QUANTIFYING LONG RUN AGRICULTURAL RISKS AND EVALUATING FARMER RESPONSES TO RISK

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Optimal Capital Structure as Business Risk Changes

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Abstract

Optimal capital structure is one of the more important decisions farmers make. This study quantitatively examines how optimal capital structure may change as land quality changes. Results suggest that farmers on poor quality land will raise more hogs and own less farmland if the increased riskiness of marginal land is not bid into the mean returns to assets.

KEYWORDS: optimal capital structure, discrete stochastic programming.

The issue of optimal capital structure is an issue that has received a great deal of thought. Several pieces of agricultural economics literature have contributed to an understanding of how debt should adjust qualitatively as conditions change. However, it is still difficult to give proprietary firms quantitative estimates of a reasonable capital structure. The purpose of this paper is to provide quantitative estimates of the optimal capital structure for a farmer on average land and on marginal land.

One of the motivations for this paper comes from seemingly different conclusions expressed by different authors. According to some authors, one can not predict a change in leverage as business risk increases (Penson and Lins). According to others as business risk decreases, leverage and/or financial risk increases (Gabriel and Baker, Collins 1985b).

Several authors have provided results which need to guide quantitative analysis on optimal leverage. The optimal leverage ratio is often represented in undergraduate texts as the point where the average cost of capital is minimized (Penson and Lins; and Barry, Hopkin, and Baker). Lee et al. suggest that the upper end of a debt to asset ratio will be near 50% as this is the point where lenders begin to limit credit.

One of the important costs of having too much debt is the cost of obtaining the ability to meet cash obligations as they come due. Barry, Hopkin, and Baker define this as liquidity and discuss risks associated with maintaining liquidity. When assets need to be sold off to maintain liquidity, the asset is likely to be less liquid because principle buyers of farm assets are usually other farmers. Barry, Baker, and Sanint discuss the usefulness and the limitations of holding credit reserves. Unused borrowing capacity can be one means of maintaining liquidity, however, Barry, Baker, and Sanint also provide evidence suggesting that credit reserves are negatively correlated with the need to use credit reserves.

Gabriel and Baker suggest a trade-off between business and financial risk as well as trade-offs within the business portfolio. They suggest a decline in business risk would lead to an increase in financial risk, reducing the effects of a decline in financial risk. Collins supports and extends the above results by showing that leverage is likely to increase under farm

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programs (1985b). Featherstone et al. continue the line of reasoning suggesting that farm programs may induce a large enough increase in leverage to increase the probability of equity losses.

Robison and Barry present several results which also need to guide empirical work on optimal capital structure. They suggest that a farmer under financial stress may actually increase the amount of leverage as a means of forestalling or perhaps avoiding bankruptcy. They also show that holding credit reserves is an efficient way of maintaining liquidity.

Others have considered the optimal capital structure of a firm using dynamic models. Collins' dynamic model suggests that the steady state optimal leverage ratio is constant (1985a). Lowenberg-DeBoer and Boehlje use Vicker's model to study financial and production decisions.

A Theoretical Model

Collins' model can provide an explanation of the seemingly different interpretations of how leverage might behave as business risk changes (1985b). Collins' hypothesizes that if you assume that farmers maximize the expected utility of the rate of return to equity, the farmer's utility function is negative exponential, and the rate of return on assets is distributed as a normal distribution, optimal leverage ratio can be expressed as:

$$(1)\quad \delta^{*} = 1 - \frac{\rho \sigma^{2}{}_{A}}{[\bar{R}_{A} - k]}$$

where δ^{*} is the optimal leverage ratio, (Debt/Assets) ρ is the Pratt-Arrow relative risk aversion coefficient, $\delta^{2}{}_{A}$ is the variance in the rate of return to assets, $\bar{R}_{A}$ is the mean return to assets, and k is the borrowing rate.

Equation 1 can be differentiated with respect to the variance in the return to assets to determine how leverage will change when business risk changes. Collins assumes that the mean rate of return to assets is independent of the level of business risk. For some applications such as government policies, this assumption is likely valid. However, for other applications such as the purchase of an insurance policy or differences in the quality of land, the mean rate of return would likely change as business risk changes. For example, if an insurance policy is purchased, business risk likely decreases. However, the mean rate of return on assets will also decrease by the premium. Using Collins' results that a decrease in business risk increases leverage and a decrease in the mean rate of return on assets decreases leverage, a situation arises where the change in leverage ratio due to a change in business risk is indeterminate. It then becomes an empirical question as to whether or not the direct effect of an increase in business risk of decreased leverage offsets the indirect effect of an increase in the expected rate of return on assets and increased leverage.

