

Demographic, Economic, Environmental, and Political Determinants of Developed Land Area in the U. S.

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Introduction

- The area of developed land increased 47.4%, from 29.5 million to 43.4 million hectares (72.8 million to 107.3 million acres), during 1982-2002 in the lower 48 states of the U.S.
- In these 48 states the increase in developed area accelerated between 1982-2002.
- Land development often accompanies economic growth.
- Urbanization of land use can adversely impact the environment.
 - 247,500 acres of wetlands lost during 1992-1997.
 - Vehicle miles increase and so can greenhouse-producing gas emissions.
 - Climate changes.
- Models of land-use change for continents and large countries have become important for forecasting climate change.
- Policies to reduce adverse environmental impacts and forecasts related to land-use change should be grounded in appropriately-scaled, theoretically-motivated empirical models.

Previous Economic Research

- In economic theory, the area of developed or urban land depends on
 - population and income per capita and, given constant agricultural rents,
 - growth rates of expected housing rents, population, and expected returns to urban use.
- In empirical analyses with aggregated data (e.g., Vesterby and Heimlich, 1991) economic or population growth did apparently induce land development but the quantitative effect was not estimated.
- Brueckner and Fansler (1983) estimated an empirical model of the size of the urbanized area in any county in the U. S. in 1970 as a function of the county's population, average household income, agricultural rent, and proxies for commuting cost.
- In recent empirical models of an individual's decision whether or when 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 and
 - distance of the parcel to the nearest highway or urban center.
- In the recent models, however, the effects of population, real economic production per capita, associated growth rates, real gas prices, and other factors influenced by federal or state policy have not been estimated.
- Use of spatially explicit, parcel-level data makes such estimation relatively difficult, if not prohibitively expensive.
- Our model is most closely related to that of Brueckner and Fansler.

Conceptual Framework

- Landowners maximize wealth, financial and non-financial.
- A landowner develops a parcel under two conditions:
 - Discounted net benefits of developed land use exceed the sum of the discounted net benefits of undeveloped land use and conversion costs.
 - This gain is at least as large as the discounted gain from subsequent conversion.
- A landowner keeps his or her parcel in a developed state if the present value of financial and non-financial returns from developed use exceeds the present value of returns from undeveloped uses net of the costs of re-conversion.
- If owners manage land to maximize wealth, then developed area depends on undiscounted current and future returns to developed and undeveloped uses of parcels, conversion costs, discount rates, and land-use regulations.
- The area of developed land in a given state and year equals the sum of the areas of individual parcels that owners developed in previous years and did not convert back.

Variables

- DEVAREA \equiv area (1000 ha.) of non-federally owned urban land, built-up areas, and rural transportation land in a state in 1982, 1987, 1992, and 1997
- POP \equiv average mid-year population (1000s) of a state for 77-81, 82-86, 87-91, and 92-96.
- AGMINEPC \equiv average real agricultural and mining production per capita during previous five years (1996 dollars per person)
- NAGNMPC \equiv average real non-agricultural and non-mining production per capita during previous five years (1996 dollars per person)
- POPGRATE \equiv average growth rate of population in state during 78-81, 82-86, 87-91, and 92-96 (percentage points)
- AGMGRATE \equiv average growth rate of real agricultural and mining output per capita during 78-81, 82-86, 87-91, and 92-96 (percentage points)
- NAMGRATE \equiv average growth rate of real non-agricultural and non-mining output per capita during 78-81, 82-86, 87-91, and 92-96 (per. pts.)
- INTERATE \equiv average real mortgage interest rate in a state during 78-81, 82-86, 87-91, and 92-96 (percentage points)

Variables cont.

