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FARMER BEHAVIOR UNDER RISK OF FAILURE

by

William E. Foster
and
Gordon C. Rausser

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William E. Taster and Gordon C. Pasour

This article addresses input decisions under risk of farm failure. Without risk of failure, the farmer would first maximize his expected utility as if he relied only on farm revenue (including concurrent off-farm employment, if applicable), and then compare this level of farm-derived utility with the utility available elsewhere (less moving expenses, etc.). If the farm-derived expected utility exceeds non-farm utility the farmer remains a farmer. With risk of failure, however, if the farmer chooses to continue another season, the ensuing revenues may be so low as to preclude future decisions to stay in agriculture (i.e., failure). The critical level of revenue below which the farm fails may be a function of household-maintenance expenditures, farm debt, and so forth. This level is likely to rise with farm size, but at a decreasing rate. Therefore, smaller scale, commercial farms are more likely to be at risk than larger farms.

The discrete difference between on-farm and off-farm returns leads to asset fixity. (For example, see G. Johnson and Quance, M. Johnson and Pasour). A farmer's human capital fixity in particular presents important complications to conventional economic analysis of agricultural supply, which relies on strict maximization of expected utility (or of expected profit) derived solely from farm production. If the difference between on-farm and off-farm utility is large, the farmer will take actions to avoid leaving agriculture; these actions may lead to seemingly inefficient farm management decisions. Robison, Barry, and Burghardt, for example, explore the use of credit as a means of forestalling costs associated with liquidating fixed assets to meet cash flow obligations. Their model implies that a farmer has a greater incentive to acquire debt as bankruptcy grows more likely, consistent with the "go-for-broke" behavior seen in highly-stressed borrowers.

Also important is the influence of the risk of failure on farm input decisions. The purpose of this paper is to draw out the implications of failure risk both on farm production decisions, specifically on the differing incentives to use cash-draining inputs in
contrast to those inputs that do not require immediate cash outflow. The second section presents a model of input use where there is a difference between on-farm and off-farm returns to a farmer's human capital, and shows that under failure risk the use of non-cash-draining inputs may increase with a decrease in output price. The third section presents a specific partial equilibrium model to illustrate the concepts developed in the second, and to demonstrate the possible effects of failure risk on equilibrium output price. The fourth section turns to the practical application of the ideas developed in this study and to the role commodity programs play in reducing the effect of costly farm failure. The empirical analysis is of corn production in Illinois using the model of how the threat of failure affects input choices. The study focuses on the affects of farm size and other structural variables on farmer divergence from strict profit maximization.

Farmer Behavior under Risk of Forced Adjustment

Two major sources have been hypothesized regarding the fixity of physical assets. The first involves the lumpy nature of the production process. Galbraith and Black, for example, hypothesize that large fixed costs associated with reorganizing the farm operation make short run adjustment unprofitable. Changes in the economic environment would induce changes in productive capacity only if they were of sufficiently high magnitude and of sufficiently long duration. The second source of fixity involves the difference between the on-farm value of assets and their alternative, off-farm value (G. Johnson and Quance). Low salvage value may reflect transportation costs, specificity of capital to the farm operation, and limited, asymmetric information regarding quality of the item (Akerlof). Whatever the cause of low salvage values, once acquired productive capacity changes only with discrete (perhaps large) changes in the on-farm-use value.

A farmer's human capital is subject to a similar fixity. Although a farmer's labor may be divisible between on-farm and off-farm employment, his human capital
specific to farm management is lumpy. Or from another perspective, one may view the "salvage" value of human capital (the opportunity cost of being a farm manager) as less than the on-farm value (the opportunity cost of not being a farm manager). The discrepancy between a farmer’s salvage value and his on-farm value may reflect the specificity of the capital and/or the personal, or psychic, premium on earning an income from owning and operating a farm.\(^1\) In dollars (accounting for moving costs, etc.), a farmer may seem to have a high salvage value, but in utility, derived from these non-farm dollars, the salvage value is low.

A notable distinction between a farmer’s human capital and other factors that may be subject to fixity is that certain minimal expenditures are necessary in order to stay in farming. The farm family must eat, clothe itself, and otherwise live happily alongside its neighbors. In addition, the decision to farm may incur other fixed commitments: minimal debt service, minimal use of certain publicly-provided goods (e.g., water), insurance, and so forth.

The adjustment of a farmer’s human capital out of agriculture is not always an active decision. Forced adjustment occurs when farm production does not cover the minimal, necessary costs. Without this risk of forced adjustment, or failure, the farmer would simply compare the expected utility of farming with the utility of leaving farming and make the optimal discrete decision to continue. Instead the risk of failure leads to seemingly inefficient production decisions.

Input response to risk may entail anything from too-quickly depleting soil quality, to placing greater stress on farm labor at the expense of leisure.\(^2\) Inputs that are purchased prior to the production process are under-utilized in the sense that their marginal products are higher than what would be optimal under strict maximization. Those that can be utilized without immediate cash expenditure ("mined" or "borrowed off of"), such as soil quality and farm household labor, are over-utilized. Commodity production may be increased or decreased, relative to the case where there is no
difference between on-farm and off-farm utility, depending on the degree of complementarity of factors.

An Algebraic Model.

A model of a farmer’s behavior under risk of failure is inherently intertemporal. The farmer must trade-off the amount of utility he gets in any year from farming with the probability of failure.\(^3\) Intertemporal models may lead to intractable complications; therefore, the following mathematical model makes certain simplifying assumptions. Specifically, the farm manager faces a discrete difference between on-farm and off-farm returns; random events independent over time; the alternative utility that the farmer receives off the farm, if he fails, is a constant value; and once failed the farmer leaves farm management forever. These assumptions produce the following results. Farm decision rules as functions of prices are constant over time; the expected farm-derived utility in any period is constant; the cost of moving out of agriculture is the difference (also constant) between optimal yearly expected farm-derived utility and off-farm utility. Furthermore, the farmer’s objective function can be written in terms of yearly expected farm-derived utility, off-farm utility, and the probability of failure.