Casual Evidence

Figure 1 illustrates the average leverage ratios for Illinois and Iowa from 1969-1987. These are state averages taken from USDA's state balance sheet summary statistics. Iowa and Illinois are two cornbelt states with similar agriculture. However, Iowa is more susceptible to weather variablity than is Illinois. Although the evidence is by no means conclusive, several things can be observed. For every year from 1969 through 1987[2], the average leverage ratio in Iowa was greater than Illinois. Equation 1 could suggest a number of reasons why this might occur. They include farmers in Iowa are more risk neutral than in Illinois, the variance in the rate of return to assets is greater in Illinois than in Iowa, the expected rate of return in Iowa is greater than in Illinois, and/or the cost of debt is lower in Iowa than in Illinois, or the model is not an accurate representation of debt choice. If one accepts the premise that the model is an appropriate tool that explains debt choice, only the reason that the rate of return is larger in Iowa than in Illinois seems plausible.

Figure 2 illustrates the rate of return to assets for Illinois and Iowa from 1976 through 1987. The returns to assets are before capital gains and are presented here to illustrate that the return to assets in Iowa has been greater than it has in Illinois. The mean rate of return to assets in Iowa before considering capital gains was 4.75% with a standard deviation of 2.47% over the period. In Illinois, the mean was 3.84% with a standard deviation of 1.55%. When capital gains are taken into account, for the 1976 through 1987 period, the mean rate of return in assets and the standard deviation was larger in Iowa than in Illinois.

An Empirical Model

The data above suggest that perhaps the increase in leverage due to an increase in the rate of return may more than offset the decrease in leverage due to a increase in the variance of the rate of return to assets. However, given that the data is state data the evidence is by no means conclusive. The remainder of the paper will examine a farmer's investment in a cornbelt farm where land is of average quality or of marginal quality.

One methodology that can be used to model production and investment decisions is discrete stochastic programming (DSP). McCarl and Musser suggest that incorporation of risky cash flows can be achieved only in dynamic programming or DSP models. McCarl discusses DSP or stochastic programming with recourse in a 1986 paper.

The ability to incorporate dynamics, random events, and constraints that differ across states makes the DSP framework ideal for use in modeling liquidity risk for a farm firm. The decision variables for a DSP model focused on farm planning might include what mix of crops and livestock to produce, how much to borrow or repay, and whether to hire labor or supply off-farm labor. Random events might include crop and livestock yields and prices (or revenues), changes in land values, and interest rates.

Notation

In order to present the mathematical model, notation is defined in this section. Variables will be in upper case and parameters will be in lower case.

[2] A longer data series would be desireable for both the debt to asset ratios and the return on assets by state but to the best of the author's knowledge these are not available.

Subscripts

Subscripts indicate the year, the current state of nature and the previous state of nature. Let:

t = denote the year in which a decision is made, ($t=1,\ldots,T$) where T is the end of the planning horizon;

i = denote the number of the state at time $t+1$, ($i=1,\ldots,I_{t+1}$) where I_{t+1} is the number of stages for period $t+1$;

j = denote the number of the state at time t, ($j=1,\ldots,I_t$) where I_t is the number of states for period t.

Variables

IOE = the initial amount of owner's equity (dollars).

L_{ti} = land owned at the end of period t in state i (acres).

PL_{ti} = land purchased at the beginning of period t in state i (acres).

SL_{ti} = land sold at the beginning of period t and state i (acres).

R_{ti} = Owned land planted into 1/2 corn and 1/2 soybeans at the beginning of period t in state i (acres).

W_{ti} = owned land planted into wheat at the beginning of period t in state i (acres).

RC_{ti} = cash rented land planted into 1/2 corn and 1/2 soybeans at period t in state i (acres).

RS_{ti} = share rented land planted into 1/2 corn and 1/2 soybeans at period t in state i (acres).

M_{ti} = amount of machinery owned after all period t decisions have been made in state i (dollars).

AM_{ti} = number of acres with a machinery set at the end of period t in state i (acres).

PM_{ti} = land needing machinery purchase at the beginning of period t in state i (acres).

H_{ti} = the number of units of hogs raised during period t in state i (sows).

HB_{ti} = amount of hog buildings owned after all period t decisions have been made in state i (dollars).

PHB_{ti} = amount of hog buildings purchased at the beginning of period t in state i (dollars).

OE_{ti} = Owner's equity at the beginning of period t in state i after all decisions have been made (dollars).

D_{ti} = amount of debt at the beginning of period t in state i after all decisions have been made (dollars).

OFI_{ti} = off-farm investment during period t in state i (dollars).

OFL_{ti} = amount of good field days spent on an off-farm job during period t in state i (hours). (A good field day is a day when an operator can do field work).

