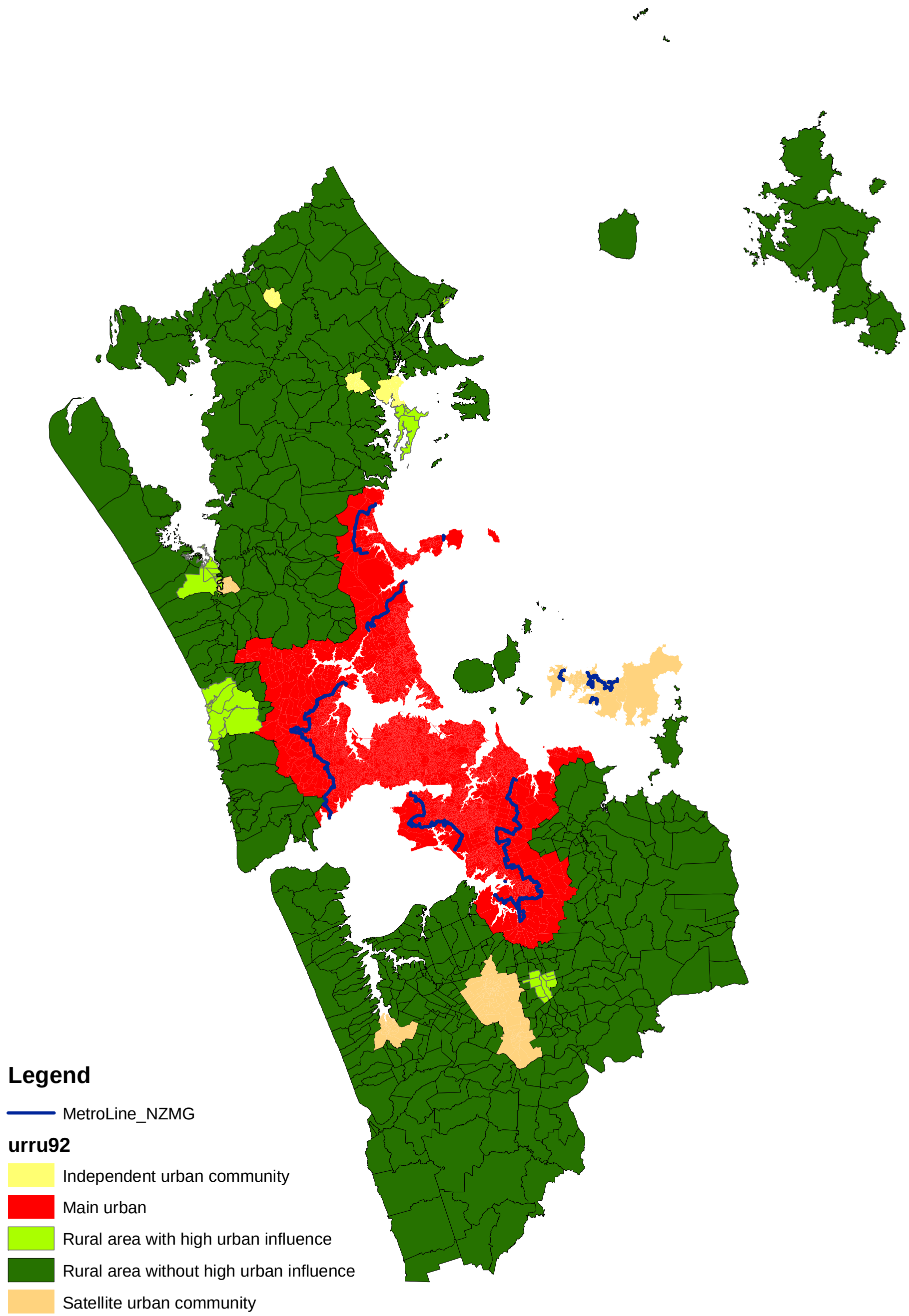
Distance of meshblock j to the coastline is denoted $COAST_j$. The distance in kilometres (km) is measured from the geographic centroid of the meshblock to the nearest point on the coastline.

Distances from the CBD and other nodes are measured as the distance of the centroid of meshblock j from the centroid of the Auckland CBD (taken to be the Britomart transport centre) and other chosen "peak points" throughout the region. The choice of non-CBD peak points recognises that Auckland is a polycentric city; hence land values are a function of multiple activity nodes throughout the region. This is particularly apparent in the more 'far-flung' parts of the greater Auckland region where provincial centres, such as Wellsford, are local nodes of activity. It is also apparent within the urban area where former provincial centres, such as Manurewa, still form local activity nodes.

To the north and west of the urban area, the following nodes are adopted: Wellsford, Leigh, Mahurangi, Omaha, Warkworth, Snells Beach, Orewa, Helensville, Parakai, Muriwai, Kumeu and Piha. To the south of the urban area, Pukekohe, Waiuku and Bombay are chosen. Within the urban area, in addition to the CBD, nodes are: Takapuna, Newmarket, Pakuranga, Mangere Airport, Otahuhu, Manukau City, Manurewa and Papakura.

The choice of nodes is made on the basis of two approaches. First, we include those areas beyond the metropolitan area defined by Statistics New Zealand in its Urban/Rural Profile for 1992 (the start of our sample) as 'satellite urban community', 'independent urban community' and 'rural area with high urban influence'. Map 1 indicates these areas and areas that we define as 'rural area without high urban influence'. Second, within the metropolitan area, we inspect the data for 1991 identifying localized high-priced areas reflecting obvious activity nodes (such as Newmarket or Mangere Airport) and/or historic centres (such as Papakura and Manurewa).

Figure 1: Map 1: Urban profile for 1992



Source: Statistics New Zealand

The distance of meshblock j from node k is denoted $DIST_{jk}$ subject to imposition of a minimum distance of 0.25km, even where the meshblock is the node. The same minimum is adopted for $COAST_j$. The reasons for adopting the 0.25km minimum are twofold. First, each meshblock has positive area, so zero distance is not a complete characterization of the distance of a meshblock from the local node (or coast) even where that meshblock forms the local node. The chosen minimum (250 metres) is a short walking distance so appears reasonable as a characterization of a meshblock from its own centroid.

