This paper provides a conceptual model that links agricultural profits, property taxes, interest rates, and capital gains to the sale of agricultural land by profit-maximizing owners. The model motivates an empirical analysis of New Jersey data from 1949 to 1990. Results suggest that nonagricultural considerations may overpower the economic incentives provided by such policies as farmland assessment. Consequently, alternative policies (e.g., purchase of development rights and land use zoning) may be needed to sustain agriculture in rapidly urbanizing areas.

The next section presents the conceptual model and derives hypotheses for key economic variables. This section is followed by a description of the data and econometric methods. After a discussion of results, the paper concludes with a summary and policy recommendations.

Conceptual Framework

Land allocation decisions depend on the ability of land to provide benefits. An owner of A_t acres of agricultural land who is considering sale must weigh the benefits from continued agricultural use against the benefits obtained from sale. Profits from agricultural use, $\pi^a(A_t,p_t)$, depend on the stock of agricultural land, A_t, and on prices of outputs and nonland inputs, p_t. Selling d_t acres of land obtains the price $p^d(d_t)$ per acre.[4] For simplicity, let $\pi^a(\cdot)$ and $p^d(d_t)$ be net of income and other taxes except for agricultural property taxes and let τ^a represent the property taxes paid per acre of agricultural land.[5] In addition, let $p^d(d_t)$ be net of transactions costs (e.g., realtor's commissions).

To maximize the wealth derived from the land asset, the owner determines how much land, if any, to offer for sale. The owner's optimum decision is to choose d_t in order to maximize the present value of discounted profits (including land sales),

$$\int_0^\infty [\pi^a(A_t,p_t) - \tau^a A_t + p^d(d_t)d_t]e^{-rt}dt,$$

subject to a constraint that describes the flow of land from agriculture,

$$\dot{A}_t = d_t.$$

It is possible that institutional or other considerations (e.g., zoning) may limit the amount of land that can be sold by the owner in any one period. The owner can acknowledge these by allowing

$$0 \leq d_t \leq d_{\max,t}.$$

Optimum land use decisions for the owner can now be identified using the Hamiltonian

$$(1) \qquad H = \pi^a(A_t,p_t) - \tau^a A_t + p^d(d_t)d_t - \lambda_t^a d_t,$$

where λ_t^a represents the value to the owner of an additional acre of agricultural land (i.e., the costate variable). The owner's optimum sales of land, d_t^*, can be determined from $\partial H/\partial d_t$ and the Maximum Principle (Chiang 1992, 167–71),[6]

$$(2) \quad d_t^* = \begin{cases} 0 & \text{if } p^d + p^{d\prime}d_t < \lambda_t^a, \\ d_t^* & \text{if } p^d + p^{d\prime}d_t = \lambda_t^a, \text{ and} \\ d_{\max,t} & \text{if } p^d + p^{d\prime}d_t > \lambda_t^a. \end{cases}$$

These conditions mean that the owner maximizes profits by selling land at the maximum rate ($d_{\max,t}$) whenever the marginal benefit from selling land, $p^d + p^{d\prime}d_t$, exceeds the marginal opportunity cost of removing the land from agriculture, λ_t^a. When marginal benefits fail to exceed marginal opportunity costs, the land should be maintained in agriculture (i.e., converting at the minimum rate, $d_t^* = 0$). Between these two extremes, the owner will maximize profits by converting at the singular rate d_t^* when the proceeds from selling land are just equal to the value of land in agriculture. The value to the owner of land in agriculture deserves more attention.

The value of land in agriculture derives from its ability to provide profits. This can be seen from the owner's requirement for the evolution of λ_t^a over time,

[4] The model described in this section maintains the assumption that lands most suited for agriculture are employed first, followed by lower quality lands. Such diminishing marginal returns to land area require that $\partial\pi^a(A_t,p_t)/\partial A_t > 0$ and $\partial^2\pi^a(A_t,p_t)/\partial A_t^2 < 0$. The amount of land offered for development, d_t, will be considered to be sufficiently large that per acre prices must fall to sell larger tracts, i.e., $p^{d\prime}(d_t) < 0$ and $p^{d\prime\prime}(d_t) < 0$. Most individual land ownerships in our study region (New Jersey) exhibit these characteristics.

