Loan refinancing decision model

by Patricia Pidruchney

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
Montana State University

Abstract:
This thesis investigates a refinancing policy which minimizes the expected future loan levels of borrowers. A dynamic programming model is used to determine the optimal refinancing decision for varying state values of loan level, nominal interest rate, and contract interest rate. The objective is to minimize the loan balance at the end of the planning period. Loan refinancing was determined to occur whenever the current nominal interest rate, plus the transaction cost of refinancing the loan is less than the borrower's current contract rate regardless of loan level. Future loan values were examined for selected loan levels and contract interest rates for five years. The probability of refinancing in the first five years was about five percent.

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APPROVAL

of a thesis submitted by

Patricia Pidruchney

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Signature Patricia Pidruchney

Date May 25, 1984

This thesis is dedicated in honour of my parents, John and Elsie.

VITA

Patricia Pidruchney, the youngest child of John and Elsie Pidruchney, was born on March 9, 1956 in Myrnam, Alberta, Canada. She has three sisters and one brother. Patricia was raised on her family's mixed farm located ten miles southeast of the village of Myrnam.

Patricia received her elementary and secondary education in Myrnam and graduated from Myrnam High School in the spring of 1974. She enrolled at the University of Alberta in Edmonton the following autumn and received her Bachelor of Science degree in Agriculture (with distinction) in the spring of 1978. She accepted employment with Cargill Grain Company, Ltd. of Canada as an assistant elevator manager at Vermilion, Alberta, and continued farming with her father. Patricia worked for Cargill until the fall of 1979, at which time she was employed by Lakeland College in Vermilion as an instructor in Agricultural Economics.

In the fall of 1982 Patricia was granted a sabbatical leave from Lakeland College to enroll in the graduate program at Montana State University. She received her Master of Science degree in Applied Economics from Montana State University in the spring of 1984.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This thesis investigates a refinancing policy which minimizes the expected future loan levels of borrowers. A dynamic programming model is used to determine the optimal refinancing decision for varying state values of loan level, nominal interest rate, and contract interest rate. The objective is to minimize the loan balance at the end of the planning period. Loan refinancing was determined to occur whenever the current nominal interest rate, plus the transaction cost of refinancing the loan is less than the borrower's current contract rate regardless of loan level. Future loan values were examined for selected loan levels and contract interest rates for five years. The probability of refinancing in the first five years was about five percent.

CHAPTER 1

INTRODUCTION

In recent years, farmers have faced relatively low real income resulting in declining real equity as well as high nominal interest rates. Consequently, debt capacity has become of increased concern to agricultural lenders and borrowers. Many highly leveraged farms are experiencing cash flow problems and are financially vulnerable.

Interest expenses have grown to about 15 percent of total production expenses, up from about 7 percent in 1973 (U.S.D.A., 1982). Interest expense may be reduced by either reducing the debt level or obtaining a lower interest rate. Reduction of debt may be only possible by liquidation or reorganization. Interest rate reduction may be obtained by financing from alternative lenders or refinancing from the same lenders if interest rates are below the current contract.

If the borrower refinances to take advantage of lower interest rates, the borrower may have to pay an origination fee (all charges resulting from originating a loan). The borrower can choose between obtaining the lower interest rate and paying the origination fee or maintaining the current loan and contractual interest rate. The decision of the borrower will depend upon his/her objectives. Possible objectives are maximizing the present value of the firm and minimizing the level of the loan at the end of a specified planning period. This study is concerned with the repayment capacity of the farm. Therefore, the primary objective is to develop a refinancing decision rule which minimizes the loan balance at the end of a specified planning period. The decision of the borrower also depends on the situation of the borrowers. Variables describing the situation of the borrowers (state variables) which are hypothesized to influence the refinancing decision are the current contractual interest rate, the current obtainable alternative interest rate, the origination fee, income, and income taxes.

Dynamic programming (DP), a method commonly used to optimize a multistage process is used to obtain the optimum refinancing decision rule.

Chapter 2 is a review of literature concerning fluctuating farmland equity and cash flow responses, the roles of inflation, interest rates, marginal tax rates and previous applications of dynamic programming. In Chapter 3, the theory, the model and its assumptions, and the maintained hypothesis are developed. The decision model results and analysis are presented in Chapter 4. Chapter 5 summarizes the model findings, its shortcomings and conclusions of the study.

CHAPTER 2

LITERATURE REVIEW

Recent research on farm debt capacity has focused on relationship between asset values, income, inflation and interest rates. This chapter reviews literature on (1) the debt capacity of the firm, (2) the relationship between inflation and interest rates, and (3) the applicability of dynamic programming to developing an optimum refinancing decision rule.

Debt Capacity

Generating sufficient income for debt servicing and collateral are critical to the borrower's ability to secure a loan. Collateral is related to the value of the firm's asset. Under static conditions the expected equilibrium relationship between asset value and income is:

$$V = \frac{Y}{r(1-T)-f} \qquad (1)$$

where V = imputed value of the asset

y = after tax income

r = discount rate which may be represented by contract rates or nominal interest rates

T = marginal tax rate

f = rate of inflation in after-tax income

The effects of inflation on land price increases have been the focus of several studies. Higher land prices have value over the planning period because such increases add to the wealth position (equity) of the owner (Plaxico and Kletke, 1979). Melichar (1979) showed that asset appreciation, adjusted for inflation (real capital gains), roughly equaled changes in net farm income during the late 1970's. This is consistent with equation (1) if taxes are ignored. Melichar also demonstrates that, according to the asset pricing theory, a farm economy characterized by rapid growth in the real current return to assets will generally experience large annual real capital gains and a low rate of current returns to assets. Plaxico and Kletke (1979) also evaluate alternative methods of valuing the stream of unrealized capital gains. Kletke and Plaxico (1978) utilize a capital budgeting approach to analyze varying land purchase financing schemes.

