A FIXED-EFFECTS MODEL OF THE IMPACT OF MINIMUM-LOT-SIZE ZONING ON RESIDENTIAL DEVELOPMENT

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Abstract of the Thesis

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Minimum lot size zoning has a long history of implementation as a growth control tool at the local level. But due to the relative scarcity of land use data with high quality, the actual effect of minimum lot size on residential land development is ambiguous and further investigation based on explicit empirical evidence is required. Our panel data on acres of land use in 83 New Jersey Highlands communities in 1986, 1995 and 2002 provide an ideal platform for exploring the true relationship between large-lot-zoning and residential land consumption. In this paper, we first construct a theoretical framework that illustrates why the relationship should be nonlinear, providing the correct specification for the independent variable of interest. Then two land use share models—the fixed effect model and OLS with a time dummy—are applied to the panel dataset. Results from a series of model adequacy tests demonstrate clear superiority of the fixed effect model. The empirical results based on the fixed effect method suggest that residential land development first increases with minimum lot size at a diminishing rate, and it declines after reaching the maximum point at the minimum lot size of 5.298 acres. Our results provide preliminary evidence that large-lot-zoning can only reduce residential growth if it is set at a relatively high level. The results also imply that up-zoning can be an effective tool for reducing land consumption.

Key words: fixed effect, growth control, minimum lot size, land use, large-lot-zoning, regional heterogeneity, residential development, urbanization

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Introduction

A variety of evidence shows that recent urban land consumption patterns evolve into a new trend, characterized by spatially expansive, fragmented and fast-growing residential land development in exurban and rural-urban fringe areas. The rapid rates of expansion of residential land have greatly exceeded paces of population growth in many areas, leading to a low-density and land-intensive urbanization process (Irwin and Bockstael, 2002).

Researchers or planners attempt to explain this trend of land consumption in suburban areas by a number of factors, most of which could be combined into several main causes. Gordon and Richardson (1997) contend that large-lot development is the natural result of household preferences and market forces. Households' preferences for single-family housing and rural lifestyles, along with rising incomes and declining transportation costs, cause the density gradient to decline and induces scattered low-density development (Anas, Arnott, and Small, 1998; Brueckner, 2000). The "Pull and Push Theory" complements Gordon and Richardson's analysis of the causes of suburbanization. This hypothesis argues that push factors such as high taxes, lower school quality, higher crime rates, and congestion force high-income individuals to move to lower density suburban communities that offer a preferred bundle of public goods and at a lower price (pull factors) (Carrion and Irwin, 2004).

Without control and regulation, the normal suburbanization process could come into a rapid, unplanned and uncoordinated growth, which would generate a series of negative consequences for society (Nelson et al., 1995). Various land use management policies have been adopted by local governments to combat over-rapid land consumption and control the pattern and pace of urbanization. Among these, minimum lot size zoning appears to be on the rise as a growth control tool (Gottlieb and Adelaja 2005). This kind of zoning restricts the minimum lot size on which houses can legally be built in a municipality.

How to explain the continued popularity of zoning over other forms of land use control? Fischel (1978) explains that with minimum-lot-size zoning, municipal service expenditures of existing residents are much lower than they would be under some other system. Many alternative land control methods would also require that land be purchased or owners otherwise compensated.

But one problem with large-lot zoning is that it might actually increase urban sprawl, rather than reduce it. There are four main reasons:

I. It could reduce residential densities. Then with the same number of residential lots sold, an increase in lot sizes would clearly increase total land consumption.

II. It could increase the equilibrium quantity of housing produced. Demand for homes could increase because of the amenity and fiscal protections that large-lot zoning provides to neighborhoods and towns.

III. It could cause residential development to become more fragmented (Irwin and Bockstael, 2007)

IV. It could increase the total amount of land converted from agricultural to residential use over a given period of time (Moss, 1977; Irwin, Hsieh and Libby, 2001).

All of these “unintended aspects” generate long-term debate about the effectiveness of large-lot-zoning at alleviating growth. Therefore, further empirical evidence of the direct effects of minimum lot size zoning on the amount of residential land conversion is desired, as it sheds light on whether and the extent to which minimum lot size zoning can actually constrain urban land development and justify itself as a feasible growth control method at local level.

This paper will explore these “unintended consequences” of large-lot zoning, focusing especially on total land conversion. Total amount of land conversion is an important summary measure that has the potential to capture both (I) and (II) in the list above. Our advanced panel data on actual acres of land developed, which are achieved from the GIS image of 83 New Jersey Highlands municipalities in 1986, 1995, and 2002, provide attractive prospects for the empirical analysis. Two types of land use share models—the fixed effect model and the OLS—have been applied to the longitudinal dataset in examining the effects of required minimum lot size on the relative share of residential land. Our empirical results provide preliminary evidence that the validity of widespread use of minimum lot size zoning at deterring growth is guaranteed only if it has been set at an adequately stringent level.

Basic Conceptual Framework, Prior Work

The following equation describes the potential effects of large-lot zoning on land consumption, as described in I through IV above (see also Field (2001)):

$$C = q(x)\left(\frac{C}{q(x)}\right) \tag{1}$$

In equation (1), C represents total land converted to residential use in a municipality over a given period of time, $q(x)$ represents the number of new homes constructed as a function of minimum lot size, x, and $\frac{C}{q(x)}$ represents the average lot size of these new homes. Therefore the effect of large-lot zoning on total land consumption is an open question to be determined by the direction and magnitude of the change in its two components, $q(x)$ and $\frac{C}{q(x)}$. The next section reviews a number of theoretical and empirical studies that address the impact of zoning on $q(x)$, $\frac{C}{q(x)}$, and C.

Expected Impact of MLS Zoning on the Number of New Homes

Researchers argue that different types of zoning can affect the equilibrium quantity of residential land development by causing shifts on the demand or supply side or both (Irwin, Hsieh, and Libby 2001; Mayer, Somerville, 2000; Levine, 1999). Unfortunately some of these articles do not clearly distinguish the demand (or supply) of housing units from that of developable land. Several others illustrate their reasoning with more precisely-defined terms. Considering the likely constraints on housing supply and the amenity benefits associated with large-lot zoning, minimum lot size requirements can both increase demand and constrain supply in a housing market, leaving the net effects of zoning on the number of new homes indeterminate (Mayer, Somerville, 2000; Pogodzinski, Sass, 1990).