- INFLRATE \equiv average state inflation rate during 78-81, 82-86, 87-91, and 92-96 (per. pts.)
- GASPRICE \equiv average real price of motor gasoline in state during the previous 5 years (1996 dollars per gallon)
- SHAREDDEM \equiv average share of Democrats in a state's lower legislative house during the previous 5 years (per. pts.)
- CRPAYPA \equiv average real net outlay of the Conservation Reserve Program per enrolled hectare in a state during previous five years (1996 \$/ha.)
- CRPAREA \equiv average enrolled area (1000 ha.) of the Conservation Reserve Program during the previous five years
- WATER \equiv surface area (1000 ha.) of streams, rivers, lakes, and bays in state in 82, 87, 92, and 97
- FEDAREA \equiv area (1000 ha.) of federally owned land in 1982, 1987, 1992, and 1997
- NOFEDCRP \equiv area (1000 ha.) of non-federally owned land minus the CRP area in 1982, 1987, 1992, and 1997

Sources of Data

- The Natural Resources Conservation Service is the source of data for DEVAREA, CRPAYPA, WATER, CRPAREA, FEDAREA, and NOFEDCRP.
- Data on population and the number of state legislators by political party affiliation after each election came from the Census Bureau.
- The Bureau of Economic Analysis provided gross products of agriculture, mining, and all sectors in 1996 and quantity indices to calculate annual real (1996 \$s) gross products of agriculture, mining, and the entire state during 1977-1997.
- Data on fixed annual interest rates for 30-year conventional mortgages came from the Federal Home Mortgage Corporation.
- The Energy Information Administration published annual nominal prices of motor gasoline in a state for 1977-1997.

Table 1: Descriptive Statistics (metric)

Variable	Mean	Std. Deviation	Minimum	Maximum
DEVAREA (1,000 hectares)	694.9	544.4	60.4	3,467.0
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
NONAGMPC (1996\$/person)	\$22,059.55	\$4,643.75	\$13,618.82	\$37,340.56
POPGRATE (percentage pts.)	1.09	1.12	-1.50	5.74
AMGRATE (percentage pts.)	3.20	5.01	-6.99	30.73
NAMGRATE (percentage pts.)	1.90	1.31	-2.73	5.49
INTERATE (percentage pts.)	6.40	2.15	-2.84	14.03
INFLRATE (percentage pts.)	4.59	2.68	-0.88	15.65
GASPRICE (1996\$/liter)	\$0.38	\$0.07	\$0.27	\$0.59
SHAREDEM (percentage pts.)	58.99	17.62	22.00	96.82
CRPPAY (1996\$/hectare)	\$78.53	\$119.87	\$0.00	\$992.27
CRPAREA (1,000 hectares)	128.0	273.5	0.0	1,636.0
WATER (1,000 hectares)	408.6	373.5	21.2	1,637.2
FEDAREA (1,000 hectares)	3,310.1	5,714.6	1.4	24,229.6
NOFEDCRP (1,000 hectares)	12,191.0	9,923.7	265.1	66,610.1

Table 1: Descriptive Statistics (English)

Variable	Mean	Std. Deviation	Minimum	Maximum
DEVAREA (1,000 acres)	1,717.1	1,345.2	149.2	8,567.0
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
NONAGMPC (1996\$/person)	\$22,059.55	\$4,643.75	\$13,618.82	\$37,340.56
POPGRATE (percentage pts.)	1.09	1.12	-1.50	5.74
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INTERATE (percentage pts.)	6.40	2.15	-2.84	14.03
INFLRATE (percentage pts.)	4.59	2.68	-0.88	15.65
GASPRICE (1996\$/gallon)	\$1.45	\$0.26	\$1.01	\$2.23
SHAREDEM (percentage pts.)	58.99	17.62	22.00	96.82
CRPPAY (\$s/acre)	\$31.78	\$48.51	\$0.00	\$401.57
CRPAREA (1,000 acres)	316.2	675.9	0.0	4,042.4
WATER (1,000 acres)	1,009.6	923.0	52.4	4,045.4
FEDAREA (1,000 acres)	8,179.2	14,120.8	3.5	59,871.3
NOFEDCRP (1,000 acres)	30,123.9	24,521.6	655.1	164,593.6

Econometric Model and Estimation Procedures

- A fixed-effects model, not a random effects model, is usually appropriate for a sample of all cross-sectional units—all states except Alaska in this case—at specific points in time.
- A fixed-effects model for this analysis is $\ln Y_{it} = \alpha_i + X_{it}\beta + \varepsilon_{it}$,
- The dependent variable was the log of one of these variables:
 - share of developed land (DEV DEN=DEV AREA/NOFEDCRP)
 - ‘odds’ of developed land (DEV DEN/1-DEV DEN)
- Advantages of these models over log of area of developed land
 - estimated shares will never exceed one or be negative,
 - shares represent a standardization of different sizes of states
- $E(\varepsilon_{it}) = 0$ and α_i represents unobserved state i -specific factors that might be correlated with X_{it} .
- A linear-in-exogenous-variables and nonlinear-in-exogenous-variables version of each type of model were estimated with PANEL in TSP (V4.5). Hence, four models were estimated.