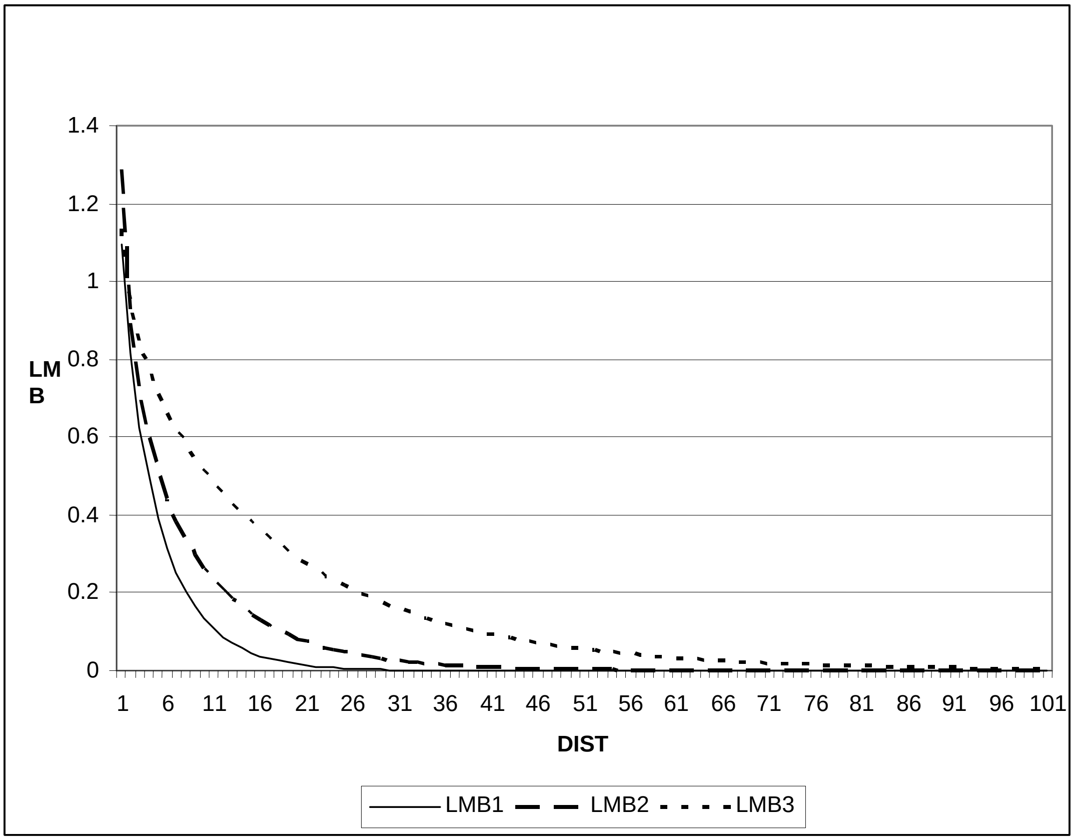
Second, we model the effects of distance by a non-linear function that includes a logarithmic transformation; thus zero is a non-eligible distance value. For each relevant distance, we model the natural logarithm (ln) of LMB_{jt} as a function of both $DIST_{jk}$ and $\ln(DIST_{jk})$ plus a constant (covering the relevant area). This enables freely estimated functions that vary non-linearly with distance where the degree of non-linearity is chosen by the data. The same non-linear functional form is chosen to measure the effect of distance from the coast on meshblock land value.

For example, Figure 2 demonstrates the effects of distance on LMB (holding LWH constant and omitting sub-scripts for clarity) for alternative values of a_1 and a_2 in expression (1):

$$LMB = \exp\{a_1 * DIST + a_2 * \ln(DIST)\} \qquad (1)$$

In the figure, LMB1, LMB2, LMB3 have (a_1, a_2) respectively as (-0.2, -0.1), (-0.1, -0.2) and (-0.05, -0.1). Relative impacts of distance across locations can be ascertained by taking the ratio of the value for LMB at one distance to that for another distance. For instance, for LMB1, the value at 0.25 km is 1.093, whereas the value for the same variable at 5 km is 0.313. Thus centrally-located land is valued at 3.5 (=1.093/0.313) times land that is 5 km distant from the centre in this example.

Figure 2: Price as Non-linear Function of Distance



We cap distance from the coast and distance from all nodes other than the CBD at 5 km (i.e. the effect beyond 5 km from the node or coast is assumed identical to the effect at 5 km). The reason for imposing this constraint is to reflect the idea that a local node has only a local effect on land values. For instance, the effect of Manurewa (in Auckland's south) on any area north of the isthmus must reasonably be expected to be zero no matter what the distance of the (northern) meshblock is from Manurewa. No distance cap is placed on the effect of distance from the CBD. We expect each of the overall distance effects to be negative over the relevant range except possibly where a feature has a localized negative amenity effect (as could occur, for example, with an airport).

We make use of a further feature of the Statistics New Zealand urban/rural profile for 1992. Specifically, we include a dummy variable (rural92) in the equation for meshblocks that we have categorised as 'rural area without high urban influence'.

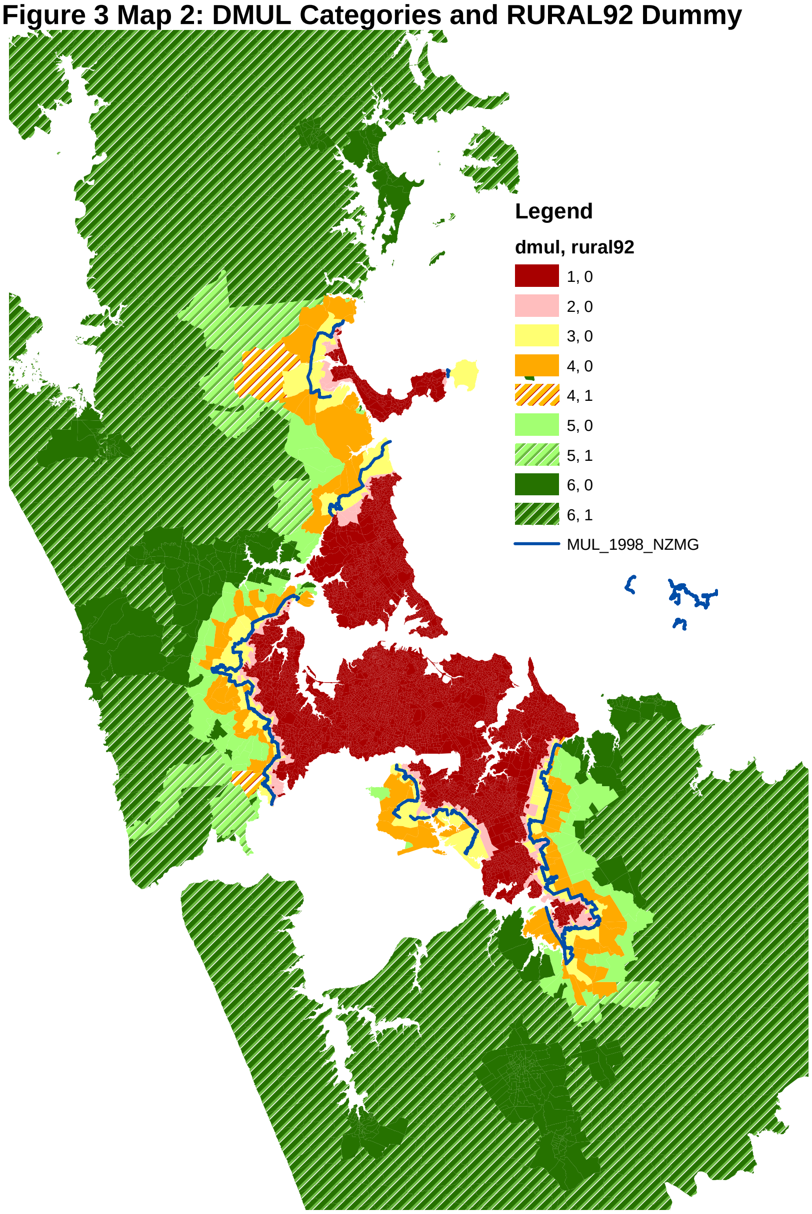
MUL impacts are captured by use of dummy variables. We construct six variables, $DMUL1_j$, …, $DMUL6_j$, (where each dummy variable is either 0 or 1 for meshblock j), that start from the inner urban area moving outwards. Meshblocks that lie wholly inside the (1998) MUL boundaries have either $DMUL1_j$=1 or $DMUL2_j$ =1. The distinction between the two is that meshblocks contiguous with the MUL (or contiguous with a meshblock that has the MUL running through it) have $DMUL2_j$=1 and $DMUL1_j$=0; all other 'inner' meshblocks have $DMUL1_j$=1 and $DMUL2_j$=0. Meshblocks that have the MUL running through them are called 'cross meshblocks' and have $DMUL3_j$=1. Meshblocks that lie fully outside the MUL have one of $DMUL4_j$, $DMUL5_j$ or $DMUL6_j$=1. Meshblocks with $DMUL4_j$=1 lie fully outside the MUL but are contiguous with it or with a cross meshblock. Meshblocks with $DMUL5_j$=1 lie immediately outside the meshblocks with $DMUL4_j$=1; all other meshblocks have $DMUL6_j$=1.