There is some empirical evidence confirming the effects of zoning on the production of new housing. Although most authors in this category attribute their findings to impacts of zoning on the supply side, the dependent variable used in these studies – net new housing construction – necessarily reflects an equilibrium outcome of land use regulations, with developers deciding what to bring to market in response to their own costs and consumer willingness to pay. Levine (1999) finds that the local growth-control enactments, which include down-zoning of residential land to lower densities, negatively affected the production of new housing in California between 1979 and 1988. The results of Mayer and Somerville (2000) show that as a type of land use regulation which lengthens the development process, zoning not only lowers the steady-state level of new housing construction, but can also reduce the speed of adjustment of new construction to demand and cost shocks.

Another important category of research provides indirect information on the relationship between minimum lot size zoning and the number of new homes. These are the studies based on conceptual models considering an individual landowner's development decision. The direct output of this type of model is the probability of conversion from agriculture-dominant or undeveloped land to urban use or developed land for a given parcel at a certain point in time. If we focus only on conversion from undeveloped land to residential use, farmland owners are confronted with a binary choice of keeping their land at its current status or selling it to housing developers for subdivision (Bell and Irwin, 2002). Current land use regulations are likely to be one determinant of this choice by landowners: through this pathway they should influence the quantity of new housing brought into the local housing market.

Many studies investigate land use outcomes using this individual land use conversion framework. Carrion and Irwin (2004) use a discrete choice model in attempt to explain the effects of large-lot zoning on residential land use development at the urban-rural fringe. The zoning variable is represented by a dummy variable which indicates whether or not each parcel is subject to a minimum lot size restriction of three acres or more. The negative and significant effect of Carrion and Irwin's zoning variable implies that parcels constrained by three-acre zoning are less likely to convert to residential use, other things equal.

Irwin and Bockstael (2002) use a land use conversion model to test the impacts of negative externalities among developed residential land parcels on residential land use patterns. The model is described as a hazard function which enables the surrounding neighborhood development to enter as a time-variant predictor. Although their main purpose is not to investigate large-lot zoning, their results indicate that such zoning, which is specified as the logarithmic form of the maximum allowable development density, has a significant negative effect on residential development decisions.

Kline and Alig (1999) construct an empirical model that describes the probability that forests and farmland in western Oregon and western Washington have developed since 1961 as a function of socioeconomic variables and zoning restrictions implemented under the state's land use planning program. The zoning variable here is the proportion of time that each county has had the state land use plan in effect. Their results suggest that the zoning restrictions prescribed by Oregon's land use planning program have not significantly reduced the likelihood of development of these resource lands.

An evident weakness of the discrete choice models lies in the limited insights they generate in the absence of additional work, such as simulation analysis. The probability of conversion to residential use, the only output directly known from these models, provides little information on either total amount of land converted or the pattern of future land use changes. The development probability distribution over a specific region must be combined with other data sources over the landscape such as size and degree of fragmentation of individual parcels, to further detect the likely changes regarding the amount and patterns of conversion (Bell and Irwin, 2002).

Notwithstanding this drawback of the discrete choice conversion literature, the weight of the existing evidence suggests that minimum lot size zoning is likely to reduce equilibrium housing production — although in many cases the zoning variable is entered as a dummy, and is therefore unable to calibrate with precision the effect of different levels of x. One exception to this rule is O'Donnell (2007), who measured the "acreage-weighted average minimum lot size" in 83 New Jersey communities in 1995. O'Donnell found that the impact of this measure on the number of building permits issued over the next five years was a concave quadratic, with a maximum occurring at 3.6 acres minimum lot size. The notion of a turning point in the impact of minimum lot size zoning on housing production *or* land development is reasonable. It has heavily influenced the present study, which is conducted on O'Donnell's sample of communities in New Jersey.

Expected Impact of Minimum Lot Size Zoning on Average Residential Lot Size (Future Residential Density)

It might seem obvious that minimum-lot-size zoning will increase average residential lot size $\frac{C}{q(x)}$. But this is not necessarily the case. The minimum lot size constraint may simply not bind. In the extreme case, there may be no observed relationship between minimum lot size and developed lot size across a sample of municipalities, because the market has chosen lot sizes that are well above the regulatory minima.

Even if a relationship between minimum lot size regulation and actual lot size is observed across a sample of communities, it could be because developers have lobbied the local government to provide lot-size restrictions at precisely the level of x they would have chosen anyway. Developers may do this because the amenity protection conferred by minimum lot size zoning allows them to sell more homes. That outcome, of course, would represent an impact of the minimum lot size zoning policy on $q(x)$, and not on $\frac{C}{q(x)}$. A more general point is that the level of minimum lot size zoning and the so-called "free market" lot size are jointly determined by factors such as potential land values, growth pressures, and the socio-economic makeup of the community (Wallace, 1988; Pogodsinski and Sass, 2000; Fischel, 1990). This fact greatly complicates any statement made about the causal relationship between minimum lot size zoning and the residential lot sizes observed in a particular place at a particular time.

Orr (1975) proposes a conceptual model which hypothesizes that minimum lot size zoning can be nonbinding, can affect density without changing occupancy of income classes or can change both occupancy and density. His empirical findings show that minimum lot size requirements have significantly reduced net household density, but have little effect upon occupancy, implying that they are set just above the free market pattern of residential development. Orr concludes that MLS zoning binds, but not severely.

The results of an empirical study by McConnel, Wall and Kopits (2005) suggest that zoning restrictions, measured by the number of permissible lots per acre, have significantly reduced the actual number of lots in a subdivision and hence contribute to lower-density residential development in Calvert County, Maryland. The zoning variable is discovered to be exogenous in the model by applying a Hausman test for potential endogeneity. The prediction for the total 30 censored observations, which is based on the censored regression, shows that only 10% more lots would have been added if zoning restrictions were removed. But there is a substantial difference between average predicted lot size in the absence of zoning rules and the average actual lot size for areas with the strictest density requirements (5-acre minimum lot size). At least these areas can be designated as constrained areas in which zoning is binding.

Using data from subdivisions developed in the Baltimore-Washington suburbs during the mid-1990s, Lichtenberg and Hardie (2007) estimate the effects of minimum lot size both on average lot size and on the number of lots in each subdivision. A Hausman test justifies their decision to treat the zoning variable as exogenous. The coefficients on minimum lot size are significant both in the average lot size equations and in the lot subdivision equations, suggesting that without minimum lot size zoning, developers would provide a larger number of smaller lots.

To examine the effect of five different types of land-use controls in combating urban sprawl, Pendall (1999) measures minimum lot size zoning as the proportion of land in a county to which density restrictions apply. He finds that such counties have much fewer new residents per 100 new urban acres than counties with weaker restrictions on density. This suggests that local governments with a goal of compact development should discourage low-density zoning because of its sprawl-inducing effects. But formal tests on whether zoning restriction is binding, or what the market outcome of residential density would be without zoning, are not within the scope of Pendall's study.