Table 2: Models of the Log of the Share of Developed Land

VARIABLE	Parameter	S. Error	<i>p</i> -value	Parameter	S. Error	<i>p</i> -value
POPDEN	5.609E-02	1.018E-01	[.583]	2.505E-01	9.877E-02	[.012]
AGMINEPC	-2.470E-05	1.602E-05	[.125]	-2.529E-05	1.414E-05	[.076]
NONAGMPC	6.886E-06	3.681E-06	[.064]	4.430E-05	9.338E-06	[.000]
NAGMPCSQ				-7.423E-10	1.643E-10	[.000]
POPGRATE	-3.097E-03	7.534E-03	[.682]	-2.114E-03	6.938E-03	[.761]
AMGRATE	7.261E-04	8.428E-04	[.390]	6.640E-04	7.474E-04	[.376]
NAMGRATE	9.568E-03	3.316E-03	[.005]	7.908E-03	2.942E-03	[.008]
INTERATE	-2.727E-02	4.056E-03	[.000]	-2.708E-02	3.796E-03	[.000]
INFLRATE	-3.687E-02	4.812E-03	[.000]	-3.552E-02	4.379E-03	[.000]
GASPRICE	-3.842E-01	1.578E-01	[.016]	-3.415E-01	1.576E-01	[.032]
SHAREDEM	-3.363E-03	6.947E-04	[.000]	-2.543E-03	6.269E-04	[.000]
CRPPAY	-8.532E-05	4.040E-05	[.037]	-2.354E-04	1.051E-04	[.027]
CRPPAYSQ				2.005E-07	1.198E-07	[.097]
CRPDEN	-1.138E+00	4.355E-01	[.010]	-1.310E+00	3.923E-01	[.001]
WATDEN	-5.043E-01	1.515E+00	[.740]	-1.449E+00	1.369E+00	[.292]
FEDDEN	6.879E-01	4.616E-01	[.139]	3.391E+00	1.014E+00	[.001]
FEDSQDEN	-1.138E+00	4.355E-01		-1.581E-04	5.351E-05	[.004]
49 State Constants	Adjusted R ² , <i>F</i> statistic, Schwarz Information Criterion					
	0.9966, 187.04, -205.546			0.9973, 224.16, -224.396		

Table 3: Models of the Log of the ‘Odds’ of Developed Land

Variable	Parameter	S. Error	<i>p</i> -value	Parameter	S. Error	<i>p</i> -value
POPDEN	1.975E-01	1.081E-01	[.070]	3.953E-01	1.059E-01	[.000]
AGMINEPC	-2.745E-05	1.702E-05	[.109]	-2.802E-05	1.515E-05	[.067]
NONAGMPC	1.099E-05	3.910E-06	[.006]	4.801E-05	1.001E-05	[.000]
NAGMPCSQ				-7.382E-10	1.761E-10	[.000]
POPGRATE	-5.001E-03	8.004E-03	[.533]	-3.516E-03	7.438E-03	[.637]
AMGRATE	7.447E-04	8.953E-04	[.407]	6.989E-04	8.013E-04	[.385]
NAMGRATE	1.010E-02	3.523E-03	[.005]	8.386E-03	3.154E-03	[.009]
INTERATE	-2.755E-02	4.308E-03	[.000]	-2.752E-02	4.070E-03	[.000]
INFLRATE	-3.727E-02	5.112E-03	[.000]	-3.607E-02	4.694E-03	[.000]
GASPRICE	-3.442E-01	1.676E-01	[.042]	-3.082E-01	1.689E-01	[.070]
SHAREDEM	-3.748E-03	7.380E-04	[.000]	-2.906E-03	6.720E-04	[.000]
CRPPAY	-1.023E-04	4.292E-05	[.019]	-2.622E-04	1.126E-04	[.021]
CRPPAYSQ				2.126E-07	1.285E-07	[.100]
CRPDEN	-1.241E+00	4.626E-01	[.008]	-1.427E+00	4.205E-01	[.001]
WATDEN	-5.949E-01	1.610E+00	[.712]	-1.621E+00	1.468E+00	[.271]
FEDDEN	6.056E-01	4.904E-01	[.219]	3.577E+00	1.087E+00	[.001]
FEDSQDEN				-1.736E-04	5.736E-05	[.003]
49 State Constants	Adjusted R ² , <i>F</i> statistic, Schwarz Information Criterion					
	0.9968, 178.10, -193.697			0.9975, 210.95, -210.764		