The reason for including a layer of meshblocks ($DMUL5_j$=1) just outside those with $DMUL4_j$=1 is twofold. First, there is a possibility at all times that the MUL may be shifted outwards. The stated policy is that any such shift should be contiguous with the existing metropolitan area. This policy stance, coupled with a positive probability of a future outward shift of the growth boundary imparts an option value for meshblock land just outside the existing MUL. This may affect both neighbouring meshblocks and those a little further out but to differing degrees. Second, it is possible that undeveloped land contiguous with built-up areas is less attractive in an amenity sense than land slightly further distant. Additionally, zoning rules relating to lot size, building type, allowable activities, etc may apply differentially to areas that are slightly further distant from the metropolitan edge. We have no specific information on these variables, so these effects, if present, are incorporated in the estimated DMUL coefficients.

We hypothesise that land just outside the MUL (i.e. with $DMUL4_j$=1) will be valued less than land inside the growth boundary ($DMUL1_j$=1 or $DMUL2_j$=1), with cross meshblocks ($DMUL3_j$=1) being valued in between since some of their land is within and some outside the MUL boundary. We do not have strong priors on whether land just inside the MUL (i.e. with $DMUL2_j$=1) will be valued more or less highly than inner-most land ($DMUL1_j$=1) after controlling for distance and other effects. It is possible, especially in early years, that this land is more rural in character and therefore valued at a lower rate than inner-most land, but as the metropolitan area has expanded DMUL2 land will no longer bear this discount. We let the data indicate the relevant patterns for each year.

Map 2 depicts the MUL dummies, together with the 1998 MUL boundaries. It also depicts the rural dummy used for the study. In estimation, we omit DMUL1j from the equation, so all results are expressed relative to the inner-most (main urban) meshblocks.

Figure 3 Map 2: DMUL Categories and RURAL92 Dummy



A further group of variables that we include in our baseline equation is a set of dummy variables representing the different TAs in the region. Each of six TAs – Rodney ($TA4_j$), North Shore ($TA5_j$), Waitakere ($TA6_j$), Manukau ($TA8_j$), Papakura ($TA9_j$) and Franklin ($TA10_j$) - has a dummy =1 when meshblock j is in that TA and 0 otherwise. Auckland City is excluded, so coefficients on the TA dummies indicate any systematic variation in land values by TA relative to Auckland City, after controlling for other effects. Such differences may relate to different social amenities, infrastructure and/or property taxes (rates).

The resulting baseline equation is presented as (2):

$$\begin{aligned}
\ln(LMB_{jt}/LWH_t) = \Sigma_k \{ \alpha_k + \beta_k{*}DIST_{jk} + \gamma_k{*}\ln(DIST_{jk}) \} \\
+ \delta_1{*}COAST_j + \delta_2{*}\ln(COAST_j) \\
+ \varepsilon_2{*}DMUL2_j + \varepsilon_3{*}DMUL3_j + \varepsilon_4{*}DMUL4_j + \varepsilon_5{*}DMUL5_j + \varepsilon_6{*}DMUL6_j \\
+ \varphi_4{*}TA4_j + \varphi_5{*}TA5_j + \varphi_6{*}TA6_j + \varphi_8{*}TA8_j + \varphi_9{*}TA9_j + \varphi_{10}{*}TA10_j \\
+ \eta_1{*}RURAL92_j + \mu_{jt} \qquad (2)
\end{aligned}$$

Within (2), k=0 represents the CBD (Britomart); k>0 represent the other 23 nodes; μ_{jt} is the residual term (discussed further below).

All variables included in the baseline model with the exception of RURAL92 are distance or administrative variables; all are treated as exogenous. The baseline specification recognizes that land values are driven by human decisions, especially location decisions, relating to each of these variables. In some circumstances, location decisions (and hence land values) are also affected by other agents' location decisions. For instance, the neighbourhood effects literature (Haurin et al, 2003) indicates that people will bid more highly for land located near wealthier and/or higher status individuals. Population density may also affect the value placed on land, both directly (through increasing the number of people bidding for a particular area of land) and indirectly (e.g. through increased provision of social amenities catering for the denser population).

Omission of controls for these effects could bias the coefficient estimates in the baseline model. However it is also the case that each of these 'social' control variables reflects the physical and administrative features (e.g.

population density is greater around the coast reflecting the benefits of living in a coastal location). They may also be endogenous (e.g. population density may be affected by land values). Inclusion of their effect could therefore bias the coefficient estimates in the opposite direction.

To test the robustness of our results (and to provide what we consider as reasonable upper and lower bounds for our estimated coefficients), we estimate a second, extended, model. This model includes all variables in the baseline model with the addition of three variables measuring: the median income in the meshblock in 1991 ($MEDINC1991_j$), the meshblock's population density in 1991 ($POPDENS1991_j$) and a summary measure ($NZDEP1991_j$) of the meshblock's relative deprivation status in 1991 (Crampton et al, 2000). We expect the first two of these variables to have positive coefficients and the third to be negative. Each of these variables is measured in 1991, the year before the start of our sample, to minimize endogeneity problems.

The residual term, μ_{jt}, may exhibit a number of non-classical properties. First, it may be heteroskedastic; we therefore use heteroskedasticity-adjusted standard errors (all reported significance tests are based on these standard errors).

Second, we have the potential for spatial autocorrelation which is common in similar studies (e.g. Samarshinghe and Sharp, 2007). Spatial autocorrelation is present when the error in one meshblock is (positively or negatively) related to the error in a spatially proximate meshblock. Spatial proximity here may be measured by distance between meshblock centroids. Our use of distance functions from 24 nodes (including the CBD) and from the coast is designed to lessen the problems of spatial autocorrelation. Initially, therefore, we estimate the baseline and extended models by OLS and test the residuals for spatial autocorrelation using Moran's I statistic (a spatially analogous test to the Durbin-Watson time series autocorrelation test).

If spatial autocorrelation is indicated by the Moran I test, we test the robustness of our results by estimating three further models using both the baseline and extended specifications. First, we estimate these models supplemented by area unit effects by adding 350 dummy variables for area units (which are akin to 'suburbs') to our models. Second, we estimate a spatial lag model and, thirdly, we estimate a spatial error model. Each of the latter two models requires specification of a spatial weight matrix; we use distance between meshblock centroids as the basis for specifying these weights. We then examine the robustness of our estimates of the boundary effect across the different models using the different estimation techniques.

3 Data

All distance data, TA boundaries and coastal boundaries have been derived using standard GIS techniques, employing linear distances. RURAL92 data and definitions of other urban and rural types are obtained from Statistics New Zealand (urban/rural profile for 1992). The Statistics New Zealand 1991 census is the source of data for MEDINC1991, POPDENS1991 and (indirectly) for NZDEP1991.

MUL boundary data, obtained from Auckland Regional Council, refers to the MUL boundaries set in 1998. Since that time, there have been four, mostly minor, boundary changes, mostly at the end of our sample (between 2002 and 2005); their effects may not be reflected in rateable values (our land value data source) up to 2004. We therefore use the 1998 boundaries throughout our analysis. We note here that the MUL did not exist formally prior to 1998, although its 1998 boundaries to a large extent mirrored pre-1998 zoning boundaries. It is possible, therefore, that the estimates of the MUL boundary effect in earlier years will show a lesser effect than for the estimates of 1998 and beyond.

