Agricultural Land Values and Future Land Development*

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Introduction

The loss of agricultural land to developed uses has been a public policy issue for decades. During the 1970s, there was widespread fear that the loss of productive agricultural land would substantially diminish the United States’ capacity to produce food, with national as well as international consequences. These concerns appear to have been overstated since subsequent land use surveys found that annual conversions of rural land to developed uses represented a small fraction of the total agricultural acreage. In recent decades, attention has focused on the local benefits from agricultural lands such as open space, environmental quality, and impediments to urban sprawl. Many of these benefits have public good characteristics and, as a consequence, will tend to be undersupplied by private producers. Accordingly, states and local municipalities use a variety of land use controls and tax policies to retain land in rural uses in rapidly developing areas (Aiken 1989, Dunford 1980).

If land markets are competitive and net returns to future uses of the land (land rents) are known with certainty, then the price for land will equal the present discounted value of the stream of rents. Thus, if rents from development exceed agricultural rents at some time in the future, the current price of agricultural land will reflect the higher rents from future development. The central purpose of this paper is to identify the influence of future development on agricultural land values. Many authors have analyzed the determinants of agricultural land values (e.g., Hushak and Sadr 1979, Shonkwiler and Reynolds 1986, Palmquist and Danielson 1989, Just and Miranowski 1993, Mendelsohn et al. 1994, Shi et
al. 1997). What distinguishes our study is the use of econometric models based on land price and urban growth theory developed in the urban economics field. By developing a theoretical motivation for our econometric model, we hope to shed light on the critical factors driving land development and improve our estimates of their effect on agricultural land values and conversion decisions.

Theoretical Background

We provide a theoretical motivation for our econometric model in terms of both variable choice and functional form. We present a modified version of Capozza and Helsley (1989) that emphasizes and introduces greater realism into the treatment of agricultural land. Land can be allocated to agriculture and development. If land markets are perfectly competitive and landowners have perfect foresight, the current (time 0) price of agricultural land is

\[
P(t^*, z, r, C) = \int_0^{t^*} A(s, z)e^{-rs} ds + \int_{t^*}^{\infty} R(s, z)e^{-rs} ds - Ce^{-r t^*}
\]

where \(A(t, z)\) is the agricultural rent in time \(t\), \(z\) is a vector of spatial coordinates identifying the location of land, \(R(t, z)\) is the rent from developed land, \(C\) is the cost of converting agricultural land to the developed use, \(t^* \in [0, \infty)\) is the time of conversion, and \(r\) is the interest rate.

Equation (1) states that the price of agricultural land equals the discounted agricultural rents up until conversion time plus the discounted development rents net of conversion costs. We assume that after \(t^*\) the land remains in the developed use indefinitely.

Agricultural rents, \(A(t, z)\), are the annual net returns to crop, forage, and other farm-related
activities on a parcel of land at location $z$. Agricultural rents may exhibit spatial variation
due to variation in land quality and temporal variation due to changes over time in
exogenous prices and other economic factors. We follow Capozza and Helsley (1989) in
specifying the properties of rents from developed land, $R(t,z)$: $\partial R(t,z) / \partial z_1 < 0$, where $z_1$
denotes the distance to the closest metropolitan area, and $\partial R(t,z) / \partial t > 0$. The first result
relates to increasing commuting costs and the second to increasing population.

An owner of an agricultural land parcel at location $z$ chooses the development time $t^*$
to maximize the value of the land. Assuming an interior solution, the first-order condition
for a maximum is $R(t^*,z) = A(t^*,z) + rC$, implying that land should be kept in agriculture
until rents from urban uses equal those from agricultural uses plus the opportunity cost of
conversion expenditures. The first-order condition implicitly defines $t^*$ as a function of $z$,
$r$, and $C$. These terms as collected in a single vector denoted $w$. Substituting the
expression for the optimal conversion time into (1) yields a reduced-form expression for
the price of agricultural land,

$$ P(w) = \int_0^{r^*(w)} A(s,z)e^{-rs} ds + \int_{r^*(w)}^\infty R(s,z)e^{-rs} ds - Ce^{-r^*(w)} $$