[5] The specific rate τ^a used here is equivalent to τ, the *ad valorem* property tax rate for all real property, multiplied by the ratio of assessed value of agricultural land to market value of land. Many states, including New Jersey, maintain agricultural land area by assessing agricultural land at its current use value rather than the value in its highest and best use. For this owner such a policy amounts to lowering τ^a.

[6] To streamline notation, the argument d_t for the price of developed land $p^d(d_t)$ will be suppressed. The notation $p^{d\prime}$ will represent the first derivative of $p^d(d_t)$. Second order conditions for a maximum require that $\partial^2H/\partial d_t^2 < 0$. Because $\partial^2H/\partial d_t^2 = p^{d\prime} + p^{d\prime\prime}$, these conditions are met as long as per acre prices must fall to sell larger tracts (see note 4). Transversality conditions require that $\lim_{t\to\infty} \lambda_t^a = 0$ (Chiang 1992, 101–3).

$$\dot{\lambda}_t^a = r\lambda_t^a - \frac{\partial H}{\partial A_t}$$

$$(3) \qquad = r\lambda_t^a - \frac{\partial \pi^a(\cdot)}{\partial A_t} + \tau^a$$

Solving for λ_t^a gives the differential equation

$$(4) \qquad \lambda_t^a = \frac{\partial \pi^a(\cdot)/\partial A_t}{r} - \frac{\tau^a}{r} + \frac{\dot{\lambda}_t^a}{r},$$

which can be used to obtain the value to the owner of land in agriculture, i.e.,

$$(5) \qquad \lambda_t^a = \frac{\partial \pi^a(\cdot)/\partial A_t}{r} - \frac{\tau^a}{r} + e^{rt}C_0$$

(where C_0 is a constant of integration). Equation (5) shows that agricultural value consists of the present value of profits, $\partial\pi^a(\cdot)/\partial A_t$, minus the present value of property taxes, τ^a. The owner maximizes profit by comparing agricultural land value (equation [5]) with developed land value ($p^d + p^{d\prime}d_t$) using the decision rules in equation (2).[7]

The owner's optimum responses to changes in economic conditions can be obtained from the comparative statics of the implicit function $p^d + p^{d\prime} - \lambda_t^a = 0$. For example, after substituting for λ_t^a using equation (5), the owner's optimum conversion rate d_t^* will change in response to exogenous changes in (per acre) profits or taxes according to

$$\frac{d(d_t^*)}{d\pi_A^a} = \frac{1/r}{p^{d\prime} + p^{d\prime\prime}} < 0, \text{ and}$$

$$\frac{d(d_t^*)}{d\tau^a} = \frac{-1/r}{p^{d\prime} + p^{d\prime\prime}} > 0, \text{ respectively.}^8$$

Thus, the owner will maximize profits by decreasing conversion when marginal profits increase and by increasing conversion when property taxes increase. The next section investigates whether these responses are consistent with New Jersey data.

Data and Estimation Procedures

Quantifying the influence of property taxes as a means to preserve agricultural land (i.e., slow conversion) requires observations of agricultural land area, agricultural profits, interest rates, and property taxes. The owner's problem given above represents these as A_t, π_A^a, r, and τ^a, respectively (equation [5]). In the empirical specification, we have also included changes in agricultural land value as an explanatory variable ($\dot{\lambda}_t^a$, equation [4], referred to below as capital gains).[9] State-level observations on these data are obtained from the U.S. and New Jersey departments of agriculture and are derived from the 1949–91 time series used by Adelaja, Decter, and Tavernier to support the New Jersey State Econometric Model of Agriculture.

Land area and economic data for agricultural commodities are aggregated into state-level statistics for agricultural land area and marginal per acre net revenue from agriculture.[10] Agricultural land area, A_t, for each year includes area devoted to field crops, vegetables, fruits, and livestock. Net revenue for each year, $\pi^a(\cdot)$, is the sum of revenue derived from field crops, vegetables, fruits, and livestock, minus the costs of labor, capital, intermediate, and energy inputs. Property taxes specifically are not deducted from this net revenue figure (see "Conceptual Framework," above). Marginal net revenue per acre, π_A^a, is approximated using average net revenue per acre $\pi^a(\cdot)/A_t$. Real net revenues per acre are obtained by deflating nominal net revenues by producer price indices.

