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Various improvements can be made to farmland, including clearing or draining the land and controlling erosion. Individual landowners must decide whether to undertake such improvements. These decisions require knowledge of the value of the improvements as well as the costs. In addition, there are various government programs designed to encourage (or in some cases to discourage) changes in the characteristics of farmland. Evaluating such programs also requires estimating the benefits of the resulting changes.

Estimating the value of improvements (or conversely the costs of damages) sometimes has been done by estimating the increased (reduced) productivity of the land and then placing a value on that productivity (e.g., Walker, 1982). However, it is also of interest to study the value placed on such improvements in the land markets because these markets will take into account adjustments resulting from the improvement, some of which may not be foreseen in a productivity study. There have been various studies of the relationship between farmland values and the characteristics of the land. For example, such an "hedonic"[1] equation has been used by Chicoine (1981) to examine the behavior of farmland values when the land is subject to urban influences. Pope (1985) used similar techniques to show that characteristics related to consumptive uses of rural land as well as agricultural productivity influence land values.[2] Recently, several articles (Miranowski and Hammes, 1984; Ervin and Mill, 1985; and Gardner and Barrows, 1985) have used hedonic techniques to study the effects of soil quality and erosion on land values. Miranowski and Hammes found that three measures of topsoil quality (topsoil depth, potential erosivity, and pH) all had the expected signs and were statistically significant. On the other hand, the other two studies had mixed results and generally concluded that land values were not predictably related to actual or potential erosion.

Potentially land value studies can be used to address important policy issues as well as develop information that may be useful to farmers. However, the design of the study and the interpretation of the results must be carefully considered. The hedonic model frequently has been used in urban economics to study the characteristics of houses, and some of the articles cited have referred to part of that literature. However, there are significant differences in the hedonic model as it has been applied to a consumer product such as housing and the hedonic model as it should be applied to an agricultural factor of production such as land. This paper develops the theoretical basis for hedonic models of factors of production, discusses using the model to value land improvements, and demonstrates its application.

The next section develops a model of the relationship between the characteristics of a parcel of farmland and its price. This hedonic price schedule is the equilibrium result of the interaction of farmers and landowners in the land market. The behavior of each of these groups is considered. In the third section, this model of the land market is used to show that under some circumstances the hedonic price schedule alone is sufficient to provide a measure of the benefits of a farmland improvement. The relationship between the results based on rental prices and the results based on asset or sales prices is also considered. In the fourth and fifth sections these theoretical developments are used in an empirical study and examples of the policy applications of the results are discussed. While there are many cases in which the benefit measures discussed in section three are appropriate, other circumstances will require a second step in the estimation procedure where the underlying demands (and possibly supplies) for the characteristics of the land are estimated. These techniques and the data requirements are discussed in the sixth section.

Equilibrium Land Prices and Individual Behavior

The rental price for a parcel of farmland depends on the characteristics of the parcel. These characteristics might include number of acres, topsoil depth, topography, soil productivity, and any number of other characteristics desired by farmers. Thus, there is a functional relationship between price and the characteristics of the farmland,

$$R = R(z_1,\ldots,z_n), \tag{1}$$

where R is the rental price of the parcel and $z=(z_1,\ldots,z_n)$ is a vector of the n characteristics of the farmland. This is the hedonic price equation.[3] If it were possible to costlessly separate the characteristics of one parcel and repackage them into other parcels, then arbitrage would result in a linear hedonic function. Since it is obviously quite costly or impossible to repackage the characteristics of farmland, the functional form of the price equation is not restricted to be linear. Typically, the actions of an individual demander or supplier of land will not affect the equilibrium price schedule, although the individual can influence the rental price he pays by altering the choice of characteristics. The rental price schedule is determined by the interaction of farmers bidding for the use of the land and landowners offering the land for rent. A farmer who operates on his own land can be considered implicitly to rent the land from himself and has the option of renting to someone else.

On the demand side are individuals who wish to use the land as an input to their production of agricultural crops. The multiple-output, multiple-input farm production function can be written implicitly as,

$$g(x, z, \alpha) = 0, \tag{2}$$

where x represents the vector of net outputs ($x_i > 0$ implies x_i is an output, whereas $x_i < 0$ implies x_i is an input) exclusive of land, z is the vector of characteristics of land as before, and α is a vector of farmer characteristics that influence their productive ability.

Farmers maximize profits, but to concentrate on their willingness to pay for the use of particular parcels of land, let us consider their variable profits[4] on a parcel of land. These profits are the difference between the value of outputs and the value of non-land inputs. Maximizing these profits on a particular parcel of land yields the following problem,

$$\max_{x} \pi^{dv} = \sum_{j=1}^{m} p_j x_j \text{ subject to } g(x, z, \alpha) = 0, \ \pi^{dv} \geq 0, \tag{3}$$

where π^{dv} is the "variable" profits of this demander of land and the p_j are the prices of outputs and non-land inputs. This maximization problem can be solved for output supply and non-land input demand functions, $x = x(p, z, \alpha)$. These can be substituted back into equation (3) to yield the variable profit function,

$$\pi^{*dv} = \pi^{*dv}(p, z, \alpha) = \sum p_j x_j(p, z, \alpha). \tag{4}$$

If a farmer's land costs are subtracted from "variable" profits, one obtains π^d, actual profits[5]. A farmer's bid for a particular parcel of land will depend on the characteristics of that parcel, the prices of outputs and other inputs, the level of profit, and the farmer's production skills. The bid function, θ, is defined by

$$\theta(z, p, \pi^d, \alpha) = \pi^{dv}(p, z, \alpha) - \pi^d. \tag{5}$$

The partial derivative of the bid function with respect to a characteristic of the land is $\theta_{z_i} = \partial\pi^{dv}/\partial z_i \geq 0$, since the variable profit function is nondecreasing in fixed factors (Diewert, 1978) and the z, desirable characteristics of land, enter in the same manner as fixed factors. The second partial derivative of the bid function with respect to a characteristic is $\theta_{z_i z_i} = \partial^2\pi^{dv}/\partial z_i^2 \leq 0$, since the variable profit function is concave in fixed factors (Diewert, 1978). The partial derivative of θ with respect to p_j is equal to x_j by the envelope theorem, so it is positive for outputs and negative for inputs. The partial derivative of θ with respect to profits is -1, since higher profits require an offsetting reduction in the bid, ceteris paribus.

