Demographic, Economic, and Political Determinants of Land Development in the U. S.

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Selected short paper prepared for presentation at the Annual Meeting of the American Agricultural Economics Association in Denver CO, July 1-4, 2004.

An earlier and less comprehensive version of this paper was presented at the 35th Annual Meeting of the Southern Agricultural Economics Association, Mobile AL, 4 February 2003 and a related poster was presented at the AGU Chapman Conference on Ecosystem Interactions with Land Use Change, Santa Fe NM, 17 June 2003. The Natural Resource Conservation Service, USDA supported this research through Grant Agreement No. 69-4639-1-0010. Ritu Sharma entered most of the demographic, economic, and political data and used SAS for preliminary estimation. Basman Towfique entered land-use data. Peter Berck, Hal Harris, Mark Henry, Karina Schoengold, and Webb Smathers commented on preliminary results. I am responsible for any remaining error.

Abstract

Two reduced-form, econometric models of developed land area were estimated with the data from the USDA's National Resource Inventory and numerous other sources for 49 states during 1982-1997. In these linear and semi-quadratic fixed-effects models, developed land area is smaller where the average real gas price or conservation reserve program payment per enrolled acre during the previous five years is higher. This area also decreases as the average share of lower-house Democrats or real per-capita agricultural-mining production during the previous five years grows. Increases in a state's average population and average annual growth rate of real non-agricultural and non-mining output per capita during the previous five years induce land development. Policies that increase real CRP payments per enrolled acre, improve the real returns to agriculture and mining, reduce population growth, or raise real gasoline prices are likely to reduce land development.

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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, p. 36). Conversion of land from forestry, annual crop production, and other ‘undeveloped’ uses to residential, commercial, and other ‘developed’ uses accompanies economic growth. However, this land-use change can adversely affect wildlife, water quality, and other natural resources (e.g., Heimlich and Anderson, pp. 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, p. 73). Vehicle miles can increase with urban expansion (e.g., Kahn) and, by implication, emissions of greenhouse-producing gases can too. For this and other reasons, urban and rural uses of land affect climate in the U.S. (e.g., Bonan) and the world (e.g., Bounoua et al.). Models of land-use change for continents and large countries have become important for forecasting climate change (e.g., DeFries, Bounoua, and Collatz.).

Policies to reduce these negative externalities and forecasts of climate change as a function of land-use change should be grounded in up-to-date, appropriately-scaled, theoretically-motivated empirical models. In theory, land development depends on population and income per capita (Muth, pp. 16-20) and growth rates of population (Capozza and Helsey, p. 301), expected housing rents (Arnott and Lewis, p. 164), and expected returns to urban use (Capozza and Li, p. 897). In early empirical analyses (e.g., Clawson; Zeimetz et al.; Vesterby and Heimlich), economic or demographic growth is also the main determinant of land development but the quantitative impact in a multivariate statistical model was not estimated. In recent empirical models of a land owner's decision of whether (e.g., Bockstael) or when (e.g., Irwin and Bockstael) to develop a parcel of land, the quantitative effects of factors that determine differences in financial returns to residential and agricultural uses of this parcel have been estimated. Examples of these factors are zoning restrictions or distance of parcel to the nearest urban center. In these models, however, the effects of population, economic production per capita, associated growth rates, gas prices, and other factors that federal or state policy makers can influence have not been estimated. Use of spatially explicit, parcel-level data makes such estimation relatively difficult, if not prohibitively expensive.

In this paper the effects of demographic, economic, and political factors on statewide land development throughout the U.S. except Alaska are estimated and analyzed. Decomposition of real economic production and growth rates matters (e.g., Muth; Norris). In theory, discounted rents and conversion costs depend on the real interest rate. Moreover, in bid-offer models of land rent, distances to the central business district and, more generally, the associated transport costs are the primary reason for changes in these rents over space. Of course, land-use policies (e.g., Irwin and Bockstael) affect rents and vary across state and time. Federal farm programs usually increase the profitability of traditional agriculture. Finally, rents tend to be higher the more abundant and closer are water resources to those properties (e.g., Bastian et al.).