Taken together, the findings of these studies suggest that minimum lot size zoning does indeed reduce residential density. The only caution is that not all of the studies address the issue of causality. Those that do rely heavily on the Hausman test to dismiss it as a concern.

Impact of Minimum Lot Size Zoning on Total Land Conversion

So far we have reviewed the empirical literature on the impacts of minimum lot size zoning on $q(x)$ and on $\frac{C}{q(x)}$. Except for the few insignificant or ambiguous findings, most studies on the number of new homes, whether by assessing the construction of new homes or exploring the binary landowner conversion decision, show evidence that minimum lot size zoning decreases the number of new homes. Most density studies confirm that minimum lot size zoning generally contributes to greater average lot sizes. Therefore no quick judgments can be made on how minimum lot size zoning ultimately affects total land conversion, because the impacts on $q(x)$ and $\frac{C}{q(x)}$ appear to run in opposite directions. We might therefore want to use the direct path, and review evidence on the impact of minimum lot size zoning on the total land consumption variable, *C*.

Two theoretical studies from urban economics provide insights into how to tackle this problem. Using a two-sector model which comprises a sector of suburban housing under a minimum lot size constraint and an agricultural sector, Moss (1977) concludes that minimum lot size requirements increase land prices, accelerate the process of rural-land conversion, and increase metropolitan land area. Using a residential economy model in a semi-closed city with the rich living in the suburbs and the poor in the central city, Pasha (1996) contends that suburban minimum lot size zoning flattens the rent gradient, reduces land values, and leads to more residential land conversion and a larger metropolitan area.

The works of Moss and Pasha suggest that the impact of minimum lot size zoning on land prices is a mediating factor for determining the effect on land consumption. This is fortunate, as a great number of studies have focused on the effect of zoning on real estate prices (Irwin, Hsieh and Libby, 2001; Gottlieb and Adelaja, 2005). But as the studies of Moss and Pasha indicate, it is no easy matter to determine the effect of land price changes on total land conversion. Those two authors identified the same expansive effect of MLS zoning on land conversion, but with opposite price effects as the intervening mechanism!

A more straightforward approach would be to use data on land use or land use change as the dependent variable. If parcel-level data are available, the residential conversion probabilities estimated by the discrete choice model can be combined with the size of each parcel to compare the amounts of residential land conversion across time and regions. If aggregate land use data are available, land use share models are widely used to examine the effects of minimum lot size zoning and other factors on rural-to-urban land conversion (Irwin, Hsieh and Libby, 2001).

Using a discrete choice logit model, Wu and Cho (2007) find that all four types of local land use regulations *except* zoning ordinances significantly influence the probability of land development in five western states. Later using expansion factors to proxy the acreage of each site, they estimate that land use regulations have reduced developed land by 10% in the whole region. Although zoning was not significant, the Wu and Cho study shows how to explore the impact of zoning on total land conversion using only the output of a discrete choice model.

Two empirical studies using the land use share model are now reviewed. Using county-level data from Ohio, Irwin, Hsieh and Libby (2001) find that the relative share of undeveloped to urban land is negatively and significantly influenced by zoning, represented by the proportion of land in each county that is formally zoned. Although this finding would appear to support the hypothesis that zoning facilitates land conversion, endogenous zoning is likely to be especially problematic in this case. In contrast to the choice of larger versus smaller minimum lot size, the initial adoption of a zoning regime in a township that previously had no zoning will clearly be driven by growth pressure and recent development. Adoption of any township zoning is the independent variable in the Irwin, Hsieh, and Libby study.

In a recent study based on 59 communities in Oakland County, Michigan, Foley (2005) estimates a convex quadratic relationship between weighted average minimum lot size and the rate of land consumption over time. Foley's results suggest that residential land development first declines with minimum lot size at a diminishing rate, and then begins to increase at a minimum lot size of 5.15 acres. The surprising (and preliminary) conclusion is that 5 acres is an optimal minimum lot size for purposes of growth control, while the largest minimum lot sizes in this Michigan sample did not deter homebuilding enough to offset the expected positive effect on land consumption per acre.

It is clear why the debate continues on the validity of using minimum lot size zoning to regulate urban development. Theoretical studies in the urban economics tradition claim that minimum lot size zoning contributes to greater urban growth, while corresponding empirical evidence is scarce and far from conclusive. These are grounds for expending greater effort to investigate the problem based on explicit empirical evidence. The following section will develop a theoretical framework for this paper's empirical test of the impact of minimum lot size zoning on land conversion. This will be followed by a discussion of empirical setup, data, and results.

Theoretical Model of the Impact of Minimum Lot Size on Land Conversion

Our goal is to calculate total land consumption in a given community over a horizon period as a function of the minimum lot size imposed on undeveloped land. We will be especially interested in identifying nonlinearities or turning points in this relationship. Such turning points seem reasonable on theoretical grounds, as argued below.

Assume that the zoning decision of an individual community does not significantly affect the housing market at the regional level. Many substitute communities and alternative lot sizes exist throughout the region. Also assume a planning horizon over which the community will not "build out", so the amount of developable land in the community does not place an additional constraint on C. Under these assumptions, equation (1) above describes land consumption as a function of minimum lot size zoning in a given community.

We now add a rather strong, but defensible assumption. Once the community selects a level of x, the regulatory minimum lot size, all undeveloped land will be subdivided at exactly this minimum lot size, x. This leads to a great mathematical convenience: the mode, minimum, maximum, and average future residential lot size are all exactly equal to x. There is no need to speculate about or parameterize a distribution of future lot sizes in the community above the legal minimum, as in Adelaja (2004).

What could justify such a radical assumption about the lot sizes that developers will build in a community, given a particular legal minimum? Although it seems extreme at first glance, this assumption is actually more consistent with the literature in urban economics than the alternative. A prediction of homogeneous housing within a single municipality arises from the Tiebout-Hamilton model of local public finance (Tiebout, 1957; Hamilton, 1976). In this fifty-year-old theory, anybody who owns a lot that is larger than the average lot size in the community will effectively cross-subsidize the public services of everybody else. This is because public goods are consumed in equal quantities, but taxes are based on the size of your real estate holdings. In a world with a large number of community substitutes, wealthy homeowners will avoid such a situation, and will look for communities in which everybody owns a lot the same size as their own. Setting aside the issue of incumbent residents for the moment, incoming residents will prefer that all newly-developed lots are the same size. This will at least ensure that they do not cross-subsidize the public services of other newcomers. The only stable equilibrium for this model of community choice is one in which all new lots within a community are subdivided at the minimum legal size. Heterogeneity in the size of homes and backyards occurs largely across municipalities, rather than within them.[1]

