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THE PRODUCER PERSPECTIVE ON TECHNICAL CHOICE IN AGRICULTURE

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THE PRODUCER PERSPECTIVE ON TECHNICAL CHOICE IN AGRICULTURE

Modern agricultural production methods have been acclaimed for the bounty they have produced but are criticized increasingly in the relatively wealthy nations in which they are used extensively. These criticisms arise from concerns for the impacts of these methods on food safety, environmental quality, farm worker occupational safety, long-term agricultural productivity, and for some the structure of agriculture. At least some of these concerns are well-founded. Modern agricultural practices are a major cause of surface water pollution in many countries and are being increasingly identified as an important source of groundwater contaminants (Hallberg; Young). Evidence is also increasing on health hazards for farm residents, farm workers, and consumers (Madden). Policy responses designed to influence technical choices include cross-compliance provisions and the Low-Input/Sustainable Agriculture (LISA) Program arising from the 1985 Food Security Act, and the Federal Insecticide Fungicide, and Rodenticide Act.

Conventional analysis of the choice of production methods by agricultural firms assumes that they are primarily adopters rather than innovators. The set of technical alternatives is therefore largely exogenous. It also assumes that agricultural firms are competitive price takers who seek to maximize profit. Changes in technique by individual firm's are explained by changes in the relative profitability of the available alternatives due to changes in prices or price expectations, tax structure, the regulatory environment, or by changes in the available technology. Change in the techniques available to firms is explained primarily by public and private research and development expenditures. The dominant explanation of the factor bias of new technology is the induced innovation hypothesis.

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Profit maximization and induced innovation have been used successfully to explain the directions of input use in agriculture (Capalbo and Vo; Daberkow and Reichelderfer; Thirtle and Ruttan). The anti-environment bias of the modern agriculture methods is explained in this context by the absence of price or regulatory incentives reflecting the cost of agricultural externalities, the existence of price incentives and policy distortions that lead to using environmentally harmful inputs more intensively, and unintentional distortions in public and private research towards environmentally harmful methods (Archibald; Madden; Reichelderfer and Phipps; Runge).

Although we accept the basic outline of this characterization of agriculture, current issues related to agricultural production technologies suggest a broader perspective than the neoclassical profit maximizing firm when analyzing policies to ameliorate environmental and other negative impacts. Increasing concern for perceptions of chemical intensive techniques of the health of farm populations and imperfect substitution between farm family and hired labor and management suggest that farm profits may not separable from other arguments in preference functions. If this is so for a significant component of the farm population, the nprofit maximization may no longer be an appropriate objective function to understand agricultural production choices and the potential benefits from shifts chemical-saving techniques. Rather, a utility maximization model is necessary to understand tradeoff between consumption (profits) and health and leisure. In addition, product quality and farm worker health issues likely would impact farmers through the output and labor markets, respectively.

This paper presents a preliminary utility theoretic model of a farm household to examine the producers perspective on technical choice in the current policy context. The model abstracts from risk and dynamics in order to obtain tractable implications.

Farm Household Model

A farm household model seems essential to understand modern producer evaluation of technology and the potential responses of the agricultural production sector to policy constraints on technical choice. Inasmuch as family labor and management may be substituted only imperfectly for hired labor and management, the specialized knowledge of the farm household and income-leisure tradeoffs must be accommodated. Furthermore, farm populations share in the increasing societal interest in food and occupational safety and environmental quality. Thus, preferences relevant to the impact of their production methods on household members and society in general should be considered in modeling. Increasing interest of farmers in organic and other alternative farm methods support this view.

This paper presents a model of an owner/operator household producing a single commodity (q). The household's preferences are defined over arguments relating to the safety of household members, leisure, and income. The existence of farmer preferences defined over product attributes (eg., food with chemical residues vs. organically grown products), the safety of farm workers, off-site environmental impacts, and on-site aesthetics (eg., weed free fields vs. weedy fields) should be recognized and would be of interest to model. However, in the interest of brevity this model focuses on preferences that are reasonably assumed to be significant considerations in the decision making of most modern, well-informed farm households. Many of the variables in the model, such as output, realistically would be vectors. Again for brevity, the model uses scaler representations of these vectors.

The household utility function is written

$$U = U(y, l, r) \tag{1}$$

where y is household income, l is leisure, and r is household exposure to harmful production residuals. U is assumed to be continuous and quasi-concave. The marginal utility of income (U_y) and leisure (U_l) are positive but the marginal utility of on-farm residuals (U_r) is negative.

One approach (eg. Archibald) to modeling production with environmental effects is to assume an implicit production function in inputs, outputs, and residuals. However, Mittlehammer, Matulich, and Bushaw note some significant fundamental restrictions of this method including all ratios of partial derivatives being non-zero and the impossibility of allocating some inputs to only one output. In addition, no input can simultaneously reduce residuals and increase production. To avoid these limitations, this model uses separate response functions similar to Griffin and Bromley and Shortle and Dunn.