Our land value data are described fully in Grimes and Liang (2007). Land values (i.e. rateable values for land used for property tax purposes) are obtained from Quotable Value New Zealand for meshblocks in each of the seven TAs. Revaluations take place mostly on a three-yearly rotational basis. We have interpolated these data to annual frequency using vacant section sale price data for each TA. The interpolation is undertaken so that we can compare land values across the region for any given year (given that land is valued in different years within a triennial cycle in different TAs).

Since the underlying values are obtained triennially, we estimate our equations for every third year. We have full data from 1992 through to 2003 for every TA and through to 2004 for all TAs other than Papakura and Franklin. We estimate our models for the years 1992, 1995, 1998, 2001 and 2003. For each of these years we have approximately 8,000 meshblock observations. Additionally, we have estimated the same models for five TAs (i.e. excluding Papakura and Franklin) for each of the earlier years plus 2004 in place of 2003. By estimating the models for different years, we can assess how the spatial relationships alter over time.

Prior to estimation, we examine some summary statistics for land values in the context of our MUL dummy variable (DMUL) definitions. Table 1 summarizes real per hectare land values for land covered in each of the DMUL categories plus the total for the greater Auckland region. All values have been deflated by the average of Hamilton and Wellington land values; hence the figures represent per hectare values relative to average land values in these other two cities.

A number of factors are apparent from Table 1. First, land prices decrease monotonically from DMUL1 land to DMUL5 land for every year. The average value for DMUL6 land, which includes some high priced nodes plus coastal as well as rural land is, on average, higher than other land beyond the MUL boundary (but less than land inside the boundary).

Second, all categories of land within the Auckland region have increased in value over the sample relative to land in Hamilton and Wellington cities. Even DMUL2 land (i.e. on the outskirts of the Auckland metropolitan area) was worth 2½ times the value of Hamilton and Wellington land in 2003.

Table 1: Summary by DMUL Status of Real Per Hectare Land Value

Year:	1992	1995	1998	2001	2003	Obs.	% change: 1992-2003
DMUL1	3.933	3.581	4.708	5.164	6.268	6524	59%
DMUL2	1.782	1.797	2.344	2.182	2.520	281	41%
DMUL3	0.923	0.919	1.268	1.210	1.413	183	53%
DMUL4	0.125	0.134	0.161	0.170	0.216	92	73%
DMUL5	0.132	0.130	0.156	0.154	0.183	77	39%
DMUL6	0.434	0.425	0.568	0.566	0.595	883	37%
Total	3.325	3.039	3.997	4.359	5.276	8040	59%

Note: All measures in the table use a consistent sample of meshblocks throughout the sample period.

Third, real rates of increase in land values have varied across the region according to DMUL category. The total real rate of increase in land values is equal to that for the 'inner' area and exceeds all other categories except for land just outside the MUL boundary. The 73% (real) increase in DMUL4 land could indicate an increased option value for land just beyond the MUL, reflecting a perceived increasing probability of an outward shift in the MUL as real Auckland land values escalate. Alternatively, it may reflect an increasing amenity value for properties beyond the urban limit. Other than for this category, the highest rate of increase in land values is for the core metropolitan area (DMUL1). Its rate of increase exceeded that for the peripheral metro area (DMUL2); the latter may already have been priced (in early years) to reflect development potential. Alternatively, agglomeration and congestion factors may be reflected in a higher premium for inner relative to outer parts of the metropolitan area.

Table 2 splits the MUL boundary into four separate segments that we label: Rodney, North Shore, Waitakere and Manukau/Papakura. These four segments reflect four distinct MUL boundaries depicted in Map 2. (The small segment of land to the west of Manukau is excluded as a separate segment but is included in the Total figure.) The table reports, for each year, the ratio of the mean per hectare land value within DMUL2 for each segment relative to the mean per hectare land value within DMUL4 for that segment.

Table 2: Ratio of DMUL2:DMUL4 Land Value (per hectare) by MUL Segment

Year	1992	1995	1998	2001	2003
Rodney	22.609	24.146	22.995	19.353	17.836
North Shore	16.390	17.034	17.680	15.591	16.964
Waitakere	9.041	11.467	13.177	12.791	12.343
Manukau/Papakura	15.766	15.091	15.660	14.035	12.301
Total	14.438	14.589	15.580	14.004	13.054

Note: All measures in the table use a consistent sample of meshblocks throughout the sample period.

The total ratio stayed fairly constant throughout the sample with land just inside the MUL being 13-16 times as valuable (per hectare) as land just outside the MUL boundary. Patterns differed across segments, however, with a declining ratio in Rodney and Manukau/Papakura and an initially increasing ratio in Waitakere.

These raw figures indicate a prima facie case for a boundary effect around the MUL across all MUL segments. However these figures do not control for other effects (e.g. proximity to the coast, distance from the CBD or social and physical amenity values). Our estimates in the next section are designed to estimate the boundary effects more precisely after controlling for such effects.

4 Results

Results from estimating the baseline model as separate cross-sections for each of 1992, 1995, 1998, 2001 and 2003, using OLS, are presented in Table 3. Meshblocks from all seven TAs are included in each of these cross-sections. For clarity, we present all coefficients other than those pertaining to the non-CBD nodes.[1] We have also estimated the same model for 5 TAs (excluding Papakura and Franklin) through to 2004. These results are very similar to the 7 TA case, so we concentrate our discussion solely on the 7 TA results.[2]

[1] Distance functions for the non-CBD nodes are almost all negative and frequently significant, as expected. Full results are available on request.
[2] The 5 TA results are available on request.