Conceptual Framework

Our model of land development is a modification of Irwin and Bockstael's model. Assume that perfectly competitive landowners maximize the net present financial value of their holdings and, thus, allocate land to the highest discounted valued use(s). If so, an owner of a parcel will develop it or sell it to a developer in year *T* provided that two conditions hold. First, the sum of the discounted (to *T*) net benefits of current and future use of developed land, say residential use, $\sum_{i=0}^{\infty}\frac{R(T+i)}{(1+r)^i}$, exceeds the sum of the forgone discounted net benefits of undeveloped land use, such as agriculture, $\sum_{i=0}^{\infty}\frac{A(T+i)}{(1+r)^i}$, and the costs of conversion in that year, $C^R(T)$. That is, $\sum_{i=0}^{\infty}\frac{R(T+i)-A(T+i)}{(1+r)^i}-C^R(T)>0$. Second, the net income of conversion in *T*, $\left[\sum_{i=0}^{\infty}\frac{R(T+i)-A(T+i)}{(1+r)^i}-C^R(T)\right]$, is at least as large as the sum of returns from use of the undeveloped land in that year *A(T)* plus the discounted net income from conversion a year later, $\left[\sum_{i=1}^{\infty}\frac{R(T+i)-A(T+i)}{(1+r)^i}-\frac{C^R(T+1)}{(1+r)}\right]$. In symbols, this second condition simplifies to $R(T)-A(T)-C^R(T)\geq A(T)-\frac{C^R(T+1)}{(1+r)}$.

Furthermore, a landowner will not convert in *T* a previously developed parcel if the sum of the present values of returns from developed uses exceeds the sum of the present values of returns from undeveloped uses net of the costs of conversion back to undeveloped uses. In symbols, a landowner keeps a parcel in its developed state if $\sum_{i=0}^{\infty}\frac{R(T+i)}{(1+r)^i}>\sum_{i=0}^{\infty}\frac{A(T+i)}{(1+r)^i}-C^A(T)$.

The sum of the areas of the individual parcels that landowners develop in a particular year or developed in previous years and do not convert back is the area of developed land in a state in that year. If land owners maximize discounted wealth, then developed area depends on undiscounted current and future returns to developed and undeveloped uses of parcels, conversion costs, interest rates, and land-use regulations.

Variables and Data Sources

The U. S. Department of Agriculture's Natural Resources Conservation Service has conducted the National Resources Inventory (NRI) every five years since 1982. This inventory entails periodic aerial sampling of hundreds of thousands of parcels with ground truthing to estimate, among other things, the area of developed land for each state of the U.S. except Alaska (NRCS, p. 3). Sampled and estimated areas have reflected growing season conditions in individual states in those years (NRCS, p. 3).

The Natural Resources Conservation Service has not collected financial data from individual owners of parcels in their samples. Moreover, to keep identities of parcel owners confidential, NRCS does not release longitude and latitude coordinates of the exact locations of sampled parcels. Hence, data on financial returns from uses of specific parcels, conversion costs, discount rates of individual owners in the NRI sample, and non-pecuniary benefits and costs to owners of these uses cannot be collected. However, data on variables that affect these returns, costs, and discount factors are available.

Table 1 presents descriptive statistics for the area of developed land and exogenous variables that affect land development. DEVAREA represents the area of non-federally owned large urban and built-up areas, small built-up areas, and rural transportation land in a state in 1982, 1987, 1992, and 1997 (NRCS, p. 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, p. 88). Rural transportation land includes all highways, roads, railways, and other rights-of-way outside of urban and built-up areas (NRCS, p. 86).

To reflect the periodic, during-the-year timing of the NRI and non-instantaneous land conversion, demographic, economic, and political variables were constructed to summarize conditions during the five or four years prior to the year in which areas of developed land were sampled and estimated. This construction also eliminates the possibility that these variables could be endogenous. For example, POP represents the mean of the mid-year populations in a state for 1977-1981, 1982-1986, 1987-1991, and 1992-1996 (Census Bureau 2002, 1996, 1995). POPGR is the mean of the annual growth rates of state population for 1978-1981, 1982-1986, 1987-1991, and 1992-1996.