Capital gains, $\dot{\lambda}_t^a$, for each year are calculated as the annual change in the market value of agricultural land. The average value of agricultural real estate includes the value of buildings and improvements. For the period over which New Jersey data are available, land value is roughly 20% of total property value. The observation for $\dot{\lambda}_t^a$ used in the following analysis is calculated as $(\lambda_t^a - \lambda_{t-1}^a)/\lambda_{t-1}^a$, where λ_t^a is 20% of the average price of agricultural real estate in New Jersey in year t.

---

[7] An alternative solution technique is to highlight the economics of the optimal path (cf. optimal extraction, Hotelling). Define $p^d + p^{d\prime}d$ as the marginal revenue from land sales, MR. For a singular solution, equation (2) requires that along the optimal path, $(\dot{MR} + \partial\pi^a/\partial A - \tau)/MR = r$, i.e., the owner should sell land so that the rate of growth in marginal revenue, plus the net quasi-rents provided by agricultural land use (also expressed as a rate), is just equal to the opportunity cost of capital.

[8] The derivatives of $p^d + p^{d\prime} - \lambda_t^a = 0$ with respect to the variables of interest (see below) are continuous. We maintain that these exist and are nonzero in the neighborhood of d_t^* and the prevailing economic conditions. Consequently, the requirements of the implicit function theorem are met (Chiang 1974, 216–22) and derivatives may be obtained from the differentials of $p^d + p^{d\prime} - \lambda_t^a = 0$. (To conserve space, subscripts will be used to denote partial derivatives and suppress arguments, so that $\partial\pi^a(\cdot)/\partial A_t = \pi_A^a$.)

[9] Agricultural land value (i.e., λ_t^a) for the deterministic problem does not depend on capital gains (equation [5]), although these may accrue when land rents or taxes change. A model including stochastic rents or taxes is needed before unanticipated capital gains would appear in the solution to the differential equation for λ_t^a. The authors thank an anonymous reviewer for making this observation.

[10] The New Jersey State Econometric Model of Agriculture (NJSEMA) groups thirty-five farm commodities into four categories: field crops, vegetables, fruits, and livestock. Variable inputs are also divided into four categories: land, labor, capital, and intermediate inputs (e.g., feed, chemicals, and seed), and energy inputs.

Real land values are obtained by deflating nominal values by producer price indices.

Interest rates, r, are the real rates charged for production credit in New Jersey. These are obtained from the New Jersey Department of Agriculture and measure the real opportunity cost of capital used in agricultural production during the sample period.

The effective tax rate, τ^a, is calculated by multiplying the state *ad valorem* property tax rate by the ratio of assessed value to market value. Property tax rates are measured in dollars per hundred dollars of assessed value. For years prior to the Farmland Assessment Act of 1964, assessed value and market value are treated as identical.

In order to directly obtain the relative quantitative impact of changes in economic variables on agricultural land area, a log-log specification of the form

$$\text{(6)} \qquad \ln A_t = x_0\beta_0 + [\ln(x_t)]'\beta + u_t$$

is used. The vector x_t' is defined as $[\pi_A^a \ \dot{\lambda}_t^a \ r_t \ \tau_t^a]$. With this specification, the estimated coefficient for the kth variable, $\hat{\beta}_k$, measures the elasticity of land area, since (suppressing time subscripts)

$$\text{(7)} \qquad \beta_k = \frac{\partial \ln A}{\partial \ln x_k} = \frac{\partial A}{\partial x_k} \cdot \frac{x_k}{A}.$$

Equation (6) shows that $\hat{\beta}_k$ measures the percentage change in land area attributable to a 1% change in x_k. Consequently, the relative magnitudes of $\hat{\beta}_k$ for different variables are directly comparable, are independent of the units used to measure the economic variables, x_k, and yield information about the relative impact of changes in economic variables on agricultural land area.