Table 4: Marginal Effects on Developed Land Area (1000 acres)

VARIABLE	Log-of-the-Share-of-Developed-Land Model		Log-of-the-‘Odds’-of-Developed-Land Model	
	Linear	Nonlinear	Linear	Nonlinear
POP	0.005	0.021	0.014	0.028
AGMINEPC	-0.017	-0.018	-0.017	-0.018
NONAGMPC	0.005	0.007	0.007	0.009
POPGRATE	-2.152	-1.469	-3.182	-2.237
AMGRATE	0.505	0.461	0.474	0.445
NAMGRATE	6.649	5.495	6.428	5.336
INTERATE	-18.952	-18.817	-17.526	-17.510
INFLRATE	-25.622	-24.684	-23.714	-22.949
GASPRICE	-266.946	-237.273	-219.006	-196.104
SHAREDEM	-2.337	-1.767	-2.385	-1.849
CRPPAY	-0.059	-0.141	-0.065	-0.145
CRPAREA	-0.093	-0.107	-0.087	-0.100
WATER	-0.041	-0.119	-0.042	-0.113
FEDAREA	0.056	0.235	0.042	0.206

Table 5: Elasticities of Developed Land Area

VARIABLE	Log-of-the-Share-of-Developed-Land Model		Log-of-the-‘Odds’-of-Developed-Land Model	
	Linear	Nonlinear	Linear	Nonlinear
POP	0.039	0.175	0.114	0.229
AGMINEPC	-0.027	-0.028	-0.029	-0.029
NONAGMPC	0.152	0.223	0.221	0.288
POPGRATE	-0.003	-0.002	-0.005	-0.004
AMGRATE	0.002	0.002	0.002	0.002
NAMGRATE	0.018	0.015	0.017	0.014
INTERATE	-0.175	-0.173	-0.162	-0.162
INFLRATE	-0.169	-0.163	-0.158	-0.153
GASPRICE	-0.147	-0.131	-0.121	-0.108
SHAREDEM	-0.198	-0.150	-0.202	-0.157
CRPPAY	-0.007	-0.010	-0.007	-0.011
CRPAREA	-0.009	-0.010	-0.009	-0.011
WATER	-0.026	-0.075	-0.027	-0.073
FEDAREA	0.233	-0.501	0.197	-0.585

Results

- The log-of-the-‘odds’-of-developed-land model is preferable.
 - A modified R^2 is higher than R^2 in other models, given $MR^2 = 1 - SSR/S_{yy}$ and $SSR =$ the sum of squared residuals between actual and predicted area of developed land.
- The nonlinear-in-exogenous-variables versions are preferable because squared variables are statistically significant and adjusted R^2 s are higher than adjusted R^2 s in linear versions.
- The positive effect of POPDEN is statistically significant in the nonlinear version of the share model and both versions of the ‘odds’ model.
 - An extra person in a state during the previous 5 years induces, on average, an extra 0.028 hectares, or 0.068 acres, of developed land (nonlinear ‘odds’ model).
 - A one percent increase in the population leads to a 0.23% increase in the area of developed land (nonlinear ‘odds’ model).