Table 3: Baseline Model : OLS Results

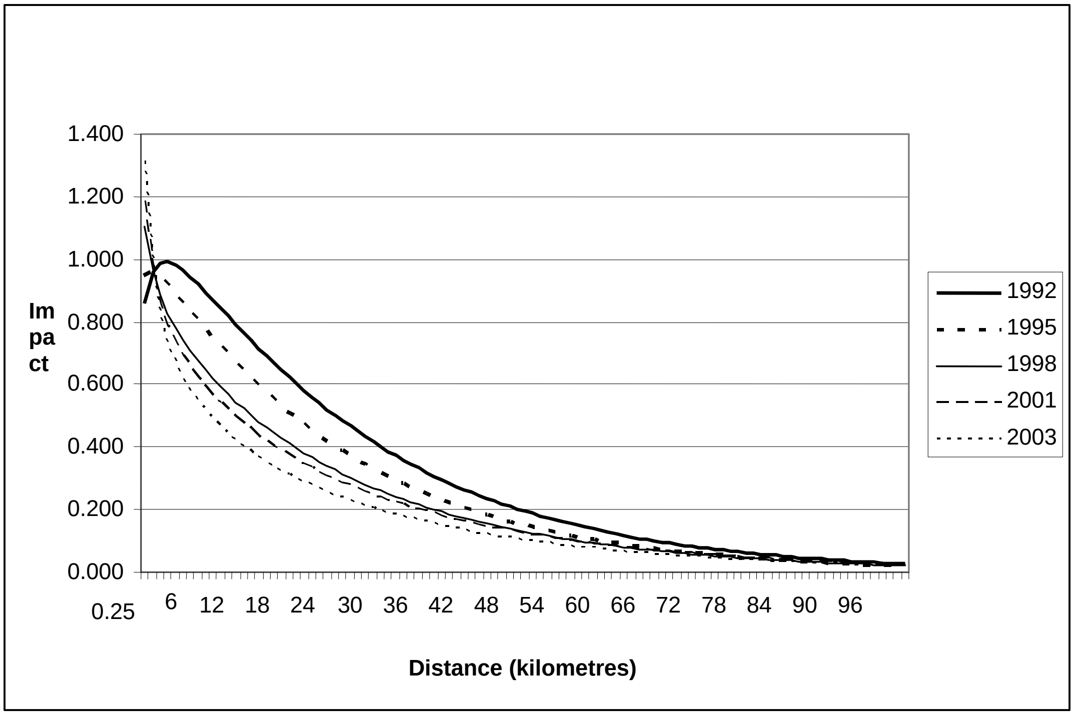
Baseline Model: 7 TAs	Dependent Variable is ln(LMB/LWH)				
Explanatory Variables:	**1992**	**1995**	**1998**	**2001**	**2003**
DMUL2	-0.295***	-0.187***	-0.113**	-0.069	-0.030
DMUL3	-1.362***	-1.129***	-1.028***	-0.922***	-0.817***
DMUL4	-2.667***	-2.642***	-2.682***	-2.624***	-2.491***
DMUL5	-2.466***	-2.336***	-2.418***	-2.454***	-2.302***
DMUL6	-2.231***	-2.064***	-2.169***	-2.208***	-2.042***
TA4	-0.784***	-0.230**	-0.369***	-0.432***	-0.606***
TA5	0.115***	0.323***	0.042	-0.307***	-0.235***
TA6	-0.438***	-0.0972***	-0.285***	-0.532***	-0.505***
TA8	0.069	0.507***	0.297***	0.078	0.109**
TA9	-0.291*	-0.148	-0.084	-0.505***	-0.813***
TA10	0.078	0.456***	0.024	-0.214*	-0.284***
RURAL92	-1.034***	-1.245***	-1.222***	-1.202***	-1.256***
COAST	-0.003	0.004	-0.014	0.005	-0.003
ln(COAST)	-0.103***	-0.105***	-0.0872***	-0.101***	-0.0937***
CBD	-0.0408***	-0.0404***	-0.0349***	-0.0316***	-0.0298***
ln(CBD)	0.103**	0.032	-0.0766*	-0.131***	-0.203***
Observations	7716	8005	8019	8059	8051
R-squared	0.729	0.729	0.768	0.783	0.804
*** p<0.01, ** p<0.05, * p<0.1					
In addition, an overall equation constant plus constant terms, linear terms and logarithmic terms relating to 23 other nodes are included in the equation, but not reported for clarity.					

Baseline Model: Non-MUL Terms

Coefficients on the distance functions for both COAST and CBD are such that there is a negative effect of both variables over their relevant ranges (i.e. for all distances in the case of CBD,[3] and up to 5 km in the case of the coast). This occurs even where one of the linear or logarithmic coefficients is positive. To demonstrate this more clearly, the impact of distance from the CBD on land values for each year is plotted in Figure 4.

[3] Other than a slight non-monotonicity at short distances in early years, as discussed below.

Figure 4: Impact of Distance from CBD on Real Land Values: Baseline Model



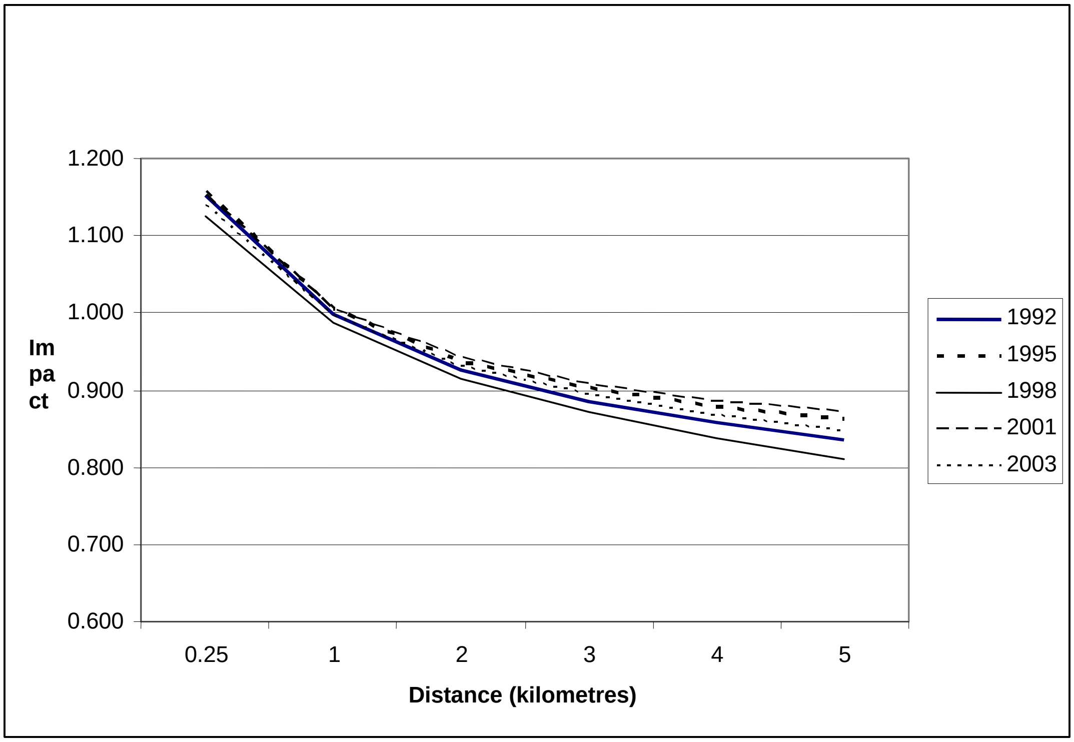
In Figure 4 the impact of distance from the CBD on real land values in Auckland has changed virtually monotonically from 1992 to 2003. In 2003, the impacts of distance from the CBD at 0.25 km, 5 km, 25 km and 50 km were 1.315, 0.621, 0.247 and 0.102 respectively. Thus land within the CBD was valued at just over twice the rate of land 5 km distant,[4] five times the rate of land 25 km distant, and almost thirteen times the rate of land 50 km distant. In 1992, by contrast, land values rose slightly over the first three kilometres (and were still slightly higher at 5 km than at the heart of the CBD. The ratios of CBD land value to land at 25 and 50 kms were 1.7 and 4.4 respectively in 1992.

Land value has therefore become more concentrated in the area close to the CBD between 1992 and 2003. This is consistent with increasing agglomeration effects based on the CBD. This result is important for understanding the evolution of the Auckland economy, and may also be important in interpreting the MUL boundary effects that we examine subsequently.

[4] I.e. = 1.315/0.621 = 2.12 .

Figure 5 graphs the impact of distance from the coast on land values. Unlike the CBD distance effect, the effect of distance from the coast on the real value of land around Auckland has been remarkably consistent over time. Furthermore, changes have not been consistently in one direction; the 2003 effect is very close to that of 1992. Overall, a coastal location has commanded a premium over locations that are more distant from the coast over the whole period.

Figure 5: Impact of Distance from Coast on Real Land Values: Baseline Model



Of the other non-CBD variables, the coefficient on RURAL92 indicates that rural land is consistently cheaper than urban land even after accounting for distance and other effects. The TA dummies show that Auckland City is generally slightly more expensive than most TAs, other than Manukau. Franklin tended to be more expensive earlier in the period but not in later years.