Traditional agriculture and mining are the primary economic activities that use undeveloped land. To account for these differences in the location of productive activities and, thus, potential impacts on rents, economic production per capita is separated into real agricultural and mining output per capita and all other real production per capita. In particular, AGMINEPC and NANMPC represent the means of real (1996 $s) agricultural and mining output per capita of agricultural and all other production per capita in a state for the five years prior to 1982, 1987, 1992, and 1997 (BEA). Real agricultural production per capita, by construction and data availability, includes real output of forestry and fishing. AGMGR and NANMGR are the means of the annual growth rates of real agricultural and mining output per capita and all other real production per capita for 1978-1981, 1982-1986, 1987-1991, and 1992-1996.

The Federal Home Mortgage Corporation provided data on the fixed interest rates for 30-year conventional mortgages for the U.S per year for 1977-1997 (FHMC). The real interest rate in a particular state and year was calculated as this nominal interest rate for the nation in that year minus the state's inflation rate in that year. A state's inflation rate equals the ratio of state's price index in a given year to the index in the previous year minus one. The price index equals the state's nominal gross state product divided by its real (1996 $s) gross state product. SINTRATE represents the mean real interest rate for 30-year conventional mortgages in a state for '78-'81, '82-'86, '87-'91, and '92-'96.

The Energy Information Administration of the US Department of Energy publishes annual, statewide data on the nominal price of motor gasoline, measured in dollars per million British Thermal Units (EIA). The real (1996 $s) price of motor gasoline equals the nominal price in a particular state and year divided by the state's price index for that year. GASPRICE represents the average real price of motor gasoline in a state for the five years prior to 1982, 1987, 1992, and 1997.

There is no available published information that summarizes the degree of zoning in a particular state and year. However, reputations and legislative records of the two major political parties suggest differences in their approach to regulation (Friedman). SHAREDEM equals the mean of the shares of Democrats in the lower house of a state's legislature for the five years prior to 1982, 1987, 1992, and 1997. These shares were calculated with data on the number of state legislators by political party affiliation after each state election (Census Bureau 2001, 1999, 1992, 1986, and 1984).

Another political determinant is the Conservation Reserve Program (CRP). The CRP provides farmers with rental payments and cost-share assistance to plant trees or other resource-conserving vegetative covers to improve the quality of water, control soil erosion, and enhance wildlife habitat (Farm Service Agency). CRPAYPA and CRPAREA represent average real (1996 $s) net outlay per enrolled acre and the enrolled area of the CRP during the five years prior to 1982, 1987, 1992, and 1997 (Barbarika).

The 1997 National Resources Inventory was also the source of data for two possible environmental determinants of developed land use: the stock of potentially developable land, NFEDNCRP, and water resources, WATER (NRCS, pp. 11-24). In particular, NFEDNCRP represents the area of land that was not owned by the federal government minus the area enrolled in the CRP in 1982, 1987, 1992, and 1997. WATER represents the surface area of streams, rivers, lakes, bays, and other permanently open bodies of water in a state in these four different years (NRCS, p. 89). The areas of non-federally owned land and surface water can change over time due to purchase, sale, donation, and exchange by federal agencies of land and creation of lakes (NRCS, pp. 36-39).

Econometric Model and Estimation Procedures

Let X'_{it} represent a 1 x K row vector of determinants of the area of developed land in state *i* and year *t* and β be a K x 1 parameter vector of marginal effects of these variables. A fixed-effects model of developed land area is $Y_{it} = \alpha_i + X'_{it}\beta + \varepsilon_{it}$, in which *i* = state 1, 2, …, and 49 and *t* = time period 1, 2, 3 and 4 to reflect the data. The intercept α_i represents a state *i*-specific effect and, more importantly, embodies unobserved state-specific factors that might be correlated with X_{it}, observed characteristics of state *i* in time period *t* (Greene, p. 285). The error term ε_{it} represents random processes and also researcher ignorance. Assume $\mathrm{E}(\varepsilon_{it}) = 0$. Hence, $\alpha_i + X'_{it}\beta$ is a first-order approximation of the unknown functional form of a reduced-form model of expected area of developed land in state *i* and time *t*. In contrast to a random-effects model, a fixed-effects model is likely to be appropriate for a sample of all cross-sectional units—all states except Alaska, in this case—at specific points in time (Greene, p. 293).