Tweeten (1981) discusses farmland pricing and cash flow in an inflationary economy. He concludes that farmland is not overpriced and that the current rate of return on farmland, while invariant to the expected rate of inflation, causes increases in cash flow requirements to service debt. Robison and Brake (1980) demonstrate that accurately anticipated inflation creates liquidity or cash flow problems for farm firms as capital gains increase in relation to cash returns. They also illustrate that, if lenders extend credit on the basis of income available to debt servicing, inflation may indirectly reduce the firm's real rate of equity growth. The two recommendations developed from their study are: (1) to institute variable interest rates for long-term loans; and (2) to adopt increasing - rather than constant - loan repayment schedules to more accurately match borrowers' income streams with their loan repayments. Watts and Dunn (1983) have developed a similar model which incorporates taxes.

Inflation and Interest Rates

Many researchers have discussed the impact of inflation on agricultural finance. Of concern to agricultural economists during the last decade has been the impact of inflation on debt servicing capacity. However, as early as 1930, Fisher assumed that the cost of capital is invariant with inflation (Darby, 1978).

Lins and Duncan (1980) suggest that as farm credit markets become more closely linked to national financial markets, interest rates to farmers will more likely track financial market rates, thus suggesting an equilibrium analysis approach to capital investment in agriculture.[1] Robison (1980), Robison and Brake (1980), Lins and Duncan (1980), and Klinefelter, Penson and Fraser (1980) recognize that inflation has differing impacts over time on input and output prices received by farmers.[2] Consequently, they recommend shorter term loans and variable or renegotiable interest rates. LaDue (1980) agrees with this recommendation, but suggests that loan policies be indexed by inflation. White and Musser (1980) use a capital budgeting model which explicitly allows for differing inflationary impacts on the discount rate[3] and net returns to reaffirm that inflation reduces net present value of returns of depreciable assets.

Tweeten (1981) and Robison and Brake (1980) have presumed that the real rate of interest is the discount rate that represents: the market equilibrium between present versus future consumption; and rates of return on alternative, riskless investments in financial assets in a non-inflationary economy (Mansfield, 1979). Watts and Dunn (1983) concur with this interpretation of real rate of interest, and they further define the nominal discount rate to be the nominal interest rate, or opportunity cost rate. They prove that the value of the residual claimant (i.e., the farm) multiplied by the real rate of interest (which is approximately the nominal discount rate less expected the rate of inflation) is the debt level which can be serviced. However, they argue that this calculation is misleading because income inflation is incorporated into the valuation of the asset but not into the debt repayment capacity. Robison and Brake (1980) arrive at a similar conclusion.

Income taxes affect the cash available for debt repayment in that income generated by the investment is taxable and interest on the loan is tax deductible. Darby (1975) claims that the nominal interest rate must rise by 1/(1-t) basis points for each basis point increase in the expected rate of inflation, where t is the marginal income tax rate, in order that borrowers' and lenders' expected payments and receipts are unaffected in real terms. The real discount rate used in the calculation of the imputed value of an asset is, therefore, the nominal interest rate, adjusted for taxation less inflation. Feldstein (1976, 1983) concurs with Darby's findings and shows that the equilibrium associated with a given rate of money growth depends on the exact fiscal structure in the economy.

Gandolfi (1982) illustrates the equilibrium relationship between income tax rates, income, capital gains, inflation and interest rates.

He shows that the response of nominal interest rates to changes in inflationary expectations lies between that predicted by the Fisher and Darby-Feldstein effects[4] because (a) the effective tax on capital gains is less than on real income, and (b) investment and savings vary with the after-tax real rates. Carlson (1979) applied the Darby-Feldstein effect to a paper company and found that because of the imperfect capital investment market nominal interest rates oscillated between the Fisher and Darby-Feldstein effects. Atwood and Helmers (1983) compares after tax net payments amortized with constant real interest rates and constant nominal interest rates. Their conclusion that future loan payments should be increased is accurate, but taxation calculations are not endogenous to their model.

Neither Tweeten (1981) nor Robison and Brake (1980) incorporate the effect of income tax on cash flow, although Robison and Brake (1980) do recommend such an extension. As a result of that recommendation, this thesis incorporates the income tax rate structure, interest rates, and net farm cash income to derive a refinancing decision rule. The decision rule is developed by dynamic programming.

Dynamic Programming Models

Dynamic programming is a powerful analytic and computational method for calculating many multi-stage decision processes in farm management as well as in other disciplines. Burt and Allison (1963) define a multi-stage process as being characterized by the task of finding a sequence of decisions which maximizes - or minimizes - an appropriately defined objective function. Stages are time intervals into which the dynamic process is divided. Each stage is a point in the process at which a decision is or can be made. The state of the process describes the condition of the process at a particular stage. Decisions at a given stage may influence the state in which the process will be found in the following stage: the control may either be complete in which the future state is known with certainty (deterministic dynamic programming); or it may be incomplete, in which the probability distribution of the future state is affected by the current decision (stochastic dynamic programming).