A farmer yearly produces a commodity, the per-acre amount of which is denoted by \(y\), by combining two factors of production: 1) \(x\) are those which must be yearly purchased out of cash revenues prior to realization of actual production and price received, and 2) \(k\) are those which may be utilized in the year but paid for in the indeterminate future. Examples of the factor \(x\) include hired labor, fertilizer, etc. Examples of input \(k\) include land quality, farm household labor, owned machinery, etc. The per-acre production function in a given year is given by

\[
y = y(x, k, \varepsilon)
\]

where \(\varepsilon\) represents some random effect on output \(y\), such as weather. The number of acres produced is given by \(A\), which is a constant. The farmer faces every year an unknown price \(p\), a random variable \((p > 0, E[p] = \mu)\), with some time-invariant probabil-
density function given by \( g(p) \). The constant per-unit cost of the factor \( x \) is given by \( w \), and of factor \( k \) is given by \( i \).

Failure is defined as inability to cover the minimal expenditures in a year necessary to farm, \( f \); that is, failure is defined by

\[
A [py - wx] < f \quad (2)
\]

If the farmer fails, he leaves farming and earns some sure utility level \( I \) each year thereafter. For ease of presentation, we assume that production is certain and price is the only random variable. This particular assumption is relaxed in the next section.

The yearly probability of failure, \( \pi \), is given by \( \pi(x,k) = \int_0^{p_d} g(p) dp \); where \( p_dy - wx = f/A \). The utility from farming in any year is given by

\[
U(p,x,k) = U[A(py - wx - ik)] \quad (3)
\]

and the expected utility from farming is simply

\[
\bar{U}(x,k) = E[U(p,x,k)] \quad (4)
\]

Finally, the constant discount rate for future expected utility (either from farming or not farming) is given by \( \beta \). Define \( \bar{U}_N \) as the expected value of utility from farm income conditional on not failing, \( \bar{U}_F \) as the expected value conditional on failure. That is, \( \bar{U} = (1 - \pi)\bar{U}_N + \pi\bar{U}_F \).

Table 1 presents possible future events that the farmer must consider if he chooses farming. After summing over all possible streams of utilities\(^4\), one may represent the farmer’s objective function as

\[
\tilde{V}(x,k) = \frac{\pi \beta - I + \bar{U}(x,k)}{1 - \beta(1 - \pi(x,k))} \quad (6)
\]

The term \( I \beta/(1-\beta) \) is the expected earnings from agricultural work, after failure. (Note the discount factor on this off-farm income is \( \beta(1-\beta) \), not \( 1/(1-\beta) \), because the farmer starts earning \( I \) the year following failure.) The term \([1 - \beta(1-\pi)]\) represents the
discount rate of future incomes. As the probability of failure increases, the farmer would tend to discount the future more heavily.

A more compact representation of the farmers criterion function is derived by subtracting from \( \bar{V} \) in expression (6) the income stream if the farmer left agriculture before the first year:

\[
V(x,k) = \bar{V}(x,k) - \frac{1}{1-\beta} I = \frac{\bar{U}(x,k) - I}{1 - \beta[1 - \pi(x,k)]} \tag{7}
\]

The value \( V() \) represents the rent, or surplus, from being a farm owner. The numerator, \( \bar{U} - I \), represents the farmers expected surplus in any given year. The value \( I/(1 - \beta) \) is the salvage value of a farmer's human capital. When \( V(x,k) > 0 \), a farmer's human capital is fixed for limited changes in \( \bar{U} \) and \( I \).

Let \( k^* \) and \( x^* \) satisfy the first-order conditions of maximizing the objective function given by expression (7)\(^5\):

\[
\frac{\partial y}{\partial k} = i\frac{E[U']E[U'p]}{1 + \theta} \tag{8a}
\]
\[
\frac{\partial y}{\partial x} = w\frac{E[U']E[U'p]}{1 + \theta} \frac{1 + \theta E[U'p]E[U'p] \rho_d}{1 + \theta} \tag{8b}
\]
\[
\theta = V\beta g(p_d)p_d/[AyE(U'p)] \tag{8c}
\]

Here marginal utility is given by \( U' \). The parameter \( \theta \) measures the influence of human capital fixity (measured by \( V \)) on farm production decisions. Expression (8c) makes explicit that the influence of human capital fixity on production depends on several elements: the discount rate, the probability distribution of price, farm size, and the correlation of marginal utility and price. If fixity has no influence on production decisions, then \( \theta = 0 \), and as \( \theta \) grows production decisions deviate from strict maximization. Compare these first order conditions to that of strict maximization of \( E[U] \):

\[
\frac{\partial y}{\partial k} = i\frac{E[U']E[U'p]}{1 + \theta} \]
\[
\frac{\partial y}{\partial x} = w\frac{E[U']E[U'p]}{1 + \theta} \]

Because \( \theta > 0 \), the farmer appears to over-utilize \( k \) based on conventional marginal conditions. Further, it is reasonable to suppose that the critical price defining failure,
$p_d$, is small relative to expected price. If $p_d$ is such that $E[U'p] > E[U']p_d$, then the farmer appears to under-utilize $x$.

Now suppose the rest of the economy improves relative to the agricultural sector. As the costs of failure ($\bar{U} - I$) grows insignificant, then $\theta \to 0$, and the farmer behaves as if he were maximizing the utility derived solely from farming ($\bar{U}$). We may interpret $g(p_d)$ as a measure of the degree to which a farmer can marginally influence the probability of failure via production decisions. For example, if random price were associated with a familiar bell-shaped probability density function, then farmer input decisions decreasing $p_d$ by a unit at low levels would have less affect on the probability of failure than if $p_d$ were decreased by a unit near the mean price. Suppose the probability distribution of commodity price changes such that $g(p_d) \to 0$ (that is, suppose the bell-shaped density of price shifts rightward with an increase the the mean price), then farm decisions move toward production efficiency. Regardless of potential cost of failure (i.e., $\bar{U} - I$), if there is no influence at the margin, $g(p_d) = 0$, then again the farmer acts as if he were maximizing farm-derived utility. One point to be emphasized from this discussion of expression (8) is that in this model human capital fixity ($V > 0$) is necessary but not sufficient to cause "inefficient" production decisions.

With the general representations of $V(\cdot)$ and $g(\cdot)$ one cannot immediately determine the effect of changing farm size on the optimal choices of factors. Although $p_d$ decreases with an increase in $A$, which decreases $\theta$, $g(p_d)$ may decrease or increase. In addition $V$ increases with an increase in farm size, positively affecting $\theta$. If, however, $p_d$ is small relative to $\mu$, then $g(p_d)$ likely decreases with farm size (as would be the case if $p$ were normally distributed). The effect of decreasing $f$, and thus decreasing the probability of failure, would bring $k^*$ and $x^*$ into line with productive efficiency.