Fixed-effects models of developed land area were estimated with the ordinary least squares (OLSQ) command in Time Series Processor (TSP), Version 4.5 (Hall and Cummins). A fixed-effect model with 13 exogenous variables and the square of each of these variables was initially estimated to detect possible non-linear effects, such as Vesterby and Heimlich (p. 287) found for population. Squared variables with insignificant effects were dropped and the resultant semi-quadratic model was re-estimated. A fixed-effect, linear-in-variables model was also estimated.

Given evidence from Lagrange multiplier tests in favor of H_1: $\text{var}(\varepsilon_{it}) = \sigma_i^2 \neq \sigma_j^2 = \text{var}(\varepsilon_{jt})$, heteroskedastic-consistent standard errors were calculated with the Eicker-White estimator divided by (T-K)/T (Hall and Cummins, p. 185). In models with *n* fixed effects for all cross-sectional units, *K* other explanatory variables, and *T* time periods, the appropriate divisor in the Eicker-White estimator is $nT - n - K/nT$, or $147 - K/196$ for these data. Preceded by the frequency statement FREQ (PANEL, T=4), OLSQ correctly calculated the Durbin-Watson statistic, $d = \sum_{i=1}^{49}\left(\sum_{t=2}^{4} e_{it-1}e_{it}\right) \Big/ \sum_{i=1}^{49}\left(\sum_{t=1}^{4} (e_{it})^2\right)$, for these balanced panel data. Given evidence from Durbin-Watson tests in favor of first-order autocorrelation, H_1: $\rho > 0$, and, thus, $\text{cov}\,[\varepsilon_t, \varepsilon_{t-1}] \neq 0$, Prais-Winsten transformations of the dependent variable were regressed on identical transformations of state-specific intercepts and exogenous variables to correct for these non-spherical disturbances.

Matrices

$$\begin{bmatrix} \sqrt{1-\hat{\rho}^2}\,Y_{i1} \\ Y_{i2}-\hat{\rho}Y_{i1} \\ Y_{i3}-\hat{\rho}Y_{i2} \\ Y_{i4}-\hat{\rho}Y_{i3} \\ \sqrt{1-\hat{\rho}^2}\,Y_{j1} \\ Y_{j2}-\hat{\rho}Y_{j1} \\ Y_{j3}-\hat{\rho}Y_{j2} \\ Y_{j4}-\hat{\rho}Y_{j3} \end{bmatrix}$$

and

$$\begin{bmatrix} \sqrt{1-\hat{\rho}^2} & 0 & \sqrt{1-\hat{\rho}^2}\,X_{i12} \cdots \sqrt{1-\hat{\rho}^2}\,X_{i1K} \\ (1-\hat{\rho}) & 0 & X_{i22}-\hat{\rho}X_{i12} \cdots X_{i2K}-\hat{\rho}X_{i1K} \\ (1-\hat{\rho}) & 0 & X_{i32}-\hat{\rho}X_{i22} \cdots X_{i3K}-\hat{\rho}X_{i2K} \\ (1-\hat{\rho}) & 0 & X_{i42}-\hat{\rho}X_{i32} \cdots X_{i4K}-\hat{\rho}X_{i3K} \\ 0 & \sqrt{1-\hat{\rho}^2} & \sqrt{1-\hat{\rho}^2}\,X_{j12} \cdots \sqrt{1-\hat{\rho}^2}\,X_{j1K} \\ 0 & (1-\hat{\rho}) & X_{j22}-\hat{\rho}X_{j12} \cdots X_{j2K}-\hat{\rho}X_{j1K} \\ 0 & (1-\hat{\rho}) & X_{j32}-\hat{\rho}X_{j22} \cdots X_{j3K}-\hat{\rho}X_{j2K} \\ 0 & (1-\hat{\rho}) & X_{j42}-\hat{\rho}X_{j32} \cdots X_{j4K}-\hat{\rho}X_{j3K} \end{bmatrix}$$

exemplify these transformations during the four periods of time in adjacent states *i* and *j*.

