Determinants of Statewide Land Development in the United States

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Abstract

A reduced-form model of developed land area was estimated with data from 49 states for 1982-1997. This area increases with a state's lagged population and its real economic growth rate. The area of developed land is also higher in states with larger areas of water and regions with higher educational performance. Developed areas are lower in states with higher real per capita agricultural production.

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Introduction

Land development is ubiquitous in the U.S. The area of developed land increased 34%, from 73.246 million acres to 98.252 million acres, during 1982-1997 in the U.S. except Alaska (NRCS, 36). Although it accompanies economic growth, conversion of land from forestry and other agricultural uses to residential, commercial, and other 'urban' uses can adversely affect wildlife habitat, water quality, and other natural resources (Heimlich and Anderson, 31-35). For example, land development led to a gross loss of 247,500 acres of Palustrine and Estuarine wetlands in these 49 states during 1992-1997 (NRCS, 73). Moreover, fiscal impacts differ with the type of land development. For example, residential use of land, in contrast to commercial use, generates less tax revenues than government expenditures on services to support new residents (Farmland Information Center).

Policies to address negative externalities and models to estimate fiscal impacts of land development should be grounded in a microeconomic understanding of the determinants of this type of land conversion. In theoretical models, land development depends on increases in population and income per capita (Muth, 16-20) and growth rates of population (Capozza and Helsey, 301), expected housing rents (Arnott and Lewis, 166), and expected returns to urban use (Capozza and Li, 897). In early empirical analyses (e.g., Schmid, Clawson, Zeimetz et al., Vesterby and Heimlich), economic or demographic growth is also the main determinant of land development but the quantitative impact was not estimated. Recent empirical models of land development have been estimated with spatially explicit, parcel-level data to conform to individual decision-making (e.g., Bockstael, Irwin and Bockstael). These models, however, do not estimate the effects of economic growth on land development because use of micro-level data makes such estimation difficult, if not impossible.

In this paper we empirically analyze the determinants of statewide development of land throughout the U.S. except Alaska. The effect of economic growth on this development is decomposed into increases in real agricultural and non-agricultural production per capita and population because theory (Muth) and limited empirical evidence (Norris) indicate that the effects might be different. Rates of economic growth should differentially affect the rates of growth of expected agricultural and non-agricultural land rents because income elasticities differ across goods. According to hedonic price theory and empirical evidence (Bastian et al., Smith, Poulos, and Kim), prices of agricultural and residential lands are higher the more abundant and closer are environmental amenities to those properties. Hence, the effects of a state's natural resource endowments, given its developable land area, are part of our analysis. Our analysis also addresses the effects of regional school quality on land development.

Conceptual Framework

Our model of land development originates but differs from the model of Irwin and Bockstael. Assume that landowners maximize the net present value of their holdings. If so, an owner of parcel *j* will develop it or sell it to a developer *T* years from now provided that two conditions hold. First, the discounted (to *T*) net benefits of developed land use, say residential use, $\sum_{t=0}^{\infty} \frac{R(j,T+t)}{(1+r)^t}$, exceed the sum of the forgone discounted net benefits of undeveloped land use, such as agricultural production, $\sum_{t=0}^{\infty} \frac{A(j,T+t)}{(1+r)^t}$, and the costs of land conversion in that year, $C^R(j,T)$. That is, $\sum_{t=0}^{\infty} \frac{R(j,T+t)-A(j,T+t)}{(1+r)^t} - C^R(j,T) > 0$. Second, the profit of this conversion is at least as large as the discounted profit from conversion a year later,

$A(j,T)+\frac{1}{(1+r)}\left[\sum_{t=1}^{\infty}\frac{R(j,T+t)-A(j,T+t)}{(1+r)^{t}}-C^{R}(j,T+1)\right]$, and any year after the next. A previously developed parcel will remain so in *T* if the present value of returns from developed uses exceeds the present value of returns from undeveloped uses net of the costs of conversion.