The Markovian requirement of stochastic dynamic programming states that the optimal decision to be made at a particular stage of the process depends only on the state of the process at that stage and not on the state at any preceding stages (Hillier and Lieberman, 1980; and Burt and Allison, 1963). Howard (1960) associates the Markov process with two basic concepts: "state" of a system and "state transition." A system occupies a state when it is completely described by the values of variables that define the state. A system makes state transitions when its describing variables change from the values specified for one state to those specified for the state in the next stage. Hillier and Lieberman (1980) illustrate the recursive relationship that is fundamental to dynamic programming models with a transportation problem of minimizing distance. It is the recursive relationship that allows the solution procedure to move backward stage by stage, finding an optimal policy at each state of the stage, until an optimal policy is found when starting at the initial stage.

This thesis develops a decision rule which specifies whether or not a borrower should refinance under a variety of conditions (states). The pertinent state variables are current loan levels, contract rates and interest rates, and the loan origination fee.

FOOTNOTES

[1]Establishing a relationship between capital and the independent variables; inflation, taxation, and interest rates.

[2]Lins and Duncan (1980) quoted Samuelson who said: "The problem with inflation is not so much price increases, but rather the inefficiencies caused by changes in relative prices."

[3]Discount rate is the time preference rate in accordance to the Separation Theorem (Mansfield, 1979).

[4]Fisher effect is defined by Darby (1975) as: nominal interest rate will exceed real interest rate by the expected rate of inflation. There is no tax argument in the Fisher effect.

CHAPTER 3

THEORETICAL DEVELOPMENT, MODEL FORMULATION, AND MAINTAINED HYPOTHESIS

Profit maximization is a commonly assumed objective in farm management research. However, if a farm operator secures a substantial loan to acquire land at a fixed contract rate, the lender may be concerned about the borrower's loan repayment capacity and the length of time required to pay off the loan. Consequently, the farm operator may select an alternative objective function of minimizing the loan balance at the end of the planning period, thereby reducing his credit risk as a borrower. Refinancing the loan to take advantage of lower interest rates may hasten repayment. However, refinancing may result in an origination fee. The formulation of the dynamic programming model is discussed in this chapter.

Refinancing Decision Model

Dynamic programming is used to develop an optimal refinancing decision rule. The optimal multi-stage decision process is characterized by a sequence of refinancing decisions which minimizes the loan level at some future time. The process is divided into time intervals or stages of one year. The decision to refinance is made at the beginning of each stage. The state of the process, at a particular stage, describes the condition of the process, and is defined by the values of the state variables: loan level, contract interest rates, and nominal interest rates. The decision made at a given stage influences the state in which the process will be found in the following stage or state transition. The transition for the state variable - loan levels - is deterministic. The increments of loan levels for a stage are fixed and remain constant throughout all subsequent stages. Eleven determinate contract rates are used for each of the stages. The same eleven values are used for nominal interest rates, but this state is stochastic - that is, a probability distribution is used to determine the state in the next stage. Hillier and Lieberman (1980) point out that the probability distribution associated with future states is a function of the current state and/or policy alternative at the current stage. The optimal policy developed is the sequence of refinancing decisions made at each stage for all possible combinations of states and stages.

Principle of Optimality

The principle of optimality justifies the linkage of the n stage decision process to the n-1 stage process. If immediate returns from each decision in the current state and stage and the optimal returns from each possible state in the next stage are known, then an optimal decision can be made at the current state and stage. Therefore, a subsequent decision of the policy is optimal at every stage with respect to the previous stage. The process is continued by recursively considering previous stages. The decision made would be a maximized total of: (a) the immediate return, and (b) the optimal return from the subsequent stage process starting in the current state.

The principal of optimality states that this process yields an optimum. To quote Bellman (1962), "An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision."

Relationship of Time and Stages in Dynamic Programming

In DP, chronological time is conventionally represented by movement from left to right. Stages are incremented from right to left. As illustrated in Figure 1, increments of stages are represented in descending order of time.

Time (t)	1	2	3	4	. . .	t-3	t-2	t-1	t	t+1
Stage (n)	n	n-1	n-2	n-3	. . .	4	3	2	1	0

Figure 1. Relationship of time and stages in dynamic programming.

General Recurrence Relation of Discrete Dynamic Programming

The standard recurrence relation of DP is:

$$V_n(i) = \text{Min}[q_n^k(i) + \sum_{j=1}^{M} P_n^k(i,j)V_{n-1}(j)] \quad (2)$$

$i = 1, 2, \ldots, M(n)$

$n = 1, 2, \ldots$

$V_j(0) = a_j \qquad j = 1, 2, \ldots, M$

Solution of this relation will yield an optimal policy where:

$V_n(i)$ = the total value of a n stage process beginning in state i under an optimal policy.

k = the set of decision alternatives.

$q_n^k(i)$ = the expected immediate cost given the i^{th} state, k^{th} decision alternative, and the n^{th} stage of the process.

$P_n^k(i,j)$ = the transition probability for being in the j^{th} state in stage n-1, given the process is in the i^{th} state and the k^{th} decision is made in stage n of the process. The transition matrix is a square matrix with non-negative entries such that the sum of the entries in each row is one (Howard, 1960).

$V_0(j)$ = a_j = the terminal values or the value at the end of the process.

$V_{n-1}(j)$ = the total value of an n-1 stage process where an optimal policy is used and the initial state of the process is j.

Recurrence Relation Used in Refinancing Decision Model

The recurrence relation used in the refinancing decision model was:

$$V_n(L_{n,}\rho,i) = \min_k \left[\sum_{j=1}^{J} P_n^k(i,j)\ V_{n-1}(L_{n-1},\rho,i\right] \quad (3)$$

or $$V_n(L_{n,}\rho,i) = \min_k E[V_{g,h,j}(n-1)] \quad (4)$$

$L,\rho,i = 1, 2, \ldots, M(n)$

$n = 1, 2, \ldots$

$V_0(j) = a_j \qquad j = 1, 2, \ldots, M$

$k = 1, 2$

where:

$V_n(L_n, \rho, i)$ = expected loan balance at the end of n stage where an optimal refinancing policy is used and the initial states of the process are L, ρ, and i.

k = the two decision alternatives, to keep the contract interest rate or to refinance the loan at current interest rates.