Results cont., 1

- The negative effect of AGMINEPC is statistically significant in the nonlinear versions of the share and ‘odds’ models.
 - If average real agricultural and mining output per capita in the previous five years is \$100 more in one state than another, the former state will have 1,780 fewer hectares, or 4,400 fewer acres, of developed land.
 - A 10% increase in average real agricultural and mining output per capita in the previous 5 years leads to a 0.29% decrease in developed land area.

Results cont., 2

- The positive effects of NONAGMPC and NAMGRATE are significant in all models.
 - An increase of \$100 in average real per capita output other than agriculture and mining in the previous five years induces 940 more hectares, or 1,700 more acres, of developed land.
 - However, an increase beyond \$32,522, which is more than two standard deviations above the sample mean, makes the area of developed land smaller than it would have otherwise been.
 - A 10% increase in the previous five-year average real non-agricultural and non-mining output per capita induces a 2.9% increase in developed land area.
 - An increase of one percentage point in the previous five-year average growth rate of real non-agricultural and non-mining output per capita leads to a subsequent increase of 5,336 hectares, or 13,184 acres, of developed land.

Results cont., 3

- The negative effects of INTERATE and INFLRATE are statistically significant in all models.
 - A one percentage point decrease in a state's real interest rate leads to an extra 17,510 hectares, or 43,267 acres, in developed land, on average.
 - A one percentage point decrease in a state's inflation rate induces, on average, an extra 22,949 hectares, or 56,707 acres, of developed land.
- The negative effect of GASPRICE is significant in both versions of the share and 'odds' models.
 - An increase of \$1 per liter in the previous five-year average price of gasoline leads to an average decrease in developed area of 196,104 hectares.
 - A 10% increase in the average previous five-year price of gas induces, on average, a 1.1% decrease in the area of developed land.
- The negative effect of SHAREDEM is statistically significant in all models.
 - A one percentage point increase in the share of Democrats in a state's lower legislative house leads to 1,849 fewer hectares, or 4,569 fewer acres, of developed land.

Results cont., 4

- The negative effect of CRPAY is statistically significant in all models.
 - An increase of \$10 in the previous five-year average CRP payment per enrolled hectare (acre) leads to a decrease of 1,451 hectares (8,860 acres) of developed land.
 - A 10% increase in the previous five-year average CRP payment per enrolled acre induces a 0.11% decrease in the area of developed land.
- The negative effects of CRPDEN are statistically significant in both models.
 - The area of developed land is 100 hectares (acres) smaller, on average, in a state with 1000 more hectares (acres) enrolled in the CRP during the previous five years.
 - A 10% increase in the previous five-year average area enrolled in the conservation reserve program leads to, on average, a 0.11% decrease in developed land area.

Discussion

- Previous estimates of marginal consumption of urban land have been 0.088 hectares (0.219 acres) and 0.28 hectares (0.619 acres), in comparison to 0.028 hectares (0.068 acres) here. But real output per capita and other determinants of urban land area were not held constant in those studies.
- Two types of economic growth induce land development.
 - As population grows for a given level of income per capita, the demands grow faster for developed-land uses than for undeveloped-land uses.
 - As real non-agricultural and non-mining output per capita and its growth rate increase, the real current and future returns to developed uses of land increase.
- One type of economic growth reduces land development.
 - As real agricultural and mining output per capita increase for a given population, the real returns to undeveloped uses of land increase.

Discussion cont., 1

- As the real interest rate increases, the discounted cost of converting land in the future decreases and, thus, the net gain of postponement increases.
- As the inflation rate increases, the real return on financial assets, such as savings, decreases relative to non-financial assets, such as land. As a result, the demand for land as an asset increases and the supply of financial assets decreases.
 - Would the demand for developed land increase more than the demand for undeveloped land? Is developed land a better inflation hedge than underdeveloped land? If so, why?
- As the inflation rate increases, banks charge a higher real interest rate to developers who borrow than farmers who borrow because the expected real value of large loans are riskier than those of small loans and become even riskier.
- Developers might respond to nominal, not real, interest rates.