Assume that rental markets for developed and undeveloped land are perfectly competitive and in equilibrium in any given year. A particular state *i* in the U.S. in year *T* has LR_{iT} and LA_{iT} units of developed and undeveloped land, the sum of which represents the state's total usable land area, L_i. The area of developed land equals the sum of the areas of parcels of land that are developed in year *T* or previous years and not converted back. In formal terms, if L_{ij} is the area of the *j*-th of *J* parcels in the *i*-th state, then $\mathrm{LR}_{iT} = \sum_{j=1}^{J}\mathrm{L}_{ij}\ \forall j$ such that

$$\sum_{t=0}^{\infty}\frac{R(j,T+t)-A(j,T+t)}{(1+r)^{t}}-C^{R}(j,T)>A(j,T)+\left[\sum_{t=1}^{\infty}\frac{R(j,T+t)-A(j,T+t)}{(1+r)^{t+1}}-\frac{C^{R}(j,T+1)}{(1+r)}\right]$$

for undeveloped parcels in *T-1* that are developed in *T* and

$$\sum_{t=0}^{\infty}\frac{R(j,T+t)}{(1+r)^{t}}>\sum_{t=0}^{\infty}\frac{A(j,T+t)}{(1+r)^{t}}-C^{A}(j,T)$$

for previously developed parcels. (The *i* subscript has been suppressed to economize space.)

LR_{iT} represents equilibria in the rental markets for developed land in that state. As such, LR_{iT} will be a function of current and future returns to developed and undeveloped uses of all parcels of land, conversion costs for all parcels, current and future interest rates, and, more fundamentally, variables that determine these quantities, $Z(T+t)$. These exogenous variables include the amount of natural resource amenities that people value for non-agricultural purposes, school quality, total usable land area, and expected growth rates of inflation and real income. In symbols, the reduced form equation, neither supply nor demand, for developed land in particular state in year T is

$$\mathrm{LR}_{iT} = f\Big(R(ij,T+t), A(ij,T+t), C^{R}(ij,T), C^{A}(ij,T), r(t), Z(i,T+t)\ \forall j \text{ and } \forall t\Big)$$

Econometric Model and Estimation Procedure

Random processes that occur in a particular year regardless of the state, in a particular state regardless of the year, and in both a particular state and time might affect land development. To reflect these processes and our lack of a functional form for the reduced form model, we specify the following linear-in-parameters statistical model:

$$\mathrm{LR}_{iT} = \alpha_{iT} + \beta' X_{iT} + \varepsilon_{iT} = \alpha + \beta' X_{iT} + \tau_i + \eta_T + \varepsilon_{iT} = \alpha + \beta' X_{iT} + u_{iT},$$

where $i = 1, 2, \ldots, 49$, $T = 1982, 1987, 1992$, and 1997, α and β' are 1 x 1 and 1 x *K-1* parameter vectors, and X_{iT} is a *K-1* x 1 vector of variables that determine the area of developed land in state i in year T.

This model is known as a random effects model (Greene) because the intercept, α_{iT}, is a random variable with mean α and variance that is the sum of the variances of a state-specific effect, τ_i, and a year-specific effect, η_T. The state-specific effect has a subtle connection to serial correlation. If τ_i is positive in a particular year, then it is positive in all other years in that particular state. The effect is equivalent mathematically to first-order autocorrelation in which $\rho = 1$. The year-specific effect represents some uniform nation-wide influence in a particular year on land development. These random effects and an additional effect that is both state- and year-specific comprise the random error, u_{iT}. Hence, this model is also known as the variance, or error, components model. We assume this error structure because our sample observations of developed areas at various points in time come from almost the entire population of states, not just a subset, and inferences about the effects of variables unconditional on a particular state are more interesting to us for policy analysis. We used SAS's Fuller-Battese method, which is an feasible generalized least squares procedure to estimate the parameters of this model.

Data and Variables

Table 1 presents descriptive statistics for variables in the econometric model. The National Resources Inventory of the USDA's Natural Resources Conservation Service was the source of data for areas of developed and non-federal land and water in 1982, 1987, 1992, and 1997 for each state of the U.S. except Alaska (NRCS). The dependent variable, DEVAREA, comprises urban and built-up areas and rural transportation land (NRCS, 82). Urban and built-up areas include residential, industrial, commercial, and institutional land, construction sites, railroad yards, cemeteries, airports, golf courses, landfills, sewage treatment plants, and urban roadways (NRCS, 88). NONFED is the area of land in a state that is not owned by the federal government.