$P_n^k(i,j)$ = transition probability of nominal interest rates being in the j^{th} state, in stage n-1 given the process is in the i^{th} state and the k^{th} decision is made in stage n of the process.

$V_0(L_n, \rho, i)$ = aj = the terminal or ending loan balances of the decision process.

$V_{n-1}(L_{n-1}, \rho, i)$ = the total expected loan balance after n-1 stage where an optimal refinancing policy is used and the initial states of the process are L, ρ, and i.

Description of Variables

The three state variables are loan level (L), contractual interest rates (ρ), and current interest rates (i). Discrete levels of states were used to calculate future expected loan balances. Seven loan intervals incremented at $37.50 were chosen with a maximum loan level of $225/ac. This level was sufficiently higher than the average farm dryland real estate value for Montana of $152 (U.S.D.A., 1983).

The eleven nominal interest rates used were midpoints of intervals calculated from a statistical analysis of FLB interest rates. The sample data used included the years 1950 through 1982. The FLB interest rate ranged from 4.11 percent to 11.5 percent.

The contract rates used in the program are the same as those used for the nominal interest rates.

Only two decision alternatives exist in the program: to keep the contract interest rate; or to refinance to a different contract rate, using the current nominal interest rate and a penalty transaction cost of refinancing. The transformation function for keeping the contract rate has the form:

$$V_{n-1} = (1+\rho)L_n - Y \qquad (5)$$

where:

ρ = the contract interest rate.

L_n = loan level at stage n.

Y = after tax income available to repay loan.

L_{n-1} = outstanding loan balance in the subsequent stage.

The transformation function for the second alternative - to refinance - is:

$$V_{n-1} = (1+i+c)\ L_n - Y \qquad (6)$$

where:

i = the nominal interest rates

c = transaction cost of refinancing the loan; assumed to be a percentage of the loan

$V_{n-1}(L_{n-1},\rho,i)$, where V_{n-1} is the expected loan balance in the subsequent period, may not be computed at stage n-1. L_{n-1} may not be equal to one of the predetermined levels for loan balance. When this occurs, the value used for $V_{n-1}(L_{n-1},\rho,r)$ is an interpolation between V_{n-1} associated with adjacent loan levels similar to the functional equation approach used by Bellman and Dreyfuss (1962).

Stage 1 interpolation is unnecessary because the outstanding loan balances are deterministic: the borrower only has one year left in his repayment period and therefore knows what his contract rates are at the beginning of this time period. Stages 2 through n require the usage of linear interpolation in order for the DP process to more accurately approximate V_{n-1}. The recursive equation in Stage 2 is:

$$V_n(L_n,\rho,i) = \min_k E[V_{n-1}(L_{n-1},\rho,i)] \tag{7}$$

where the expected values (future loan balances) for a given loan level, contract rate, and nominal interest rate are compared to determine whether or not the borrower should refinance. The interpolation function used to estimate V_n for the state L is:

$$V_n(L_n,\rho,i) = [\frac{L_1-L}{L^u-1}]\ [V_{n-1}(L^u_{n-1},\rho,i] - V_{n-1}(L^1_{n-1},\rho,i] + V_{n-1}(L^1_{n-1},\rho,i) \tag{8}$$

where:

L_1 = loan balance calculated in stage 1 using the transformation function specific to the decision alternative.

L^1_{n-1} = lower adjacent loan level in stage n-1.

L^u_{n-1} = lower adjacent loan level in stage n-1.

The decision rule can be anticipated by inspecting the two transformation functions:

$$V_1 = \min_{k=2} \begin{Bmatrix} (1+\rho)\ V_0 - Y \\ (1+i+c)\ V_0 - Y \end{Bmatrix} \tag{9}$$

where $V_0 = L_0$ = original loan level and, because Y is a constant, it can be factored out to yield

$$V_1 = -Y + \min_{k=2} \begin{Bmatrix} (1+\rho)\ V_0 \\ (1+i+c)\ V_0 \end{Bmatrix} \quad \text{or} \tag{10}$$

$$V_1 = -Y + \min_{k=2} \begin{Bmatrix} (1+\rho)\ L_0 \\ (1+i+c)\ L_0 \end{Bmatrix} \tag{11}$$

The minimum of ρ or $(i + c)$ will be selected to choose the optimum of V_n, the future expected loan values. Therefore, the optimal policy may result in the decision rule to refinance only if nominal interest rate plus refinancing charge is less than the current contract rate.

Because the nominal interest rate is the stochastic state, a probability distribution of nominal interest rates is developed using a time series analysis. The transition probability matrix determines the probability of nominal interest rates being in the j^{th} state in stage n-1, given the process is in the i^{th} state and in stage n. The data used to represent nominal interest rates to develop the transition probability matrix are average annual Federal Land Bank rates (U.S.D.A., 1981).

Time Series Analysis of Nominal Interest Rates

Four autoregressive time series models for the nominal interest rates are statistically estimated. The variables are defined as:

FLB = Federal Land Bank interest rate in current time period

FLBL = FLB interest rate lagged one period

FLBLL = FLB interest rate lagged two periods

LFLB = log of FLB interest rate in current time period

LFLBL = log of FLB interest rate lagged one time period.