The bid function shows the payment a farmer would be willing to make for the use of any parcel of land, given a particular profit level. In equilibrium the increase in the bid of a farmer with a marginal increase in one of the characteristics of the land must equal the increase in the market rental price of land with a marginal increase in that characteristic. Otherwise the farmer could increase profits by using land with different characteristics. In addition to these marginal conditions, the farmer's total bid for a parcel must equal the rental price of the parcel.

To derive the market equilibrium rent schedule, we also must consider the behavior of landowners. For this purpose it is useful to separate the vector of characteristics, $z = (z_1,\ldots,z_n)$ into two sub-vectors, $\bar{z} = (z_1,\ldots,z_k)$ and $\tilde{z} = (z_{k+1},\ldots,z_n)$, where the components of $\bar{z}$ are characteristics exogenous to the landowner and the components of $\tilde{z}$ are within his control. The landowner seeks to maximize profits from renting the parcel of land by altering the characteristics within his control,

$$\max_{\tilde{z}} \quad \pi^S = R(\bar{z},\tilde{z}) - C(\bar{z},\tilde{z},r,\beta) \text{ subject to } \pi^S \geq 0, \qquad (6)$$

where π^S represents the profits of the landowner, $C(\cdot)$ is a joint cost function with the usual properties, r is a vector of input prices, and ß is a vector of technical parameters which may vary between landowners. Equation (6) yields first-order conditions requiring that the marginal cost of the characteristics under the landowner's control be equal to the marginal characteristics price in the market.

An offer function, $\phi(\bar{z}, \tilde{z}, \pi^S, r, \beta)$, representing the prices at which the landowner would make parcels available to the market, can be defined in a manner analogous to the bid function,

$$\phi(\bar{z}, \tilde{z}, \pi^S, r, \beta) = \pi^S + C(\bar{z}, \tilde{z}, r, \beta). \quad (7)$$

However, since some of the characteristics are beyond control of the landowner, he is limited in the amount of some of the characteristics he can offer. The partial derivative of the offer function with respect to an endogenous characteristic is non-negative, since it is equal to the marginal cost of that characteristic, and the second partial derivative is also non-negative, since it is equal to the slope of marginal cost function at a profit-maximizing equilibrium. An increase in profits increases the offer price by an equal amount.

A landowner would maximize profits by equating the marginal offer price for the characteristics under his control to marginal price in the market. For characteristics beyond his control, the characteristic price and thereby his offer price would be completely demand-determined. The offer price for the exogenous characteristic would be equal to the market price, since at a lower offer price the landowner would forego profits and at a higher offer price the offer would not be accepted.

Thus, both farmers and landowners take the market price schedule as parametric, but that schedule is determined by the interactions of these two groups. The price schedule changes to eliminate excess demand or supply for parcels with each set of characteristics. The number of parcels available for farming is not fixed, since the land has alternative uses. The rental price of land with a given set of characteristics in these alternative uses fixes a lower limit on the agricultural land price necessary to keep the land in farming. If the potential price of a parcel for agricultural use is below this limit, that parcel is taken out of agricultural use. Similarly, the number of potential agricultural demanders of parcels is not fixed. As land prices increase, some demanders choose other occupations in the interest of maximizing wealth. The hedonic price schedule estimates this market equilibrium price schedule.

These concepts can be represented graphically in Figures 1 and 2, which are modifications of the diagrams in Rosen (1974). The first diagram represents the relationship between the rental price of parcels of farmland and the quantity of one of the characteristics of the land that is exogenous to the landowner, $\bar{z}_i$. The quantities of all other characteristics are held constant in the diagram. The equilibrium rental price schedule R(z) is increasing in the characteristic because it is a desired characteristic, but R(z) is not restricted by the theory to be concave or convex. Two contours of the bid function, θ^1, are shown for farmer 1. Higher profits ($\pi^d < \pi^{d'}$) imply lower bids as shown by the dashed bid function. Given the equilibrium rent schedule, this farmer selects $\bar{z}_{io}$ of the characteristic, since the maximum attainable profit is π^d, given the rent schedule. For the landlord this characteristic is outside his control, so the contours of the offer function

ϕ^1 have a right angle at the fixed amount of the characteristic he has available. The offer contours for landlord 1 with $\bar{z}_{io}$ of the characteristic to offer are higher for higher levels of profit ($\pi^s > \pi^{s'}$). These profits are completely determined by the equilibrium rent schedule. While each of the farmers and landlords individually takes the equilibrium rent schedule as given, collectively their actions determine it as market-clearing bids and offers evolve. The first step in the empirical work is determining R(z).

Figure 2 represents the same relationships in terms of marginal rather than total bids. The equilibrium marginal price schedule $R_{\bar{z}_i}$ is the partial derivative of R with respect to $\bar{z}_i$. Here it is downward sloping because the price schedule is concave, but it might also be upward sloping if the price schedule had been convex. The marginal bid schedule (given the equilibrium level of profits) of farmer 1, $\theta^1_{\bar{z}_i}$, is necessarily downward sloping because of the concavity of the profit function in z. A marginal bid schedule for a second farmer is also shown. The intersection of the marginal rent schedule and the marginal bid schedule simultaneously determines the amount of the characteristic and the marginal price paid for the characteristic. It should be noted that these marginal bid schedules assume that the quantities of other characteristics are held constant, while in some circumstances the farmer would take the prices of the other characteristics as given. This case is difficult to show graphically but can be handled mathematically and empirically.