Derived as they are from time-series observations, the errors u_t are likely to exhibit autocorrelation. In the estimates that follow, we maintain the assumption that $u_t = \rho u_{t-1} + v_t$, where the v_t have zero mean and constant variance over time. Estimated Generalized Least Squares methods are employed to make use of this information (Judge et al., 442–44) and to obtain efficient estimates of β.

Results

After correcting for autocorrelation, the model fits the data well (adjusted $R^2 = 0.86$; see table 1). Because the hypothesis that $\rho = 0$ cannot be conclusively rejected using a bounds test ($d = 1.468$ falls between the upper and lower bounds for this sample size and specification), some autocorrelation may persist in the model shown in table 1.

Table 1. Estimated Elasticities for Land in Agricultural Uses in New Jersey, 1949–1990[a]

Variable	Symbol[b]	Parameter Estimate
Intercept		11.605***[c]
		(17.179)[d]
Net farm income (dollars per acre)	π_A^a	0.007
		(0.220)
Capital gains (percent)	$\dot{\lambda}_t^a$	−0.569***
		(−7.411)
Property tax rate (dollars per $100)	τ^a	−0.066**
		(−1.940)
Interest rate (percent)	r	−0.136**
		(−1.904)
Adjusted R^2		0.86
d[e]		1.47
N		42

[a]Elasticities, ($\hat{\beta}$), are estimated from $ln(Area_t) = x_0\beta_0 + [ln(x_t)]'\beta + u_t$, corrected for autocorrelation using Generalized Least Squares (Judge et al., 434–55).

[b]See text.

[c]** Indicates $P < 0.05$, and ***indicates $P < 0.01$.

[d]Numbers below estimates are asymptotic t-statistics.

[e]Durbin-Watson statistic. For this specification, $d_L^* = 1.36$, and $d_U^* = 1.72$, ($P < 0.05$); thus, autocorrelation cannot be conclusively rejected.

Overall, land area is inelastic with respect to the variables included.

Higher interest rates and property taxes reduce the amount of land in agriculture, as the comparative statics of the owner's problem would suggest. The impact of net agricultural revenue is also consistent with the conceptual model, but the estimated coefficient cannot be distinguished from zero at the usual levels of significance. The influence of capital gains may be more consistent with speculation than with the value of land in agricultural use. Each of these results will be discussed in more detail below.

Net Farm Income

The relative unimportance of net farm income may be attributable to abundant nonfarm employment opportunities in nearby urban areas. For example, New Jersey farmers in 1990 earned 36% more in off-farm income than in net farm income (U.S. Department of Agriculture 1991). Apparently, only a relatively small share of their net income is linked to the success of their farm operations. In addition, farmland in urbanizing areas may be idled prior to its sale for development (i.e., the "impermanence syndrome" [Lockeretz 1989]). Lopez, Adelaja, and Andrews find related evidence that supply elasticity decreases with suburbanization. High demand for farmland and increased opportunities for land sales may lead New

Jersey farmers to become less responsive to agricultural market signals.

Capital Gains

The elasticity for capital gains (-0.569; see table 1) is greater in absolute value than for any other variable, but the direction of effect (negative) is not what the model suggests for λ_t^a. However, it is possible that the value of agricultural land sold (see above) is not as good a measure of λ_t^a as one would hope for. For example, equation (4) requires that λ_t^a measure the owner's derived demand for agricultural land inputs. In contrast, the average sales price of agricultural land may be a better measure of p_d than of λ_t^a. (Equation [2] suggests that these may be equivalent only for a singular conversion rate.[11])

Farmland may be overvalued when conversion is imminent as a result of speculation by buyers who have only limited interest in agricultural use (Nelson). For speculative buyers, agricultural use values may be only incidental "dividends" in what amounts to an investment for capital gain. While it is difficult to quantify how many owners of New Jersey farmland are speculators, it is worth noting that only 46% of New Jersey farmers listed farming as their principal occupation (U.S. Department of Commerce, Bureau of the Census 1989, *1987 Census of Agriculture*, Part 30, *New Jersey*). The negative elasticity for capital gains may represent demand for agricultural land by speculators, rather than owners wishing to continue agricultural use.