SHL_{ti} = Amount of summer labor hired per good field day during period t in state i (hours).

FHL_{ti} = amount of fall and spring labor hired per good field day during period t in state i (hours).

Technical Coefficients

Fixed technical coefficients are used to indicate the hours of good field day labor required for each of the production activities. Let:

hrs = labor needed on good field days during the summer for rotation corn and soybeans (hours).

hrf = labor needed on good field days during the fall for rotation corn and soybeans (hours).

hws = labor needed on good field days during the summer for wheat (hours).

hhs = labor needed on good field days needed for hogs during the summer (hours).

hhf = labor needed on good field days for hogs during the fall (hours).

rsf = hours used in the fall divided by hours used in the summer for off-farm employment

p_i = the probability of ending up at a terminal state for i = $1,\ldots,I_{t+1}$, where I_{t+1} is the number of terminal nodes.

Financial Coefficients

The following are the coefficients associated with the financial aspects of this model. They include coefficients used for: external credit rationing, liquidity risk, accounting, working capital and debt use, depreciation, and machinery and hog facilities requirements. Let:

dm = one minus the rate at which machinery depreciates (%).

ma = the value of machinery assets needed to farm the each acre of land (dollars).

fh = the value of hog facilities needed for each sow (dollars).

db = one minus the rate at which hog facilities depreciate (%).

pl_{ti} = price of land in period t and state i (dollars per acre).

wr = working capital needed for rotation corn and soybeans grown on owned land (dollars per acre).

ww = working capital needed for wheat grown on owned land (dollars per acre).

wrs = working capital requirement for rotation corn and soybeans grown on land leased via a crop share (dollars per acre).

wrc_{ti} = working capital needed for rotation corn and soybeans grown on cash rented land for period t and state i (dollars per acre).

wh_{ti} = working capital requirement for hogs for period t in state i (dollars per sow).

tc_{ti} = transactions cost for land sale during period t in state i (dollars per acre).

pr_{ti} = after-tax profit for rotation corn and soybeans grown on owned land for period t in state i (dollars per acre).

pw_{ti} = after-tax profit for wheat grown on owned land for period t in state i (dollars per acre).

prc_{ti} = after-tax profit for cash rented rotation corn and soybean land for period t in state i (dollars per acre).

prs_{ti} = after-tax profit for share rented rotation corn and soybean land for period t in state i (dollars per acre).

ph_{ti} = after-tax profit for hogs in period t in state i (dollars per sow).

adm = after-tax depreciation on machinery.

adf = after-tax depreciation on hog facilities.

$rint_{ti}$ = after-tax interest rate for period t in state i paid for farm borrowing.

$rinv_{ti}$ = after-tax interest rate for period t in state i for off-farm invested capital.

aofw = after-tax wage for off-farm employment (dollars per hour).

aplf = after-tax wage paid to fall hired labor (dollars per hour).

apls = after-tax wage paid to summer hired labor (dollars per hour).

cg_{ti} = capital gain on owned land for period t in state i (dollars per acre).

d_{ti} = the credit capacity for period t and state i in dollars (if $cg_{ti} \geq 0$, $d_{ti} = 0$ otherwise $d_{ti} = 1$). If the capital gain on land is negative, the current debt limit is equal to last period's debt limit plus ten percent of equity.

e_{ti} = the weights for credit capacity for period t and state i (if $cg_{ti} < 0$ then $e_{ti} = .1$ otherwise e_{ti} is one).

θ = the "risk aversion" coefficient. $\theta \geq 0$ indicating that the individual is risk neutral ($\theta = 0$) or risk averse ($\theta > 0$). θ is the Pratt-Arrow measure of relative risk aversion.

Right-hand Side Coefficients

be = the decision maker's beginning owner's equity (dollars).

pl = the maximum amount of land purchased in a period.

s = the maximum amount of good field time available during the summer (hours).

f = the maximum amount of good field time available during the fall (hours).

c = the amount of withdrawals made by the family for living expenses (dollars).

bofl = the maximum amount of off-farm labor allowed (hours).

shlb = the maximum amount of summer hired labor (hours).

fhlb = the maximum amount of fall hired labor (hours).

wb = the maximum amount of wheat grown on owned land. This is the amount of wheat base that a farmer has under government programs.

The Mathematical Model

A mathematical model of a representative corn-soybean-hog farm consistent with the above notation is described in this section.

Objective Function

$$(2) \text{ maximize} \quad u = \sum_{i=1}^{I_{t+1}} p_i \frac{(OE_{T+1,i})^{1-\theta}}{1-\theta}$$

The objective is to maximize the expected utility (u) of terminal net worth where the farmers utility function is assumed to be a power utility function. Featherstone, Preckel, and Baker discuss the power utility function and suggest a method to evaluate negative terminal net worth using a power function. The expected utility of the decision maker is maximized subject to the following sets of constraints.