From above, the stream of rents from developed land is determined by location and
population change. Thus, equation (2) indicates that the current price of agriculture land
is a nonlinear function of annual agricultural rents, the interest rate, conversion costs,
distance to the metropolitan area, and population change in the metropolitan area. The
above analysis considers the influence of only one metropolitan area on land prices. It is
easy to extend the model to show that, at a given location, the stream of rents from future
development can depend on proximity to and population change in multiple urban areas.
In the empirical application presented below, we account for the influence of multiple metropolitan areas.

**Statistical Model and Data Used in the Application to New York**

In this section, we develop an estimatable version of the agricultural land value equation (2). To model the nonlinear relationship between land values and explanatory variables, we use a second-order approximation of $P(w)$ with the full set of interaction terms. Polynomial functions are commonly used to approximate nonlinear relationships (e.g., production functions in Christensen *et al.* 1973) and have the advantage for estimation of being linear in the parameters. Our estimating equation is

\[
P_{it} = \alpha_{0t} + \alpha_1 AR_{it} + \alpha_2 PC1_{it} + \alpha_3 TT1_{it} + \alpha_4 PC2_{it} + \alpha_5 TT2_{it} \\
+ \beta_{11} (AR_{it})^2 + \beta_{22} (PC1_{it})^2 + \beta_{33} (TT1_{it})^2 + \beta_{44} (PC2_{it})^2 + \beta_{55} (TT2_{it})^2 \\
+ \gamma_{12} AR_{it} PC1_{it} + \gamma_{13} AR_{it} TT1_{it} + \gamma_{14} AR_{it} PC2_{it} + \gamma_{15} AR_{it} TT2_{it} \\
+ \gamma_{23} PC1_{it} TT1_{it} + \gamma_{24} PC1_{it} PC2_{it} + \gamma_{25} PC1_{it} TT2_{it} \\
+ \gamma_{34} TT1_{it} PC2_{it} + \gamma_{35} TT1_{it} TT2_{it} + \gamma_{45} PC2_{it} TT2_{it} + \varepsilon_{it}
\]

where $P_{it}$ is the average per-acre value of agricultural land in county $i$ at time $t$, $AR_{it}$ is average annual per-acre net return from agricultural land, $PC1_{it}$ is the change in population in the closest metropolitan area, $TT1_{it}$ is travel time from the geographic center of county $i$ to the center of the metropolitan area, $PC2_{it}$ and $TT2_{it}$ have corresponding definitions with respect to the second closest metropolitan area, and $\varepsilon_{it}$ is a random error. We assume that conversion costs are constant across counties and time and interest rates are constant across counties but may vary across time. The effects of conversion costs and interest rates are measured by time-varying constant terms $\alpha_{0t}$. 

As in a number of earlier studies, we use Census of Agriculture data on the value of land and buildings to measure agricultural land values \( (P_a) \). The land value data are per-acre county-level averages derived from self-reported estimates by farm operators. Respondents are instructed to report the current market value of land and buildings owned, rented or leased from others, and rented and leased to others. Market value refers to the value the land and buildings would sell for under current market conditions. We use observations for three years (1982, 1987, and 1992) and for all counties in New York except those counties with limited agricultural activity. Nominal values are converted to constant (1992) dollars with the Consumer Price Index.

Agricultural rents \( (AR_a) \) are measured as the real annual per-acre net return to agricultural uses of land. Net returns for a county are computed as the market value of agricultural products sold (e.g., crops, livestock) plus government payments less total farm production expenses. Land values are assumed to reflect the long-run net return to agriculture. We use a simple procedure conformable to the available data to estimate the long-run net return in addition to time- and location-specific components. The two-way fixed factor model

\[
AR_{it} = \mu + \delta_t + \phi_i + \nu_{it}
\]

is estimated with pooled sets of deflated net returns data. The model specifies net returns as the sum of a time- and location-invariant return \( (\mu) \) plus a time-specific component \( (\delta_t) \), a county-specific component \( (\phi_i) \), and an error component \( (\nu_{it}) \). To reflect information available to landowners at each point in the sample period, we estimate (4) with pooled data for 1974, 1978, and 1982; 1978, 1982, and 1987; and 1982, 1987, and
1992. The values of $AR_i$ for 1982, 1987, and 1992, respectively, are computed as the predicted values from the estimated models.