LFLBLL = log of FLB interest rate lagged two time periods.

Se = standard error of the estimate

e_{it} = error term for models where i = 1,2,3,4 and t represent current time period

α_i = intercept parameter where i = 1,2,3,4

β_i = estimated coefficient parameter where i = 1,2,3,4

Two hypothesis tests are performed on the estimated coefficient. The first test is $\beta = 0$. If $\beta = 0$, then interest rates are not serially correlated. The second hypothesis test is $\beta = 1$. If the value for this parameter is not significantly different from one, then a random walk may be an appropriate relationship of nominal interest rates. T-ratios are calculated for each hypothesis. The normality of the errors associated with each regression is checked with the chi-square test.

Model A - 29 Degrees of Freedom

$$FLB = \alpha_1 + \beta_1 \, FLBL + e_{it} \quad (12)$$

where:

$$
\begin{array}{llll}
FLB = & -.139 & + 1.0589\ FLBL & \\
 & (0.32) & (.048) & \text{standard errors} \\
 & (-.434) & (22.067) & \text{t-ratios (for hypothesis } \beta = 0) \\
 & (3.559) & (-1.227) & \text{t-ratios (for hypothesis } \beta = 1)
\end{array}
$$

and

$S_e = 0.477$

$\chi^2 = 6.1096$ (2 degrees of freedom)

$\bar{R}^2 = .9449$

Durbin-Watson = 1.3537

The normality of the error structure is unacceptable since the goodness of fit or chi-square was rejected at the 95% confidence level. For a one-tail test with $\alpha = 0.05$ and 29 degrees of freedom, the t value is 1.669. The hypothesis $\beta = 0$ is rejected since the computed $t = 22.067$; however, $\beta = 1$ is not rejected since the calculated t is 1.227. Model B is a logged version of Model A.

Model B - 29 Degrees of Freedom

$$LFLB = \alpha_2 + \beta_2\ LFLBL + e_{2t} \tag{13}$$

where:

$$
\begin{array}{llll}
LFLB = & 0.011 & + 1.0124\ LFLBL & \\
 & (.076) & (.0414) & \text{standard error} \\
 & (.144) & (24.45) & \text{t-ratios (for hypothesis } \beta = 0) \\
 & (13.01) & (0.2995) & \text{t-ratios (for hypothesis } \beta = 1)
\end{array}
$$

and

$S_e = .0646$

$\chi^2 = 1.3926$ (2 d.f.)

$\bar{R}^2 = .9522$

Durbin-Watson = 1.5494

The chi-square in the model is accepted at the 50% confidence level. However, the estimated coefficient, β, in both log and linear forms is insignificant from one; therefore, the hypothesis that the estimated coefficient behaved as a random walk is not rejected. Although an estimated coefficient greater than 1 is unstable, the estimated coefficient in the above model is not significantly different from one. The Durbin-Watson statistic in this model is also greater than the Durbin-Watson statistic in Model A. The hypothesis of zero autocorrelation is accepted in this model, whereas it is inconclusive in Model A. Therefore, this model does not reject a random walk time path followed by nominal interest rates.

Second order autoregressive models were also investigated. Model C is a second order linear autoregressive model and Model D is a second order log autoregressive model.

Model C - 27 Degrees of Freedom

$$FLB = f(FLBL, FLBLL)$$

$$FLB = \alpha_3 + \beta_3\ FLBL + \beta_4\ FLBLL + e_{3t} \qquad (14)$$

$$FLB = 1.786 + 1.3855\ FLBL - 2.2432\ FLBLL$$

(1.043)	(.1772)	(1.165)	standard error
(1.712)	(7.820)	(-1.926)	t-ratios (hypothesis β = 0)

where:

$S_e = .4637$

$\chi^2 = 3.2479$ (1 d.f.)

$\bar{R}^2 = .9438$

Durbin-Watson = 1.6034

The computed t at $\alpha = .05$ equals 1.703 . Because the t-ratios for $\beta = 0$ are not significant at a 95% confidence level, but significant at a 90% confidence level, the hypothesis that nominal interest rates follow a random walk model is maintained. The chi-square, rejected at the 95% confidence level, is less acceptable than Model A's error distribution. The sum of the coefficients equal -0.858, which indicates a stable relationship. Model D is a logged transformation of Model C.

Model D - 27 Degrees of Freedom

LFLB = f(LFLBL, LFLBLL)

$$LFLB = \alpha_4 + \beta_5 \text{ LFLBL} + \beta_6 \text{ LFLBLL} + e_{4t} \qquad (15)$$

LFLB = .0383 +	1.326 LFLBL +	-.3339 LFLBLL	
(.0788)	(.1853)	(.1897)	standard error
(.4865)	(7.1547)	(-1.760)	t-ratios (hypothesis $\beta = 0$)

where:

Se = .0633

$X^2 = 2.246$ (1 d.f.)

$\bar{R}^2 = .952$

Durbin-Watson = 1.8109

The chi square is less acceptable than Model B's error distribution. Since there is no substantial change in $\bar{R}^2$ between Model A and Model C, and Model B and Model D, it is inferred that the second order lag does not substantially contribute to the explanation of the estimated coefficient. Thus, Model B was selected.

To develop the transition probability, the sample nominal interest rates were analyzed for normality. The time series models resulted in an error distribution that was more acceptable in the logged format than in the linear model. The logged interest rates ranged from 1.4134-2.4423. The logged intervals of an arbitrarily chosen 0.1 width establish the eleven transition states. The midpoints of these intervals are then transformed into the antilog format to represent the different categories of transition probabilities. A cumulative probabilities table of the standard normal distribution is used to calculate the probabilities for the transition matrix. Probability values are calculated by taking the difference of the interval values and their respective means and dividing by the standard error of Model B.