Discussion cont., 2

- As the real price of gas increases, the costs of commuting increase, and the demands for low-density uses of developed land decrease.
 - A given number of people with a given income will live and work in denser areas as transport costs increase.
- As the share of Democrats in the lower legislative house in a state increases, local government officials are more likely to have policies that inhibit land development.

Discussion cont., 3

- As the land area enrolled in the conservation reserve program and real payments per hectare of enrolled land increase, the real returns to undeveloped uses of land also increase and, hence, the area of developed land decreases.
- Given a state's water bodies, CRP land, and constant surface area, a larger stock of federal land in a state implies two things:
 - 1) a smaller stock of non-federal and non-CRP land in the state, land that could have been or could still be developed
 - 2) more environmental amenities and better access to them

The first effect implies a smaller area of developed land.

The second effect implies a larger area of developed and an even smaller area of undeveloped land if users of developed land value the larger quantities and better access to environmental amenities more than the users of undeveloped land do.

Future Research: Irreversible Development

- Land development is statistically reversible in these models. In other words, the area of developed land can decrease in these models.
- Conversion of land from undeveloped to developed uses can occur at the parcel level.
- However, conversion from developed to undeveloped uses is never observed with state-level data.
- What structure on the econometric model does irreversibility of land development require? Here's one answer:

Econometric Model of Irreversible Land Development

$$\text{DEVAREA}_{it} = \frac{\exp^{\beta X_{i,t-1} + \varepsilon_{i,t-1}}}{\exp^{\beta X_{i,t-1} + \varepsilon_{i,t-1}} + 1} (\text{NFEDCRP} - \text{DEVAREA})_{i,t-1} + \text{DEVAREA}_{i,t-1}$$

- Note the previous developed area— $\text{DEVAREA}_{i,t-1}$ —can not decrease.
- The stock of land for development is $\text{NFEDCRP}_{i,t-1} - \text{DEVAREA}_{i,t-1}$.
- The proportion of the stock of land for development is a logistic cumulative density function that depends on measurable, knowable factors that affect returns of developed uses relative to undeveloped uses, $\beta X_{i,t-1}$, and on random influences, $\varepsilon_{i,t-1}$.
- In short, the area of developed land in state i and at time t equals land development in the state during the previous period and the area of developed land at the start of the previous period.

Econometric Model of Irreversible Land Development, cont.

- The proportion of land that gets developed between t and $t-1$ is, given this specification, is a logit model:

$$\frac{\text{DEVAREA}_{i,t} - \text{DEVAREA}_{i,t-1}}{(\text{NFEDCRP}_{i,t-1} - \text{DEVAREA}_{i,t-1})} = \frac{\exp^{\beta X_{i,t-1} + \varepsilon_{i,t-1}}}{\exp^{\beta X_{i,t-1} + \varepsilon_{i,t-1}} + 1}$$

- Transform this model into the log of the ‘odds’ of land development, which can be estimated with least squares:

$$\ln\left(\frac{\text{DEVAREA}_{i,t} - \text{DEVAREA}_{i,t-1}}{\text{NFEDCRP}_{i,t-1} - \text{DEVAREA}_{i,t-1}}\right) = \beta X_{i,t-1} + \varepsilon_{i,t-1}$$

Future Research: Costs of Land Conversion

- The real price of gas was the only explanatory variable in the models that affected the undiscounted real costs of land conversion.
- However, forests and steep land are more costly to develop than crop land and flat land are.
- The NRI contains the area of forest and an erodibility index of crop land by state over time. Either variable could be included in the model of irreversible development.

Tentative Implications for Policy

- Family-planning and other policies that reduce population growth will likely reduce land development.
- Policies that improve the real returns to agriculture and mining will likely reduce conversion of undeveloped land.
- Policies that improve productivity of sectors other than agriculture and mining will likely induce land development.
- Federal Reserve actions that increase the nominal interest rate, for a given inflation rate, will likely reduce urban growth.
- A tax on the price of gasoline is likely to reduce land development.
- Greater success of Republicans in state elections is likely to encourage land development.
- Policies that increase the area enrolled in the conservation reserve program and real payments per enrolled hectare will likely reduce land development.

Thanks for your attendance and attention.

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