Owned Land Usage Constraints

(3a) $-PL_{11} + SL_{11} + R_{11} + W_{11} \leq 0$

(3b) $-L_{t-1j} - PL_{ti} + SL_{ti} + R_{ti} + W_{ti} \leq 0$

for $t = 1,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.[3]

These constraints are used to ensure that owned land sold or used for rotation corn and soybeans or wheat is less than or equal to land previously owned on newly purchased.

Owned Land Accounting Constraints

(4a) $-PL_{11} + SL_{11} + L_{11} = 0$

(4b) $-L_{t-1j} - PL_{ti} + SL_{ti} + L_{ti} = 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

The owned land accounting constraints are used to transfer owned land to the next period. These constraints simply require that the land owned last period plus purchases minus land sales is equal to ending owned land.

Acres with Machinery Accounting Constraints

(5a) $-PM_{11} + AM_{11} = 0$

(5b) $-dm\ AM_{t-1j} - PM_{ti} + AM_{ti} = 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints keep track of the machinery capacity. These constraints are necessary because machinery depreciates. Last year's machinery is only able to service a portion (one minus the machinery depreciation rate) of the land it was able to last year.

Machinery Assets Accounting Constraints

(6a) $-ma\ PM_{11} + M_{11} = 0$

(6b) $-dm\ M_{t-1j} - ma\ PM_{ti} + M_{ti} = 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints transfer the value of machinery from year to year. The depreciated value of last year's machinery set plus the value of new machinery purchases is equal to machinery transferred to the next period.

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[3] It is important to get the indices correct when connecting different states of nature across time in a DSP. It is straightforward to compute the indices of the arcs emanating from a given node because at a given stage, the number of arcs per node is equal across states. The computation of the indices is based on three things: the index of the arc traversed in the previous period (j), the total number of nodes in the current period (I_t), and the total number of nodes in the previous period (I_{t-1}).

Machinery Purchases Constraints

(7a) $R_{11} + W_{11} + RC_{11} + RS_{11} - PM_{11} \leq 0$

(7b) $-dm\ AM_{t-1j} + R_{ti} + W_{ti} + RC_{ti} + RS_{ti} - PM_{ti} \leq 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints set the machinery purchases. The depreciated machinery set from the previous year plus new purchases must be sufficient to service the acreage farmed.

Hog Facilities Purchases Constraints

(8a) $fh\ H_{11} - PHB_{11} \leq 0$

(8b) $-db\ HB_{t-1j} + fh\ H_{ti} - PHB_{ti} \leq 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints set the amount of hog facilities to be purchased. The depreciated amount of facilities plus new hog facility purchases must be greater than the number of sows the farmers intends to raise this year.

Hog Assets Accounting Constraints

(9a) $-PHB_{11} + HB_{11} = 0$

(9b) $-db\ HB_{t-1j} - PHB_{ti} + HB_{ti} = 0$

for $t = 2,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints transfer the value of hog facilities from year to year. The depreciated value of last year's hog facilities plus the value of new hog facility purchases is equal to hog facilities transferred to the next period.

Debt Limit Constraints

(10a) $-e_{1,i}\ OE_{11} + D_{11} \leq 0$

(10b) $-d_{ti}\ D_{t-1j} - e_{ti}\ OE_{ti} + D_{ti} \leq 0$

for $t = 1,\ldots,T$ and $j = 1,\ldots,I_{t-1}$. Given j, i goes from $(j-1) * I_t/I_{t-1} + 1$ to $j*I_t/I_{t-1}$.

These constraints represent the external credit rationing from the lender. If last year's capital gain associated with land was positive, then the amount of debt available to be borrowed is equal to a proportion of owner's equity. If, however, the capital gain associated with land is negative, then the maximum amount of credit available to this farm operator is the amount of debt held last year.

Summer Labor Constraints

(11) $hrs\ R_{ti} + hws\ W_{ti} + hrs\ RC_{ti} + hrs\ RS_{ti} + OFL_{ti} + hhs\ H_{ti} - SHL_{ti} \leq s$

for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.

These constraints ensure that labor used for 10 weeks during the summer is not more than or equal to that available. The amount of labor used on good field days during the summer for crops and the hog enterprises plus the amount hired out must be less than labor available from the permanent labor force plus the summer labor hired in.

Spring and Fall Labor Constraints

(12) $hrf\ R_{ti} + hrf\ RC_{ti} + hrf\ RS_{ti} + rsf\ OFL_{ti} + hhf\ H_{ti} - FHL_{ti} \leq f$
for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.