Explanatory power of each of the equations is high for a cross-section with 8,000 observations. The R^2 statistic increases throughout the period from 0.729 in 1992 and 1995 to 0.804 in 2003. Overall, the high explanatory power and the sensible coefficients on each of the non-MUL terms give confidence that the MUL boundary effects are estimated within the context of a suitable model for urban and peri-urban land values.

Baseline Model: MUL Boundary Effects

In interpreting the MUL boundary effect, we first examine the behaviour of prices just within the MUL boundary. If the broader model is suitable for modelling land values across the region, we would expect that prices just within the MUL boundary will not be significantly different from those well within the boundary once distance and other controls have been accounted for. The exception would be if there were still major holdings of rural land within this 'zone'.[5]

Meshblocks in this zone have DMUL2=1. The coefficient on this term for the baseline equations in Table 3 are not significantly different from zero in either 2001 or 2003 implying that in later years the overall model fits the value of land situated just inside the MUL boundary as well as it fits land that is closer to the CBD. In prior years, this zone of land is slightly under-priced relative to the overall model, with the degree of under-pricing increasing as the sample goes backwards. This finding is in keeping with the hypothesis that a greater portion of this land was rural earlier in the period than in later years. Overall, the DMUL2 coefficients imply that the model is valuing land close to the MUL boundary in a satisfactory manner.

Land situated just outside the MUL boundary has a sharply decreased price compared with land situated just inside the MUL even with the inclusion of distance and other controls. In 1992, the difference between the coefficients on DMUL2 and DMUL4 was 2.372; since then the difference in coefficients has varied in a tight range between 2.455 and 2.569. Noting that the dependent variable in equation (2) is logarithmic, these coefficients indicate that land just

[5] This land is not classed as rural according to the Statistics New Zealand definition which classifies land as rural only for land that is well outside the 1998 MUL boundary.

inside the MUL boundary is around 12 times more expensive per hectare than is land situated just outside the MUL.[6]

If this figure is caused by an MUL boundary effect, we would expect the cross meshblocks (DMUL3=1) to reflect the partial effect of the MUL, as indeed occurs. Each of the DMUL3 coefficients is significantly negative. Consistent with the declining coefficient on DMUL2, the coefficient on DMUL3 has been declining sharply over time, suggesting that much of the land in these cross meshblocks is now being developed or being priced for future development.

The MUL boundary effect declines as distance from the MUL increases (in an outward direction). For every period, the coefficient on DMUL4 exceeds that on DMUL5 which exceeds that on DMUL6. This indicates that the basic model (excluding the MUL dummies) fits the data better as distance from the MUL boundary increases, reinforcing the interpretation that the boundary effect indicated by the difference between the DMUL2 and DMUL4 coefficients is indeed related to the existence of the MUL boundary.

Extended Model

Results from estimating the extended model as separate cross-sections for each of 1992, 1995, 1998, 2001 and 2003, using OLS, are presented in Table 4. Meshblocks from all seven TAs are included in each of these cross-sections; again we present all coefficients other than those pertaining to the non-CBD nodes.[7]

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[6] I.e. exp(2.5)=12.18.

[7] One or more of the social variables included in the extended model is not available for a few meshblocks, so the number of observations falls slightly relative to the baseline model. We have estimated the extended model for 5 TAs (excluding Papakura and Franklin). Again, the results are very similar so we confine our discussion to the 7 TA estimates.

Table 4: Extended Model : OLS Results

Extended Model: 7 TAs	Dependent Variable is ln(LMB/LWH)				
Explanatory Variables:	**1992**	**1995**	**1998**	**2001**	**2003**
DMUL2	-0.168***	-0.109**	-0.041	-0.032	-0.002
DMUL3	-1.037***	-0.892***	-0.792***	-0.780***	-0.680***
DMUL4	-2.235***	-2.263***	-2.311***	-2.380***	-2.255***
DMUL5	-2.038***	-1.970***	-2.046***	-2.191***	-2.051***
DMUL6	-1.698***	-1.607***	-1.737***	-1.886***	-1.747***
TA4	-0.778***	-0.269***	-0.393***	-0.449***	-0.629***
TA5	-0.0662**	0.132***	-0.121***	-0.471***	-0.382***
TA6	-0.352***	-0.023	-0.226***	-0.492***	-0.467***
TA8	-0.191***	0.239***	0.065	-0.132***	-0.0781*
TA9	-0.470***	-0.340***	-0.247**	-0.678***	-0.968***
TA10	-0.083	0.255**	-0.142	-0.360***	-0.419***
RURAL92	-1.134***	-1.285***	-1.254***	-1.257***	-1.293***
COAST	0.013	0.010	-0.008	-0.001	-0.010
ln(COAST)	-0.145***	-0.131***	-0.115***	-0.110***	-0.101***
CBD	-0.0285***	-0.0271***	-0.0242***	-0.0212***	-0.0204***
ln(CBD)	0.036	-0.055	-0.131***	-0.214***	-0.276***
NZDEP1991	-0.0896***	-0.0941***	-0.0795***	-0.0698***	-0.0628***
POPDENS1991	0.0285***	0.0268***	0.0249***	0.0180***	0.0167***
MEDINC1991	0.0145***	0.0154***	0.0142***	0.0138***	0.0125***
Observations	7586	7859	7868	7898	7890
R-squared	0.808	0.81	0.832	0.832	0.845
*** p<0.01, ** p<0.05, * p<0.1					
In addition, an overall equation constant plus constant terms, linear terms and logarithmic terms relating to 23 other nodes are included in the equation, but not reported for clarity.					

The distance effects are calculated to be very similar to those in the baseline model, with land values becoming more concentrated towards the city centre over time. In 2003 the ratios of land values within the CBD relative to those 5, 25 and 50 km distant are calculated at 2.5, 5.9 and 12.0 respectively. This compares with ratios of 1.0, 1.7 and 3.4 respectively in 1992. As in the baseline model, coastal effects have remained broadly constant over time. Rural and TA effects are similar to the baseline model.

The three social variables are all highly significant with the expected signs. Meshblocks with high population density and high median incomes are valued more highly than other meshblocks, while more deprived areas are associated with low land values. As discussed earlier, the direction of causality in these relationships could run both ways (unlike the direction of causality using distance measures, which can only be uni-directional).

Very similar patterns are observed for each of the MUL variables as in the baseline model. The coefficient on DMUL2 (i.e. on meshblocks just inside the MUL boundary) declines monotonically throughout the sample as does the coefficient on the cross meshblocks (DMUL3). The difference between the coefficients on DMUL2 and DMUL4 rises between 1992 and 1998, and stays between 2.25 and 2.35 over 1998 – 2003. In 2003, land just inside the MUL is valued at 9.5 times that just outside the MUL. In every year, the MUL effect declines as distance outside the MUL increases.

These results control for the effects of population density and also for characteristics of residents that may in turn impact on land prices. One argument previously cited to account for higher values of land inside relative to outside the MUL boundary is that people value the rural amenity value of being on the outskirts of the city (i.e. just within the MUL). This will bid up prices for land just inside the MUL boundary, possibly creating an artificial distinction between land values on either side of the boundary.

Our results indicate that this is not likely to be part of the explanation for the observed boundary effect for two reasons. First, the estimate for DMUL2 is not significantly different from zero in later years (and is negative in earlier years). Thus the distance variables are capturing the values of land just inside the MUL boundary, implying that there is no extra amenity value placed on this land. Second, even if there were such higher amenity value, it is likely that higher income (and less deprived) households will move into the sought-after area. Our extended model controls for these household characteristics and hence indirectly controls for such amenity values.