Valuing Land Improvements

The theory of land rental prices developed in the previous section can be used as a basis for valuing land improvements (i.e., evaluating changes in the characteristics of land). The necessary techniques differ greatly depending on the nature of the improvements. Improvements made by an individual landowner or public policies with a limited scope will not influence the equilibrium price schedule. In this case using land value studies to value the improvements is quite straightforward. However, some government policies toward land will have a significant impact on the equilibrium land rent schedule. Under these circumstances value measurement becomes more complex. The discussion of this case is postponed until a later section.

In the former case, suppose one wishes to evaluate the benefits of a land improvement made by an individual landowner or resulting from a government program that does not have a widespread impact. Such a "small" improvement will change the prices of the improved land but will leave the market price schedule unchanged. This is because the market is made up of a large number of parcels of land, so the improvement of one or a few parcels will not appreciably change the price of parcels other than those directly affected. The land that is improved will simply move from one category to another. Before the improvement the profit levels for all farmers with comparable abilities were equilibrated. After the improvements the profit levels will still be equilibrated at the same level. If profits increased on the newly improved land, others would bid for that land raising its price to the level of comparable parcels. The unusual profits would disappear. Thus, there is no willingness on the part of the farmers to pay for the improvement. On the other hand, owners of the improved land receive all of the benefits of the improvement in increased rents. The net benefits are then the increase in rental price of the affected parcels less any costs to the landowners of the improvements. The change in rents can be forecast easily, since the constant price schedule is known from the hedonic equation. Graphically, in this case the equilibrium rent schedule of Figure 1 is not affected by the change. The landlord's willingness to pay for the change is simply the change in rental price along that schedule when the characteristic changes.

If the improvement to be evaluated affects a large number of land parcels, then the price schedule is changed. However, as shown in Freeman (1975), Lind (1975), and Bartik (1985), under certain circumstances it is possible to use the initial price schedule to provide an upper-bound for the value of the benefits of the improvements. The necessary conditions for this to hold are that the other characteristics of the land are not changed in response to the improvement and the landowner's costs are uninfluenced by the improvement. For some types of agricultural policies, these assumptions may be reasonable.

Thus, hedonic results are frequently useful for evaluating the benefits of land improvements and in some other cases can be used to place an upper-bound on the benefit measure. However, the techniques have been discussed in terms of rental prices. Frequently better data are available on sales prices of land than on rental prices. What modifications are necessary to use such asset prices? If people rent land for a relatively short period of time, their only interest will be in the current productive capabilities of the land. Thus, the rental prices will reflect only those current capabilities. On the other hand, the value of land as an asset depends on the present value of future rents. The land may be used for different purposes in the future, so different characteristics may be relevant in the future. These characteristics would then influence asset value but not rental value. For example, proximity of farmland to a major population center might increase land values even though it did not increase agricultural productivity. In the same vein, a characteristic that is of value in agricultural use such as soil productivity may be discounted in the asset price if that characteristic is not as highly valued in some alternative use (e.g., commercial use) that is anticipated in the near future.

A second modification that is necessary to use asset prices is a consideration of the effects of taxes on asset values versus rental values. There is usually a property tax on farmland, so the future yield of a piece of farmland will be the rental price minus the property tax, which depends on the land value. The asset value is the present value of rents net of taxes, whereas the value of the productivity increase due to the improvement is the present value of the change in rents. Benefits would be underestimated if the property tax were ignored. This effect is partially offset because property tax payments are deductible in calculating income taxes. This reduces but does not eliminate the underestimation due to the property tax.

Data Collection

Erosion control is an important issue throughout most of the country, whereas drainage of farmland, although not as widespread, can have important effects on the productivity of a tract of land. To demonstrate the use of land value studies in evaluating land improvements, the above model was applied to these two types of improvements using data from North Carolina.

Cross-sectional data for this analysis came from a survey that included sales that occurred during the period October 1, 1979 to March 31, 1980 (Danielson, 1981). Persons surveyed included brokers, realtors, appraisers, bankers, tax supervisors, loan representatives and others knowledgeable of farm sales. Data consisted of estimates of the value of farmland, the extent of buyer/seller activity for land and information on actual sales of farmland during the survey period. The survey yielded 252 observations having a full complement of the data needed for this analysis. The survey provided data on the characteristics of each tract, as well as on the buyer and the seller of the tract. The survey data were supplemented with several pieces of county-level information from the 1980 Census of Population and the 1982 Census of Agriculture. Information obtained from the U.S. Soil Conservation Service was used to estimate the level of several soil characteristics for each tract. These included agricultural productivity, the need for drainage, erosion level and the suitability of the land for septic tanks. Ideally, these soil characteristics would be measured through on-site evaluation. However, this was not feasible because of the large number of tracts in the survey and their being scattered throughout the state. Instead, a procedure was developed to generate this information from existing soil survey data and studies. First, the tracts were located on a county highway map using location information from the North Carolina Rural Real Estate Survey. Then, with the help of a soil scientist trained in soils interpretation,[6] tract location was transferred to a general soil classification map so the most prevalent of 98 soil types could be identified for each tract. Finally, 32 soil productivity groups (USDA, 1975) were correlated with the soil classifications to provide soil quality measures, erosion estimates and drainage requirements for each tract.