These constraints require that spring and fall labor hired for 24 weeks on good field days will not exceed what is available. The amount of spring and fall labor used for crops, hogs, and off-farm employment must be less than or equal to labor available from the permanent labor force plus the fall labor hired in.

Balance Sheet Constraints

(13) $pl_{ti}\ L_{ti} + HB_{ti} + M_{ti} + wr\ R_{ti} + ww\ W_{ti} + wrc_{ti}\ RC_{ti} + wrs\ RS_{ti} + wh_{ti}\ H_{ti}$
$+ OFI_{ti} - OE_{ti} - D_{ti} = 0$
for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.

These constraints are accounting constraints which simply say that assets equal debt plus owners equity. These constraints also set the amount of debt.

Owner's Equity Constraints

(14a) $IOE - tc_{11}\ SL_{11} - OE_{11} = 0$
(14b) $pr_{ti}\ R_{t-1j} + pw_{ti}\ W_{t-1j} + prc_{ti}\ RC_{t-1j} + prs_{ti}\ RS_{t-1j} + ph_{ti}\ H_{t-1j}$
$- adm\ M_{t-1j} - adf\ HB_{t-1j} - rint_{ti}\ D_{t-1j} + rinv_{ti}\ OFI_{t-1j} + aofw\ OFL_{t-1j}$
$- aplf\ FHL_{t-1j} - apls\ SHL_{t-1j} + OE_{t-1j} + cg_{ti}\ L_{t-1j} - tc_{ti}\ SL_{ti} - OE_{ti} = c$
for $t = 2,\ldots,T+1$ and $j = 1,\ldots,I_t$. Given j, i goes from $(j-1) * I_t/I_{t-1} +$ 1 to $j*I_t/I_{t-1}$.

These constraints calculate the owner's equity. Owner's equity is the income from both farm and nonfarm activities such as crops, hogs, off-farm employment, and off-farm investment minus expenses such as hired labor expense, depreciation, and interest expense minus a withdrawal for family living and consumption plus last years ending owner's equity. Included in this calculation of owner's equity is an adjustment for a change in the market value of land (cg_{ti}). The adjustment in land value is included to calculate market value net worth.

Initial Period Bounds

(15) $IOE = be$

This constraint sets the initial conditions for the farm operation. The initial amounts of owner's equity for this paper is $750,000.

Other Bounds

(16a) $OFL_{ti} \leq bofl$ for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.
(16b) $SHL_{ti} \leq shlb$ for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.
(16c) $FHL_{ti} \leq fhlb$ for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.
(16d) $W_{ti} \leq wb$ for $t = 1,\ldots,T$ and $i = 1,\ldots,I_t$.
(16e) $PL_{ti} \leq pl$ for $t = 2,\ldots,T$ and $i = 1,\ldots,I_t$.

These constraints place an upper limit on the off-farm employment, the hired labor and the wheat activities. The labor bounds are needed to limit the size of the farming operation. The wheat bound is needed when farm programs are in effect as this bound represents the amount of wheat base the farm operator has. The maximum amount of land purchased is constrained to 80 acres in other than the initial period.

Stochastic Environment

The above mathematical model contains many stochastic variables. These include interest rates, yields, prices, land values, and cash rents. This section describes the procedures used to define the stochastic environment. The real interest rate is assumed to follow a stochastic process that is independent of all other prices. Interest rate follows a random walk process with the error term assumed to be distributed normally with a zero mean and standard deviation equal to .02 based on 1960 through 1985 data. The base real interest rate is assumed to be 4%.

Gallagher provides evidence that U.S. corn yields are negatively skewed with an upper limit on output and occasional low yields. Based on Gallagher's work, it is assumed that corn, soybean, and wheat yields have negatively skewed distributions. Crop yields were assumed to trend upward. Corn yield was expected to increase by one bushel per acre per year, while wheat and soybean yields were expected to increase by 0.5 bushel per acre. The stochastic nature of corn, soybean, and wheat yields are modeled assuming a lognormal distribution where yields are assumed to be correlated with each other based on data from 1960 through 1984.

Corn, soybeans, wheat, and hog direct production costs as well as tax rates, wages, consumption, machinery prices and hog facility prices are assumed to be nonstochastic for this study. Machinery complements chosen and further information on the model can be found in Featherstone.

Policy Environment

This section describes the policy environment and the modeling of variables affected by government farm programs. This study examines optimal capital structure under loan rates and target prices consistent with the 1985 programs. PC-WHEATSIM and FEEDSIM models (Holland and Sharples; Chattin, Hillberg, and Holland) were used to stochastically simulate corn, soybean, and wheat prices under the 1985 programs. These models were chosen because they are designed to perform stochastic simulations of alternative farm programs.