The resultant transition matrix formed using the logged form of interest rates is presented in Table 1 and the antilog format is presented in Table 2.

Determination of Available Cash Flow

The values used for the original loan level are based on a realistic range of current farm real estate values. Cash available to reduce the outstanding principal is determined from a farm budget. A farm budget was developed for a representative dryland wheat farmer in Chouteau County, Montana. The farm consists of 2000 acres in a 50-50 crop-fallow rotation.

Machinery complements consist of:

- one 175 HP 4 WD tractor
- one 37 ft. toolbar
- one 37 ft. spring tooth harrow
- one 32 ft. grain drill
- one 21 ft. tandem disk
- one 37 ft. rodweeder (attachment to toolbar)
- one 20 ft. (header) combine (140 HP); diesel
- one 8 inch x 27 ft. grain auger

Table 1. Transition probability matrix (log linear transformation).

LFLB interest rate intervals jth state / midpoint	LFLB interest rate intervals 1.4-1.5 / 1.45	1.5-1.6 / 1.55	1.6-1.7 / 1.65	1.7-1.8 / 1.75	1.8-1.9 / 1.85	1.9-2.0 / 1.95	2.0-2.1 / 2.05	2.1-2.2 / 2.15	2.2-2.3 / 2.25	2.3-2.4 / 2.35	2.4-2.5 / 2.45
ith state / midpoint											
1.4-1.5 / 1.45	.78	.22	0	0	0	0	0	0	0	0	0
1.5-1.6 / 1.55	.22	.56	.22	0	0	0	0	0	0	0	0
1.6-1.7 / 1.65	0	.22	.56	.22	0	0	0	0	0	0	0
1.7-1.8 / 1.75	0	0	.22	.56	.22	0	0	0	0	0	0
1.8-1.9 / 1.85	0	0	0	.22	.56	.22	0	0	0	0	0
1.9-2.0 / 1.95	0	0	0	0	.22	.56	.22	0	0	0	0
2.0-2.1 / 2.05	0	0	0	0	0	.22	.56	.22	0	0	0
2.1-2.2 / 2.15	0	0	0	0	0	0	.22	.56	.22	0	0
2.2-2.3 / 2.25	0	0	0	0	0	0	0	.22	.56	.22	0
2.3-2.4 / 2.35	0	0	0	0	0	0	0	0	.22	.56	.22
2.4-2.5 / 2.45	0	0	0	0	0	0	0	0	0	.22	.78

Table 2. Transition probability matrix (antilog format).

FLB interest rate intervals jth state midpoint	4.06-4.48 4.26	4.49-4.95 4.71	4.96-5.47 5.21	5.48-6.05 5.75	6.06-6.69 6.36	6.70-7.39 7.03	7.40-8.17 7.77	8.18-9.02 8.58	9.03-9.97 9.49	9.98-11.02 10.49	11.03-12.18 11.59
ith state midpoint											
4.06-4.48 4.26	.78	.22	0	0	0	0	0	0	0	0	0
4.49-4.95 4.71	.22	.56	.22	0	0	0	0	0	0	0	0
4.96-5.47 5.21	0	.22	.56	.22	0	0	0	0	0	0	0
5.48-6.05 5.75	0	0	.22	.56	.22	0	0	0	0	0	0
6.06-6.69 6.36	0	0	0	.22	.56	.22	0	0	0	0	0
6.70-7.39 6.36	0	0	0	0	.22	.56	.22	0	0	0	0
7.40-8.17 7.77	0	0	0	0	0	.22	.56	.22	0	0	0
8.18-9.02 8.58	0	0	0	0	0	0	.22	.56	.22	0	0
9.03-9.97 9.49	0	0	0	0	0	0	0	.22	.56	.22	0
9.98-11.02 10.49	0	0	0	0	0	0	0	0	.22	.56	.22
11.03-12.18 11.59	0	0	0	0	0	0	0	0	0	.22	.78

- one 2-ton, single axle, farm truck with box and hoist
- one second 2-ton, single axle, farm truck with box and hoist
- one 3/4-ton pick-up truck

The cost to operate the farm on a per acre basis for 1982 (Fogle, 1982a, 1982b) is presented in Table 3. Calculation of variable and fixed costs for machinery are compiled in Table 4. Depreciation is used as a sinking fund for replacement of machinery.

Table 5 presents the gross and net income estimation for 1982. An average yield is used, and the price per bushel is an average of 1982 inflated values (Montana Agricultural Statistics, 1976-1977, 1978-1979, 1980-1981). The inflator used is the implicit price deflator for gross national product (Economic Report of the President, 1983). This index is used because it is a general measure based upon a cross section of the entire economy based upon production inputs and consumptive items.

The cash available for repayment of the loan is assumed to be the net income. Hence the total cash available for repayment of the loan by the representative farmer is $22,790 in 1982. No deductions are made for living expenses, labor, or opportunity cost of investment. However, the estimated cash available for repayment is adjusted for income taxes.

Table 3. Total costs of a farm operation for 1982 (per 2 acres).

Variable Costs		
Fertilizer		$7.10
Agriculture chemicals		4.45
Seed		3.82
Machinery repairs		
Trucks		4.14
Tractor and combine		6.81
Other machinery		4.21
Fuel and lubrication		8.70
Miscellaneous (farm and motor supplies)		4.67
	Subtotal	$43.90
Fixed Costs		
Depreciation and THI		
Trucks		11.46
Tractor and combine		16.27
Other machinery		6.83
Taxes		3.27
	Subtotal	$37.83
	TOTAL	$81.73

Table 4. Machinery fixed and variables costs (per 2 acres).