Interest Rates

Increases in interest rates are associated with decreases in agricultural land area ($\hat{\beta}_r = -0.136$; see table 1). This result is consistent with profit-maximizing land sale decisions and the interpretation of agricultural and as an asset capable of providing income in the form of quasi-rents, $\pi^a(\cdot)$. Equation (5) suggests that as interest rates increase, the discounted net value of future agricultural use decreases, leading the owner to favor selling the land (equation [2]). It should be noted that p^d, the price offered for land, may also comprise a stream of annual services discounted at the same rate of time preference (e.g., residential services). In this case, there would be only a nonneurtral interest rate effect if the agricultural land owner had less access to credit than those offering to buy agricultural land. The comparative static effect could not, a priori, be determined, and would depend on which sequence of net benefits was affected most by the change in interest rate.

Property Tax Rate

Although the direction of influence for property taxes is as one would expect, the quantitative effect of changes in the tax rate is relatively small ($\hat{\beta}_\tau = -0.066$; see table 1). It is possible that because property taxes represent a relatively small fraction of land value, marginal changes in taxes only slightly diminish the value of land in agriculture. While property taxes may decrease the value of agricultural land (equation [4]), the aggregate effect does not appear to be quantitatively significant in changing land allocations in New Jersey. This is in striking contrast to recent findings by Lopez, Shah, and Altobello (table 1), who estimate a Northeast regional elasticity of -1.065. The difference in response to property tax rates suggests that there are potentially large differences among states in the Northeast. As a result, policies may need to be tailored to specific circumstances. The design of policies will be considered in the next section.

Summary, Conclusions, and Policy Implications

This paper provides a conceptual model that links agricultural profits, property taxes, interest rates, and capital gains to the sale of agricultural land by profit-maximizing owners. Overall, an econometric specification based on the model fits New Jersey data well. Higher interest rates, property taxes and speculative capital gains increase conversion of agricultural land. Land area is generally inelastic with respect to changes in economic conditions.

Further empirical work could reveal that assessment may perform differently for land use categories within agricultural use (e.g., field crops, vegetables, fruits, and livestock), and for specific locations. For example, the 1992 *Census of Agriculture* indicates that the value of livestock production and overall grain production declined in New Jersey between 1982 and 1992, while vegetable production increased and nursery production doubled. This suggests that producers may substitute higher-valued crops for grain and livestock

[11] State-level land prices are formed in part by aggregate decision rules similar to equation (2) for all potential land sellers. However, the market clearing price and quantity of land depend also on land buyers (i.e., those who offer prices p^d for the land). As a result, one could interpret the market clearing prices and quantities of land as equilibria between supply and demand. Changes in land market equilibria each year could arise because of changes in supply, demand, or both. Consequently, the price variable used to derive λ_t^a may in fact track changes in land market equilibria, rather than movement along the supply schedule that results from aggregating equation (2). Unraveling specific demand and supply influences would require a simultaneous equation system that is beyond the scope of this paper.

(U.S. Department of Commerce, Bureau of the Census 1994). The aggregate net change in agricultural land area may be small, despite exchanges within agricultural use. Preferential tax treatment might be relatively more effective in preserving the area of lower-valued uses. A spatially detailed analysis could employ geographic information (e.g., maps and aerial photographs) to determine which agricultural land uses were present in urbanizing areas, and could further examine the effectiveness of farmland assessment on these specific locations.[12]

The relative importance of capital gains over property taxes suggests that farmland assessment may need to be supplemented with other policy instruments to sustain agricultural land area in New Jersey. Farmland assessment allows agricultural land to be taxed at lower rates than nonagricultural uses, increasing its relative value. However, the results obtained here suggest that the quantitative impact of this policy may be small compared to the influence of increased demands for agricultural land (represented by increases in its market price).