Population change (in thousands of persons) in metropolitan areas ($PC_{1i}$ and $PC_{2i}$) are derived from mid-year population estimates by the Bureau of Census. We measure the change in population over the preceding three-year period in the first and second closest Metropolitan Statistical Areas (MSA), as defined by the Office of Management and Budget (OMB). By using the OMB definition of an MSA, we measure population change in the city center in addition to surrounding suburban areas. According to our theoretical model, development rents will increase over time as the population of metropolitan area increases. Since $PC_{1i}$ and $PC_{2i}$ reflect past changes in population, we are assuming implicitly that landowner expect past changes to continue in the future.

We measure travel times ($TT_{1i}$ and $TT_{2i}$) from the geographic center of counties to MSA centers. The variables are calculated using PCMiler and represent the shortest travel time (in minutes) over major roads. We assume that additional metropolitan areas are too distant to influence agricultural land values. For example, the travel time to the third closest metropolitan area is, on average, 2.5 hours. Moreover, modeling the effects of the third closest metropolitan area requires estimation of an additional fourteen parameters. Finally, we collect data from the Bureau of Census on per-capita income for each county and year to use as a potential explanatory variable of heteroskedastic effects across counties.
Estimation Methods and Results

The model (3) is estimated with cross-sectional and time-series data on 54 New York counties and three time periods (1982, 1987, 1992). We specify separate equations for each time period and impose cross-equation equality restrictions on all parameters except the constant terms. The system of equations is distinct from many pooled data applications because each equation represents one Census year and contains the cross-sectional units (counties). Consequently, we expect the error terms to have a heteroskedastic structure within the equations. In particular, we expect the error variance to increase with the level of the reported land value since reporting or data compilation errors would have a greater effect on average land values in counties with high-valued land.

Godfrey (section 5.4) notes that hypothesis tests of homoskedasticity should be carefully conducted in systems of equations. In particular, many of the single-equation tests have poor small sample properties and are not robust to heteroskedasticity in other equations. To avoid these difficulties, we conduct the Pagan-Hall test (Godfrey, pp. 190-1) under the class of alternatives representing multiplicative heteroskedasticity, 

\[ \sigma^2_{it} = \sigma^2 \exp(b'x_{it}) \]

The variance matrix for the parameters is provided in Godfrey (Equation 4.6), and the Pagan-Hall test is a Wald test of the null hypothesis \( b = 0 \). The instruments selected for the conditional variance model are the real per-capita income in each county and the square of this value. After adjusting the chi-square(3) critical values for overall size with the Bonferroni inequality, we found that we could not reject homoskedasticity at any reasonable level.
Note that our time series is too short to permit use of traditional correction for serial correlation in pooled models. Although the five year gap between Census years should diminish the impact of serial correlation, we estimate separate equations for each year using the Seemingly Unrelated Regressions (SUR) estimator to account for potential temporal relationships. Table 1 presents estimation results for the full model in (3). Overall, the three cross-sectional equations fit the data well as indicated by the large adjusted $R^2$ statistics. As well, many of the parameter estimates are significantly different from zero at the 5% level.