To be more specific, suppose the farmer is risk neutral; that is, $E(U') = E(U'p) = 1/\mu$. The first order conditions may then be written as

$$\frac{\partial y}{\partial k} = \frac{I}{\mu(1 + \theta)}$$

(9a)
As noted above, relative to \( \theta = 0 \), the marginal product of \( k \) is set lower and the marginal product of \( x \) is set higher. (This is true given \( p_d < \mu \).) What happens to the actual levels of \( k \) and \( x \) depends on the degree of substitutability. For example, suppose \( k \) and \( x \) represent single factors. Let the parameter \( \theta \) begin from a point where fixity has no influence on production, either because the cost of failure is zero \( (V = 0) \), or because the farmer has no influence at the margin over the probability of failure \( (g(p_d) = 0) \). The following comparative statics show the effect on factor decisions due to an increase in \( \theta \), indicating an increase in the influence of fixity. Differentiating (9a) and (9b) with respect to \( k \), \( x \), and \( \theta \) yields:

\[
\frac{\partial y}{\partial x} = w (1 + \theta \frac{\mu}{P_d}) (1 + \theta)
\]

(9b)

\[
\theta = V \beta g(p_d) p_d / (A \mu y)
\]

(9c)

where \( \Delta > 0 \) is the determinant of the matrix of second partial derivatives of \( y \) with respect to \( x \) and \( k \), which is assumed negative definite. Not surprisingly these effects are of ambiguous sign. However, if the two inputs are substitutes (i.e., \( \gamma_{ik} \)), then the effect of increasing the measure of fixity, \( V \), or of increasing at the margin the farmer's influence on the probability of failure, \( g(p_d) \), is to decrease the use of cash-draining inputs and increase the use of those inputs which are not cash draining: \( \frac{\partial k}{\partial \theta} > 0 \) and \( \frac{\partial x}{\partial \theta} < 0 \). This will hold for some \( x \) and \( k \) where the inputs are complements; that is, where \( \gamma_{ik} \) is positive but sufficiently close to zero. The derivative of total product with respect to \( \theta \) represents the effect on supply of increasing the importance of immediate cash revenues. Increasing the deviation of optimal input decisions from strict profit maximization may either increase or decrease supply, again depending on the degree of substitutability of inputs:

\[
\frac{\partial y}{\partial \theta} = \gamma_k \frac{\partial k}{\partial \theta} + \gamma_x \frac{\partial x}{\partial \theta}
\]
Note that for \( \theta = 0 \), one can solve the above comparative static results to find that the sufficient condition for output to increase is given by \( y_{x1} < \frac{w}{I} y_{x1} \).

The marginal conditions in (9a), (9b), and (9c) can be viewed more generally by writing the first-order conditions, given by expressions (9), as

\[
\frac{\partial y}{\partial x} = \rho_1 \frac{w}{\mu}, \tag{10a}
\]
\[
\frac{\partial y}{\partial k} = \rho_2 \frac{i}{\mu}, \tag{10b}
\]

where the \( \rho \)'s reflect a general systematic rule of behavior, with strict profit-maximization as a special case (\( \rho_i = 1 \)). From expressions (9), the \( \rho \)'s are related through their mutual dependence on \( \theta, \mu, \) and \( p_d \): \( \rho_1 = \rho_2 (1 + \mu p_d). \) These \( \rho \)'s are termed adjustment factors. For practical purposes, we take the \( \rho \)'s as functions of certain observable variables, which are not simultaneously also choice variables. For example, in the empirical section that follows, it is through government programs' influence on these adjustment factors that one determines the effectiveness of programs at reducing the effect of risk of farm failure.

A Special Case: An Over-Production Trap

This section considers a specific model of a producer's behavior under risk of forced adjustment. This example is presented in two parts. In the first, the producer avoids risk by expending greater effort in producing a cash income in order to increase the likelihood of covering the minimal necessary expenditures to retain farm ownership. The purpose here is to show the possibility of a backward-bending supply curve, the discrete jumps in supply that may occur at various level of expected price, and the conditions under which a reduction in price variance reduces supply and improves productive efficiency.

The second part of this example considers market equilibrium. A stable, long-run equilibrium is defined where the probability of forced adjustment is zero, and where expectations are rational. This example shows that rational-expectations equilibria can
arise where the producer is permanently taking the risk of failure into account when making production decisions (i.e., producing "inefficiently"), but the observed probability of failure is zero.

We will term the producer behavior where output expands in response to falling output price survival mode, and the equilibrium where supply is backward bending, with a zero probability of failure, a survival mode equilibrium. If an outside observer finds a small probability of forced adjustment or failure, this does not necessarily imply the farmer is out of survival mode and making decisions based on maximizing farm-income-derived utility. Causality may flow the other way. This example demonstrates a case zero probability of failure exists, the farmer is rationally producing "inefficiently" (i.e., contrary to strict profit maximization), and supply increases with a fall in expected price. The important point is that the probability of failure is low (in this case, zero) because the farmer produces in this (strictly defined) inefficient manner.

Furthermore, if a survival-mode equilibrium exists with an inelastic demand curve, then another rational-expectations equilibrium with productive efficiency also exists. This two equilibria condition illustrates an over-production trap. That is, due to over-production, market conditions are such that over-production is optimal for individual farmers. Moreover, if in concert farmers reduced production to that of a conventional equilibrium, no individual would have incentive to expand. With an elastic demand curve a survival-mode equilibrium may exist, but this cannot strictly be called a trap, because only a single rational-expectations equilibrium exists.