Spatial Autocorrelation

Both the baseline and extended models have been estimated with OLS. The significance tests employ standard errors that are robust to heteroskedasticity. However, there is still the possibility that spatial autocorrelation will be present which may bias the coefficient estimates and/or make them inefficient (Anselin, 1988).[8]

We test for the presence of spatial autocorrelation in our estimated models using Moran's I statistic (a spatial analogue of the Durbin-Watson test). The null hypothesis is that there is no spatial autocorrelation in the residuals. We are unable to calculate Moran's I for the complete set of residuals owing to computer memory constraints given the large dataset that we are using. Instead, we test for autocorrelation amongst the residuals (derived from the full model) at the level of each TA. We employ tests at different spatial scales: up to 0.25 km, up to 1 km, up to 2 km, up to 5 km and up to 20 km.

The tests cover the two models (baseline and extended), each for 5 years (1992, 1995, 1998, 2001, 2003), each for 7 TAs with 5 spatial scales: a total of 350 test statistics. Rather than presenting each of these results, we summarize the findings. We find significant spatial autocorrelation for virtually all the results over a range of 0-1 km, 0-2 km and (mostly) over ranges of 0-0.25 and 0-5 km. We do not find spatial autocorrelation over a greater spatial range (0-20 km).

As a result of these tests, we estimate the same underlying relationships using three different techniques. The most basic supplement to our approach is to retain OLS as the estimation technique, but to add dummy variables for area units. There are approximately 350 area units across the greater Auckland region compared with 8,800 meshblocks. Area units are akin to suburbs in a metropolitan area and so may capture the impact of shared amenities and desirable locations. The drawback of this approach is that if the area unit boundaries near the city outskirts are similar to the MUL boundaries, the two effects will be highly collinear and so will make it more difficult to detect the MUL boundary effect.

Second, we estimate a spatial lag model in which values in a meshblock are modelled as a function of underlying determinants and of values in nearby meshblocks. Third, we estimate a spatial error model in which the residual for a

[8] Coefficient estimates will be consistent but inefficient when there is spatial error autocorrelation; they will be biased and inconsistent where a spatial lag model is the true model.

meshblock is modelled as a function of the residuals in nearby meshblocks. Spatial lag and spatial error models in general can be summarized as follows:

$$\mathbf{Y} = \boldsymbol{\rho}\mathbf{WY} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\mu} \tag{3}$$

$$\boldsymbol{\mu} = \boldsymbol{\lambda}\mathbf{W}\boldsymbol{\mu} + \boldsymbol{\varepsilon} \tag{4}$$

$$\boldsymbol{\varepsilon} \sim \mathbf{N}(\mathbf{0}, \boldsymbol{\Omega}) \tag{5}$$

where **Y**, the dependent variable (in our case, real meshblock land values) is an nx1 vector, **X** is an nxk matrix of k explanatory variables as per our baseline and extended models with associated parameters **β**, **W** is a specified row standardized spatial weight matrix (in our case with weights given by distances up to 20 km), **ρ** measures the extent to which one observation is spatially dependent on its neighbours,[9] and **λ** measures the extent to which an error of one observation is related to errors of neighbouring observations.

We have estimated the OLS model with the addition of area unit dummies for the 7 TA sample for each year under examination. The results again show a strong, albeit muted, MUL effect for both the baseline and extended models. The MUL effect increases over most of the period. For instance, in the baseline model, the estimated ratios of DMUL2 to DMUL4 land values are: 2.9 in 1992, 4.3 in 1995, 5.5 in 1998, 6.3 in 2001, and 5.8 in 2003. In the extended model, the corresponding ratios are 2.6 in 1992, rising to 3.5 in 1995, 4.4 in 1998, 4.9 in 2001, and 4.7 in 2003. For the reasons outlined earlier (especially the collinearity between peripheral urban area unit boundaries and the MUL boundary) these estimates are likely to be material under-estimates of the MUL boundary effect.[10]

[9] I.e. similar to the coefficient on a lagged dependent variable in a time series context, but in a two dimensional and bi-directional sense.

[10] Another problem with this approach is that the distance functions (especially the unrestricted functions from the CBD) will now only be detecting distance effects, on average, within area units. This would not be a problem for a linear distance function but is problematic for a non-linear distance function since the slope of the 'true' distance function is different for inner meshblocks than for meshblocks further afield. The estimates with the area unit fixed effects impart the same average slope for each meshblock which could bias the estimates for other coefficients, including the MUL boundary effect. We thank Dave Maré for this observation.

The second, more complex approach is to estimate a spatial lag model (i.e. **ρ**≠0, **λ**=0). Spatial lag models have very large memory requirements and we are unable to estimate the model using all 8,000 observations. Instead we take a 50% stratified random sample where stratification is performed on the basis of the 6 DMUL dummies.

We estimate the model for 2001 and examine whether the results differ substantially from the OLS model. For the baseline model the estimate of **ρ** is 0.349 (significant at 1%); the coefficient on DMUL2 is -0.034 (not significant at 10%) and that on DMUL4 is -2.618 (significant at 1%), implying a ratio of land values across the MUL boundary of 13.2.

For the extended model the estimate of **ρ** is 0.302 (significant at 1%); coefficients on DMUL2 and DMUL4 are 0.044 (not significant at 10%) and -2.268 (significant at 1%) respectively, implying a ratio of land prices across the boundary of 10.1.

The third approach is to estimate a spatial error model, again using the 50% stratified sample. For the baseline model the estimated value of **λ** is 0.966. Estimates of DMUL2 and DMUL4 are similar to before, with the implied ratio of land within DMUL2 being 13.2 times that of DMUL4 land. For the extended model the estimated value of **λ** is 0.956. Estimates of DMUL2 and DMUL4 are again similar to before, with the implied ratio of land within DMUL2 being 10.2 times that of land within DMUL4.

Each of these estimates is similar to the estimates with the OLS model. For the 2001 baseline estimates, the ratio of DMUL2: DMUL4 land values are estimated to be 12.9, 13.2 and 13.2 for the OLS, spatial lag and spatial error model respectively. For the extended model, the comparable ratios are estimated at 10.5, 10.1 and 10.2 respectively. In the case of this dataset, the OLS modelling strategy therefore yields reliable estimates of the parameters of interest even where a spatial lag or a spatial error model is more appropriate. This is perhaps not surprising given that the boundary effect indicated by the raw data is so strong. For this reason, we do not extend the spatial lag or spatial error modelling further.[11]

The only estimates that give a materially different result are those that add the 350 area unit dummies to the OLS equation. These estimates almost certainly provide an under-estimate of the boundary effect. Even here, however, the effect is estimated to be in the order of a factor of 5 (extended model) or 6 (baseline model) near the end of the sample, having risen sharply over time.

5 Conclusions

Land prices summarize the value that agents place on a particular location, subject to constraints on exercising their preferences. The value of a location may reflect use for residential purposes, industrial and commercial purposes, or rural (agricultural and related) purposes. In a regional economy that is not subject to land use constraints (such as zoning), land will be allocated to alternative uses according to the highest private use value for that location.[12]

Once zoning restrictions are introduced into the analysis, certain agents may be thwarted from using particular locations for the uses that they desire even though those uses have the highest private land use values. In these situations, the market value of the affected land will be lower than it would be in an unregulated market, and it will instead be valued at the second-best (or n'th-best) land use.

