Staff Paper #321 July 1992

AN ANALYSIS OF THE IMPACTS OF LANDOWNERSHIP ON THE ENVIRONMENTAL QUALITY

by

Huoying Wu and Jerry R. Skees

An Analysis of the Impacts of Landownership on the Environmental Quality

Huoying Wu
The Institute of Economics
Academia Sinica
Taipei, Taiwan

and

Jerry R. Skees
Dept. of Ag. Econ.
University of Kentucky
Lexington, KY 40546-0276

August, 1992

* selected paper presented at 1992 AAEA (American Agricultural Economics Association) annual meetings, Baltimore, Maryland, August 9-12, 1992.

Abstract

A dynamic optimization model is developed in this paper to examine the impacts of different landownership on the efforts in reducing the damages to the environmental quality.

Value of living quality and land quality are considered in this paper. A typical farm agent is assumed to maximize the sum of the value of the living quality and the total farm income. Then a comparative static analysis is conducted.

22193

An Analysis of the Impacts of Landownership on the Environmental Quality

Environmental issues are receiving increased attention. Issues like soil conservation, water quality, food safety, and agricultural chemicals are central to many environmental and food safety concerns.

However, there is limited research examining the impact of a bimodal structural distribution on the environment. Will the trend toward fewer but larger farms have unfavorable consequences for soil conservation as Lee(1980) stated? What are the impacts of land tenure patterns on soil conservation, chemical use, and water quality? Are renters less likely to practice soil conservation than owners? Are full-time farmers better at protecting natural resources than part-time farmers? Studies in these issues will provide a better understanding of changes in environmental management induced by structural change.

This paper develops a theoretical model which examines the impacts of different landownership on the efforts in protecting environmental quality. It is formulated as a dynamic optimization problem.

This paper examines the farm agent's efforts in protecting the environment by considering the value of living quality which is usually ignored by other researchers. The importance of inclusion of this value has been expressed by McConnell (1983) that "the problem of water pollution is paramount, not agriculture's future productive capacity." In his view, the problem of water quality from soil erosion is far more important than the decrease in future farm income. Similar concerns have been expressed by Wade and Heady (1979). Thus, when modelling the farm agent's behavior toward environment-protection, not only farm agent's income but also the value of living quality needs to be considered.

In short, in contrast to previous literature, two types of trade-offs are considered in this paper. One is the contemporal trade-off between the income level and the living quality. The other is the intertemporal trade-off between current income and future income level. By assuming a typical farm agent maximizes the sum of the value of the living quality and the total farm income which he can obtain from rented land or owned land, we examine the effects of exogenous variables on the efforts farmers make in reducing damage to the environment, such as the length of renting contract, cost of efforts in protecting the environment, off-farm wage rates, agricultural output prices, and depreciation of farm land caused by soil erosion, overuse of agricultural chemicals, or over utilization of farm land.

A farm agent can be referred to a farm family that will last for generations, or it can be a farm corporation. Thus, the planning time horizon can be infinite. In this paper, a farm agent will be referred to the farm family specifically. A farm family considers not only the current generation's well-being but also the well being of future generation's. Efforts in conserving the environment can include reducing the usage of agricultural chemicals, adoption of rotation, participation in soil conservation, etc. Those efforts involve both monetary costs and opportunity costs. Living quality can include food quality/safety, air quality, water quality, soil quality, etc. Any effort the farm agent makes can reduce the damage to the environment, such as air pollution, water pollution, or soil erosion. Those efforts will result in a better living environment. Meanwhile the natural resource and future productivity can be conserved.

The paper proceeds as follows. First, a continuous-time model is presented for examining the renter's efforts in protecting the environment. The owner's case can be seen as a special case of this model in a convergent version when the length of rental goes to infinity. Then, the implications from the optimality conditions and comparative static studies are discussed. Finally, the conclusion is presented.