The marginal effect of a regressor (in the following case, agricultural rents) on land values is estimated by

$$\frac{\partial LV}{\partial AR} = \hat{\alpha}_1 + 2\hat{\beta}_{11} \bar{AR} + \hat{\gamma}_{12} \bar{PC1} + \hat{\gamma}_{13} \bar{TT1} + \hat{\gamma}_{14} \bar{PC2} + \hat{\gamma}_{15} \bar{TT2}$$

where hats indicate parameter estimates and bars indicate mean values. We use mean values across counties and time to estimate the marginal effects for all regressors (Table 2). As expected, counties with higher agricultural rents have higher land values, all else equal. On average, a $1 per acre increase in annual agricultural rents increases the agricultural land value by $5.03 per acre. As well, higher population change in the closest and second closest metropolitan areas increases land values by increasing development rents. An increase in population change of 1000 people increases land values by $97 per acre and $101 per acre, respectively. Land values are declining in travel time to the closest metropolitan area. On average, increasing the travel time by one minute decreases land values by $20.18 per acre. Unexpectedly, we find that land values are increasing in the travel time to the second closest metropolitan area.
In Figure 1, we illustrate the effects on land values of simultaneous changes in travel times and population changes. Mean travel times to the closest metropolitan area ($TT_1$) and mean metropolitan area population changes ($PC_1$) are decreased and increased in 1 minute and 200 person increments, respectively. As expected, a 1 minute decrease in travel time has a greater effect on land values as distance to the metropolitan area decreases. Holding population change constant at $PC_1$, the effect of a 1 minute decline in travel time ranges from $32 per acre (at TT_1-9) to $8 per acre (at TT_1+10). Holding travel time constant, there is an almost linear relationship between metropolitan area population change and land values. For a 200 person increase in population change, land values increase by approximately $20 per acre.

Conclusions

In this paper, we develop and estimate a model of agricultural land values derived from a theoretical model of markets for developed and agricultural land. In an application to New York State, we find that the data on agricultural land values are largely consistent with our theory. This finding has implications for future studies of agricultural land values. First, it is important to account for the nonlinear relationship between land values and explanatory variables. In our application, we find that most of the coefficients on squared and crossed terms are significantly different from zero at the 5% level. These nonlinearities can be traced to the intertemporal nature of land price formation.

Second, it is important to establish a theoretical rationale for variable selection. Several agricultural land value studies use county-level population measures as proxies for
future development rents. Our theoretical model implies, however, that the influx of new residents to a county drives up future development rents and that, accordingly, a county’s current population characteristics may not be indicative of future population change. In our model, urbanized areas expand into surrounding rural areas to accommodate a growing population. We have assumed that population change in the urban and suburban counties defining an MSA is an indicator of future population growth in surrounding areas.