Growth limits are one form of zoning restriction. If effective, they limit the expansion of a city beyond prescribed boundaries. If they are binding, land immediately on the inward side of the boundary will be valued at a higher rate (per hectare) than land immediately on the outward side of the boundary after controlling for other factors (such as land price gradients from the CBD or the

[11] It would be possible to provide confidence intervals based on a Monte Carlo procedure for the 50% stratified random samples. However the strong similarity of estimated effects across all three approaches coupled with the large computing requirements make this approach superfluous in determining the relevant boundary effects. In addition, we could use LM tests to distinguish between alternative statistical models, but the virtually identical estimated boundary effects again make this superfluous for our analysis.

[12] This does not mean that the resulting land use is efficient; externalities may result in an inefficient allocation, thus forming a prima facie case for zoning decisions and other land use constraints.

coast). If the growth limits do not constitute a binding constraint, the land price gradients will not display a step change at the point of the growth limit.

Auckland formally adopted the Metropolitan Urban Limits (MUL) as a growth boundary in 1998, although these boundaries reflected earlier growth limits. Little analysis has hitherto been conducted to examine the effects of these growth boundaries on Auckland land prices – both generally and at the MUL boundary. Ours is the first publicly available study to do so.[13] We face many challenges in conducting such a study. First, data must be gathered, not just on land values near the boundary, but also on values across the region so that the boundary effects can be modelled in the context of region-wide determinants of land values. Our work in this regard, using Rateable Values (obtained from Quotable Value New Zealand) for land in each meshblock across the seven Auckland Territorial Authorities, is documented in Grimes and Liang (2007). We use that data in this analysis.

A second challenge is to specify a model that captures the highly divergent values of land across urban and rural uses in a diverse region using only a small number of parameters. The same model (but not necessarily the same parameters) should be able to capture values across a span of time exceeding a decade. Our model captures approximately 80% of the variation in land values of around 8,000 observations in each year, thus successfully meeting this challenge.

Our estimated underlying (non-regulatory) determinants of land values across the region all accord with theoretical priors. Specifically: (i) land is highly valued near the city centre, declining (non-linearly) as distance from the CBD increases; (ii) the ratio of CBD land values to outer land values has increased virtually monotonically over time, consistent with greater agglomeration economies since the early 1990s; (iii) land is generally more highly valued near other local nodes than in areas more distant from them; and (iv) land is valued more highly near the coast than in areas more distant from coastal locations.

[13] See Auckland Regional Growth Forum (1999) for reference to unpublished work.

The third challenge is to adopt methods that capture the impact of the MUL boundary on land prices. We do so by incorporating six variables that identify land which is: (i) well inside the MUL boundary, (ii) just within the boundary, (iii) sitting astride the boundary, (iv) sitting just outside the boundary, (v) sitting just beyond the previous areas of land, and (vi) sitting well beyond the boundary. For our model of regional land values to be considered adequate, we require the second category of land (i.e. land just within the boundary) to be modelled systematically by the model in the same manner as land well within the boundary (at least in situations where the land is being used principally for urban purposes – i.e. where the growth limit is binding). Our model meets this challenge, especially in later years when the growth limit is increasingly binding.

Fourth, we subject the model to different specifications that capture the possibility that land values reflect the characteristics of the people living within each area as well as more general location characteristics. Inclusion of such variables may impart a downward bias to the boundary effects estimates if people's location patterns are influenced directly by the growth limit and/or by the price effects of the growth limit. Nevertheless, their omission could bias the boundary effects upwards if there is a significant omitted variable problem caused, for instance, by presence of rural amenity value in certain locations. The latter effects may be correlated with the characteristics of people living in these locations. We estimate a baseline model that excludes such effects and an extended model that includes three such variables. Our findings are robust to inclusion or exclusion of these 'social' variables, albeit with a slightly muted boundary effect where the social variables are included.

Finally, we test whether the estimated parameters are robust to alternative ways of modelling the spatial patterns in the data. Our baseline and extended models are initially estimated using OLS with no explicit regard to the spatial pattern of residuals (other than the inclusion of 24 local nodes for areas that may be expected to have high localized land prices). These estimates display significant spatial autocorrelation. When we re-estimate the models explicitly as a spatial lag model, there is almost no change in the parameters of interest (i.e. the boundary effect). Similarly, when we re-estimate the models as a spatial error model, the parameters remain stable.

The only case where we find a material difference in parameter estimates is where we attempt to soak up spatial autocorrelation through the inclusion of 350 area unit dummies in addition to the other variables in the model. The problem with this approach is that the area unit boundaries near the growth limit may be (exactly or approximately) contiguous with the MUL boundary, in which case the latter will not have explanatory power for the relevant areas over and above the area unit effect. Another problem is that other estimates may be biased due to the inappropriate specification of the distance functions induced by the inclusion of the area unit effects.

As expected, the inclusion of area unit effects reduces the estimated boundary impact. For these models, the estimated boundary effect in 1992 is approximately 2.5 to 3 (i.e. the ratio of land value just inside the boundary is around three times the value just outside the boundary), rising to around 4.5 to 6 over 2001-2003. It is conceivable that the area unit dummies are capturing some amenity effects that are not captured adequately by our other models. However, the estimated boundary effects in the area unit model almost certainly represent an under-statement of the actual boundary effect for reasons outlined above.

All our other estimates of the boundary effect find a boundary land value ratio of between 7.9 and 13.2, with the lower estimates coming earlier in the sample period when the growth boundary is likely to have been less of a binding constraint. These estimates variously control for distance effects (from the CBD, local nodes and the coast), TA effects (reflecting different amenities and property taxes by local authority), rural land-use, social and population factors (population density, incomes and relative deprivation status), spatial lags and spatial errors. The boundary effects near the end of the sample are almost always stronger than the beginning of the sample, albeit with some slight drop-off between 2001 and 2003.

This latter result may relate to the manner in which the boundary effect impacts on land prices throughout the region. A binding constraint on expansion will not be reflected solely on land prices just inside the boundary: the effect will be spread throughout the boundary interior. For instance, a certain location outside the growth limit may, in the absence of restrictions, potentially be used for low-cost housing, but the growth restriction forces would-be residents to locate elsewhere within the urban area (or in a different urban area altogether). They may locate instead in an affordable apartment near the city centre or in a low cost suburb well within the city limits rather than in a larger house near the growth boundary. Price pressures are therefore spread throughout the region.

Our data indicate that Auckland house prices as a whole have risen substantially relative to other urban (Hamilton and Wellington) prices in the North Island. This rise in relative values is likely to reflect, at least in part, the increasingly binding impact of the MUL over time.

The data indicate that the largest relative land price increases between 1992 and 2003 have occurred for land located just outside the urban boundary. This could reflect increasing amenity value being placed on this land or an increasing option value being placed on this land for future development. With overall Auckland land values rising by almost 60% relative to other urban land values over these twelve years, relaxation of the growth limit (consistent with optimal inventory policy posited by Knaap and Hopkins, 2001) is a reasonable conjecture on the part of land-owners and property investors. Some small relaxations in the boundary have occurred in recent years, but too recent for us to be able to model their impacts. Future research will be able to examine what impacts these specific relaxations have had on local land prices.

Other work for which the zoning effects are relevant includes analysis of infrastructure investments that extend beyond the Auckland metropolitan boundary. For instance, Auckland's northern motorway extends beyond the North Shore portion of the MUL through non-metropolitan land, then into the Rodney portion of land within the MUL, then once again beyond the metropolitan boundary to the north. Our analysis here indicates that this infrastructure investment is likely to have differential effects on these areas due to the zoning boundaries. The magnitude of these differences is currently the subject of further study.

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