The Model

Assume that the farm agent either rents or owns the land in order to allow for comparisons of the economic implications for both renters and owners. Initially, no off-farm income is assumed here. This assumption can be relaxed to evaluate the effects of part-time farming on environmental quality. In that case, the farm agent will need to allocate the total available labor time between off-farm and farm work at each time period.

Case 1: Renters

A simple description of farm family production function at time t is

$$f(L(t),Q,K(t),X(t)), \qquad \text{..........(1)}$$

where L is the labor inputs, Q is the land rented for production, K is the quality of rented land, and X is the effort made in reducing the pollution caused by agricultural production such as practicing soil conservation or reducing the usage of agricultural chemicals. Q is fixed. Growth in farm size is not considered in this paper. The production function, f() represented in equation (1), is assumed to be a continuous, twice differentiable function with first derivatives $f_L > 0$, $f_K > 0$, $f_X < 0$ and second derivatives $f_{LL} < 0$, $f_{KK} < 0$, $f_{XX} < 0$.

A first constraint affecting the farm agent's profit is the quality of land. The change in the land quality defined by the deterioration process:

$$\dot{K}(t) = g(X(t), F(t)) - \delta K(t), \qquad \text{..........(2)}$$

where g is a function of effort in reducing pollution, X(t), or improving the productivity through other efforts, F(t), such as using natural fertilizer, and δ is the rate of depreciation. The quality of land deteriorates through soil erosion or other ways. Function g is assumed to be strongly concave with $g_X > 0$ and $g_{XX} < 0$. The quality of land can be improved or the depreciation process can be slowed if the farm agent devotes time and efforts. This equation may be viewed as a dynamic constraint facing the farm agent. Changes in land quality only come from depreciation and efforts in improving land quality.

A second constraint affecting the farm agent is the pollution level. The increments to pollution level can be written as

$$\dot{Y}(t) = m(X(t), Z(t)), \qquad \text{..........(3)}$$

where Y is the measurement of the degree of pollution, such as air pollution, water pollution, which is caused by agricultural production, and Z indicates other factors which influence the pollution level and is a vector of variables outside the control of the farm agent. Function m is assumed to be strongly convex in its first argument, X, with a negative first partial, $m_X < 0$ and $m_{XX} > 0$. More efforts will reduce the increments to the pollution level at a decreasing rate. The increment to the current pollution level at each time period is controlled by the agent's efforts and other factors. It is a decreasing, continuous, and first differentiable function of efforts. Namely, efforts farm agents made in protecting the environment can reduce or slow the rate of the pollution problem. When m_X is very small or close to zero, the efforts which the farm agent makes do little to help reduce the overall pollution level. Thus, in this case the farm agent can not control the pollution level or influence his living quality. Then the problem is simplified to the traditional assumption that the farm agent maximizes the present value of total net farm income.

The farm agent is assumed to maximize the present value of total net farm income and value of living quality over the planning (contract) time horizon plus the value of remaining effects of the pollution on the living quality:

$$\underset{X(t)}{Max} \int_0^T e^{-\rho t}[\text{value of living quality} + \text{net farm income}]\, dt + R(Y(T)).e^{-\rho T}$$
$$= \int_0^T e^{-\rho t}[h(Y(t),\ \epsilon(t)) + Pf(L(t),Q,K(t),X(t)) - q(J(t)) - c(X(t))]\, dt + R(Y(T)).e^{-\rho T}$$

..........(4)

where T is the length of renting contract, P is the output price, $q(J(t))$ is the variable input costs function, $J(t)$ is a vector of variable inputs, c is the unit cost of efforts, ρ is the time-preference rate, and R is the remaining effects of the terminal pollution level on the living quality after the end of the rental contract. Living quality can include food quality, air quality, water quality, etc. Assume living quality can be measured pecuniarily and is dependent upon the pollution level. Then, the value of living quality is measured by $h(Y, \epsilon)$, where ϵ is other factors which affect the living quality and h is strongly convex in its argument Y with a negative first partial. h() is a continuous, first differentiable, and a decreasing function of pollution levels and other factors. $R(Y(T))$ is the measurement of the value of residual impacts of pollution level at the end of the rental contract on the living quality over the rest of the planning time horizon. R is assumed to be strongly convex.