Using this strong assumption drawn from the public finance literature, equation (1) can be re-written with minimum lot size x in place of average future density:

$$C = q(x)x \qquad (2)$$

A community considering an increase in its minimum lot size is concerned about the effect of an increase in x on total land consumption C. We take the first derivative of (2) with respect to x:

$$\frac{\partial C}{\partial x} = x\frac{\partial q(x)}{\partial x} + q(x) \times 1 \qquad (3)$$

Multiplying through by ∂x:

$$\partial C = x\partial q(x) + q(x)\partial x \qquad (4)$$

The expression in (4) is analogous to the expression for the impact of a change in price on total revenue, given a price elasticity of demand. The change in total land consumed is equal to the current lot size times the change in the demand for lots, plus the existing demand for lots times the change in the size of each lot. All future lots are offered at uniform size – just as in revenue analysis, every unit is bought at the same price. The quantity response (the "elasticity") is what determines the ultimate outcome. As in revenue analysis, the change in total *C* can be either positive or negative, which is what makes this an interesting empirical problem in the first place.

We need to know something about the equilibrium housing quantity function *q(x)* and about its slope, $\partial q(x) / \partial x$. The shape of function *q(x)* for a single community should be related to characteristics of the regional housing market, like the pure demand for various lot sizes (driven by income and preferences within the region), and the lot sizes associated with homes that have already been built in the region (available substitutes).

We impose the fewest possible restrictions on the shape of *q(x).* We assume that *q(x)* is a single-peaked function that rises to a maximum occurring at some unknown lot size *x** and then falls monotonically. Concavity is not assumed.

This assumed shape for *q(x)* is theoretically plausible. First, it seems clear that as *x* becomes very large, an increasing number of potential buyers will be unable to afford the enormous estates that result. Therefore *q(x)* must eventually decline with increasing *x*.

Second, when *x* is very small, two separate factors lead to a prediction of rising equilibrium housing quantity in a community. The distribution of suburban incomes within any region is nearly normal, and residential lot size is a normal or luxury good (Adelaja, 2004; Cheshire and Sheppard, 1998). This market demand profile should cause more homes to be built as *x* moves upward from a level as low as, say, 3,000 square feet. In addition, any minimum lot size generates at least some protection against neighborhood disamenities and fiscal cross subsidies. This is argued to increase housing demand in any town that increases its minimum lot size, other things equal (Irwin, Hsieh, and Libby 2001). It is reasonable to suppose that the amenity effect of zoning is characterized by diminishing returns, so it is likely to be a relatively powerful demand curve shifter at low levels of *x*. Finally, there is no obvious reason to consider *q(x)* to be double-peaked rather than single-peaked. O'Donnell (2007) found empirical evidence for this rising-and-then-falling shape of *q(x)*, although admittedly his quadratic specification forced the estimated function to be single-peaked.

With these modest restrictions on the shape of *q(x),* we can use equation (3) above to explore the conditions under which $\frac{\partial C}{\partial x} > 0$, leading to sprawl concerns arising from down-zoning.

Using (3), the condition for minimum lot size causing "sprawl" or increased land conversion may be written as follows:

$$x\frac{\partial q(x)}{\partial x}+q(x)>0 \tag{5}$$

Re-arranging terms and multiplying through by 1/*x* gives

$$\frac{\partial q(x)}{\partial x}>\frac{-q(x)}{x} \tag{6}$$

which is equivalent to:

$$\frac{-\partial q(x)}{q(x)}<\frac{\partial x}{x} \tag{7}$$

To the left of x^*, $\partial q(x)$ is always positive under our assumptions for the shape of $q(x)$. If $\partial q(x)$>0, then (6) and (7) are always true. It follows that increases in minimum lot size up to x^* must increase overall land consumption. (Note that this may not be a serious policy concern if x^* happens to be very small, like one tenth of an acre. Down-zoning proposals in agricultural areas typically begin with an *x* that is at least 2, and then move this minimum lot size up to 10 acres or more.)

To the right of x^* $\partial q(x)$ is negative, and the evaluation of conditions (6) and (7) is less straightforward. We multiply both sides of (7) by $x/\partial x$ to put the sprawl condition into elasticity form:

$$\frac{-\partial q(x)}{q(x)}\bigg/\frac{\partial x}{x}<1 \tag{8}$$

Condition (8) says that to the right of x^*, an inelastic downward slope of function $q(x)$ will cause total land consumption to fall with rising x, while an elastic downward slope of function $q(x)$ will cause total land consumption to increase with rising x. This condition is intuitively sensible; indeed, it is the precise analogue of the price-revenue problem discussed above.

The point elasticities of $q(x)$ to the right of x^* are unknown under our initial assumptions. At a sufficiently high level of *x*, of course, $q(x)$ and *C(x)* must both fall to zero, as the market for such enormous estates disappears (or alternatively, farms and residential estates become indistinguishable in land cover terms). It could be, however, that these “sufficiently high levels” of *x* simply do not exist in our dataset, so that residential land consumption is never observed to fall.

We shall therefore model three possibilities for the shape of *C(x)* calculated over a real-world domain of x’s: (a) it rises and then falls; (b) it rises continuously; or (c) it rises, falls, and then rises again – the ultimate decline to zero being outside the range of the data. In a regression specification, all three of these possibilities can be captured by programming the independent variable of interest as a cubic function. That is the approach we take below, as justified by the economic arguments presented here. The important point is simply that there is plenty of reason to believe that the relationship between minimum lot size and residential land consumption across a sample of communities will be nonlinear.

Empirical Study Design

Empirical Specification

The basic land use data to be used to generate our dependent variable are the actual acres of land dedicated to different land use categories within each of 83 municipalities in 1986, 1995 and 2002. The land use share model is normally considered an ideal approach for capturing aggregate land use in a jurisdiction, so it has been chosen as our basic empirical model. Because we are concerned with the amount of land converted from vacant to residential, we focus on residential and undeveloped land as our two land share categories.