The statistic to test whether the state-specific constants differ is $F(n-1,\ nT-n-K) =$

$$\frac{(R^2_{Fixed}-R^2_{Pooled})/(n-1)}{(1-R^2_{Fixed})/(nT-n-K)},$$

in which *Fixed* and *Pooled* indicate a fixed-effects model and a pooled model with only a single intercept for all *n* states and *T* time periods. Under the null hypothesis that the state-specific constants are the same, this statistic is an *F* random variable with n-1 numerator and nT-n-K denominator degrees of freedom.

Results

Parameter estimates, standard errors, *p*-values associated with the implied *t*-statistics, and sample-mean elasticities are in Table 2 and 3. The R^2 of each model is relatively high; even if all but one intercept is eliminated, the coefficient of determination, R^2_{Pooled}, is 0.885 in the linear model and 0.938 in the semi-quadratic model. The values of the *F* random variables for the linear and semi-quadratic models are $F(48, 134) = 25.68$ (p-value $< 10^{-47}$)and $F(48,131) = 24.02$ (p-value $< 10^{-44}$). Hence, the state-specific constants differ and a linear model with one intercept is not appropriate. Furthermore, these fixed-effects models are more appropriate than the associated random-effects models; given the large values of Hausman's χ^2 test statistic, one rejects the null hypothesis that the state-specific constants are uncorrelated with the other exogenous variables in favor of the alternative that these constants are correlated. In terms of adjusted R^2, the log of the likelihood function, and Schwarz's criterion, the semi-quadratic model variables fits the data slightly better than the linear model does. Variance inflation factors (VIFs) of the untransformed exogenous variables did not indicate serious multicollinearity; two of the variables had VIFs between 2.2 and 2.6 and the other nine had VIFs between 1.2 and 2.0.

The positive effect of POP in both models and negative effect of POPSQ in the semi-quadratic model are significant. In the semi-quadratic model, each additional person in a state during the previous five years induces, on average, an additional 0.422 acres of developed land. A one percent increase in the average previous five-year population leads to a subsequent 1.2% average increase in developed land area.

The negative effect of average real agricultural and mining output per capita in the previous five years, AGMINEPC, is statistically significant and similar in both models. An increase of $100 in AGMINEPC leads to approximately 6,000 fewer acres of developed land. A 10% increase in average real agricultural and mining output per capita in the previous five years leads to a 0.7% decrease in developed land area.

The positive effect of average real non-agricultural and non-mining output per capita output in the previous five years, NANMPC, is statistically significant in the semi-quadratic model, albeit at the 92.5% confidence level. In particular, an increase of $100 in average real per capita output other than agriculture or mining in the previous five years induces 1,434 more acres of developed land. In other words, a 10% increase in NANMPC induces a 3.9% increase in developed land area. The average annual rate of growth of real non-agricultural and non-mining output per capita in the previous five years, NANMGR, also encourages land development. The *p*-value associated with the *t*-statistic is smaller and the parameter estimate is larger in the semi-quadratic than the linear model. In particular, an increase of one percentage point in NANMGR leads to an increase of 23,309 acres of developed land in the semi-quadratic model.

The negative effect of GASPR is statistically significant in both models, although the absolute value of the effect and the confidence level are lower in the linear model. In the semi-quadratic model an increase of $1 in the previous five-year average price per million BTUs of motor gas--an approximate increase of $.124 per gallon--leads to a decrease in developed area, on average, of 41,617 acres. A 10% increase in GASPR subsequently reduces developed land area by 6.0%, on average.