To facilitate input into the mathematical programming model, the results from PC-WHEATSIM and FEEDSIM were further transformed. For this study, it is assumed that the decision maker perceives corn, soybean and wheat prices to follow a stochastic process in which the price of corn is a sum of the previous years price, and a normally distributed zero-mean random error term. The data used to calculate the random error term were the data generated by FEEDSIM and PC-WHEATSIM. The beginning mean prices were assumed to be $2.52 per bushel for corn, $5.99 per bushel for soybeans, and $2.70 for wheat. The setaside requirements for corn was assumed to be 20% and the setaside requirements for wheat was assumed to be 30%. It was also assumed that acreage set aside increased average corn yield and wheat yield by 1.9% and 3.2%, respectively. The cost of maintaining a set aside acre was assumed to be $30 per acre.

Hog price is assumed to follow a similar stochastic process. Annual hog price is affected by the previous year's hog price, the previous years corn price, and a zero mean random error process. The beginning mean hog price was assumed to be $44 per cwt. The random errors of the corn price, soybean price, the wheat price, and the hog price equations are distributed multivariate normal with a mean of zero.

Agricultural policies are assumed to affect cash rent via the effect on crop prices and affect land values through cash rent (Featherstone and Baker). Equations for cash rent and land price were estimated using historical nominal returns, cash rent, and land values in Indiana from 1960 to 1984. Cash rent is a function of past cash rent and the residual returns to an acre of corn and soybeans grown in rotation. In the short-run, a one dollar change in the real returns to rotation corn and soybeans will raise real cash rent by 8.1 cents. In the long-run, a one dollar change in returns will increase cash rent by 60.3 cents.

The modeling of land price under alternative policies is based upon the familiar capitalization formula. Land price is a function of rent and lagged land prices. Land price exhibits cyclical behavior similar to that documented by Burt. In the short-run, a one dollar increase in cash rent is capitalized at the real rate of 16.8%. In the long run, a one dollar increase in rent is capitalized at the real rate of 5.7%.

The probability distributions specified above are continuous. However, discrete outcomes are necessary for the DSP model. A multivariate discrete approximation was made for the multivariate continuous probability space. The method used for this study divided the multivariate continuous probability space into regions. For each region, the probability of being in the region and the conditional means of the region were calculated using the numerical integration technique discussed in Kaylen and Preckel. The vector of conditional means in each region was then chosen as the discrete outcomes.

The farm model was chosen to be a four year model with 900 terminal nodes. The model has 4,262 constraints, 6,225 activities, and 900 nonlinear variables. Nine states of nature were chosen for the first year, 5 states for the second and third years and 4 states for the fourth year.

Average Land versus Marginal Land

Time series data on average land crop yields and marginal land crop yields are difficult to find. For this study, it was assumed that yields on marginal land were 12.4 bushel less for corn, 3.8 bushel less for soybeans, and 5.4 bushel less for wheat. Statistics on mean yields, the standard deviation of yields, and the coefficient of yields for corn and soybeans are located in table 1. The coefficient of yield variation for corn and soybeans is larger on marginal land than on average land.

Equilibrium land price and cash rent were determined using the land and cash rent models in Featherstone and Baker. Land prices and cash rents were set to equilibrium values to prevent land price dynamics from affecting the "steady state" solution. Land prices and cash rent distribution statistics can be found in table 2. Cash rents and land prices have a slight upward trend due to the upward trend in yields.

Without adjusting the equations estimated by Featherstone and Baker, the mean rate of return on assets is not larger for the riskier land (table 3). Thus we are in a situation which would suggest the results hypothesized by Gabriel and Baker and Collins (1985b). The mean is lower and the standard deviation is higher for the rate of return to assets on land.

Results

The farm level effects of the purchase of a cornbelt farm on marginal land and average land is examined for four different risk aversion coefficients. The Pratt-Arrow relative risk aversion coefficients range from .005 which is close to the profit maximizing solution to 17.5 which is a fairly risk averse individual. The range is based on McCarl's suggestion that the absolute risk aversion coefficient should fall between 0 and 10 divided by the standard error of income. The farmer was assumed to have $750,000 of initial equity. External credit rationing is assumed to occur at a debt to asset ratio of 50%.

The expected terminal net worth, the standard deviation of terminal wealth, the coefficient of variation of terminal wealth, and the certainty equivalent of terminal wealth are found in table 4. Under both land types, the terminal wealth, the certainty equivalent of ending terminal wealth, the standard deviation of terminal wealth, and the coefficient of variation of terminal wealth is expected to decrease as the risk aversion level increases. The mean, standard deviation, and certainty equivalent of terminal wealth is larger if the farmer is on average land than if the farmer is on marginal land, although not by a large amount. The coefficient of variation of terminal wealth is also lower on the marginal farm than on the average farm in three of the four cases examined. Thus, even though the rate of return on assets is more risky for the cropping enterprises on the marginal land farm, the individual chooses to organize the portfolio to make the riskiness of equity smaller in most cases.