As in Irwin, Hsieh and Libby (2001), we define k as an index of all categories of land uses, where $k = a$ for undeveloped land and $k = b$ for residential use. With the designation of undeveloped land as the reference category, the expected share of residential land and undeveloped land can be expressed with the multinomial logit model as:

$$P_{ib} = \frac{\exp(X_i\beta_b)}{\sum_{k=1}^{K}\exp(X_i\beta_k)} \tag{9}$$

and $$P_{ia} = \frac{1}{\sum_{k=1}^{K}\exp(X_i\beta_k)} \tag{10}$$

where i refers to the municipality, X are vectors of predictor variables, and β are vectors of estimable coefficients. Applying a logarithmic transformation to $\frac{P_{ib}}{P_{ia}}$ and substituting P_{ib}, P_{ia} with the observed shares y_{ib}, y_{ia} in actual acres, the model is simplified as:

$$\ln\left(\frac{y_{ib}}{y_{ia}}\right) = X_i \beta_b + \varepsilon_i \qquad (11)$$

where ε is the error term. Equation (11) reflects the general form of the dependent variable to be used in our empirical analysis, which is the logarithm of the share of land in residential use with respect to undeveloped land. For convenience we let it equal $\ln(r_i)$. (Another advantage of this specification is that the dependent variable is not bounded by zero or one, and can therefore be estimated using OLS.)

Given the longitudinal feature accompanying both our zoning and land use data, a fixed effect model is incorporated into the land use share model and specified as:

$$\ln(r_{it}) = \alpha_i + \lambda_t + \beta X_{it} + \varepsilon_{it} \qquad (12)$$

where t represents the year, α represents a set of municipal-specific fixed effects (omit one for the reference category), λ represents a set of year-specific parameters to capture the temporal trend (omit one for the reference category), and i, β, X, and ε are the same as previous notations.

There are two obvious advantages for using the fixed effect model in our empirical analysis. First, with the regional fixed effects accounting for all stable municipal-specific heterogeneity, a fixed effect model eliminates unmeasured or unobservable cross-regional differences that can affect land use allocations. This helps reduce parameter estimate bias caused by omitted control variables that might be correlated with the response variable, the zoning variable or spatially correlated themselves. It is reasonable to have this concern. Because of the great administrative autonomy bestowed on each municipality from the state government of New Jersey, considerable regional diversity is expected regarding a variety of local economic and political policies, some of which might not be measurable but still have an impact on land development. Another advantage is that fixed effects adjusts for all between-municipality variations and focuses on within-municipality changes, we can trace the effects of down-zoning or up-zoning on residential land conversion.

Data Sources and Variables

To facilitate the estimation of our empirical model, data have been collected for 83 municipalities in the Highlands area in New Jersey, with repeated observations for each municipality at year 1986, 1995 and 2002 (N=249). The land use data come from New Jersey Department of Environmental Protection (NJDEP), which conducts statewide aircraft detection over the landscape with a several-year interval. Maps based on 1:24,000 aerial photography are interpreted and transformed to the GIS format.[2]

Note that because the data are based on photo interpretation rather than ground surveys, this is really a database that tries to infer land use from information on *land cover*. Importantly for our analysis, a portion of a residential backyard that remains wooded — especially if it is adjacent to a larger undeveloped woodlot — would count as undeveloped in this dataset, while a significant patch of mowed lawn would count as developed residential. Thus we are actually measuring the effect of MLS zoning on natural versus converted landscape, and *not* on the number of acres that have been subdivided into residential parcels, which is a legal or administrative definition of development. We believe this to be an advantage of our dependent variable for purposes of measuring the impact of MLS zoning on those aspects of development that are environmentally harmful.

The original data source systematically describes land use by a comprehensive list of categories. We calculate the residential use as the aggregate of 5 residential categories and define undeveloped land as the aggregate of agricultural land and forestland. Wetlands and barren land are not included in the undeveloped land category because they are not developable. The total Highlands area shows sweeping trend of residential land development over the study period, characterized by rapid exploitation of the undeveloped land and large increment of the residential areas. From 1986 to 2002, undeveloped but developable land within the whole region has decreased by 39,328 acres, accounting for 7.7 percent of that total stock in 1986, while residential use obtains a 24.7 percent stunning increase of 28,549 acres. Although diversity on the magnitude of development exists across the region, with the fastest growing municipality gaining the residential use by 188.6 percent and the slowest growing municipality undergoing even a slight vanishing of residential land by 4.2 percent, quick residential conversions of the undeveloped land are ubiquitous in most areas. Using the aggregate data for residential use and undeveloped land in actual acres we are able to construct the dependent variable (RSHARE) for the 83 municipalities at each observation point based on the specified land use share model, as is showed in equation (11).

Historical zoning data for the Highlands were collected under the terms of National Science Foundation Grant #SES 0523309, “Anti-Sprawl Activism on the

Rural-Urban Fringe: Origins and Impact."[3] Each of the 83 municipalities adopts one or more minimum lot size requirements that cover particular residential districts in each observation year. To appropriately represent the overall strictness of the minimum lot size mandates at the municipal level, a variable called weighted average minimum lot size (MLS) is calculated for each municipality in each year by assigning every adopted minimum lot size category a weight equal to the proportion of residential land area zoned for that category. Two other variables are created representing the squared weighted minimum lot size (MLSQUARE) and the cubic weighted minimum lot size (MLSCUBE) separately. During the first time interval (1986-1995), changes of the weighted average minimum lot size range from 2.55 to -1.41 acres with a mean of 0.09 acres among the 83 municipalities. From 1995 to 2002, changes of the weighted minimum lot size vary from 8.59 to -0.61 acres with a mean 0.35 acres. The overall trend is one of down-zoning, and the magnitude of down-zoning increases in the second study interval.

We specify a set of exogenous variables covering major aspects of cross-municipality heterogeneities. Some of these variables are stable over the study period and can be considered time-invariant. A variable BOROUGH, describing whether the municipality is a borough or township, is constructed, coded 1 for a borough and 0 otherwise. We include three variables designed to measure accessibility to the urban center or jobs: number of major highway (HIWAYS) measured by the total number of major highways[4] passing through each municipality, distance to New York City (NYCDIST) calculated as the sum of straight line distances from the center of each municipality to central Manhattan in miles, and existence of rail (RAIL) expressed by a dummy variable indicating there is at least one daily inbound and outbound peak-hour train stopping in the municipality. In urban economics, greater accessibility to central cities is associated with higher land prices, more development, and higher densities, other things equal. A variable for agricultural soil quality is used as a measure of the opportunity cost of residential development. DSFARMLAND is the percentage of land designated "prime farmland" within each municipality: The impact of this variable on development is expected to be negative.[5]

In addition, three time-varying variables are included as exogenous controls for within-municipality variances. We use median household income (MHINC $) intended to capture the impacts of income, a main impetus inducing people's preferences to large-lot housing and hence leading to a greater demand of residential land. According to the urban economic theory, a variety of local characteristics will determine residential location choices and therefore aggregate development of a community over time. We select two of the most important: school general fund budget per resident pupil (PPEXP $) that indexes the quality of public education, and crime rate per 1000 people (CRIME) that reflects personal security. Consistent with our land use and zoning data, data concerning these three independent variables were collected for 1986, 1995 and 2002. The household income data for the three observation years are interpolated based on New Jersey decennial census data in 1980, 1990 and 2000. The student expenditure data come from New Jersey Legislative

District Data Book and the crime data come from Uniform Crime Reports, State of New Jersey and Federal Bureau of Investigation.