In this paper, two kinds of trade-offs are considered: contemporal and intertemporal. While the contemporal trade-off exists between the living quality and the farm income, the intertemporal trade-off exists between current farm income and future farm income. In early periods, the farm agent can increase the farm income by using more agricultural chemicals or not practicing the soil conservation or crop rotations. All those behavior can increase farm production and income; however, it also damages the environment and decreases the living quality and future productivity. By practicing the crop rotations or soil conservation, the farm agent can conserve the land productivity for the future use. Namely, quality of farm land depreciates slower with these practices. Thus, current farm income can be sacrificed by future farm income. In other words, while the farm agent makes efforts in protecting the environment, he also reduces the current income although those efforts could increase the future income potential.

In short, we assume a typical farm agent lives infinitely and the farm agent would like to maximize the total value of living quality and income over the rental period of land contract by choosing the optimal level of efforts in protecting the environment. He also considers the residual impacts of pollution at the end of rental contract on the rest of life time. The farm agent is subject to the farm land quality deterioration constraint. Namely, the efforts the farm agent makes in reducing the damage to the environmental quality can slow down the depreciation process of farm land and improve both the current living quality and the future income capacity as well as decrease the current income level. Meanwhile, the future production level and living quality are also considered. This problem is then formulated as a continuous-time dynamic optimization problem. The state variables are $K(t)$ and $Y(t)$. The control variable is $X(t)$. By choosing the optimal level of efforts, $X(t)$, the farm agent will maximize the sum of the total value of living quality and income over the period of rental contract plus the value of residual impacts from the left-over pollution from rental contracts. That is,

$$\underset{X(t)}{Max} \int_0^T e^{-\rho t}[\text{value of living quality} + \text{net farm income}]\, dt + R(Y(T)).e^{-\rho T}$$

$$= \int_0^T e^{-\rho t}[h(Y(t),\ \epsilon(t)) + Pf(L(t), Q, K(t), X(t)) - q(J(t)) - c.X(t)]\, dt + R(Y(T)).e^{-\rho T}$$

$$\begin{aligned} s.t. \quad & \dot{K}(t) = g(X(t)) - \delta K(t) \\ & \dot{Y}(t) = m(X(t),\ Z(t)) \\ & K(0) = K_0 \\ & Y(0) = Y_0. \end{aligned}$$

...........(5)

The Hamiltonian is

$$H = e^{-\rho t}[h(Y(t),\ \epsilon(t)) + Pf(L(t), Q, K(t), X(t)) - q(J(t)) - c.X(t)] + \lambda(t)[g(X(t)) - \delta K(t)] + \mu(t)[m(X(t),\ Z(t))].$$

...........(6)

The necessary conditions for optimality are as follows.

Let $\lambda^*(t) = e^{\rho t}\lambda(t)$ and $\mu^*(t) = e^{\rho t}\mu(t)$,

$$\frac{\partial H}{\partial X(t)} = pf_X(t) - c + \lambda^*(t)g_X(t) + \mu^*(t)m_X(t) = 0,$$
$$-\frac{\partial H}{\partial K(t)} = \dot{\lambda}^*(t) = -pf_K(t) + q_K(t) + \lambda^*(t)(\delta + \rho),$$
$$-\frac{\partial H}{\partial Y(t)} = \dot{\mu}^*(t) = -h_Y(t) + \rho\mu^*(t),$$
$$\lambda(T) = 0,$$
$$\mu(T) = R'(Y(T))e^{-\rho T}.$$

Solving the equations of motion, we obtain

$$\lambda(t) = e^{\delta t}\int_0^t e^{-(\delta+\rho)\tau}[-pf_K(\tau) + q_K(\tau)]d\tau + \lambda(0)e^{\delta t},$$

$$\text{where}\lambda(0) = -\int_0^T e^{-(\delta+\rho)\tau}(-pf_k(\tau) + q_k(\tau))d\tau;$$

$$\mu(t) = \int_0^t -e^{-\rho\tau}h_Y(\tau)d\tau + \mu(0),$$

$$\text{where}\mu(0) = R'(Y(T))e^{-\rho T} + \int_0^T e^{-\rho\tau}h_Y(\tau)d\tau.$$

...........(7)

From the above necessary conditions we can obtain the effects of exogenous variables on X(t).