Two variables are measures of a state's natural resource endowments. WATER represents the area of lakes, bays, other water bodies, rivers, and streams that are permanent open water. Data on lengths of coastlines, COAST, reportedly came from the National Ocean Service of the National Oceanic and Atmospheric Administration (Family Education Network, Inc.). Values of COAST are "lengths of general outline of seacoast. Measurements are made with unit measure of 30 minutes of latitude on charts as near scale of 1:1,200,000 as possible. Coastlines of bays and sounds are included to point where they narrow to width of unit measure, and distance across at such points is included" (Family Education Network, Inc.).

The effects of economic growth are analyzed in two ways. In the first specification (Model 1), the size of a state's economy is decomposed into real gross state product per capita and population. Economic growth can mean a certain number of people who enjoy a higher standard of living or more people who enjoy a certain standard of living. In the second and third specifications (Model 2 and Model 3), real gross state product per capita is further decomposed into real agricultural and non-agricultural production per capita because increases in these two variables might differentially affect returns to undeveloped and developed uses of land. Lagged values of these variables were used in the models to eliminate any possibility that they could be endogenous. Model 3 includes three dummy variables for Georgia (GA), Louisiana (LA), and New York (NY) that are not in Model 1 or Model 2.

Data from the Bureau of Economic Analysis on gross products of states and their agricultural sectors in 1996 and quantity indices for 1977, 1982, 1987, 1992, and 1997 were used to calculate real (1996 $s) gross total, agricultural, and non-agricultural production for the same years. The U.S. Census Bureau provided estimates of the population of each state in July of 1977, 1982, 1987, 1992, and 1997 (Census Bureau 1999, 1996, 1995). LAGPOP represents the mid-year population in each state five years prior to 1982, 1987, 1992, and 1997. LAGGSPPC, LAGAGPC, and LNONAGPC are the real gross state, agricultural, and non-agricultural production per capita five years prior to these four different years.

The annualized growth rate of real gross state product (RGSP) during the five-years prior to a particular year T (= 1982, 1987, 1992, or 1997) is

$$\mathrm{RGSPRATE} = \left(\frac{\mathrm{RGSP}(T)}{\mathrm{RGSP}(T-5)}\right)^{\frac{1}{5}} - 1.$$

If T = 1982, 1987, 1992, or 1997, the annualized inflation rate during the five-years prior to T is

$$\mathrm{INFLRATE} = \left(\frac{1}{1+\mathrm{RGSPRATE}}\right)\left(\frac{\mathrm{GSP}(T)}{\mathrm{GSP}(T-5)}\right)^{\frac{1}{5}} - 1.$$

Fourth-grade student performance on the National Assessment of Educational Progress in mathematics over time provides one indication of the quality of schools (NCES). In particular, to create ASSESS, we assigned average scale scores of randomly sampled 9-year olds in the Northeast, Southeast, Central, and West for the years 1982, 1986, 1992, and 1996 to each state that belonged to the respective region (Allen, Donoghue, and Schoeps, 825). Fourth-graders in the Southeast and Northeast consistently had the lowest and highest scores on this test (NCES).

Results and Discussion

Tables 2-4 contain parameter estimates, their respective standard errors, values of Student's *t* statistic, and the associated *p*-values. The estimated models explain two-thirds to three-fourths of the sample variation. The adjusted R^2 increases 0.5 of a percentage point when real lagged gross state product per capita (Model 1) is decomposed into real lagged agricultural and non-agricultural production per capita (Model 2) and another 4.7 percentage points when dummy variables for Georgia, Louisiana, and New York are also added (Model 3). These dummy variables were the only statistically significant ones (α = .05) in a fixed effects model that was estimated with the slope-related regressors in Model 2. (Results of the estimation of this model are available upon request.) We estimated this fixed-effects model because we rejected Hausman's null hypothesis at the 5% significance level (Table 3) in favor of the alternative that a fixed effects model is more appropriate than a random-effects model. Model 3 best fits the data (Table 4). This random-effects model with fixed effects for three unusual states is more appropriate than a fixed-effects model for all states because we cannot reject Hausman's null hypothesis (*p*-value = .1130).

The signs of the parameter estimates are generally consistent with economic theory. In Model 3, an increase of 1000 people in a state leads to an increase of 191 developed acres five years later. In other words, for a given standard of living in the U.S., each additional person directly or indirectly 'consumes' 0.19 acres of previously undeveloped land five years later. This effect is significant for any $\alpha > 0.0001$. Moreover, a percentage point increase in the annualized rate of growth of real gross state product over a five-year period subsequently induces people to increase developed land by 13,927 acres. Increases in the growth rate of real gross state product imply increases in the expected rates of return to uses of both developed and undeveloped land. However, income and population elasticities of demand are higher for non-agricultural than agricultural uses of land. As history indicates, farmers have increased production by substituting fertilizers, pesticides, and other inputs for land. Yet, homeowners and businesses evidently prefer to spread out rather than build upward as their income or numbers increase.