The farm household produces q using hired labor (n_q), household labor/management (m_q), chemical jnputs (c), land (k), and "other" inputs (x)? In addition, the farm employs abatement or averting inputs to reduce on-farm exposure to production residuals (eg., domestic wellwater treatment, use of protective clothing when applying pesticides) and to reduce the concentration of harmful chemical residues in output (z) (eg., washing pesticides from products). Averting inputs used primarily to reduce on-farm exposure are represented by t_r while those used primarily to reduce chemical residual concentrations in output are represented by t_z. Since the use of some averting inputs may reduce output, the production function is assumed to include these as arguments and is written

$$q = f(n_q, m_q, c, x, k, t_z, t_r). \tag{2}$$

Positive but diminishing marginal products are assumed for hired (f_n) and family labor (f_m), chemicals (f_c), "other" inputs (f_x), and land (f_k) but the marginal products of the treatment inputs (f_{t_z}, f_{t_r}) are negative.

The concentration of chemical residues in the farm product is taken to be a function of the amount of chemicals used in production, the level of production, averting inputs, and hired (n_z) and family (m_z) labor used in "z" averting activities. The chemical residue function is written

$$z = g(n_z, m_z, c, q, t_z). \tag{3}$$

We assume a positive marginal effect of chemicals ($g_c > 0$)but negative marginal effects for all other variables in this function (g_n, g_m, g_q, $g_t < 0$).

On-farm production residuals are taken to be a function of chemical use, the amount of land in production, averting inputs, and hired (n_r) and family (m_r) labor used in "r" averting activities. The on-farm residuals loading function is written

$$r = h(n_r, m_r, c, k, t_r). \tag{4}$$

We assume a positive marginal effect of chemicals ($h_c > 0$) in this function and negative marginal effects for all other variables (h_n, h_m, h_k, $h_t < 0$).

The basic idea behind (3) and (4) is that production decisions determine harmful residuals flows that are diminished by the use of additional inputs. The specifications are extremely simplistic characterizations of highly complex processes. For example, the separation of labor into different functions may be plausible for some activities, but is clearly not for all. Similarly, production arguments in addition to chemicals and land will affect residual levels.

Farm income (y) is given by farm revenue less production related expenditures plus income from off-farm employment (m_o) and net land rents. Accordingly, we have

$$y = w_k(\bar{k} - k) + w_o m_o + p(z)q - w_c c - w_x x - w_n(r)(n_q + n_z + n_r)$$
$$- w_z t_z - w_r t_r \tag{5}$$

where w_k is the land rental rate, $\bar{k}$ is the household land endowment, w_o is the wage rate the farm household can earn for off-farm employment, p(z) is the price of output with a concentration of harmful chemicals of z, w_c, w_x, w_{t_z} and w_{t_r} are, respectively, the prices for chemicals, "other" inputs, product residue, treatment inputs, on-farm residuals treatment inputs, and $w_n(r)$ is the wage rate for hired farm labor given the value of r. We assume $p'(z) \leq 0$, allowing for the possibility of market incentives for products with lower chemical concentrations due to consumer preferences (eg., premiums for organic produce) and/or government policy (eg., restrictions on use and, therefore, the markets of chemical laden output). Similarly, we assume $w_n'(r) \geq 0$, allowing for the possibility that rational farm workers may demand higher compensation for work on farms with greater health hazards.

The household optimization problem is to choose n_q, n_z, n_r, m_q, m_z, m_r, m_o, c, k, t_z, and t_r to maximize (1) subject to (2), (3), (4), (5), and a time constraint

$$m_o + m_q + m_z + m_r + l = T \tag{6}$$

where T is family time. The first-order conditions for primal variables (assuming an interior solution) are:

$$L_y = U_y - \lambda_y = 0, \tag{7.1}$$

$$L_l = U_l - \lambda_t = 0, \tag{7.2}$$

$$L_r = U_r - \lambda_y w_n'(r)n + \lambda_r = 0, \tag{7.3}$$

$$L_q = \lambda_y p(z) - \lambda_z g_q - \lambda_q = 0, \tag{7.4}$$

$$L_z = \lambda_y p'(z)q + \lambda_z = 0, \tag{7.5}$$

$$L_{m_o} = \lambda_y w_o - \lambda_t = 0, \tag{7.6}$$

$$L_{m_q} = \lambda_q f_m - \lambda_t = 0, \tag{7.7}$$

$$L_{m_r} = -\lambda_r h_m - \lambda_t = 0, \quad (7.8)$$

$$L_{m_z} = -\lambda_z g_m - \lambda_t = 0, \quad (7.9)$$

$$L_{n_q} = \lambda_q f_n - \lambda_y w_n(r) = 0, \quad (7.10)$$

$$L_{n_r} = -\lambda_r h_n - \lambda_y w_n(r) = 0, \quad (7.11)$$

$$L_{n_z} = -\lambda_z g_n - \lambda_y w_n(r) = 0, \quad (7.12)$$

$$L_k = \lambda_q f_k - \lambda_r h_k - \lambda_y w_k = 0, \quad (7.13)$$

$$L_x = \lambda_q f_x - \lambda_y w_x = 0, \quad (7.14)$$

$$L_{t_z} = \lambda_q f_{t_z} - \lambda_z g_t - \lambda_y w_{t_z}, \quad (7.15)$$

$$L_{t_z} = \lambda_q f_{t_r} - \lambda_r h_t - \lambda_y w_{t_r} = 0, \text{ and} \quad (7.16)$$

$$L_c = \lambda_q f_c - \lambda_z g_c - \lambda_r h_c - \lambda_y w_c = 0 \quad (7.17)$$

where L is the value of the Lagrange function; λ_q, λ_r, λ_z, λ_y, and λ_t are, respectively, the multipliers associated with the constraints defined by (2), (3), (4), (5), and (6); and $n = n_q + n_z + n_r$.

Conditions (7.1) and (7.2) imply that λ_y is the marginal utility of income (U_y) and λ_t is the marginal utility of leisure (U_l). Condition (7.3) implies that λ_r, the marginal cost of on-farm residuals, is the forgone family utility due to chemical exposure (U_r) plus the utility of decreased income due to increased hired labor costs ($\lambda_y w_n'(r)n = U_y w_n'(r)n$). Condition (7.5) implies that λ_z, the marginal cost of product residues, is the utility of income forgone at the margin due to a reduced product price ($\lambda_y p'(z)q = U_y p'(z)q$). Accordingly, condition (7.4) implies that λ_q, the marginal benefit of output, is the increase in the utility of income at the margin due to product revenues ($\lambda_y p(z) = U_y p(z)$) and the price gain from reducing the concentration of chemicals in the product ($-\lambda_z g_q = -U_y p'(z)qg_q$).

Using (7.1) - (7.5) we can rewrite optimality conditions (7.6) - (7.17) respectively as:

Off-farm Labor;

$$\frac{U_l}{U_y} = w_o \qquad (7.6)'$$

Family Production Labor;

$$\frac{U_l}{U_y} = [p(z) + p'(z)qg_q]f_m \qquad (7.7)'$$

Family "r" Averting Labor;

$$\frac{U_l}{U_y} = [\frac{U_r}{U_y} - w_n'(r)n]h_m \tag{7.8)'$$

Family "z" Averting Labor;

$$\frac{U_l}{U_y} = p'(z)qg_m \tag{7.9)'$$

Hired Production Labor;

$$[p(z) + p'(z)qg_q]f_n = w_n(r) \tag{7.10)'$$

Hired "r" Averting Labor;

$$[\frac{U_r}{U_y} - w_n'(r)n]h_n = w_n(r) \tag{7.11)'$$

Hired "z" Averting Labor;

$$p'(z)qg_n = w_n(r) \tag{7.12)'$$

Land Use;

$$[p(z) + p'(z)qg_q]f_k + [\frac{U_r}{U_y} - w_n'(r)n]h_k = w_k \tag{7.13)'$$

"Other" Inputs;

$$[p(z) + p'(z)qg_q]f_x = w_x \tag{7.14)'}$$

"z" Averting Inputs;

$$[p(z) + p'(z)qg_q]f_{t_z} + p'(z)qg_t = w_{t_z} \tag{7.15)'}$$

"r" Averting Inputs;

$$[p(z) + p'(z)qg_q]f_{t_r} + [\frac{U_r}{U_y} - w_n'(r)n]h_{t_r} = w_{t_r} \tag{7.16)'}$$

Chemical Use;

$$[p(z) + p'(z)qg_q]f_c + p'(z)qg_c + [\frac{U_r}{U_y} - w_n'(r)n]h_c = w_c \tag{7.17)'}$$

Conditions (7.6)′ - (7.9)′ indicate the optimal allocation of farm labor between on and off farm uses. In each case the rate of substitution between income and leisure (U_l/U_y) is equal to the marginal return from the labor use activity. The marginal return from off-farm labor ((7.6)′) is the usual off farm wage rate but new results emerge for the other activities. The marginal return from family farm production labor ((7.7)′) includes the usual value of the marginal product ($p(z)f_m$) plus the gain in revenues at the margin due to the effect on product quality and price of greater output ($p'(z)qg_qf_m$). The marginal return from chemical residue (z) averting labor ((7.8)′) is the gain in revenues at the margin due to the effect on product quality ($p'(z)qg_m$). The marginal return to on-farm residuals averting labor ((7.9)′) combines the effect of willingness to exchange income for health ($(U_r/U_y)h_m$) with revenue effect from wage rate reduction effect for hired labor ($-w_n'(r)nh_m$).