Political variables matter too. In two of three cases, the qualitative effects and *p*-values are robust to the model specification. In the semi-quadratic model, developed land area is 5,965 acres smaller, on average, in a state where the previous five-year average share of Democrats in the state's lower legislative house is one percentage point higher. An increase of $10 in the previous five-year average real conservation reserve program payment per enrolled acre, CRPAYPA, leads to 2,486 fewer acres of developed land. A 10% increase in CRPAYPA induces a 0.09% decrease in the area of developed land. The effect of CRPAREA becomes significant at a high level of confidence in the semi-quadratic model. The area of developed land is 189 acres smaller, on average, in a state with 1000 more acres enrolled in the CRP during the previous five years. A 10% increase in this area leads to a 0.38% decrease, on average, in developed land area.

Discussion

The signs and magnitudes of the parameter estimates compare reasonably well with results from previous research, are consistent with economic theories about land rents and owners of land who allocate it to the highest present-valued use(s), or both.

Marginal consumption of urban land in 135 fast-growth counties of the U.S. during the early 1970s to the early 1980s was 0.47 additional acres per additional household, or 0.216 acres per additional person (Vesterby and Heimlich, p. 285). The urban area in those counties that was estimated with land-use data from aerial photographs was 0.5 million acres smaller than the area in those same counties that fit the Census Bureau's population-based definition of urban (Vesterby and Heimlich, p. 282). Marginal consumption of urban land--defined by the Census Bureau, calculated with the USDA's Major Land Uses data, and also called the urban land-use coefficient--was 0.69 acres per additional person during 1974-1987 in the continental U. S. (Reynolds, p. 277).

'Urban area' for Census purposes, however, is smaller than the National Resource Inventory's developed land area. In 1997, for example, urban area was 62 million acres, which was 36 million acres, or 37%, less than developed land area (Heimlich and Anderson, p. 12). Developed land area includes rural transportation land and large, often scattered, residential lots in rural areas. Development of these lots in rural areas, particularly lots 10 acres or larger, grew during the economic expansion of the 1990s (Heimlich and Anderson, pp. 13-14). Although differences in developed and urban land areas make direct comparisons of urban land-use coefficients impossible, the estimated increase of developed land area of 0.422 acres for each additional person in the previous five years during 1982-1997 seems credible.

Increases in developed land area that get smaller as population grows imply that rents grow more for uses of developed land than for uses of undeveloped land, but these positive differences get smaller as population grows. This differential pattern of rent increases is consistent with one or more of the following two hypotheses. First, demand increases proportionately more for uses of developed land than for uses of undeveloped land but the difference gets smaller as population grows. In other words, the population elasticity of demand for uses of developed land exceeds that for uses of undeveloped land but the excess becomes smaller as population grows. Second, the price elasticity of supply of land for undeveloped uses exceeds that for developed uses. In particular, farmers are more willing or able to substitute fertilizers, pesticides, new varieties of seeds, and other ‘modern’ inputs for land to increase production as rents for undeveloped land increase than developers are willing or able to substitute vertical space and horizontal space-saving inputs for land to produce sites for residential, commercial, industrial and other ‘urban’ activities as rents for developed land increase.

Increases in the previous five-year average real agricultural and mining output per capita do not imply increases in the previous five-year average real gross state product per capita. The sample correlation coefficient between real gross state product per capita and real agricultural and mining output per capita is only 0.07 and no linear association between the two variables exists (p-value = 0.35). Increases in the federal government’s agricultural price supports, growth in the demand for a state’s agricultural or mining exports, or weather-related decreases in supply of agricultural and mining products with price inelastic demand would lead to increases in real agricultural and mining output per capita. Hence, increases in the previous five-year average real agricultural and mining output per capita, *ceteris paribus*, most likely imply increases in real net earnings in the present and, given constant growth rates, in the future from uses of undeveloped land relative to developed land. Increases in the average conservation-reserve-program payments per acre of enrolled land in the previous five years definitely imply increases in real returns to owners of agricultural and timber land for the length of the CRP contract. As real returns for uses of undeveloped land increase, some of this land that would otherwise be converted to 'urban' uses is not developed.