Suppose there is one competitive farmer in the market producing some level of commodity, $y$, out of effort, $e$, and receiving some level of price, $p$. Production is random, and, therefore, so is price. Although price depends on quantity, the farmer acts as if he had no influence over its probability distribution function. Let the utility function from farming be the sum of the goods consumed out of farm revenues, $py$, 

over some minimal expenditure $f$, and leisure time: $U = (py - f) + (1 - e)$. Note that this utility function implies a constant marginal utility of income, and exhibits Arrow-Pratt risk neutrality. Random production is given by $y = 2e^{1/2}e$; where $e$ is a random term taking on two values (associated say with bad and good weather), $e = \epsilon_1$ or $e = \epsilon_2$ $(\epsilon_1 < \epsilon_2)$, with equal probability. Let $\bar{y}$ represent the expected or average yield, that is, $\bar{y} = 2e^{1/2}$. The demand curve is of constant elasticity $p = ay^{-b}$. Therefore random revenues can be written as

$$py = a(2e^{1/2}e)^{1-b}$$

(11)

This problem with output and price random can be reduced to a simpler conceptual problem with only one source of randomness. It is conceptually easier to redefine price as having an expected value of $\mu = ay^{-b}$ with multiplicative error of $u = \epsilon^{1-b}$, where without loss of generality $E[u] = 1$. Now the new random term $u$ can take on two values associated with the two values of $\epsilon$: $u = u_1$ or $u = u_2$ $(u_1 < u_2)$. The competitive farmer acts as if he cannot influence expected price; the farmer views revenues as $py = \mu u 2e^{1/2}$. The failure condition is where $py < f$, or where $e < (f/2\mu u)^2$.

To summarize, the farmer's objective function is given by

$$V = \frac{\bar{U}(e) - I}{1 - \beta(1 - \pi)}$$

(12)

where $\bar{U}(e)$ is the expected farm-derived utility, $I$ the alternative utility of leaving farming, $\beta$ the personal discount rate, and $\pi$ the probability of failure. The probability of failure may take on three values depending on the chosen level of output. If the farmer expends so little effort that even at the highest possible price cash receipts do not cover minimal expenses, then the probability of failure is one. If on the other hand the farmer expends enough effort that even at the lowest possible price receipts cover minimal expenses, then the probability of failure is zero. For levels of effort in a middle range, either the farmer fails or he does not, depending on the outcome of price. The probability of failure is the probability of the low price being realized, which in this example is 50%.
An important aspect of this model to note is that, except at the boundaries of these regions, expending incrementally any more or less effort will not affect the farmers probability of failure; it will only increase or decrease his benefits from farming.

One may set, without loss of generality, the non-farm utility level to zero, \( I = 0 \).

Consistent with the condition cited above, the objective function may then be represented in one of three ways, depending on whether the farmer's effort makes the probability of failure one, one-half, or zero:

\[
\begin{align*}
V &= \mu_2 e^{1/2} + (1 - e) - f \\
&= \mu_2 e^{1/2} + (1 - e) - f \quad \text{if } \pi = 1, \text{ or } e^{1/2} < \frac{f}{2u_{1}} ; \quad \text{(13a)} \\
V &= \frac{\mu_2 e^{1/2} + (1 - e) - f}{1 - 0.5} \\
&= \frac{\mu_2 e^{1/2} + (1 - e) - f}{1 - 0.5} \quad \text{if } \pi = 0.5, \text{ or } \frac{f}{2u_{1}} \leq e^{1/2} ; \quad \text{(13b)} \\
V &= \frac{\mu_2 e^{1/2} + (1 - e) - f}{1 - \beta} \\
&= \frac{\mu_2 e^{1/2} + (1 - e) - f}{1 - \beta} \quad \text{if } \pi = 0, \text{ or } \frac{f}{2u_{1}} \leq e^{1/2} ; \quad \text{(13c)}
\end{align*}
\]

Figure 1 shows one possible set of values of the function \( V \). The concave lines show the values of the objective function for given levels of \( \pi \). That is, the lowest curve represents expression (13a) over all values of effort, the middle curve represents expression (13b), and the highest curve represents expression (13c). The heavily-drawn lines show the objective function taking \( \pi \) into account for a specific pair of price outcomes; these lines represent the set of possible choices of effort open to the farmer. For the case shown in the figure, optimal effort is where

\[
e^* = \left[ \frac{f}{2u_{1}} \right]^{2} ;
\]

that is, optimal effort is chosen such that the probability of failure is zero. This illustrates the danger of taking observed probabilities of failure as exogenous to the farmer's supply decisions. Here there is no chance of failure, but the level of effort chosen is away from the point of "efficiency," \( e = \mu^{2} \), which would be optimal if risk of failure were irrelevant to decisions.

Optimal effort is conditional on regions in which expected price may fall. Optimal supply over expected price is graphically illustrated in figure 2. The farmer may not choose to be on a portion of the supply curve where \( \pi = \frac{1}{2} \), instead either
choosing a supply where $\pi = 0$, or where $\pi = 1$. The downward sloping portions of the supply curve are the regions of expected price where the farmer is in survival mode. The effect of eliminating price variability, abstracting from equilibrium effects, is illustrated in figure 2. Consider a expected price of $\mu$. Eliminating variance (i.e., setting $u_i = u_h$) yields an optimal supply of $y^* = 2\mu^2$.

Now consider the market equilibrium. A stable, long-run equilibrium is an expected market price, $\mu_e$, a level of effort $e_e^*$, and an expected supply $\bar{y}_e^*$, such that the number of producers is constant (i.e., $\pi = 0$), and where

$$\mu_e = a [\bar{y}_e^*]^{-b} \quad (15a)$$
$$\bar{y}_e^* = 2e_e^{1/2} \quad (15b)$$
$$e_e^* = e^* (\mu_e) \quad (15c)$$

Equation (15a) represents market equilibrium, (15b) represents the optimal expected supply given the optimal choice of effort, and (15c) represents the rational-expectations equilibrium where optimal effort is consistent with the equilibrium expected price. Stability implies that equilibrium price falls along the segments $cd$ and $dj$ on the supply curve in figure 2. The most interesting case is where the farmer is in survival mode, but $\pi = 0$; that is, on segment $cd$ of figure 2.

For a survival mode equilibrium to exist, expected price must be such that

$$\mu_e < \left[ \frac{f}{2u_i} \right]^{1/2} \quad (16)$$

In this case

$$\mu_e = a^{1-b} \left[ \frac{f}{u_i} \right]^{1-b} \quad (17)$$

For an inelastic demand curve ($b > 1$), the conditions for survival-mode equilibrium are given by

$$\frac{f}{u_i} < 2^{1-b} a^{2} \quad (18)$$

In fact, for all cases of demand, the above condition is simply that which provides for the standard (non-survival-mode) equilibrium. That is, if a survival-mode
equilibrium exists, then a conventional one does also. A conventional equilibrium exists where

$$\mu_c = \frac{1}{(2a)^{1+b}} \quad (19)$$

An elastic demand may also yield a stable, survival-mode equilibrium, but if one does not exist, then a conventional one would not exist as well. (The inequality in expression (18) above is reversed.) This leads to the idea of an over-production trap. For both inelastic and elastic demands, survival-mode equilibria may exist. But only in the former case is one justified in using the term trap. In the latter case, survival mode arises due only to the objectives of farmers. In the inelastic-demand case, survival mode exists because of the objectives of farmers and the accident of expectations consistent with survival mode. Farmers are trapped by their rational expectations; without altering farmers' objectives, a conventional equilibrium may be attained.