In Model 3, developed land area increases by 147 acres in response to a dollar increase in real agricultural production per person five years before. Holding lagged population, state area, and lagged real non-agricultural production per capita constant, an increase in real agricultural production per person implies an increase in real returns to agricultural use of land. The statistical insignificance of lagged real gross state product per capita in Model 1 makes some economic sense; what matters are the returns to non-agricultural use of land relative to agricultural use, not overall returns.

The estimated negative effect of inflation on developed land area makes sense if developers and users of developed land respond to nominal, not real, interest rates. For a given real interest rate, a percentage point decrease in the inflation rate and, thereby, the nominal interest rate during the previous five years leads to an increase of 16,900 acres of developed land in Model 2 (Table 3). The effect is statistically significant only at the 90% confidence level in that model and not in the other two (Table 2 and 4).

The quality of schools in particular regions of the country also affects land development. The area of developed land is an estimated 11,911 acres higher for each additional point that fourth-graders, on average, score on their mathematics assessment test. For a given population and real per capita gross state product, better schools reduce the costs to parents of educating their children and, thus, they demand larger residential lots. For similar reasons, businesses might demand larger commercial properties if better educated workers reduce production costs, net of any higher wages that these workers earn.

People prefer to live near to natural amenities (e.g., Smith, Poulos, and Kim). The amount of water area in a state significantly affects land development there (Tables 2-4). In Model 3, the developed land area of a state is 354 acres higher for each additional 1000 acres of water, given its population, real income per capita, and other characteristics (Table 4). This result is consistent with findings that people pay more to live near bays and lakes (e.g., Boyle, Poor, and Taylor). Larger water areas lead to proportionately higher increases in current and future returns to non-agricultural uses of land than returns to agricultural uses. The larger the water area, the lower the costs to people of 'consuming' water resources for recreational and aesthetic purposes and the larger the residential lots that they demand. Although farmers might pay premia for agricultural or personal use of land that is adjacent to streams, lakes, or bays (e.g., Bastian et al.), developers evidently pay higher premia than farmers pay as water area increases.

Contrary to our strong prior beliefs and anecdotal evidence, developed land areas are not higher in states with longer coastlines, all else equal. The insignificance of this result might reflect the extreme sensitivity to scale of measuring the length of a coastline (Post). Also, variability in land-use regulations and geographic features across states could mean that coastline length and the band of developable land along coastlines are not correlated.

Finally, developed land areas are an estimated 17 acres larger, on average, for each additional 1000 acres of non-federal land area in a state (Table 4). Larger non-federal land areas imply larger supplies of land for developed and undeveloped uses. Federal land area, by assumption, is less developable than non-federal land, which is primarily privately owned.

Future Research and Policy Implications

These state-level models were estimated for, among other reasons, the purpose of developing a prototype that state governments could use to forecast changes in tax revenues and government expenditures as their economies and populations grow. Although these models explain at least two-thirds and at most three-fourths of the state-level variation in developed land area, their specifications can be improved. Inclusion of variables that more precisely represent state-level school quality and the area of developable land along a state's coast should improve the explanatory power of our model. Land developments are relatively common in foothills of mountainous regions, such as California's Sierras. Hence, a model with a variable that measures the area of developable foothills might be better than these models. Variables that measure the degree to which a state regulates land use and, as urban economic theory predicts, the average cost per unit distance to transport people or goods should also be included in future analyses. Results of models estimated with county-level rather than state-level data will be required to forecast fiscal impacts of economic and demographic growth at the county-level.

Land development is, in a statistical sense, reversible in our current model. Yet, land development is almost never reversible in an economic sense. The following non-linear model incorporates irreversibility of land development:

$$\mathrm{LR}(T+5) - \mathrm{LR}(T) = \left(e^{-\beta X} + 1\right)^{-1} \mathrm{LA}(T) + \varepsilon \,.$$

(Recall that LR and LA denote developed and undeveloped land areas.) We want to estimate this model or a similarly inspired version in the future.