At last, to accommodate the implementation of our specified fixed effect model, we construct 82 municipality-specific dummy variables accounting for spatial heterogeneities across the municipalities and 2 year-specific dummy variables (DUM1995 and DUM2002) accounting for the temporal trend. DUM1995 takes the value of 1 for the year 1995 and 0 otherwise while DUM2002 takes the value of 1 for the year 2002 and 0 otherwise.

Empirical Results

Before estimating the fixed effect model, we first need to settle on the specific form of the zoning variables. Our theoretical model illustrates that the hypothesized relationship between minimum lot size and residential land consumption will be nonlinear, and there are three possibilities for the shape of this relationship depending on the scale of minimum lot size in the real dataset. There are three types of statistical evidence justifying that we should include MLS and MLSQUARE as the zoning variables in our fixed effect model. First, the scatter plot of RSHARE and MLS shows apparent pattern of nonlinearity. Secondly, based on the fixed effect model using MLS as the only zoning variable, the residual plot with respect to MLS shows that a square term needs to be added in order to correct nonlinearity. Thirdly, as our theoretical model suggests that a cubic term of MLS has the potential to capture all three possibilities for the shape of our focal relationship, we first include MLSCUBE along with MLS and MLSQUARE as the zoning variables in the fixed effect regression, but then we drop it because the associated coefficient turns out to be insignificant. Therefore in real practice, we don't need the cubic term of MLS as it is likely that the pattern captured by cube is outside the scale of our dataset.

We first run the fixed effect model with the presence of all 249 observations. Four outliers—Victory Gardens of 1986, Greenwich of 1986, Washington Twp in Warren of 1986 and Greenwich of 2002—have been detected and removed from the data set for further analysis. All of these four observations have the studentized residuals exceeding ± 3, the Cook's D above 4/n, and the DFITS greater than $\pm 2\sqrt{k/n}$. They also stand out uniquely in the residual plot over the predicted values and the normal Q-Q plot. With the outliers excluded (N=245), the descriptive statistics for all of the variables used in the estimation of our empirical models are listed in Table 1.

Table 1. Summary statistics of variables, N=245

Variable	Description	Mean	S.D.	Min/Max
RSHARE	Natural log of the ratio of acres in residential use to acres of undeveloped land	-0.76	1.07	-2.89/2.7
BOROUGH	Whether the municipality is a borough	0.41	0.49	0/1
NYCDIST	Distance to New York City (miles)	39.37	11.95	21.90/62.61
HIWAYS	Number of major highway	0.82	0.98	0/5
RAIL	Existence of rail	0.21	0.41	0/1
DSFARMLAND	Percentage of land designated prime farmland	0.18	0.15	0.0019/0.68
PPEXP	Per pupil expenditure ($)	7882.86	2570.84	3529/14154
MHINC	Median household income ($)	70500.91	20664.21	34349.8/141948.4
CRIME	Crime rate per 1000	17.87	10.34	3.8/71.5
MLS	Weighted average minimum lot size (acres)	1.87	1.74	0.13/10.14
MLSQUARE	Squared weighted average minimum lot size	6.52	13.64	0.016/102.78

We estimate both the fixed effect model and the traditional OLS model using the 245 observations in our panel dataset. The results report the coefficient estimates, standard errors and p-values for each model, as shown in Table 2. We first would like to discuss the major estimating and diagnostic results of each model separately and then by comparison we will demonstrate the clear superiority of the fixed effect technique under a panel setting.

Table 2. Fixed effect and OLS regression results of residential development

Dependent variable: RSHARE	Fixed effect model			OLS		
	Coefficient	S.E.	Pr >|t|	Coefficient	S.E.	Pr >|t|
Intercept	-1.67***	0.13	<.0001	-0.96**	0.44	0.031
BOROUGH	—	—	—	0.47***	0.099	<.0001
NYCDIST	—	—	—	-0.0056	0.0052	0.28
HIWAYS	—	—	—	0.041	0.054	0.45
RAIL	—	—	—	0.28**	0.13	0.032
PPEXP	-0.000014	0.0000092	0.13	0.000047	0.000045	0.3
MHINC	0.0000058***	0.0000015	0.0001	0.0000046	0.0000032	0.16
CRIME	-0.0011	0.0013	0.39	0.014***	0.0053	0.0076
MLS	0.056**	0.028	0.047	-0.67***	0.075	<.0001
MLSQUARE	-0.0053*	0.0028	0.062	0.048***	0.0086	<.0001
DUM1995	0.13***	0.042	0.0022	0.091	0.2	0.64
DUM2002	0.27***	0.06	<.0001	0.26	0.27	0.33
Adjusted R^2		0.99			0.59	
Moran's I		0.0029			0.051	

*significant at 90% level; **significant at 95% level;***significant at 99% level.

To ensure that our estimates fulfill the unbiased and minimum variance properties, we conduct a series of model adequacy checking for the fitted fixed effect model. We begin with the tests for heteroscedasticity. A plot of the residuals versus the predicted values reveals no particular pattern and the residuals can be contained in a horizontal band, which preliminarily verifies the constant variance assumption. The output of White test adds further sustaining evidence. With a p-value of 0.979, we confirm that the variance of the residuals is homogenous.