**Empirical Application**

The preceding sections have discussed the influence of human-capital asset fixity on production decisions. This section empirically addresses farm production based on the conceptual model. First, even under risk-neutrality the usual assumptions underlying the use of cost and profit functions are inapplicable in this case, because the marginal-product-equals-price rule does not hold. Therefore, even if one used only disaggregated data, the conventional correlations of cost shares, for example, with factor prices would not represent production technology as standard application of duality theory would suggest. The difficulty is that marginal products are set to effective prices, which are unobserved. These effective prices are the observed prices adjusted by other factors reflecting the influence of the discrete difference between on-farm and off-farm utility, and the probability of failure.

In standard applications, there are estimable equations for a production function (or cost, or profit) function and each marginal condition. If there are \(n\) choice variables
with associated prices, the standard application would have \( n + 1 \) equations from which to estimate the parameters representing the production technology (\( n \) input demands, one output supply). One may solve \( n \) input choice variables for \( n \) prices, all of which can be observed. In the non-standard case described above, however one can only solve for the choice variables in terms of the \( n \) prices and two price-adjustment factors, \( 1/(1 + \theta) \) and \( (1 + \theta \cdot \frac{1}{P_d})/(1 + \theta) \) from equations (9a) and (9b). Nevertheless, the marginal rates of technical substitution between inputs with common adjustment factors are dependent only on observable prices. Therefore, at best \( n - 2 \) choice variables can be solved in terms of observable prices and two inputs associated with different adjustment factors. And, one can obtain \( n - 1 \) equations from which to estimate production function parameters (\( n - 2 \) input demands, one output supply). This is not surprising, because this model introduces at least two additional unknowns into the choice problem. Under risk-neutrality, besides the parameters defining technology, the true cost \((\bar{U} - 1)\) of leaving farming in any period is unobserved, as is the true probability of failure as a function of farm decisions. In order to estimate the production function parameters, unconditioned on the on-farm/off-farm utility difference and the failure probability, one must allow for the influence of these two additional unknowns through some similar number of observables.

To illustrate the conceptual and theoretical models above, we examine corn production in Illinois. This study estimates a per-acre production function, assuming a particular production function, and utilizing the plausible restrictions on parameter estimates implied by the behavior model of a profit-maximizing farmer. Of course, other models also could result in production inefficiency, defined here as a wedge between marginal products and observed prices. The empirical analysis tests whether the adjustment factors driving a wedge between marginal products and prices, move in the direction implied by the conceptual model of input decisions under risk. Specifically, the empirical model tests whether or not input choices approach productive efficiency.
as farm size increase and over time (as farming is hypothesized to grow more integrated into the larger economy). Additionally, in recognition of the widespread farmer use of government programs and their influence on risk and farm decisions, the analysis examines to what degree programs affect the deviation of input choice from productive efficiency.

The empirical analysis takes four inputs (in per acre amounts) to a Cobb-Douglas production function. Consistent with the conceptual model, the inputs are separated into those that must be paid for immediately, fertilizer and hired labor, and those that may go unpaid, farm family labor and physical capital, represented by machinery use. In order to reduce the scope of the problem, the possible influence of other crops is ignored -- both in the usual joint-production sense, and, more importantly, in the sense of choosing a portfolio. The data are taken from *Summaries* of Illinois Farm Business Records from 1971 to 1979. This period was regarded as relatively prosperous for midwestern corn producers, with few downturns. Indeed parts of this period were considered "boom times," with many producers taking on greater debt consistent with a decreased perception of risk of farm failure. The period's comparative prosperity, in marked contrast to the following years of the early 1980s, would tend to work against observing any influence of failure risk on input decisions. The data are averages of farm characteristics, production levels, factor expenses, and labor employed for farms in particular size ranges and regions. Price data are from the *Summaries*, the Department of Agriculture's *Agricultural Statistics*, and the Commodity Research Bureau's *Commodity Year Book*.

Yield is represented by \( Y \), and input levels by \( X_i \); where \( i = 1 \) denotes fertilizer, \( i = 2 \) hired labor, \( i = 3 \) family labor, and \( i = 4 \) machinery. The \( w_i \) represent prices associated with the inputs, and the \( \alpha_i \) represent associated elasticities to be estimated. We assume risk neutrality of farmers and that output price is independent of output. The March quote of the December futures contract for corn represents the expected output
price. Denote this expected price by $\mu$. The model also includes as shift variables the amount of corn acreage ($Z_1$) to account for a scale effect, and the average soil quality of the farm ($Z_2$). (See the Summaries for a definition of this variable.)

The production function is represented as

$$\ln Y = \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln X_i + \sum_{j=1}^{2} \beta_j \ln Z_j. \tag{20}$$

From the general first-order conditions given by expressions (10a) and (10b), the marginal conditions for optimization are

$$\frac{\mu Y}{W_i X_i} \alpha_i = \rho_1, \quad i = 1, 2 \tag{21a}$$

$$\frac{\mu Y}{W_j X_j} \alpha_j = \rho_2, \quad j = 3, 4 \tag{21b}$$

where $\rho_k, (k = 1, 2)$ represents the unknown adjustment factors associated with the two types of inputs. The marginal product restrictions within each input group are

$$X_2 = \frac{\alpha_2 W_1}{\alpha_1 W_2} X_1, \tag{22a}$$

$$X_4 = \frac{\alpha_4 W_3}{\alpha_3 W_4} X_3. \tag{22b}$$

Therefore, one can specify the system of equations

$$\ln Y = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln \frac{W_1 X_1}{W_2} + \alpha_3 \ln X_3 + \alpha_4 \ln \frac{W_3 X_3}{W_4} + \beta_1 \ln Z_1 + \beta_2 \ln Z_2 + u_1 \tag{23a}$$

$$\frac{W_2 X_2}{\mu Y} = r_1 \frac{W_1 X_1}{\mu Y} + u_2 \tag{23b}$$

$$\frac{W_4 X_4}{\mu Y} = r_3 \frac{W_3 X_3}{\mu Y} + u_3 \tag{23c}$$

where $r_1 = \frac{\alpha_2}{\alpha_1}$, and $r_3 = \frac{\alpha_4}{\alpha_3}$. These three equations may be estimated using a seemingly unrelated regression technique that imposes non-linear restrictions on the coefficients.\(^8\)

The estimates of the production function are reported in table 3. The estimated production elasticities with respect to the inputs are positive and of plausible magnitude. One noteworthy result is the large difference between the elasticity of family labor and that of hired labor. Another result to note is the sign and magnitude of the
coefficient on acreage under corn, indicating a positive scale effect. The per-acre production function, however, exhibits decreasing returns.