Sustainable development is a policy challenge without equal. Our results provide cautious guidance for this challenge. Policies that reduce population growth will also reduce land development. For a given population, growth in real per capita income or non-agricultural production per person does not necessarily lead to increases in developed areas. Moreover, policies that increase agricultural productivity will also strengthen incentives to continue the 'undeveloped' use of the land. Land trusts, conservation easements, transferable development rights, and other methods to protect biologically important habitats will be more expensive and important in states that have better schools or proportionally larger water resources.

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Table 1: Descriptive Statistics of the Variables

Variable Name	Means	Standard Deviation	Minimum	Maximum
DEVAREA (1000 acres)	1,717	1,345	149	8,567
LAGPOP (per person)	4,817,505	5,069,669	4,13,354	30,875,920
RGSPRATE (percentage points)	3.05	1.96	-2.69	9.55
LAGGSPPC (1996 $s/person)	21,917	4,740	8,072	37,146
LAGAGPC (1996 $s/person)	566	510	64	2,879
LNONAGPC (1996 $s/person)	21,352	4,813	7,670	36,741
INFLRATE (percentage points)	4.23	2.53	-1.74	13.41
ASSESS (average scale scores)	225	7	210	236
WATER (1000 acres)	1,010	923	52	4,045
COAST (miles)	117	252	0	1,350
NONFED (1000 acres)	30,440	24,841	655	1,64,594

Table 2: Random Effects Model 1: No Decomposition of Lagged Real Gross State Product per Capita

Variable Name	Parameter Estimate	Standard Error	t-Value	Pr > |t|
INTERCEPT	-2,906.83	967.1	-3.01	0.0030
LAGPOP	0.000189	.0000014	14.00	<.0001
RGSPRATE	15.20804	847.6	1.79	0.0744
LAGGSPPC	0.005874	0.00754	0.78	0.4372
INFLRATE	-13.9427	963	-1.45	0.1493
ASSESS	12.3396	4.3682	2.82	0.0052
WATER	0.289638	0.0956	3.03	0.0028
COAST	-0.23005	0.3427	-0.67	0.5028
NONFED	0.018019	0.00338	5.34	<.0001

Adjusted R-Square = 0.6941, n = 196

p-value of Hausman test for fixed effects = 0.0675

Table 3:

Random Effects Model 2: Decomposition of Lagged Real Gross State Product per Capita

Variable Name	Parameter Estimate	Standard Error	t-Value	Pr > |t|
INTERCEPT	-2,663.27	982.2	-2.71	0.0073
LAGPOP	0.000184	0.000014	13.55	<.0001
RGSPRATE	14.89211	854.1	1.74	0.0829
LAGAGPC	-0.14718	0.0782	-1.88	0.0615
LNONAGPC	0.006528	0.00764	0.85	0.3938
INFLRATE	-16.9044	1001.2	-1.69	0.0930
ASSESS	11.61996	4.4088	2.64	0.0091
WATER	0.274908	0.0939	2.93	0.0039
COAST	-0.2133	0.3356	-0.64	0.5258
NONFED	0.019487	0.00338	5.76	<.0001

Adjusted R-Square = 0.6993, n = 196

p-value of Hausman test for fixed effects = 0.0122

Table 4: Random Effects Model 3: Decomposition of Real Gross State Product per Capita and Dummies for Three Unusual States

Variable Name	Parameter Estimate	Standard Error	t-Value	Pr > |t|
INTERCEPT	-2,741.29	963.8	-2.84	0.0050
LAGPOP	0.000191	0.000013	14.33	<.0001
RGSPRATE	13.92661	841.2	1.66	0.0995
LAGAGPC	-0.14737	0.0751	-1.96	0.0512
LNONAGPC	0.006533	0.00741	0.88	0.3793
INFLRATE	-15.5286	988.0	-1.57	0.1177
ASSESS	11.9108	4.3329	2.75	0.0066
WATER	0.353607	0.0939	3.76	0.0002
COAST	-0.30034	0.2982	-1.01	0.3151
NONFED	0.017357	0.00308	5.63	<.0001
GA	1,004.132	435.4	2.31	0.0222
LA	-960.833	499.9	-1.92	0.0562
NY	-1,612.63	466.9	-3.45	0.0007

Adjusted R-Square = 0.7463, n = 196

p-value of Hausman test for fixed effects = 0.1130