Let $\Delta = pf_{xx}(t) - c_{xx}(t) + \lambda^{*}(t)\,g_{xx}(t) + \mu^{*}(t)\,m_{xx}(t)$,
where $\Delta < 0$ by the second order condition.

$$\frac{dX(t)}{dP} = -\frac{f_x + \lambda_P g_x}{\Delta} > 0, \text{ if } \lambda_P g_x > f_x;$$
$$\leq 0, \text{ if } \lambda_P g_x \leq f_x.$$
$$\frac{dX(t)}{d\delta} = -\frac{\lambda_\delta \cdot g_x}{\Delta} > 0.$$
$$\frac{dX(t)}{d\rho} = -\frac{\lambda_\rho g_x + \mu_\rho m_x}{\Delta} > 0.$$
$$\frac{dX(t)}{dQ} = -\frac{Pf_{xQ} + \lambda_Q g_x}{\Delta} = 0.$$
$$\frac{dX(t)}{dc} = \frac{1}{\Delta} < 0.$$

...........(8)

The results of this analysis suggest that higher output price will increase the conservation efforts when the increase in the future profit is greater than the increase in the present profit. This study also demonstrates that the depreciation rate has a positive effect on the environment-protecting efforts. In other words, the farm agent will make more effort to slow down the deterioration process or even to improve the land quality as the quality of farm land depreciates more rapidly. For instance, farm agents will take more action in protecting those farm land which have serious soil erosion problems.

On the other hand, farm size does not have any significant effects on the efforts, when $f_{XQ} = 0$. Large farms will be more concerned about the land quality when $f_{XQ} > 0$. Higher costs of efforts such as adoption of new technologies could also discourage the environment-protecting effort.

When the length of rental contract approaches infinity, we have the owner cases instead of renter cases. Thus, the land owner's behavior can be viewed as a special case of this model as T goes to infinity. In addition, when the farm agent's view the living quality as being more important than the income, the farm agent will make more effort to protect their environmental quality. Including the consideration for the impact of pollution level on the future living quality leads the farm agent to practice more conservation.

Case II: owners

Suppose the farm agent can resell the farm land at time T. The resale value of the farm land depends on the expected future productivity. Farm land with higher potential future productivity will have a better resale price since future productivity is captured in the farm land's resale price. Thus, unlike the renters, owners consider the resale value which is determined by the future production capacity. This is the only distinction among renters and owners. Thus, the owner's planning time horizon is infinity. That is,

$$\int_0^{\infty} e^{-\rho t}[\textit{value of living quality} + \textit{net farm income}]\, dt$$
$$= \int_0^{T} e^{-\rho t}[h(Y(t),\ \epsilon(t)) + Pf(L(t), Q, K(t), X(t)) - q(J(t)) - c.X(t)]\, dt$$
$$+ R(Y(T)).e^{-\rho T} + V(K(T))\, e^{-\rho T},$$

where V(K(T)) is the resale value of farm assets which is determined by its future production capacity or the land quality. The resale value also depends upon the size of farm, Q, which is fixed in this model and can not be controlled by the farm agent.

When the time of resale for the owner, or equivalent to the length of rental contract in the renter's case, is large, the present value of farm land's resale price is small and is only a small portion of the total value. Thus, owner's behavior will be very similar to the renter's behavior as T goes to infinity.