Of particular interest is how the adjustment factors \( (\rho_i) \) are influenced by non-input variables. In order to investigate this, assume that the adjustment factors may be represented in the following manner

\[
\rho_1 = \frac{\mu_Y}{W_i X_i} \alpha_i = a_1 + b_1 S + c_1 T + d_1 D + e_1 M + u_{1i} \quad i = 1, 2
\]

\[
\rho_2 = \frac{\mu_Y}{W_j X_j} \alpha_j = a_2 + b_2 S + c_2 T + d_2 D + e_2 M + u_{2j} \quad j = 3, 4
\]

where \( S \) represents farm size in gross acreage, \( T \) a time index, \( D \) the per cent tillable land under program diversion, and \( M \) the proportion of off-farm income to total income.

From the discussions in the previous sections, one expects that as farm size grows the adjustment factors approach one, falling \((b_1 < 0)\) in the case of fertilizer and hired labor \((i = 1, 2)\), and increasing \((b_2 > 0)\) in the case of family labor and machinery \((j = 3, 4)\). These effects reflect that the fixed costs of farming that must be covered in order for the farmer to remain in agriculture do not grow in proportion with farm size. The larger operations relative to the smaller ones spread these fixed costs over a greater number of acres, and thus optimally sets marginal products closer to observed factor prices. The time index, \( T \), reflects an overall improvement in alternatives for farm family labor, growing integration of the farm sector and the larger economy, and other structural changes that promote stricter profit-maximizing (that is, \( c_1 < 0 \) and \( c_2 > 0 \)).

One variable of special concern indicating the integration of farm labor into other sectors is the relative importance of off-farm income to the total farm family income. As the family grows less dependent on uncertain production-based returns and more dependent on sure, off-farm sources, the farmer places less weight on avoiding poor crop revenues \((e_1 < 0 \text{ and } e_2 > 0)\). This effect would best be measured by the propor-
tion of off-farm income relative to total income for specific farm families. This set of data was unavailable. Instead the model takes the proportion of total non-farm income earned by U.S. farmers relative to total income from both farm and non-farm sources. Thus the data only reflect aggregate changes in off-farm income to commercial enterprises.9

The program variable, $D$, reflects farmer’s response to government payments. Three effects from government programs can be identified. First, programs may reduce the risk of failure and thereby promote efficiency. Second, programs may increase the opportunity cost of leaving farming, at the same time reducing failure risk, and thereby promote inefficiency. Third, programs may increase the effective output price through target prices. Despite these three distinct effects, one may be able to detect which has the greater influence by examining the pair of coefficients $d_1$ and $d_2$. If the first effect predominates, then the signs of the coefficients on $D$ is expected to be positive for family labor and machinery ($d_2 > 0$), and negative for fertilizer and hired labor ($d_1 < 0$). If the second effect predominates, then the signs on this coefficient will be reversed ($d_1 > 0$ and $d_2 < 0$). Finally, if the third effect predominates, then the signs on both coefficients will be negative for both equations ($d_1 < 0$ and $d_2 < 0$).

Using the first order conditions, specify four additional equations:

\[
\frac{\rho_1}{\alpha_1} = \frac{\mu_Y}{w_1X_1} = \frac{a_1}{\alpha_1} + \frac{b_1}{\alpha_1} S + \frac{c_1}{\alpha_1} T + \frac{d_1}{\alpha_1} D + \frac{e_1}{\alpha_1} M + \frac{\mu_{11}}{\alpha_1} \tag{24a}
\]

\[
\frac{\rho_1}{\alpha_2} = \frac{\mu_Y}{w_2X_2} = \frac{a_1}{\alpha_2} + \frac{b_1}{\alpha_2} S + \frac{c_1}{\alpha_2} T + \frac{d_1}{\alpha_2} D + \frac{e_1}{\alpha_2} M + \frac{\mu_{12}}{\alpha_2} \tag{24b}
\]

\[
\frac{\rho_2}{\alpha_3} = \frac{\mu_Y}{w_3X_3} = \frac{a_2}{\alpha_3} + \frac{b_2}{\alpha_3} S + \frac{c_2}{\alpha_3} T + \frac{d_2}{\alpha_3} D + \frac{e_2}{\alpha_3} M + \frac{\mu_{23}}{\alpha_3} \tag{24c}
\]

\[
\frac{\rho_2}{\alpha_4} = \frac{\mu_Y}{w_4X_4} = \frac{a_2}{\alpha_4} + \frac{b_2}{\alpha_4} S + \frac{c_2}{\alpha_4} T + \frac{d_2}{\alpha_4} D + \frac{e_2}{\alpha_4} M + \frac{\mu_{24}}{\alpha_4} \tag{24d}
\]

These equations may be estimated using SUR with linear cross-equation restrictions. The restrictions are obtained from estimates of the production elasticities. For example, the coefficient on the national off-farm income variable for the cash-draining inputs, say $e_1'$ and $e_1''$, are restricted such that $e_1' = \frac{\alpha_2}{\alpha_1} e_1''$. 10
The estimates of the coefficients for the adjustment-factor equations are reported in table 4. The coefficients on farm size in the adjustment-factor equations support the conclusions of the conceptual model. Over farm size the adjustment factor falls for fertilizer and hired labor and increases for family labor and machinery. The coefficients are both significantly different from zero with a degree of confidence greater than 95%. The coefficients are also of the same magnitude, although of different sign (as expected), suggesting that the effect of farm size on the deviation from strict profit maximization is roughly symmetric with respect to decisions regarding both types of inputs. Similarly, the coefficients on the variable measuring the importance of off-farm income are of expected sign. The greater the proportion of off-farm income the less the marginal products of fertilizer and hired labor exceed their observed factor prices, and the less the marginal products of family labor and machinery fall short.