Real non-agricultural and non-mining output per capita constitutes, on average, 95% of real gross state product per capita. The sample correlation coefficient between these two variables is 0.96 and the linear association between them is strongly positive (p-value $< 10^{-107}$). Hence, increases in real non-agricultural and non-mining output per capita imply increases in income per capita in a state. The income elasticity of demand for the highest-valued developed use of land along the spatial margin probably exceeds the income elasticity of demand for the highest-valued undeveloped use of that land. For example, most estimates indicate that the income elasticity of demand for housing in the long run exceeds that for food (e.g., Deaton and Muellbauer, pp. 319-320; Muth, p. 19). If so, increases in real non-agricultural and non-mining output per capita and its growth rate imply proportionately greater increases in real current and future rents for uses of developed land than rents for uses of undeveloped land.

In theory (e.g., Capozza and Helsey, p. 297) and empirical analyses (e.g., Bockstael, p. 1176), housing prices usually decline as residential locations get farther from the central business district, town center, or highway because commuting costs increase with distance. Commuting costs also increase with the real price of gas. Although prices of land for developed and undeveloped uses will decrease as transport costs increase, the decrease in the price of land for developed uses will tend to be more pronounced because commuting tends to be more time-intensive for users of developed land than users of undeveloped land. For example, people typically commute four to six days per week whereas farmers transport produce a few times per year. As a result, less land is converted to developed uses as real gas prices increase. In other words, for a given population, the area of developed land decreases as the real price of gas increases because, to economize on commute costs, people choose to live and work closer together and, thereby, create denser uses of developed land. Increases in gas prices also imply increases in the cost of converting undeveloped land into developed land.

Zoning and other land-use policies affect the returns to uses of undeveloped and developed land. As the share of Democrats in the lower legislative house increases, local government officials might be more likely to regulate land use because these officials are more likely to be Democrats themselves or, at least, the voting public is more likely to support such policies. In general, Democrats regulate the economy and its environmental impacts more than Republicans do (Friedman). As prohibitions and inhibitions on land development increase, future real returns to developed uses of currently undeveloped land decrease and the amount of land that is converted to urban uses decreases as well.

Implications for Research and Policy

Although these two models explain a relatively large proportion of the variation in developed land area across states during 1982-1997, their specifications can be improved. None of the exogenous variables served exclusively as a proxy for these costs. Forested land and steep land are more costly to develop than crop land and flat land are (Bockstael, pp. 1176-1177). The NRI contains information on the area of forest and the erodibility index of cropland in each state in each of the four years of observation.

Although standard errors were heteroskedastic-consistent, the marginal effects of the demographic, economic, and political variables were not standardized for the size of the state. A model in which the developed area's share of total land area or non-federal land net of CRP land might reduce the possibility of unreasonable predictions of land development for relatively large or small states. One specification of a share model is

$$\text{DEVAREA}_{it} / \text{NFEDNCRP}_{it} = \left(e^{-\beta X_{i,t-1 \text{ to } t}} + 1\right)^{-1} + \varepsilon_{it} .$$

Land development is, in a statistical sense, reversible in our current model. Yet, land development is rarely reversible in reality. Irreversible land development imposes certain structure on the econometric model. For example, the following non-linear model incorporates irreversibility of land development:

$$\Delta\text{DEVAREA} = \left(e^{-\beta X_{i,t-1 \text{ to } t}} + 1\right)^{-1} \left(\text{NFEDNCRP}_{i,t-1} - \text{DEVAREA}_{i,t-1}\right) + \varepsilon_{it}$$

Sustainable development is a policy challenge without equal. Our results provide preliminary suggestions for this challenge. Family-planning and other policies that reduce population growth are likely to reduce land development. Policies that improve the real returns to agriculture and mining are likely to reduce the area of developed land. Policies that increase CRP payments per enrolled acre or expand enrollment of undeveloped land in the program will strengthen the incentives for continued use of some undeveloped land. A tax on the price of gasoline will make the conversion of some undeveloped land unprofitable. Political campaigns that increase the Democrats's shares in the lower state legislatures are likely to reduce the incentives for land conversion.