The database was used to provide information on the agricultural productivity of the land as well as nonagricultural influences. Information on these nonagricultural influences was necessary, since the prices used in the study were real estate market prices or asset prices, not rental prices. Table 1 lists and describes the variables used in this study, and provides the mean, standard deviation and source of each. The two variables of primary interest in this study were the susceptibility to erosion and the desirability of drainage. One would expect that soil quality and the percentage of cropland in the parcel would also affect price. Because of transactions costs, the price per acre should be influenced by the size of the tract. The final agricultural variable concerned tobacco quota sold with the land. The poundage quota of the parcel was divided by the number of acres in the parcel to obtain a measure of the effect of the allotment on the price per acre. The nonagricultural variables included the population density of the county in which the parcel was located and the rate of increase of that population. The presence of community water and housing nearby also measured urban pressure. Finally, an interaction term between soil quality and urban influence was included. This was done because the present value of future agricultural productivity would be greater if the land were expected to remain in agriculture than if it were expected to be converted to urban use in the near future.

Empirical Results

The first step in the empirical analysis is estimation of the equilibrium price schedule. The functional form of the hedonic equation is not dictated by the theory, so it was selected empirically by applying Box-Cox techniques to the most common functional forms. By this method the semi-logarithmic form was chosen as preferable. The results of this regression are given in Table 2.

All of the variables have the expected signs, and with the exception of POPCHGE, they are all significant at the 5 percent level or better. If the soil is wet enough to require drainage, this is estimated to cause a 25.7 percent reduction in land prices[7]. At the mean land price this represents a $381 per acre reduction[8]. The susceptibility of the soil to erosion also results in a price reduction that is equal to a $2.63 per-unit increase in the erosion potential of the land on an average tract. Soil quality also has an important effect on land prices, causing land values to differ by as much as 49.6 percent. A pound of tobacco allotment was worth $2.67 on an average parcel of land. Cropland was worth $450 more per acre than forested land.

How reasonable are these estimates, and how well do they correspond to estimates derived by other methods? The soil wetness variable coefficient suggests that if wet soils were drained there would be on average a 34.6 percent increase in land values. To our knowledge, market data are not available for land values before and after drainage. However, at the time the sales data for this study were collected, wet soils requiring drainage for crop production were available for around $400 to $500 per acre in eastern North Carolina (Barnes,1981). Although there can be great variation in cost levels, Skaggs and Nassehzadeh-Tabrizi (1983) estimated that 1982 drainage costs for two common Coastal Plain soils (Rains and Portsmouth) could range from $80 to $400 per acre, depending on the type of drainage system implemented and on whether main ditches were in place. In North Carolina some but not all wetlands eligible for drainage are drained, so the market seems to be near equilibrium, with drainage costs approximately equal to the increase in land values. Assuming a cost of $450 for undrained land and a land market in equilibrium, these data imply that land value would rise by between 18 to 89 percent when drained if the drainage were to be undertaken by a profit-maximizing landowner. The estimate from our hedonic equation is well within this range.

The variable representing the potential for erosion on the land is the RKLS factor in the Universal Soil Loss Equation. This variable takes into account rainfall, soil type, and the length and steepness of slope. These factors are, for the most part, beyond the farmer's control on a particular tract, although conservation practices such as terracing can influence the last two factors. The RKLS factor can be converted to tons of erosion per acre per year by multiplying by factors for cultivation and conservation practices. If no specific conservation practices such as contouring are used, the supporting practice factor can be assumed to equal one. However, the cultivation of any crop will reduce the erosion rate below that on continuously cleaned and tilled fallow soil. Thus, the RKLS factor must be multiplied by a factor (C) less than one to yield the erosion in tons per acre per year. For example, in the Piedmont of North Carolina continuous corn cultivation on land with average productivity using turn plowing, cut silage, and residue removal yields a C factor of .494. Other common crop rotations and practices also yield C values in the same general range. In this case, erosion in tons per acre per year would be .494 times RKLS. The coefficient in the regression indicates that a one-unit reduction in RKLS would be worth, on average, $2.63. However, a one-unit reduction in RKLS represents a reduction in soil loss of only (.494 x RKLS) tons per acre per year. Thus, a one ton per acre per year reduction in soil loss would be worth (1/.494)2.63 or $5.32.

This estimate can be compared to those derived in two types of studies. First, one can relate erosion to reduced yields and then determine the value of the lost crops. The Soil Conservation Task Force of the American Agricultural Economics Association (1986) has estimated that a 10 percent yield reduction after 100 years of erosion on the 142 million acres of land growing the nation's corn and soybeans would result in lost productivity that would have a present value of $4.3 billion at a 10 percent rate of discount assuming that corn and soybeans are priced at $3.00 and $7.00 per bushel respectively. This is an average cost of $30.28 per acre. In a cornbelt study, Pierce et al.

(1984) estimate that average yields would decline by 4 percent over 100 years with an erosion rate of 7.8 tons per acre per year. This implies that the Task Force's 10 percent reduction would result from an erosion rate of 19.5 tons per acre per year if a linear relationship is assumed. Dividing the per-acre cost estimate of the Task Force by this erosion estimate yields $1.55 as the present value of the yield loss due to an erosion rate of one ton per acre per year. This can be compared with our estimate of $5.32. Two factors suggest that the Task Force/ Pierce et al. estimate is low relative to what would be expected for our study area. First, the topsoil depths in North Carolina are less than those in the cornbelt, so a given soil loss results in a greater productive reduction in North Carolina. Second, the Task Force estimate, which assumes a high level of management to optimally replace nutrients and maintain certain soil properties, does not incorporate the costs of these practices, whereas a land value study does.

The second method of comparison is examining studies using land values. Miranowski and Hammes (1984), in their chosen hedonic equations, use only soil characteristics. They estimate that a one-unit reduction in potential erosivity (RKLS in the Universal Soil Loss Equation) results in an increase in farmland value of approximately $5.70 based on 1978 data. For comparison with this study, their estimate was adjusted to 1980 dollars using an index of Iowa farmland prices (USDA, 1984). This yielded a value of $7.58. In their conclusions they equate the one-unit change in RKLS to a change of one ton of erosion per acre per year. This suggests that they have assumed the management and practice factors of the Universal Soil Loss Equation are equal to one. Their estimate is higher than the $2.63 estimate derived in this paper. Both Ervin and Mill (1985) and Gardner and Barrows (1985) obtain more mixed results and are led to question whether, in general, farmland values capture differences in erosion.