As would be expected based on the rate of return to assets, leverage on the average land farm is higher than or equal to leverage on the marginal land farm for the same Pratt-Arrow relative risk aversion coefficient (table 5). The leverage ratio is the same regardless of land quality for highly risk averse ($\Theta = 17.5$) farmers. Farmers with other risk aversion coefficients have substantially less debt on a farm with marginal land quality than on the land on average land quality.

Table 5 also contains an estimate of the average return on equity that could be expected over the four year period and the marginal rate of return on equity. Both rates of return are in unit of certainty equivalents per dollar of equity invested. The average rate of return is found by dividing the ending certainty equivalent by the initial wealth, taking the fourth root and subtracting one from the result. The marginal rate of return on equity is found by taking the shadow price on another dollar of initial wealth, converting into units of certainty equivalent using the method discussed in Featherstone, Preckel, and Baker, and then converting this amount into an annual rate.

The average and the marginal rate of return to equity is larger for a farmer farming on average land than on marginal land (table 5). The marginal rate of return is slightly higher for a slightly risk averse farmer than a risk neutral farmer for a farmer on average land. If the farmer is more than slightly risk averse, the marginal value of another dollar of equity is less. A farmer that is strongly risk averse ($\Theta = 17.5$) has a certainty equivalent rate of return greater than the average cost of debt. However, the debt adds enough risk so that the farmer, even though the assets are earning more than the cost of debt is unwilling to borrow money. In fact, the farmer on marginal land does not fully invest all of his equity in the farming operation, but invests $66,300 off the farm at a rate of return 2% below the cost of debt.

Table 6 contains information on the asset mix of the farmer. All farmers will have more owned land if the quality is average than if the quality is marginal. The farmer on marginal land specializes in hogs. In fact, the farmer invests so heavily in hogs, that a labor constraint is limiting before all the debt is borrowed by the nearly risk neutral farmers. Although no wheat is raised, wheat is more attractive to risk averse farmers. In fact if yield would increase by one bushel per acre, a moderately risk averse (θ = 3.75) farmer on marginal land would raise wheat.

Conclusions

The purpose of this paper was to examine the effect of land quality on the organization of the farm. If the market does not fully compensate farmers who take additional risk when farming marginal land, a farmer farming marginal land will have much less debt and will likely be much more diversified. However, financial theory would suggest that the additional risk should be compensated. Given the casual evidence from Illinois and Iowa, this appears to be the case. Thus, there is a need to further investigate the premium that the land market pays for land of different quality as this will likely have a dramatic effect on the optimal capital structure of the farm firm.

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Table 1. Corn and Soybean Yield Distribution Statistics on Average and Marginal Land.

Year	Corn Yield mean	Corn Yield std. dev.	Corn Yield C.V.[a]	Soybean Yield mean	Soybean Yield std. dev.	Soybean Yield C.V.[a]
	bu/ac	bu/ac	%	bu/ac	bu/ac	%
---average land---						
1	123.7	8.8	7.1	38.2	3.0	7.8
2	123.2	11.4	9.2	38.6	3.2	8.4
3	121.8	10.6	8.7	38.2	2.7	7.2
4	126.6	14.2	11.2	41.3	2.6	6.2
---marginal land---						
1	111.1	8.8	7.9	34.4	3.0	8.7
2	110.6	11.4	10.3	34.8	3.2	9.2
3	109.1	10.6	9.7	34.4	2.7	7.8
4	113.9	14.2	12.5	37.5	2.6	6.9

[a] Coefficient of variation.

Table 2. Cash Rent and Land Price Distribution Statistics on Average and Marginal Land.

Year	Cash Rent mean	Cash Rent std. deviation	Land Price mean	Land Price std. deviation
	$/acre	$/acre	$/acre	$/acre
---average land---				
1	62.84	3.34	972	20
2	64.06	6.40	992	57
3	65.25	9.30	1013	107
4	67.64	12.57	1042	165
---marginal land---				
1	49.93	3.10	748	18
2	50.73	5.89	765	52
3	51.52	8.48	781	88
4	53.54	11.45	803	151

Table 3. Mean and Standard Deviation Rate of Return on Assets Assumed in the Mathematical Programming Model

Year	Mean	Standard Deviation
	%	%
---average land---		
1	8.8	6.4
2	9.4	9.4
3	9.2	10.3
4	11.0	11.3
---marginal land---		
1	8.0	7.7
2	8.3	11.2
3	7.7	12.1
4	9.8	13.4

Table 4. Mean, Standard Deviation, Coefficient of Variation, and Certainty Equivalent of Wealth in Four Years on a Farm with $750,000 of Initial Wealth.