Machine	Purchase price (1982)	Midvalue Purchase price - salvage value / 2	Years to trade	Hours of use	Depreciation $ per 2 acres	THI Taxes Housing Insurance	Repair cost $ per 2 acres	Fuel and lubrication $ per 2 acres	Total cost $ per 2 acres
Tractor	73900	26035	10	472	5.21	1.50	1.82	3.41	11.94
Toolbar	15550	6400	10	280	1.38	.25	2.02	--	3.65
Spring tooth harrow	2050	843	10	55	.17	.03	.03	--	.23
Grain drill	25650	10557	8	83	2.48	.77	1.40	--	4.65
Tandem disk	13075	5381	10	109	1.07	.19	.53		1.79
Rodweeder	2375	978	10	111	.19	.03	.10	--	.32
Combine	77800	29531	8	222	7.38	2.18	4.99	2.11	16.66
Grain auger	2700	1079	10	70	.23	.04	.13	.08	.48
2-ton truck	26400	10220	8	200	2.56	1.88	1.94	1.22	7.60
Second grain truck	26400	10220	8	200	2.56	1.88	1.29	.92	6.65
Pickup truck	12000	4645	8	500	1.90	.68	.91	.96	3.16
Totals	266,130	105,889	--	--	25.13	9.43	15.16	8.70	58.42

Sources: Fogle, Vernon F. "The Costs of Owning and Operating Farm Machinery in Montana: 1982 Update." Bulletin 1257 (Revised) Cooperative Extension Service, Montana State University, Bozeman, and Montana Wheat Research and Marketing Committee. September 1982.

United States Department of Agriculture. "FEDS Budget." Economics Research Service. Department of Agricultural Economics. Oklahoma State University, Stillwater, Oklahoma. May 1983.

Table 5. Net income of the farm operation for 1982 (per 2 acres).

Calculation of gross income				
Column 1	Column 2	Column 3	Column 4	Column 5[1]
Year	Yield	Nominal price/bu	Deflator (Year) / Deflator 1982	1982 price/bu
1976	34.0	2.32	.639	3.63
1977	33.0	2.30	.676	3.40
1978	34.0	2.73	.726	3.76
1979	26.8	3.60	.788	4.57
1980	25.4	3.90	.862	4.52
1981	39.7	3.65	.943	3.87
1982	32.15	--	1.000	3.96[2]

1982 gross income = (1982 yield) x (1982 price/bu)
= 32.15 x 3.96
= $127.31

1982 net income = 1982 gross income - 1982 total costs
= $127.31 - 81.73
= $45.58

[1]The values in Column 5 were calculated by dividing Column 2 into Column 3.

[2]The value 3.96 was calculated by taking an average of the previous six values in Column 5.

Income taxes are calculated by using Schedule Y of the 1982 Tax Rate Schedules which is presented in Table 6. No deductions are made for state income tax or self employment tax. Cash available for loan repayment is then reduced to a per acre basis.

Table 6. 1982 tax rate schedule: Married filing joint returns.

Net income level		Total tax due	
Over	But not over	Tax level +	Marginal tax rate
$0	$3400	0	0
3400	5500	-----	12%
5500	7600	$252	14%
7600	11900	546	16%
11900	16000	1234	19%
16000	20200	2013	22%
20200	24600	2937	25%
24600	29900	4037	29%
29900	35200	5574	33%
35200	45800	7323	39%
45800	60000	11457	44%
60000	85600	17705	49%
85600	----	30249	50%

Source: Internal Revenue Service. "U.S. Individual Income Tax Return." Form 1040, Department of the Treasury, 1982.

Original loan levels per acre are incremented from zero to $225 by $37.50. The total net income $22,790.00 of the farmer is assumed to be used for loan payment.

Computer Program for Refinancing Model

A BASIC program was built to solve the refinancing DP model. The program initially analyzes the loan balance associated with each state to determine the after tax cash available to repay the principal. This information was used in the DP model to develop the optimal refinancing policy. The output was formatted to list the following columns: stage number, loan level, contract rate, interest rate, outstanding loan balance if contract rate is maintained, outstanding loan balance if refinancing occurs, and optimal decision designated by 0 (not to refinance) and 1 (to refinance).

CHAPTER 4

RESULTS AND ANALYSIS

The DP model and the resultant optimal policy derived by the solution of this refinancing decision model are presented in this chapter. Probabilistic flowcharts were used to represent loan levels over time. Expected periods of refinancing were calculated using first passage time.

This program calculated the expected outstanding loan balances in fifteen stages (years) utilizing original loan balances of zero to $225 per acre at $37.50 increments under an optimal refinancing policy for all possible loan levels, contract interest rates and nominal interest rates.

The optimal policy obtained from the DP model was that a borrower would always refinance, regardless of loan level, so long as the sum of the nominal interest rate and the origination fee was less than his current contract rate. The optimal policy was inspected under a variety of conditions. The sensitivity analysis consisted of altering origination fee and decreasing loan increments and the value of the ending loan balances.

Changing the origination fee did not change optimal policy of refinancing when the current nominal interest rate plus origination fee is less than the contractual interest rate.

If nominal interest rates are less than contract rates, the present value of future payments is less than the current loan balance. The terminal loan values were adjusted by amortizing the terminal loan balance over fifteen years and discounting the payments by the nominal interest rate. The optimal policy, however, was unaffected by this modification.