New Jersey already has legislation to support alternative policies that may be more effective. For example, the Farmland Preservation Bond Act of 1976 (and later appropriations) provides for the purchase of development rights to agricultural land. Alternatively, New Jersey's State Development and Redevelopment Plan represents some of the most comprehensive state-level land use planning in the United States. The option to convert land use may either be purchased (e.g., through purchase of development rights) or be taken (e.g., through zoning[13]), but it appears that these rights must be obtained if agricultural land is to be preserved. Preferential taxation alone may not be up to the task.

[12] The authors thank an anonymous reviewer for making these observations.

[13] Regulatory approaches such as zoning may expose the state to risk from takings litigation. For example, there have been several successful suits filed against the federal government to recover economic damages imposed by land use regulated under Section 404 of the Clean Water Act. Amounts awarded include compensation, interest, and litigation costs. In three recent cases, these amounts ranged from $761,818 to $5,556,994. Claim amounts in other pending cases include $139,334,010 on which accrued interest is $161,720,388 (U.S. General Accounting Office). Given that the accrued interest now exceeds the amount claimed, and that litigation costs will drive damages even higher, it is possible that purchasing the land or development rights outright would have been a more cost-effective way to accomplish land use goals.

References

Adelaja, A., S. Decter, and E. Tavernier. *New Jersey Agriculture: Strategies to Deal with Current Critical Problems. Executive Summary*. New Jersey Agricultural Experiment Station Publication No. SR-02134-1-93. New Brunswick, 1993.

American Farmland Trust. *Northeastern Farmland Update Newsletter of the American Farmland Trust* 4(3) (1993). North Hampton, Mass.: American Farmland Trust.

Chiang, A.C. *Fundamental Methods of Mathematical Economics*. 2nd edition. New York: McGraw-Hill, 1974.

Chiang, A.C. *Elements of Dynamic Optimization*. New York: McGraw-Hill, 1992.

Derr, D.A., and L.E. Small. "Easement Purchases and Landowners' Expectations." *Journal of the American Society of Farm Managers and Rural Appraisers* 47(2)(1983):45–48.

Hotelling, H. "The Economics of Exhaustible Resources." *Journal of Political Economy* 39(1931):137–75.

Judge, G.G., R.C. Hill, W.E. Griffiths, H. Lütkepohl, and T.-C. Lee. *Introduction to the Theory and Practice of Econometrics*. New York: Wiley, 1984.

Lockeretz, W. "Secondary Effects on Midwestern Agriculture of Metropolitan Development and Decreases in Farmland." *Land Economics* 65(3)(1989):205–16.

Lockeretz, W., ed. *Sustaining Agriculture near Cities*. Ankeny, Iowa: Soil and Water Conservation Society, 1987.

Lopez, R., A. Adelaja, and M. Andrews. "The Effects of Suburbanization on Agriculture." *American Journal of Agricultural Economics* 70(2)(1988):346–58.

Lopez, R., F. Shah, and M. Altobello. "Amenity Benefits and the Optimal Allocation of Land." *Land Economics* 70(1)(1994):53–62.

Nelson, A.C. "Preserving Prime Farmland in the Face of Urbanization—Lessons from Oregon." *Journal of the American Planning Association* 58(4)(1992):467–88.

New Jersey Department of Environmental Protection. *The Commonwealth of New Jersey Outdoor Recreation Resources Plan Summary. Green Acres Program*. Trenton, 1989.

U.S. Department of Agriculture. *Economic Indicators of the Farming Sector: State Financial Summary*. Washington, D.C.: Government Printing Office, 1991.

______. *Agricultural Statistics*. Washington, D.C.: Government Printing Office, 1951–91.

U.S. Department of Commerce, Bureau of the Census. *1987 Census of Agriculture*. Volume 1. Geographic Area Series, Part 30. New Jersey State and County Data. Washington, D.C., 1989.

______. *1992 Census of Agriculture*. Volume 1. Geographic Area Series, Part 30. New Jersey State and County Data. Washington, D.C., 1994.

U.S. General Accounting Office. *Clean Water Act: Private Property Takings Claims as a Result of the Section 404 Program*. U.S. General Accounting Office, Resources, Community, and Economic Development Division. GAO/RCED-93-176FS. Washington, D.C.: Government Printing Office, 1993.