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Table 1: Descriptive Statistics

Variable	Mean	Std. Deviation	Minimum	Maximum
DEVAREA (1,000 acres)	1,717	1,345	149	8,567
POP (1,000 people)	4,929	5,208	452	31,490
AGMINEPC (1996$/person)	1,090.18	1,372.86	98.31	10,028.25
NANMPC (1996$/person)	22,059.55	4,643.75	13,618.82	37,340.56
POPGR (percentage pts.)	1.09	1.12	-1.50	5.74
AMGR (percentage pts.)	3.20	5.01	-6.99	30.73
NANMGR (percentage pts.)	1.90	1.31	-2.73	5.49
SINTRATE (percentage pts.)	6.40	2.15	-2.84	14.03
GASPRICE (1996$/million BTUs or ≈*1996 $s/gallon*)	11.68 *1.45*	2.12 *0.26*	8.12 *1.01*	17.99 *2.23*
SHAREDEM (percentage pts.)	59.0	17.6	22.0	96.8
CRPAYPA ($s/acre)	31.78	48.51	0.00	401.57
WATER (1,000 acres)	1,010	923	52	4,045
CRPAREA (1,000 acres)	316	676	0	4,042
NFEDNCR (1,000 acres)	30,029	24,423	655	164,594

Table 2: Linear Model of Developed Land Area

Variable	Estimated Coefficient	Std. Error	*t*-statistic	*p*-value	Elasticity of Sig. Variable
POP	0.223	0.058	3.858	[.000]	0.615
AGMINEPC	-0.058	0.033	-1.786	[.076]	-0.069
NANMPC	0.014	0.010	1.441	[.152]	
POPGR	5.127	16.858	0.304	[.762]	
AMGR	-0.262	2.167	-0.121	[.904]	
NANMGR	14.831	7.665	1.935	[.055]	0.033
SINRATE	-0.890	5.078	-0.175	[.861]	
GASPR	-30.163	13.955	-2.161	[.032]	-0.436
SHRDEM	-10.544	2.458	-4.289	[.000]	-0.738
CRPAYPA	-0.309	0.149	-2.077	[.040]	-0.011
WATER	0.220	0.310	0.708	[.480]	
CRPAREA	0.037	0.068	0.547	[.585]	
NFEDNCRP	-0.006	0.058	-0.111	[.912]	
49 State CONSTANTS	$\hat{\rho}$, Adjusted R^2, Log Likelihood, and Schwarz Criterion				
	0.2407, 0.9835, -1211.01, 1374.63				

Table3: Semi-Quadratic Model of Developed Land Area

Variable	Estimated Coefficient	Std. Error	*t*-statistic	*p*-value	Elasticity of Sig. Variable
POP	0.483	0.064	7.539	[.000]	1.165
POPSQ	-6.16E-06	1.42E-06	-4.324	[.000]	
AGMINEPC	-0.060	0.029	-2.096	[.038]	-0.071
NANMPC	0.014	0.008	1.796	[.075]	0.386
POPGR	1.828	15.493	0.118	[.906]	
AMGR	0.821	1.838	0.446	[.656]	
NANMGR	23.309	8.143	2.862	[.005]	0.051
SINRATE	-0.288	4.542	-0.063	[.950]	
GASPR	-334.420	64.054	-5.221	[.000]	-0.602
GASPRSQ	12.534	2.578	4.863	[.000]	
SHRDEM	-5.965	2.040	-2.924	[.004]	-0.417
CRPAYPA	-0.249	0.120	-2.076	[.040]	-0.009
WATER	0.077	0.145	0.534	[.594]	
CRPAREA	-0.231	0.071	-3.231	[.002]	-0.038
CRPAREASQ	6.56E-05	2.37E-05	2.772	[.006]	
NFEDNCRP	-0.062	0.039	-1.608	[.110]	
and 49 State CONSTANTS	$\hat{\rho}$, Adjusted R^2, Log Likelihood, and Schwarz Criterion				
	0.1504, 0.9906, -1169.55, 1341.09				