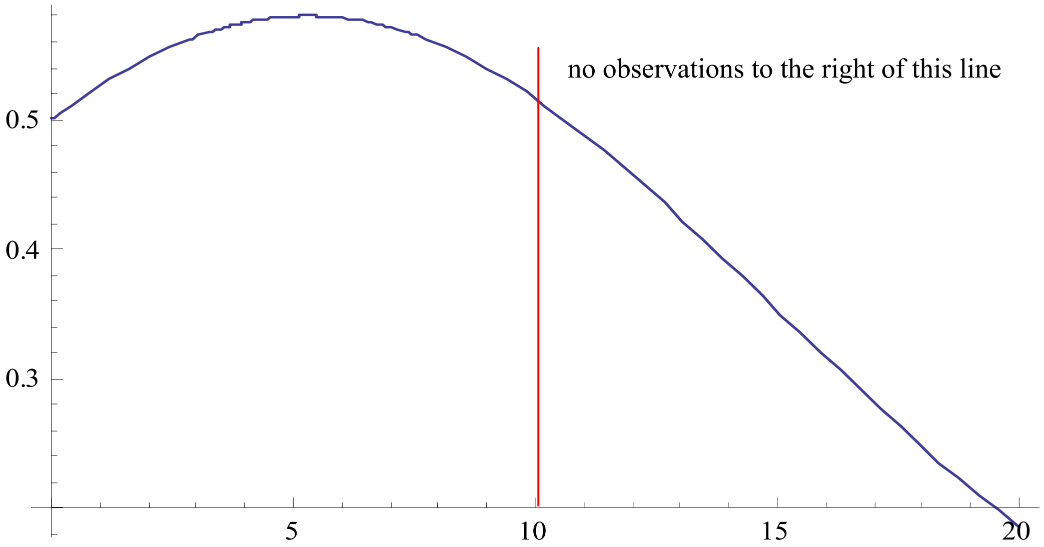
It is widely noted in literature that both the level of minimum lot size zoning and the market outcome of land development are endogenously determined by factors such as potential land values, growth pressures, and the socio-economic makeup of a municipality. Most of them are either unmeasured or unobservable factors that are captured in the error term. To the extent that the unobservable correlates with the minimum lot size zoning, estimates of the impacts of the minimum lot size zoning on residential land conversion will be biased. This problem certainly merits more concern to us given the 16-year horizontal length of the dataset we explore. Using DSFARMLAND that indexes the agricultural soil quality as an instrumental variable for MLS, we implement a Hausman test and find that no significant correlation exists between the zoning variables and the error term. This enables us to treat the zoning variables as exogenous in the fixed effect analysis.

We also have to make sure that the validity of our estimates is not jeopardized by spatial autocorrelation. Chances of obtaining a spatial correlation problem emerge when those unobserved heterogeneities across the municipality interact with each other, leading to a spatially dependent error term. We check possible spatial error autocorrelation of the fixed effect model using the Moran's I test. It first requires generating a 245*245 weight matrix comprising all the pair-connections between the

245 observations, to which a weight of 1 is assigned if any pair are same-year observations and are geographically adjacent with each other and 0 otherwise. With the Moran's I statistics of 0.00289, and the p-value of 0.435 and 0.210 resulting from the significance test based on normality and randomization respectively, we can not reject the null hypothesis of no spatial autocorrelation. Combined with what we have inferred from tests for heteroscedasticity and endogeneity, we conclude that the parameter estimates of our fixed effect model are unbiased and efficient.

The first four columns in Table 2 present the estimation statistics of the fixed effect model measuring the relevance of various factors in determining the amount of residential land with respect to undeveloped land. The Adjusted R^2 of the fitted regression is 0.99. Consistent with the expectations of our theoretical model, a parabolic-shape relationship linking the land use share and minimum lot size zoning is detected, which prominently reveals how the relative share of land in residential use varies along with changes of imposed minimum lot size. The estimated coefficient of MLS is found to be positive and significant at 95% confidence level and the effect of MLSQUARE on relative amount of residential land is found to be negative and significant at 90% confidence level. The results indicate that residential land conversion increases with minimum lot size requirement at a diminishing rate, and after reaching the maximum point it declines with minimum lot size. An estimated regression function that demonstrates the parabolic relationship between minimum lot size and the share of residential land is shown in Figure 1.

Figure 1. Estimated regression function between minimum lot size and residential development



Y axis = ratio of residential acres to open and developable acres at time *t*
X axis = weighted average minimum lot size at time *t*

Estimated equation pictured here (all other covariates set at sample mean):
$Y = e^{-.693 + .056 X - .005 X^2}$

Maximum occurs at X = 5.3
Largest value of X in the dataset is 10.1
Only 6 observations, or 2.5% of the sample, have X >= 5.3

Further, we can calculate the turning point at which residential land development is maximized by taking the first partial derivative of the estimated fixed effect model with respect to MLS and set the transformed equation equal to zero. This maximum point is found at the minimum lot size of 5.298 acres, a surprisingly large figure within the domain of minimum lot sizes observed in our dataset. Specifically, there are fewer than 10 observations in the sample that represent a minimum lot size greater than the turning point of 5.298 acres. Given this fact and the borderline p-value (0.062) of the effect of MLSQUARE, the finding that large-lot-zoning ever reduces residential land development in our dataset should be regarded as tentative. On the other hand, as Figure 1 reflects the approximate relationship between minimum lot size and the share of residential land, it seems like a paradox that municipalities adopting a minimum lot size for the purpose of slowing the speed of residential growth have ended up with more development. Our results provide preliminary evidence that the promise of large-lot zoning for reducing residential growth holds only if it has been set at a sufficiently stringent level.

Among the other time-variant explanatory variables, median household income (MHINC) is found to have a positive and significant impact on the proportion of land dedicated to residential use. The higher the level of median household income, the greater the share of land residentially converted within a municipality, which conforms the hypothesis that higher income raises people's preference for large-lot housing, leading to greater unit consumption and hence more total land consumed.

Both of the two estimated year-specific parameters associated with DUM1995 and DUM2002 are positive and statistically significant at 95% confidence level. In consistence with the general trend of continuous conversion from undeveloped land to residential use within the region, relative share of residential land kept growing during the study period. The 82 estimated regional parameters capture the cumulative differences of all the omitted attributes pertaining to a specific municipality. Given the mixed information contained in each regional parameter, we are not able to give explicit interpretation and do not list them with the other estimates.

The last four columns in Table 2 report the estimation results of the OLS model in which we hold other elements equal but replace all the municipal dummy variables used in the fixed effect analysis with the set of time-invariant exogenous variables described previously. The Adjusted R^2 of the fitted OLS is 0.59, significantly lower than the one attained by the fixed effect.

There are three exogenous explanatory variables found to have significant effects on the relative share of residential land to undeveloped land. The estimated coefficient associated with the categorical variable BOROUGH is positive and significant, indicating that boroughs in the Highlands have experienced a higher level of residential land conversion than townships. This is reasonable because boroughs in New Jersey are the historical town centers, while townships consist of mostly agricultural land that was incorporated and developed at a later date. As expected, proportion of residential land relative to undeveloped land is found to be positively and significantly affected by existence of rail (RAIL). Transportation convenience as an index of accessibility to urban center, can bring comparative locational advantages and correspondingly greater need of residential land to certain areas with respect to the others. Lastly, crime rate per 1000 people (CRIME) conveys positive and significant influence on residential land conversion, which seems opposite to the common theory that people normally avoid living in areas with poor security quality and form lower residential demand in those areas. But by comparison, the estimated effect of crime rate in the fixed effect model is negative, although insignificant. We will attempt to make an explanation on this together with other differentiae between the two empirical models after displaying the OLS result on zoning.