Part-Time Farming

In this section, the previous model is modified slightly by considering off-farm income opportunities. Namely, the problem of time allocation between off-farm and farm work is relevant. Thus, there are two control variables: X(t) and L(t). L(t) is the amount of time spent in the farm production. N is the total amount of time available or the number of labor force for the farm agent. N is fixed. No growth is considered. This assumption can be relaxed by incorporating the fertility decision in the model. The effects of off-farm income or off-farm wage rates can then be obtained.

$$\max_{X(t),L(t)} \int_0^{\infty} e^{-\rho t}[\text{value of living quality + off-farm income + net farm income}]\, dt$$

$$= \int_0^{\infty} e^{-\rho t}[h(Y(t),\ \epsilon(t)) + u(N-L(t), X(t)) + Pf(L(t), Q, K(t), X(t)) - q(J(t)) - c.X(t)]\, dt$$

The Hamiltonian is

$$H = e^{-\rho t}[h(Y(t), \epsilon(t)) + u(N-L(t), X(t), w) + Pf(L(t), Q, K(t), X(t)) - q(J(t)) - c.X(t)] + \lambda(t)[g(X(t)) - \delta K(t)] + \mu(t)[m(X(t), Z(t)].$$

The necessary conditions for optimality are as follows.

$$\frac{\partial H}{\partial L(t)} = -u_L(t) + Pf_L(t) - q_L(t) = 0,$$
$$\frac{\partial H}{\partial X(t)} = u_X(t) + pf_X(t) - c + \lambda^*(t)g_X(t) + \mu^*(t)m_X(t) = 0,$$
$$-\frac{\partial H}{\partial K(t)} = \dot{\lambda}^*(t) = -pf_K(t) + q_K(t) + \lambda^*(t)(\delta+\rho),$$
$$-\frac{\partial H}{\partial Y(t)} = \dot{\mu}^*(t) = -h_Y(t) + \rho\mu^*(t).$$

Generally, full-time farm agents are more concerned about the productivity of farm land, however there may not be much difference in how these two parties value their living quality. When the concerns about the future productivity outweigh the concerns about the living quality, full-time farm agents may make more effort than part-time farm agents in protecting their environment. Otherwise, the effect is ambiguous. When the uncertainties about yield or price are considered, part-time farm agents might have higher X(t). Namely, if part-time farm agents are better off in financial situations due to the stable source of off-farm income, they may be more willing to reduce their farm income by participating in soil conservation or crop rotations or by purchasing the equipments to reduce soil erosion and water pollution. However, it may not be true if the value of living quality is also included. Thus, we would not expect much difference in behavior between full-time and part-time farmers when the living quality is the main concern. Whether full-time or part-time agents are better in protecting the environment is unclear based on this analysis. Additional analysis is needed to provide a more comprehensive assessments of the potential impact of off-farm work on the environmental quality.

Conclusions and Future Research

This analysis shows that output prices and the deterioration rate of land quality have positive effects on the farm agent's effort in reducing damage to the living environment and future productive capacity while time-preference rate and cost per unit of effort have negative effects. The effect of farm size will depend upon the further assumption about f_{XQ}.

The results also suggest that it is possible that there is no significant differences in the environmental concern when the value of living quality outweighs the net farm income. Rented land does not always lead to an unfavorable consequences for environmental quality. This is in part because its effects on the agricultural production capacity is potentially far less than those on the pollution caused by agricultural production.

The model can be extended to incorporate the growth of labor and capital in future research. Namely, the decision of fertility in the farm family can be included. In addition, uncertainties about yield or price have not been considered in this paper. With the consideration of uncertainties, the problem can be formulated as a stochastic control problem. In order to implement these models into an empirical study, length of contract and the measurement of pollution levels will be the crucial information.

Reference

Heckman, James J. "A Life -Cycle Model of Earnings, Learning, and Consumption." Journal of Political Economy, (1976):S11-S41.

Lee, Linda K. "The Impact of Landownership Factors on Soil Conservation." Amer. J. Agr. Econ. 62(1980): 1070-76.

McConnell, Kenneth E. "An Economic Model of Soil Conservation." Amer. J. Agr. Econ. (1983): 83-89.

Wade, James C., and Earl O. Heady, "Measurement of Sediment Control Impacts on Agriculture." Water Resource Research, 14(1978): 1-8.