The results of our study also have implications for the formulation of public policies affecting land use decisions. First, we demonstrate that agricultural land values are significantly influenced by access to urban areas. This suggests that public transportation projects can have a substantial impact on agricultural land values and the incentives faced by landowners with respect to future development decisions. Second, in the U.S., preferential tax assessment is the most common approach used to forestall the conversion of agricultural land to developed uses. In practice, however, these programs do little to prevent the conversion of agricultural land because, typically, the returns to development greatly exceed those from agriculture, even with differential assessment (Malme 1993). As some authors have argued (Lopez et al. 1988, Wunderlich 1997), the only effective deterrent to farmland conversion, and the loss of associated amenities, may be compensation of landowners for foregone development rents. Our analysis provides a framework for estimating the compensation that landowners may require in a rapidly developing area.
Table 1. Estimation Results for Agricultural Land Value Model: Full Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>Estimate</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_{0.82}$</td>
<td>Constant, 1982</td>
<td>-447</td>
<td>-1.02</td>
</tr>
<tr>
<td>$\alpha_{0.87}$</td>
<td>Constant, 1987</td>
<td>-906</td>
<td>-1.92</td>
</tr>
<tr>
<td>$\alpha_{0.92}$</td>
<td>Constant, 1992</td>
<td>-1100</td>
<td>-2.37</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>$AR$</td>
<td>18.2</td>
<td>4.53</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>$PC1$</td>
<td>84.6</td>
<td>3.73</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>$TT1$</td>
<td>23.7</td>
<td>2.61</td>
</tr>
<tr>
<td>$\alpha_4$</td>
<td>$PC2$</td>
<td>-65</td>
<td>-1.74</td>
</tr>
<tr>
<td>$\alpha_5$</td>
<td>$TT2$</td>
<td>1.98</td>
<td>0.21</td>
</tr>
<tr>
<td>$\beta_{11}$</td>
<td>$(AR)^2$</td>
<td>0.02</td>
<td>2.34</td>
</tr>
<tr>
<td>$\beta_{22}$</td>
<td>$(PC1)^2$</td>
<td>-0.001</td>
<td>-7.54</td>
</tr>
<tr>
<td>$\beta_{33}$</td>
<td>$(TT1)^2$</td>
<td>0.64</td>
<td>6.38</td>
</tr>
<tr>
<td>$\beta_{44}$</td>
<td>$(PC2)^2$</td>
<td>-0.0003</td>
<td>-1.49</td>
</tr>
<tr>
<td>$\beta_{55}$</td>
<td>$(TT2)^2$</td>
<td>0.45</td>
<td>5.18</td>
</tr>
<tr>
<td>$\gamma_{12}$</td>
<td>$AR\cdot PC1$</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>$\gamma_{13}$</td>
<td>$AR\cdot TT1$</td>
<td>0.04</td>
<td>0.51</td>
</tr>
<tr>
<td>$\gamma_{14}$</td>
<td>$AR\cdot PC2$</td>
<td>-0.61</td>
<td>-3.57</td>
</tr>
<tr>
<td>$\gamma_{15}$</td>
<td>$AR\cdot TT2$</td>
<td>-0.17</td>
<td>-3.27</td>
</tr>
<tr>
<td>$\gamma_{23}$</td>
<td>$PC1\cdot TT1$</td>
<td>0.17</td>
<td>1.28</td>
</tr>
<tr>
<td>$\gamma_{24}$</td>
<td>$PC1\cdot PC2$</td>
<td>8.88</td>
<td>3.58</td>
</tr>
<tr>
<td>$\gamma_{25}$</td>
<td>$PC1\cdot TT2$</td>
<td>-0.02</td>
<td>-0.14</td>
</tr>
<tr>
<td>$\gamma_{34}$</td>
<td>$TT1\cdot PC2$</td>
<td>-1.26</td>
<td>-3.16</td>
</tr>
<tr>
<td>$\gamma_{35}$</td>
<td>$TT1\cdot TT2$</td>
<td>-1.17</td>
<td>-7.07</td>
</tr>
<tr>
<td>$\gamma_{45}$</td>
<td>$PC2\cdot TT2$</td>
<td>2.33</td>
<td>5.15</td>
</tr>
</tbody>
</table>

Adjusted $R^2$, 1982 equation = 0.90
Adjusted $R^2$, 1987 equation = 0.90
Adjusted $R^2$, 1992 equation = 0.83

# of Observations = 164
Table 2. Partial Effects of Independent Variables on Land Values: Full Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>T-Ratio</th>
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</thead>
<tbody>
<tr>
<td>$AR$</td>
<td>5.03</td>
<td>2.27</td>
</tr>
<tr>
<td>$PC_1$</td>
<td>97</td>
<td>8.53</td>
</tr>
<tr>
<td>$TT_1$</td>
<td>-20.2</td>
<td>-6.37</td>
</tr>
<tr>
<td>$PC_2$</td>
<td>101</td>
<td>6.58</td>
</tr>
<tr>
<td>$TT_2$</td>
<td>19.8</td>
<td>6.69</td>
</tr>
</tbody>
</table>

Figure 1. Effects of Travel Time and Population Change on Agricultural Land Values

Note: The axis labelled population change measures changes in the average rate of population change in closest metropolitan areas ($PC_1$). The axis labelled travel time measures changes in average travel times to closest metropolitan areas ($TT_1$).
References

Aiken, J.D.  1989.  State Farmland Preferential Assessment Statutes.  University of Nebraska, Department of Agricultural Economics, RB 310.