Our estimates suggest that cropland is worth about $450 per acre more than forestland. Since timbered land can be cleared, is this possible if the land markets are near equilibrium? Clearing land in the study area costs, on average, $400 per acre.[9] This is quite close to the estimate, especially since there are generally quality differences between land used for crops and land used for timber that might not be fully captured in the equation.

The value of tobacco allotments in 1980 was estimated in this study to be $2.67 per pound. This value probably differed significantly between counties, but comparison with other average estimates is still useful. Using 1980 Federal Land Bank data for North Carolina, Seagraves and Williamson (1981) estimated tobacco allotment values at $3.24 per pound in 1980 dollars. Pugh and Hoover (1981) estimated the North Carolina lease-and-transfer rate for quota in 1980 to be 37.79 cents per pound per year. In 1983 the value of quota was approximately five times the rental rate based on a survey of North Carolina County Tobacco Extension Agents. Using this capitalization rate, the Pugh and Hoover estimate represents a value of $1.89 per pound, so our estimate is well within the bounds of existing estimates.

Finally, the hypothesis that the capitalized value of future soil productivity would be less for land subject to alternative uses than for land expected to remain in agriculture was confirmed. The significant negative coefficient of the interaction term POPSOIL indicates that while soil quality is of significant value, this value is significantly reduced for land expected to be subject to urban conversion.

Overall, the hedonic equation appears to perform quite well. How might the results be used? Individual farmland owners could gain additional information to assist in making investment decisions. For example, the results provide an estimate of the average increase in land value due to drainage, and this increase represents the value of the increased productivity of the land. This information can be combined with drainage cost estimates and information on government programs in making the drainage decision. Similarly, farmland owners must make decisions about participation in programs to control erosion, for example by terracing. This would reduce the soil loss, and this study provides information on the value of reducing potential erosion. The farmland owner can evaluate whether this increased value justifies the remaining costs after the cost-sharing.

The results are also useful in policy decisions. For example, the Agricultural Conservation Program provides cost-sharing for erosion control practices. The benefits of such practices include both maintaining on-farm productivity and reducing off-farm damages from sedimentation. Studies such as this one help determine the value of the on-farm benefits so that the necessary level of subsidies to obtain a particular level of erosion control can be determined. The extent of participation in this program is relatively low, which allows valid estimation of benefits using only the first step in the hedonic estimation.

At times federal programs have conflicting objectives. Decisions concerning drainage versus preservation of wetlands have been subject to contradictory programs. On one hand, some policies lead to increased drainage. Examples are projects under the Watershed Protection and Flood Protection Act of 1954, the Flood Control Act of 1944, and commodity price support programs of various farm bills. On the other hand, other legislation attempts to preserve wetlands. Examples include the federal Duck Stamp Act and amendments providing for assessments on hunters for purchase and lease of wetlands, certain elements of the ACP, elements of various farm bills (soil bank, conservation reserve, swampbuster provisions), and the federal Water Bank Program. Studies such as this one can evaluate the benefits of drainage so they can be compared to the benefits of maintaining wetlands. Such information might be of help in evaluating the usefulness of the various programs.

Valuing Land Improvements for Major Policy Changes

A major policy probably will change not only the rental prices of the affected parcels but also the equilibrium rental price schedule. When the price schedule changes because of the policy, exact valuation requires a second stage in the empirical analysis to estimate farmers' demands for the improvement. This is because the profits of the farmers may be changed as well as the profits of the landowners.

While a farmer makes a choice about the characteristics of the land on which he farms, he cannot influence the parameters of the price schedule. Equation 1 can be rewritten as

$$R = R(z;\tau) \tag{8}$$

where τ represents the parameters of the function which are exogenous to the individual farmer. A major policy change results in a change in these parameters. The profit function of the farmer is the difference between equation 4 and the land rental price,

$$\pi^{d} = \pi^{*dv}(p, z, \alpha) - R(z;\tau). \tag{9}$$

Since the z are endogenous, this can be rewritten as

$$\pi^{d} = \pi^{d}(p, \alpha, \tau). \tag{10}$$

The profit function of a farmer depends on the prices of outputs and non-land inputs, the parameters of the nonlinear land rent schedule, and farmer-specific characteristics. If the rent schedule were linear, the prices of the characteristics of the land would be parametric and this would be a typical profit function. However, with the nonlinearities in the rent schedule, marginal prices are not parametric and Hotelling's Lemma cannot be applied directly. A procedure that has proved useful in other contexts (Palmquist, 1984) is treating the observed marginal characteristics prices as equal to the average characteristics prices. Actual profits, π^d, will differ from the profits calculated with this linearized rent schedule, π^{da}, and so actual profits must be adjusted:

$$\pi^{da} = \pi^d - R(z;\tau) + \Sigma\, p_i z_i, \qquad (11)$$

where the p_i are the observed marginal prices of the characteristics. Maximizing these adjusted profits will yield a profit function that depends on marginal land characteristics prices, other input and output prices, and firm-specific characteristics. In this case, Hotelling's Lemma can be used to derive input demands and output supplies that can be estimated.

The estimation in this case is complicated for several reasons. If one land market is observed, marginal prices of land characteristics will differ because of the nonlinearity of the rent schedule. However, there is only a single rent schedule faced by all farmers, so a typical identification problem arises in distinguishing between the characteristic demand equation and the equilibrium marginal price schedule (Epple, 1985, discusses this issue in a slightly different context). This problem can be seen graphically in Figure 2. Data from a single market will reveal only the points of intersection of the marginal bid functions and the one marginal price schedule. Only one point on each marginal bid function is observed, so the dotted line is as valid a representation of the bid function $\theta_{z_i}^{-1}$ as the solid line. However, identification is possible through the use of multiple markets to provide differing marginal price schedules (e.g., Palmquist, 1984) or by imposing restrictions on the estimated equations if valid restrictions are available.