Θ[a]	Mean	Standard Deviation	Coefficient of Variation	Certainty Equivalent
	thousands of dollars	thousands of dollars	percent	thousands of dollars
---average land---				
.005	1135	317	27.9	1134
.375	1134	278	24.5	1121
3.75	1113	229	20.6	1034
17.5	1052	177	16.8	913
---marginal land---				
.005	1107	275	24.8	1107
.375	1107	274	24.7	1094
3.75	1084	221	20.4	1010
17.5	1020	160	15.7	894

[a]Θ is the Pratt-Arrow relative risk aversion coefficient.

Table 5. Optimal Debt to Asset Ratio, Average Return or Equity, and Marginal Return on Equity for a Farm With $750,000 Initial Equity Farming Average and Marginal Land.

θ[a]	Debt to Asset Rate	Average Return on Equity	Marginal Return on Equity
	%	%[b]	%[b]
----------average land----------			
.005	50.0	10.9	7.9
.375	48.9	10.6	8.0
3.75	22.2	8.4	6.6
17.5	0.0	5.0	4.6
----------marginal land----------			
.005	46.3	10.2	7.9
.375	46.3	9.9	7.6
3.75	4.7	7.7	6.0
17.5	0.0	4.5	4.0

[a]θ is the Pratt-Arrow relative risk aversion coefficient.
[b]In units of certainty equivalents.

Table 6. Land Ownership, Crop Mix, and Sows Raised on a Farm with $750,000 Initial Wealth.

θ[a]	Land	Corn/ Soybeans	Wheat	Hogs	Cost for Raising Wheat
	acres	acres	acres	acres	$/acre[b]
----------average land----------					
.005	846	846	0	86	-20.13
.375	634	634	0	157	-19.84
3.75	366	366	0	121	-8.20
17.5	294	294	0	91	-16.38
----------marginal land----------					
.005	315	315	0	275	-40.61
.375	315	315	0	275	-14.30
3.75	287	287	0	120	-2.65
17.5	262	262	0	101	-11.77

[a]θ is the Pratt-Arrow relative risk aversion coefficient.
[b]Certainty equivalent dollars per acre.

Figure 1. Debt to Asset Ratios for Illinois and Iowa: December 31, 1969 to December 31, 1987

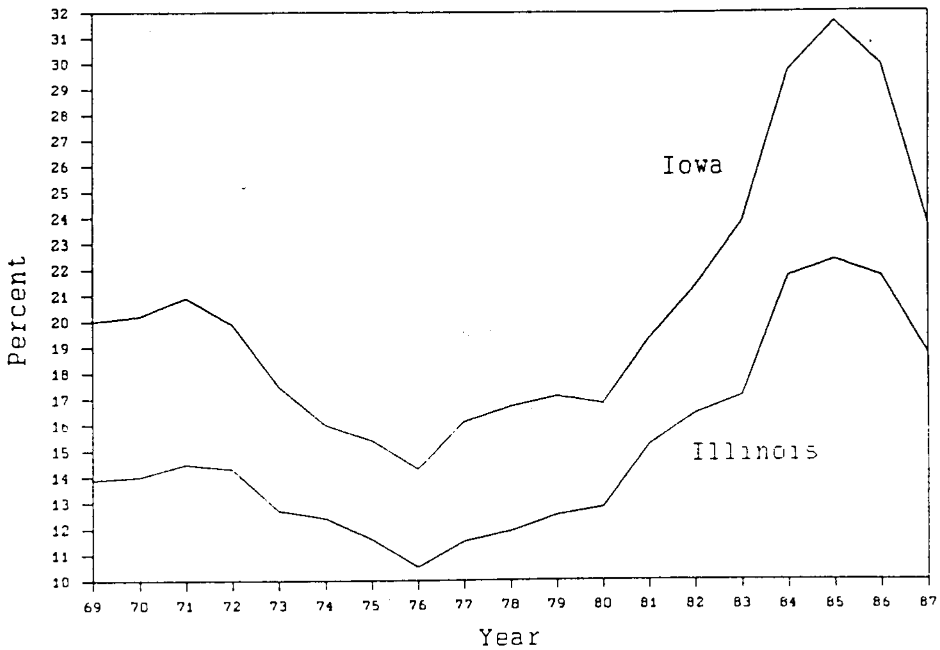

Figure 2. Rate of Return to Assets for Illinois and Iowa, 1976 through 1987