The coefficient on the off-farm income variable, however, is insignificantly different from zero in the case of hired labor and fertilizer. The coefficient for family labor and machinery is much larger than for the other inputs, and significantly different from zero with a high degree of confidence. One may conclude that increasing off-farm income affects the utilization of the different types of inputs in an asymmetric way. Off-farm income lessens the over-use (relative to strict profit maximization) of family labor and machinery, but has little if any effect on discouraging the under-use of the other inputs.

The time index represents all variables other than off-farm income that would measure the degree of integration of farming with the rest of the economy. The coefficients on this composite variable suggest that, for a given farm size, dependence on farm income, and degree of program participation, production decisions have been deviating further from pure profit maximization. These results are somewhat surprising in light of accepted wisdom that agriculture is in transition to greater integration
with the rest of the economy. First, recall that the data are for a fairly short period of time, between 1971 and 1979. Second, the results for the time variable are supported at least in part by Vasavada's work on the measurement of excess inputs. Using a dynamic adjustment model, he concludes that for aggregate levels of labor and capital, surpluses have shown a marked tendency to decline over a longer period of time (since 1948). During the 1970s, however, his results demonstrate a decline followed by an upswing in input-surplus indices. Troughs occur in 1972 for capital and 1974-1975 for labor.

Finally, the coefficients on the program variable are of opposite signs for the two adjustment-factor equations, and support the conclusion that government programs exacerbate the deviation from production efficiency.

Concluding Comments

The analytical and empirical results of this paper offer some insight into farmer behavior under risk of failure. A farmer cannot purchase complete insurance against such a risk. In addition to other responses (e.g., crop insurance, access to credit reserves) the farmer would seek to mitigate against this risk by deviating in his production decisions from what is optimal from a simple expected-profit maximizing case. Production factors with immediate cash outlay tend to have higher effective prices than without the risk, since part of their cost must be measured in the contribution to increasing the probability of failure. The marginal products of these factors are set higher than observed prices would optimally warrant. Conversely, factors that may be delayed in cash expenditure tend to have lower effective prices for the opposite reason, and their marginal products are set lower than observed prices warrant.

Factors of the last type are of particular interest, since their contribution to aggregate capacity may be of greatest significance. Farm-operator labor, or farm family labor, tends to be over-utilized at the expense of non-cash-generating alternatives (e.g., leisure time). Improving opportunities for off-farm income would encourage the
farmer to use operator labor in a similar manner to hired labor. Physical capital, including aspects of land quality and long-term productivity, owned by the farmer is treated in the same way. The conceptual analysis suggests that during periods when farmers face higher probability of failure and the difference between on-farm and off-farm utility is larger, farmers would tend rationally to increase the deterioration of their resources.

This paper also offers an empirical investigation of corn production in Illinois. This is done in order both to demonstrate the applicability of the conceptual model, and to substantiate certain conclusions that can be drawn regarding the degree of deviation from simple profit-maximization. Conventional estimation of dual functions, such as those of cost and profit, is unwarranted in the presence of risky adjustment costs. Nevertheless, the theory does admit certain restrictions to an estimable system of supply and factor demands, from which one can use output- and input-price data in the estimation of production technology. In addition to prices as explanatory variables, levels of a certain number of representative inputs (in this study, two) must be used with a corresponding reduction in the number of estimable equations. The estimation results indicate that larger farms deviate less from production efficiency than do smaller farms, where production efficiency is defined relative to strict profit maximization; and that the lesser the reliance on farm income as opposed to off-farm income the greater the production efficiency Over the period of time studied, however, farmers have been moving further from setting marginal products equal to observed prices.
Footnotes

1/ One reviewer points out the possibility that the farmer, having failed, may work for other farmers, thereby employing (at least some of) his farm-specific skills. These employed skills, however, would likely be strictly related to farm labor rather than management of inputs (including labor). Nevertheless, the opportunity cost of the farmer's management of a farm may be the value of employment by other farmers rather than employment out of agriculture altogether. Furthermore, the utility of this farm labor may be much less than that derived from farm management.

2/ For example, Thompson, Gwynn, and Sharp report the survey of married farm women in Yolo County, California, and remark: "The increased participation by women on smaller farms was found to result from the need for the entire family to use its total resource for survival rather than to a greater opportunity for women to participate on small farms."

3/ The models presented in this and the following section are similar to those discussed by Just and Zilberman. The basic model offers an explanation of farmer behavior that resembles behavior arising from a safety-first objective function (Pyle and Turnovsky).

4/ Sum along the central diagonal of Table 1, taking the product of the expected utility in any year, the probability of obtaining that expected utility, and the appropriate discount factor:

\[ \bar{U}_F \pi + \bar{U}_F \pi (1 - \pi) + \cdots = \bar{U}_F \sum_{i=0}^{\pi} \beta^i (1 - \pi)^i = \]

\[ \bar{U}_F \pi (1 - \beta(1 - \pi)) \]

Sum along a representative diagonal \( j \) steps to the left of and above the central diagonal:

\[ \bar{U}_N \pi (1 - \pi)^j \sum_{i=0}^{\pi} \beta^i (1 - \pi)^i = \]

\[ \bar{U}_N \pi (1 - \pi)^j / (1 - \beta(1 - \pi)) \quad j = 1, 2, \ldots. \]
Sum along a representative diagonal $j$ steps to the right of and below the central diagonal:

$$Ieta^{j} \sum_{i=0}^{\infty} \beta^{i}(1-\pi)^{i} =$$

$$Ieta^{j} \pi/(1-\beta(1-\pi)) \quad j = 1, 2, \ldots$$

Sum all the diagonal summations to obtain expression 6.

5/ Equations (8a), (8b), and (8c) derive from the following first order conditions for the maximization of the objective function (7):

$$\frac{\partial V}{\partial k} = D^{-1} \frac{\partial y}{\partial k} A [E(U'p) - E(U')] + VD^{-1}g(p_d)y^{y-1} = 0 ,$$

$$\frac{\partial V}{\partial x} = D^{-1} \frac{\partial y}{\partial x} A [E(U'p) - E(U')] + VD^{-1}g(p_d)y^{y-1} - VD^{-1}g(p_d)y^{y-1} = 0 ,$$

where $D = 1 - \beta(1-\pi)$.