A second difficulty arises because the farmers simultaneously select the prices and quantities of the characteristics because of the nonlinear rent schedule. Instruments must be developed for the endogenous marginal prices, and care must be exercised in selecting instruments (see Epple, 1985; Bartik, 1985; and Palmquist, 1984).

After addressing these issues, one can obtain consistent estimates for the characteristics demands derived from the adjusted profit function. These estimates could then be used to estimate the difference in farmer profits attributable to the improvement. This would require considering the difference between actual profits and adjusted profits using equation 11 (see Palmquist, 1985, for an analogous case).

Welfare measurement in the case in which the rent schedule is changed by the policy may require knowledge of the new rent schedule as well as of the old. This would be true if some farmers chose to relocate in response to the policy change. Forecasting the new rent schdeule before it happens is only possible in extremely simple situations (Epple, 1985). This means that exact measurement is only possible after the policy is implemented when the policy changes the rent schedule and causes relocation. There are various cases in which such ex post measurement is useful, but ex ante benefit estimation is also of frequent importance.

Before a policy is implemented, a forecast of the benefits is useful in deciding on the desirability of the policy. An ex ante lower-bound on the benefits is always available, and in some cases the measure is exact (see Palmquist, 1985, for the corresponding consumer case). This measure can be derived from the variable profit function in equation 4. That function represents profits before land rents are netted out, but the land characteristics are not truly fixed factors. Diewert (1974) has shown that the partial derivative of variable profits with respect to a fixed factor is the shadow price of that fixed factor. Differentiating the variable profit function with respect to the characteristics of the land yields the inverse demands for these factors. A farmer's total willingness to pay for a change in a characteristic of the land if the other characteristics cannot be altered could be obtained by integrating the inverse factor demand function between the original and the new level of the characteristic. Equivalently, the difference in the variable profit function with the two levels of the characteristic could be used.

The value measure derived from the inverse demands is exact if farmers do not adjust the quantities of any other land characteristic in response to the policy change. If they do change locations or the other characteristics of the current location change, then the measure is a lower-bound for the benefits of the policy, since the farmers only switch land if they can increase their profits by so doing. Graphically, this type of welfare measurement can be shown in Figures 3 and 4. The policy results in a shift in the equilibrium marginal rent schedule from $R_{\bar{z}_i}$ to $R_{\bar{z}_i}'$, and the farmer enjoys an increase in the quantity of the characteristic as well as a reduction in the rent schedule. In Figure 3 the policy causes the level of $\bar{z}_i$ to increase from $\bar{z}_{i0}$

to $\bar{z}_{i1}$, and this happens to be the quantity chosen by the farmer, given the new rent schedule. The farmer's welfare gain is the sum of areas a and b, area a because of the reduced rent on the original level of the characteristic and area b because of the availability of new units of the characteristic at prices below the farmer's marginal willingness to pay. The landlord, on the other hand, loses area a because of the reduced rent schedule but gains area c because of the higher level of the characteristic. The landlord's loss of area a cancels the farmer's gain of that area, so the net gain to the two individuals is area b plus area c.

More typically, the change in the characteristic resulting from the policy will be more or less than the farmer would choose to use, given the policy-induced change in the rental price schedule. These possibilities are represented in Figure 4. First, assume that the quantity of the characteristic changes to $\bar{z}_{i2}$, less than the farmer would choose, given the new equilibrium rent schedule. If transactions costs prevent the farmer from relocating, then the area b + c is the appropriate representation of the welfare gain, as before. However, if the farmer relocates, then his gain is a + b + e. The change in the landlord's welfare is still c - a, so the net gain is b + c + e. Similarly, if the characteristic changes to $\bar{z}_{i2}'$, then relocation also increases the welfare gain. With relocation the gain is b + c + e + d + f, whereas if relocation is not possible, the gain is reduced by area f. The welfare measure described provides a lower-bound on the gain even with relocation and is an exact measure if transactions costs prevent relocation.

Reliable estimation of the variable profit function or the inverse factor demands will probably require data from several markets that are separated spatially or temporally. Data that are comparable between markets and of sufficient detail for this analysis do not appear to be available at this time. The analysis of such data when they become available will allow extending the current analysis using the techniques described in this section.

Conclusions

This paper has developed a theoretical model of the determination of the equilibrium prices of farmland with heterogeneous characteristics based on the behavior of profit-maximizing farmers and wealth-maximizing landlords. This model is then used to determine willingness-to-pay for changes in those characteristics under various circumstances. This willingness-to-pay information is useful to farmers in making decisions and is also useful in designing and evaluating government programs. The necessary estimation steps depend on the particular question being analyzed.

The empirical application of this model used data from North Carolina that provide fairly complete information on the characteristics of a large number of land parcels. The results of the hedonic estimation indicate that the marginal willingness to pay for a one ton per acre per year reduction in soil erosion with a typical crop is, on average, \$5.32. Drainage of wet farmland results in an average increase in value of \$381 per acre. The reasonable magnitudes of these and other coefficients is indicative of the reliability of the hedonic results. This information is valuable for individual farmers and in evaluating programs of limited scope.