Both the OLS regression coefficients for the weighted average minimum lot size (MLS) and the squared weighted minimum lot size (MLSQUARE) are significant but with the reverse signs compared to the ones estimated by the fixed effect model. In other words, the effect of MLS on the share of residential land is found to be negative while the estimated effect of MLSQUARE is positive, suggesting that residential land conversion first falls to the minimum and then rises with minimum lot size. This is contrary to what is predicted by our theoretical model and to common logic. According to our theoretical model, if equilibrium housing quantity rises and then falls with increasing MLS, residential land consumption *must* increase initially as MLS rises from zero. It is also unlikely that after a certain point total residential land development will keep increasing, because at a sufficiently high level of minimum lot size, demand for such enormous estates disappears entirely.

We employ the same set of diagnostic methods to examine any potential model deficiency of the fitted OLS and summarize the results below briefly. First, both the residual plot to the predicted value and the result of the White test suggest that variance of the residuals is homogenous. Secondly, using DSFARMLAND as an instrument of MLS, we conduct a Hausman test. In contrast to the fixed effect model, we cannot reject the hypothesis that the weighted average minimum lot size in the OLS model is endogenously determined. Thirdly, the result of Moran's I test shows that the observed Moran's I statistics (0.051) is significantly different from the expected value at 90% confidence level, indicating that the OLS regression suffers from modest level of positive spatial error autocorrelation.

By this point, we are able to make a judgment on the relative merits of the two empirical models. As expectations from theory and evaluations based on diagnostic tests both suggest, the fixed effect model shows vigorous advantages over the OLS in the longitudinal setting of our data. As expected, with a set of regional fixed effects accounting for all between-municipality heterogeneity, and a set of year-specific fixed effects controlling for the time trend, the chances of getting omitted-variable bias have been minimized in the fixed effects model. In fact, since endogenous zoning can be characterized as a selection bias problem, and since one solution to selection bias is to include those omitted variables that determine the choice of treatment (Groen, 2004), it is understandable that the fixed effect model improves the results of a Hausman test for endogeneity.

Because it is impossible to comprehensively capture all of the municipal heterogeneities with a limited number of exogenous variables, the coefficient estimates from the ordinary OLS will easily get biased or invalidated to the extent that those omitted factors interact with minimum lot size zoning, residential land conversion or are spatially correlated themselves. Although we are not clear on the direction, it seems certain that the zoning variables in the OLS model are biased, because we do find evidence that the OLS model suffers from both endogeneity and spatial error autocorrelation. This likely explains why the fitted OLS has different (and theoretically unlikely) signs for the coefficients on the zoning and crime variables when compared to the fixed effects model. In addition, the uncaptured heterogeneity in the OLS model seems to interfere with estimation of the expected time trend, as evidenced by the surprisingly large standard errors on DUM1995 and DUM2002.

Conclusion

Spatially-scattered and over-rapid conversion of undeveloped land to residential use has been taking place all over the country for many decades. This phenomenon, with an increasing trend represented by fast residential growth in exurban and rural-urban fringe areas, is normally called urban sprawl and has generated considerable concern in the recent years. A large variety of growth control methods have been adopted and evaluated by local governments in order to alleviate the growth pressure. Among these methods, minimum-lot-size zoning is well understood and enjoys continuous popularity. Due, however, to the general lack of high-quality land use and zoning data, existing studies on the impact of such zoning on residential land development are inconsistent and far from conclusive. Our panel data on actual acres of land use across New Jersey Highlands communities observed in 1986, 1995 and 2002 make an in-depth exploration of the topic possible.

We first introduce the equation $C = q(x)\left(\frac{C}{q(x)}\right)$ which splits the potential effects of large-lot zoning on land consumption into two sources: the effect on average lot size and the effect on the number of new homes. Our literature review and the construction of our theoretical framework are both based on this equation. Our theoretical model suggests that the relationship between minimum lot size and residential land development should be nonlinear and provides the potential form for the independent variable of interest. Following this, a land use share model is specified and two types of empirical models—the fixed effects model and the OLS—are applied to the panel dataset.

We find that the fixed effects model exhibits clear advantages over the OLS. With all regional heterogeneities controlled, chances of getting omitted-variable bias have been minimized in the fixed effects model, while evidence shows that the fitted OLS results suffer biases as a result of both endogeneity and spatial autocorrelation. Approved through model adequacy testing based on econometric standards, our fixed effect model provides reliable results for detecting the true relationship between minimum lot size and residential land development. The empirical results based on the fixed effect method suggest that residential land conversion first increases with minimum lot size at a diminishing rate, and then declines after reaching the maximum point at the minimum lot size of 5.298 acres. Because coefficient estimate associated with the squared weighted minimum lot size is only significant at 90% level, the empirical finding that large-lot-zoning can ever reduce residential growth should be considered tentative. We would like to run the model on a larger sample of communities including those with weighted average MLS above five acres (if trends continue, these should become more common). Our results provide preliminary evidence that the promise of large-lot-zoning for alleviating growth is assured only if it is set a level much higher than we are currently observing. Alternatively, if that is considered to be politically difficult then *upzoning,* a movement toward smaller lot size minima, appears to be a reasonable growth control strategy as well.

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Endnotes

[1] The Tiebout-Hamilton argument is really about homogenous housing values, not about equal lot sizes. Many communities, however, enact additional zoning restrictions that, either directly or indirectly, specify the ratio of the size of the structure to the size of the lot. Such ordinances tighten the already strong relationship between a home's assessed value and its lot size. They include regulations on bulk, setback, side yards, and "floor area ratio."

[2] We thank Stephen Karp of the New Jersey Office of Smartgrowth for providing these GIS data in the form of categorized acreage by municipality.

[3] The support of the National Science Foundation for this project is gratefully acknowledged. The fieldwork and GIS assistance of NSF project participants Melanie McDermott and Vanessa Bueschel were invaluable for compiling the zoning panel data. Co-principal investigators on this grant are Paul Gottlieb, Tom Rudel, and Karen O'Neill of Rutgers School of Environmental and Biological Sciences.

[4] The major highways used to create the variable HIWAYS are US Routes 1, 9, 46, 202 and 206; Interstates 78, 95, 195, 280, 287 and 295; the Garden State Parkway and the New Jersey Turnpike.

[5] Data on distance to NYC were calculated by Paul Gottlieb using the ATLAS-GIS mapping programme in 1992; rail data were obtained from New Jersey Transit Rail Operation Summaries. The soil quality data are from the Food Policy Institute of Rutgers University, who generated the data by overlaying two data sources: Municipality Boundaries (NJDEP) and Soil Survey Geographic 2005 (USDA NRCS).