6/ The specification of survival -- covering minimal expenses -- is stylized in one important way. Minimal expenses, $f$, is a constant, and specifically not an increasing function of three items: farm size, input use, or past failure to cover all expenses (i.e., some portion of past $ik$). Although relaxing the current simplification would complicate the analysis, to make $f$ a function of the first two items would not alter the basic implications of the model as long as $f$ increases over these items at a decreasing rate. The third item is conceptually more important. If the farmer delays payment on some portion of the cost of inputs $k$, one expects that portion to contribute to higher minimal expenditures in the future (or perhaps decreased output), and thus a higher future probability of failure for all levels of inputs. This would tend to blur the distinction between $x$ and $k$ in the active avoidance of failure. Nevertheless, as long as the farmer does not have to pay a price of delaying payment that exceeds his discount rate, and at failure time all delayed payments outstanding are forgotten, then $k$ would be a more attractive input than $x$ using the simple criterion of minimizing the probability of failure.

7/ This approach is similar to that taken by Lau and Yotopoulos in their investiga-
tion of relative production efficiency. Lau and Yotopoulos take the \( \rho \)'s as constants over time for a given type of "farm." Their data uses averages of individual farms at a given size and region.

8/One potential difficulty with the SUR approach is the possible simultaneity of the representative inputs and the level of production.

9/A reviewer notes that off-farm income is some cases could be approximated by aggregate data by sales classes. Such class data, however, are not immediately applicable here. The farm sizes here for the most part are of the commercial class, although not exclusively. Moreover, the farm sizes used change over time. The results should be interpreted in this light, specifically as if the relative off-farm income across farms was a constant, and the data reflect only common changes in levels.

10/There are two noteworthy potential problems with this estimation method. First the restrictions rely on estimates of the production elasticities. Interpretation of the standard errors must rely on asymptotics and caution is advised. Second, the error terms in these four equations above may not be independent of the errors in the equations representing the production relations. Ideally, a larger seven-equation system would be estimated, production relations and adjustment factors together.
References


Illinois Cooperative Extension Service, Summaries of Illinois Farm Business Records
(Commercial Farms): annual reports from 1971 to 1979 published by the University of Illinois at Urbana-Champaign, College of Agriculture.


Figure 1  Values of the Objective Function over Effort
Figure 2  Optimal Supply over Expected Price
Table 1. Future Utility Levels Conditioned on Farm Failure

<table>
<thead>
<tr>
<th>Discount Factor</th>
<th>Probability of Income Stream</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\pi$</td>
<td>$\pi(1-\pi)$</td>
<td>$\pi(1-\pi)^2$</td>
<td>$\pi(1-\pi)^3$</td>
</tr>
<tr>
<td>1</td>
<td>$U_F$</td>
<td>$U_N$</td>
<td>$U_N$</td>
<td>$U_N$</td>
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<tr>
<td>$\beta$</td>
<td>I</td>
<td>$U_F$</td>
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</tr>
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<td>I</td>
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</tr>
<tr>
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<td>I</td>
<td>I</td>
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</tr>
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<td></td>
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</table>

Note: $U_F = \mathbb{E}[U \mid p < p_d]$ and $U_N = \mathbb{E}[U \mid p \geq p_d]$. 
Table 2. Estimates of Production Elasticities

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\alpha_0$</td>
<td>3.0282</td>
<td>6.0490</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>$\alpha_1$</td>
<td>0.1015</td>
<td>1.4472</td>
</tr>
<tr>
<td>Hired labor</td>
<td>$\alpha_2$</td>
<td>0.0174</td>
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</tr>
<tr>
<td>Family labor</td>
<td>$\alpha_3$</td>
<td>0.1407</td>
<td>4.3126</td>
</tr>
<tr>
<td>Machinery</td>
<td>$\alpha_4$</td>
<td>0.2280</td>
<td>4.3200</td>
</tr>
<tr>
<td>Corn acreage</td>
<td>$\beta_1$</td>
<td>0.2555</td>
<td>3.5311</td>
</tr>
<tr>
<td>Soil quality index</td>
<td>$\beta_2$</td>
<td>0.0085</td>
<td>11.773</td>
</tr>
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Table 3. Coefficient Estimates for the Adjustment Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient Estimate</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cash-draining inputs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>( a_1' = \frac{a_1}{\alpha_1} = \frac{\alpha_2}{\alpha_1} a_1'' )</td>
<td>17.639</td>
<td>5.580</td>
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<tr>
<td>Gross acreage</td>
<td>( b_1' = \frac{b_1}{\alpha_1} = \frac{\alpha_2}{\alpha_1} b_1'' )</td>
<td>-0.0095</td>
<td>-10.972</td>
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<tr>
<td>Time index</td>
<td>( c_1' = \frac{c_1}{\alpha_1} = \frac{\alpha_2}{\alpha_1} c_1'' )</td>
<td>0.5189</td>
<td>3.549</td>
</tr>
<tr>
<td>Percent tillable land</td>
<td>( d_1' = \frac{d_1}{\alpha_1} = \frac{\alpha_2}{\alpha_1} d_1'' )</td>
<td>0.2386</td>
<td>2.838</td>
</tr>
<tr>
<td>Ratio off-farm to</td>
<td>( e_1' = \frac{e_1}{\alpha_1} = \frac{\alpha_2}{\alpha_1} e_1'' )</td>
<td>-2.5203</td>
<td>-0.418</td>
</tr>
<tr>
<td>total income</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-cash-draining inputs</strong></td>
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<td></td>
</tr>
<tr>
<td>Constant</td>
<td>( a_2' = \frac{a_2}{\alpha_3} = \frac{\alpha_4}{\alpha_3} a_2'' )</td>
<td>-6.457</td>
<td>-2.592</td>
</tr>
<tr>
<td>Gross acreage</td>
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<td>19.491</td>
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<tr>
<td>Time index</td>
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<td>-2.566</td>
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<tr>
<td>Percent tillable land</td>
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<td>Ratio off-farm to</td>
<td>( e_2' = \frac{e_2}{\alpha_3} = \frac{\alpha_4}{\alpha_3} e_2'' )</td>
<td>24.323</td>
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<td>total income</td>
<td></td>
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