Table 1. VARIABLE DEFINITIONS, SOURCES, AND STATISTICS

Variable	Mean Value	Standard Deviation	Definition	Source
PRICE	1481.	1080.	Price of land per acre (dollars)	N.C. 1980 Rural Real Estate Survey (RRES)
EROSION	72.34	41.36	Estimated soil loss on tract; USLE, bare ground (tons per acre per year)[a]	Based on materials from Chowan-Pasquotank River Basin Study
SOILWET	.0833	.2769	Dummy: Soil wetness (1 if poorly or very poorly drained; 0 otherwise)	USDA, 1975
SOILQUAL	2.151	41.36	Quality of soil rating (poor = 1, average = 2 good =3)	N.C. RRES
SIZE	100.3	135.2	Tract size (acres)	N.C. RRES
PCROP	42.46	31.92	Percent cropland	N.C. RRES
TALLBAC	49.05	80.02	Tobacco allotment (lbs.)/ acre	N.C. RRES
POPCHGE	14.80	8.467	County population increase (1970-1980) (percent)	1980 Census of Pop.
POPDEN80	158.6	149.7	County population density (1980) (persons per sq.mi.)	1980 Census of Pop.
DHOUSING	.1230	.3291	Dummy: Community housing (1 if located nearby; 0 otherwise)	N.C. RRES
DWATER	.1071	.3099	Dummy: Community water (1 if located nearby; 0 otherwise)	N.C. RRES
POPSOIL	339.5	342.7	Interaction term, POPDEN80*SOILQUAL	1980 Census of Pop. N.C. RRES

[a] While bare ground erosion estimates are high relative to those obtained with cropping practices, they were chosen because they best reflect the inherent erosivity of the soil class.

Table 2.

HEDONIC REGRESSION RESULTS

Variable	Parameter Estimate	t-value[a]
EROSION	-0.001776	-2.185
SOILWET	-0.249524	-2.008
SOILQUAL	0.252892	3.626
SIZE	-0.001040	-4.640
PCROP	0.003093	2.946
TALLBAC	0.001804	4.418
POPCHGE	0.004524	1.237
POPDEN80	0.002327	3.147
DHOUSING	0.282726	2.950
DWATER	0.308266	3.178
POPSOIL	-0.000676	-2.045
INTERCEPT	6.334866	37.573
R-SQUARE	0.4311	
ADJ R-SQ	0.4051	