The optimality conditions for the purchased production inputs that do not enter g(.) or h(.) ((7.10)′ and (7.14)′ involve an equality of the marginal return from the use of the input with the factor price. The marginal return in each case is the value of the marginal product of the input plus the indirect effect of input use on product price from the effect of output on product quality. Hence, even though these inputs do not effect z directly there is an indirect incentive to use them to improve product quality.

The optimal chemical use condition (7.18)′ is the most complex. The marginal benefit of chemical use is the value of the marginal product ($p(z)f_c$) plus the indirect effects of the input on product price via the effect of output on product quality ($p'(z)qf_c$). This benefit must be balanced against the factor cost (w_c) plus the negative impact on the wage rate ($w_n'(r)nh_c$), the direct negative impact on product quality and price ($p'(z)qg_c$), and the negative impact on household exposure to chemicals ($(U_r/U_y)h_c$).

The marginal benefit of land use is the value of the marginal product of land ($p(z)f_k$) plus the indirect effect of land on revenue from product price improvements due to increased output ($p'(z)qg_q f_k$), and the indirect effects of land use on the wage rate ($-w_n'(r)nh_k$) and household welfare ($(U_r/U_y)h_k$) that come with spreading chemicals over more land (see 7.13)′). Optimal land use requires balancing these benefits against the rental rate of land. The farm household will rent land in or out depending upon the level of optimal use relative to its endowment.

Finally the optimal use of averting inputs ((7.15)′, (7.16)′), and hired labor used for averting activities ((7.10)′, (7.12)′), involves balancing the gains from increasing the product price, reducing the wage rate, and improving household safety against their costs. The latter includes forgone revenues due to reduced output and, indirectly, product quality in the case of the averting inputs t_r and t_z.

To contrast these conditions with more conventional models, consider the implications of assuming an objective of net income maximization with and without the price and wage effects of harmful chemical use. With price and wage effects, the family labor use conditions would be modified by substituting the off-farm wage for the rate of substitution between income and leisure in (7.7)′ - (7.9)′. Family labor would be fully employed in on-and-off-farm work with no leisure. In addition, the rate of substitution between income and on-farm residuals (U_r/U_y) would be removed from (7.8)′, (7.11)′, (7.13)′, (7.16)′, and (7.17)′. This change would imply a reduced incentive to use averting labor and other averting inputs and a reduction in the disincentives for chemical use motivated by family health considerations, other things being equal.

If the assumption of price and wage effects of harmful chemical use are also dropped, all conditions relating to averting inputs are removed. Furthermore, incentives related to the effect of production inputs on product quality and on farm residuals would be removed from the optimality conditions for the use of the inputs. These incentives were positive for all but harmful chemicals in this model.

Summary and Conclusions

The above analysis is limited in several ways. When considered as an analytical framework within which to evaluate the cost and benefits to farm households of policies to influence technical choice, uncertainty associated with policy and new technology would be important to consider. Adjustment costs associated with shifts in fixed and quasi fixed reosurces and learning would also be important.

These issues aside, that the model presented here does implies a much richer decision environment and considerable disincentives for chemical use relative to models assuming net income maximization and no price and wage effects of harmful chemical use. The model, therefore, suggests an underlying social bias for chemical-saving technical change even without adding in environmental externalities. The relevance of this environment depends primarily on the degree to which farmers perceive and react to health risks from chemical use and the extent to which product and labor markets evolve to reflect consumer and labor concerns for food and occupational safety in price and wage structures.

Evolution of household preferences, product markets, and labor markets to a state corresponding to the one this model assumes would lead to reduced use of chemicals harmful to farmers and consumers and producer benefits for production methods that are less intensive in these inputs. Given that health is a normal good, growth in farm owner, worker, and consumer incomes would provide added incentives to reduce chemical use. However, it does not follow that public intervention to influence producers choices of technology would be unwarranted. If off-site external costs due to ground and surface water quality damages remain, then the possibility of economic gains from government programs to influence decisions about production methods insofar as they relate to these damages will also remain.

This model could be agumented to provide a starting point for examining the impacts of alternative policy approaches for regulating offsite damages and food and occupational safety on farmers' choice of production methods, farm family well-being, and incentives for induced innovation both through market price effects and rent seeking in the allocation of research funding. It seems reasonable to expect that a model of this form to yield substantially different policy responses than a model assuming profit maximization with the same technology and owned resource endowments.

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