[a] All variables are significant at the 95% level or better except POPCHGE

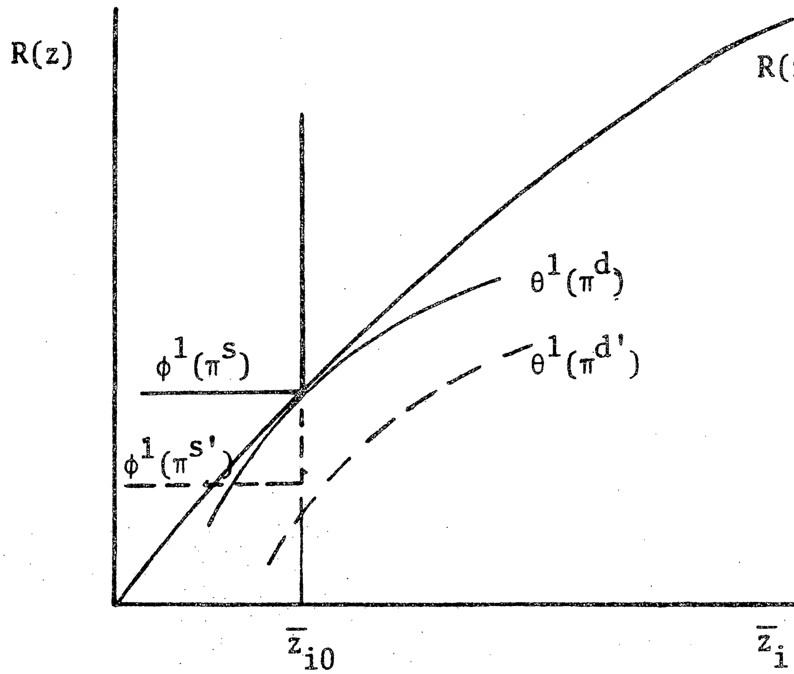

Figure 1

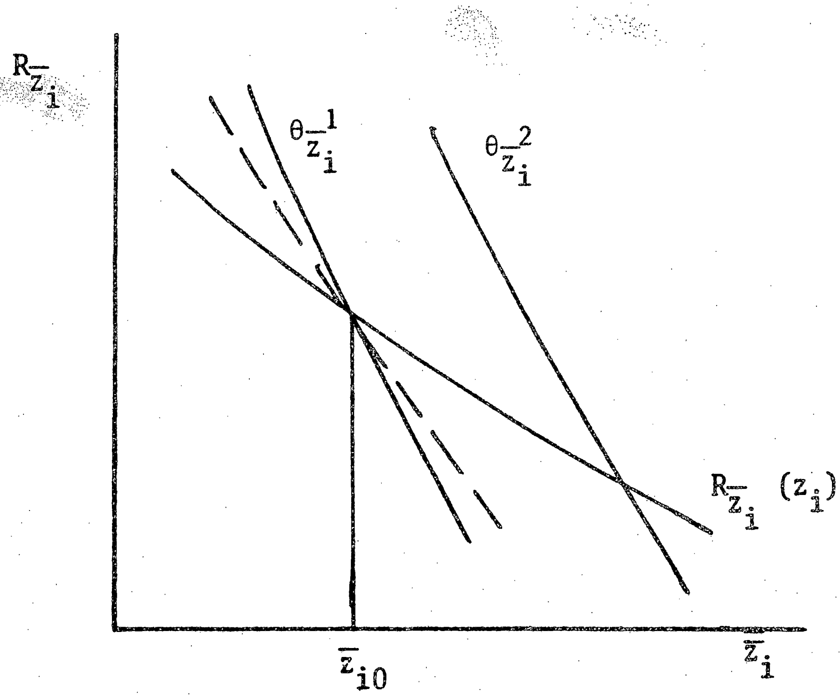

Figure 2

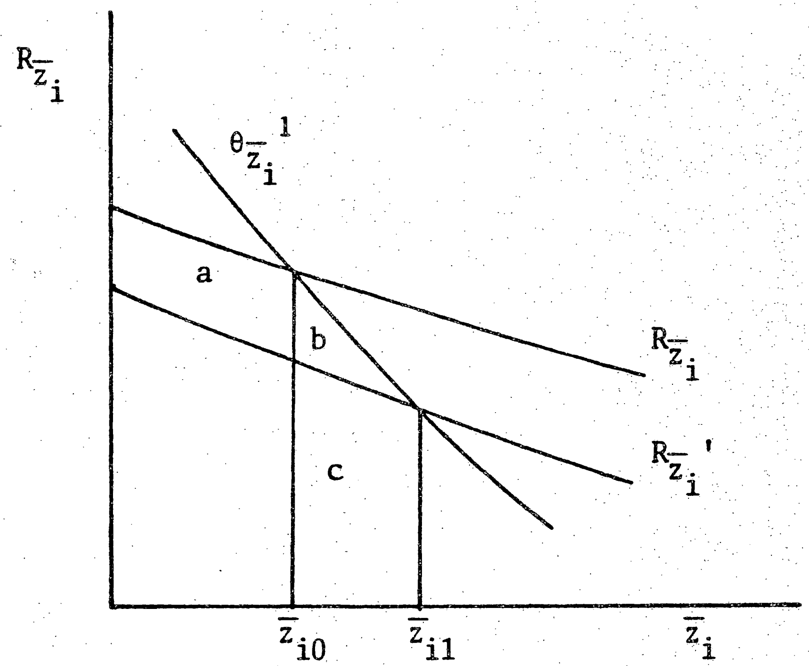

Figure 3

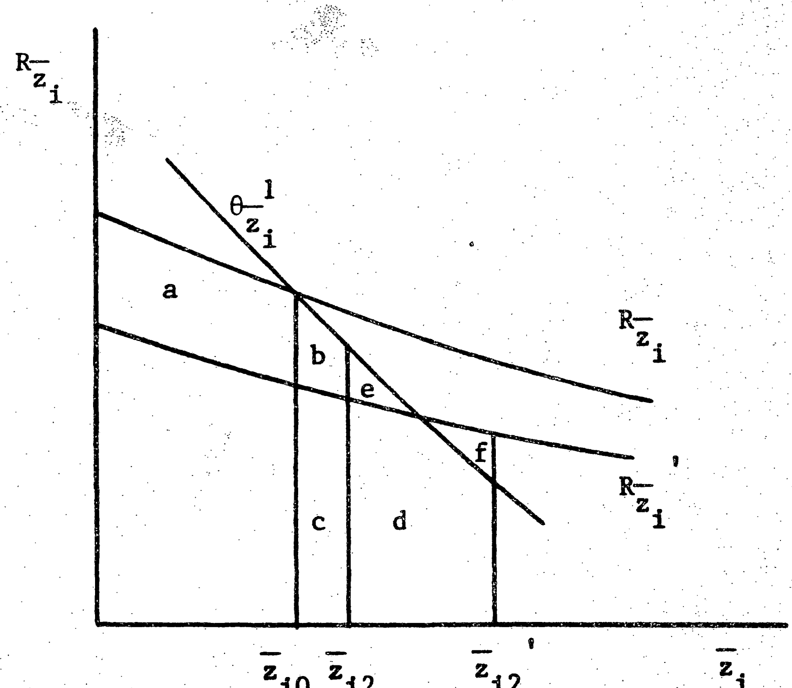

Figure 4

FOOTNOTES

* The authors are grateful to Dana Hoag, E. C. Pasour, Daniel Sumner, and Walter Thurman for helpful comments on an earlier version of this paper. However, they are not responsible for any remaining errors.

1. A hedonic regression relates the price of a differentiated product to the various characteristics that it provides.

2. A separate line of research on land values has been concerned with aggregate land values and has focused on the behavior of land prices over time and the effects of inflation and taxes on land values. Two recent contributions to this literature that also summarize previous works are Alston (1986) and Burt (1986). This important research is outside the area of inquiry in the present paper.

3. In a seminal article Rosen (1974) develops a theoretical model of the market for a differentiated consumer product. The present article adapts that model to the market for a differentiated factor of production and discusses both the estimation issues and the welfare measurement issues in that market.

4. The use of the term "variable profits" should not be misinterpreted. Variable profit is normally revenue minus expenditure on variable factors. Here the characteristics of land are not fixed. However, land costs are not netted out of variable profits as the term is used here.

5. If there are fixed factors, π^d will include payments to those fixed factors.

6. A special thanks is given to Dr. J. A. Phillips, currently Assistant Director and State Leader for Agriculture, North Carolina Agricultural Extension Service, for his able assistance in developing this information.

7. For the semi-log equation used here, a consistent estimate of the relative effect on rental price of the presence of a dichotomous characteristic is given by $\exp(\hat{\beta}) - 1$ where $\hat{\beta}$ is the estimated coefficient (Halvorsen and Palmquist, 1980). For small samples the potential bias of this estimator can be reduced by using $\exp[\hat{\beta} - 1/2\hat{V}(\hat{\beta})] - 1$ where $\hat{V}(\hat{\beta})$ is the variance of $\hat{\beta}$ (Kennedy, 1981). For discrete changes in a continuous variable, a consistent estimate of the relative effect is given by $\exp(\hat{\beta}\Delta N) - 1$ where ΔN is the change in the variable. For small samples a better estimator is $\exp[(\hat{\beta}\Delta N) - 1/2(\Delta N)^2\hat{V}(\hat{\beta})] - 1$ (Palmquist, 1982). The interpretation of the results makes use of the two small sample estimators.

8. All prices based on the estimates will be in 1980 dollars.

9. Personal communication, Rick Hamilton, extension forestry, North Carolina State University.

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