It was then hypothesized that the grid or loan intervals were possibly too large to allow for refinancing. That is, the calculated remaining loan balances of that stage remained in the same loan intervals as in the previous stage. To examine this possibility, the model was rerun with loan levels of zero to $150/ac and intervals of $12.50. The bottom three interest rates, 4.26 percent, 4.71 percent and 5.21 percent were dropped since these rates were highly unlikely in consideration of current economic conditions. A charge of two percent of the loan balance was used as the origination fee. A reduction in increment level to $12.50 also did not alter the optimal refinancing decision policy.

The optimal decision rule is independent of taxes. Therefore, the sensitivity analysis did not include modifying the program to incorporate state income tax and self employment tax.

First passage times were calculated to determine the expected period of refinancing. The expected number of years measure the amount of time required for interest rates to drop 2% (the origination fee). The probability distribution of future loan levels were examined with the use of a probabilistic flowchart. This approach is a graphic tool for describing future loan levels of a borrower given the probabilities and decision rule or policy followed.

Probability Distribution of Future Loan Balances

A probabilistic flowchart depicts future possible interest rates. The borrower originates the loan with some specified contract interest rate. Associated with this contract rate is a probability distribution of future nominal interest rates. The probabilities of these nominal interest rates are determined from the previously developed transition probability matrix. Each new branching represents the movement into the next stage. Figure 2, in the appendix, illustrates the probabilistic flowchart for an initial loan level of $150, a contract rate of 10.49 percent and a nominal interest rate of also 10.49 percent for five stages. The probabilities of varying loan levels are summarized in Table 7. There are relatively fewer loan balance outcomes than may be expected because of convergence of identical contract and nominal interest rate levels.

The other scenario examined was the instance where the borrower has such a large initial loan level, he is initially unable to make any principal payments. Figure 3, in the appendix, illustrates the situation an original loan of $225, a 10.49 percent contract rate and the option to refinance at a two percent origination fee. The only time that the borrower can make principal payments is when he refinances. The probabilities of future loan levels are summarized in Table 8.

As can be observed from these two examples, the chances a borrower refinances from the upper level of contract rates is only 4.91% (sum

Table 7. Probabilities of future loan levels for an original loan level of $150 per acre and a contract rate of 10.49%.

	Stage 5		Stage 4		Stage 3		Stage 2		Stage 1	
	Proba-bility	Future loan level	Proba-bility	Future loan level	Proba-bility	Future loan level	Proba-bility	Future loan level	Proba-bility	Future loan level
	0.9581	110.68	0.9714	119.93	0.9894	128.43	1	136.24	1	143.42
	*0.0216	109.96	*0.0179	119.16	*0.0106	127.61				
	0.0178	107.17	0.0105	116.15						
	0.0105	103.97								
Sum of probabilities	1.008**		0.9985**		0.9999**		1		1	
Expected value of loan balance		111.41		119.85		128.42		136.24		143.42

* Refinancing occurred
** Error due to rounding

Table 8. Probabilities for future loan levels for an original loan level of $225 and a contract rate of 10.49%.

	Stage 5		Stage 4		Stage 3		Stage 2		Stage 1	
	Probability	Future loan level	Probability	Future loan level	Probability	Future loan level	Probability	Future loan level	Probability	Future loan level
	0.9581	226.82	0.9714	225.91	0.9894	225.91	1	225.90	1	225.81
	*0.0216	225.19	*0.0179	225.19	*0.0106	225.18				
	0.0178	220.14	0.0105	220.11						
	0.0105	214.70								
Sum of probabilities	1.008**		.9985**		0.9999**		1		1	
Expected value of loan balance		228.35		225.79		255.90		225.90		225.81

* Refinancing occurred

** Error due to rounding

probabilities denoted by one asterisk in Tables 7 or 8) in the first five years. To contrast future loan levels associated with fixed interest rates, a flexible interest rate example was developed. Figure 4, in the appendix, depicts the probabilistic flowchart for variable interest rates originating with a loan level of $150 and an interest rate of 10.49 percent. Because of the explosive nature of this specific probability branching, three stages are presented. Table 9 summarizes the repayment probabilities.

The probability distribution of nominal interest rates is symmetrical. Therefore, in the long run the expected loan values associated with contract rates will be lower than the associated expected loan values of variable interest rates. In comparing Tables 7 and 8 with 9, it can be observed that expected loan values are similar in each of the two lending schemes. The first option, the fixed contract rate with the refinancing charge, results in an expected loan value near the contract rate level since the probability of interest deviating sufficiently to merit refinancing is small. Hence when refinancing actually occurs, its beneficial effect of decreasing the loan balance is practically negligible. Thus, there is a likely occurrence of the borrower maintaining his contract rate. The second option, the variable interest rates, resulted in an expected loan balance which was near the midpoint of the maximum and minimum of occurrences of outstanding loan balances. Some error was due to rounding of probabilities. Even though the resultant loan balances are from the third stage, a more symmetric distribution of probabilities exist than in stage five of the fixed rate scenario.

Table 9. Probabilities of future loan levels for variable interest rates with an original loan level of $150 per acre and an interest rate of 10.49%.

	Stage 3			Stage 2			Stage 1		
	Probability	Loan balance	Expected Loan balance	Probability	Loan balance	Expected Loan balance	Probability	Loan balance	Expected Loan balance
	.1338	132.91	17.78	.1716	139.16	23.88	.22	144.84	31.86
	.0378	131.61	4.97	.0484	137.79	6.67	.56	143.42	80.32
	.0106	131.41	1.39	.1232	137.59	16.95	.22	142.14	31.27
	.0271	130.12	3.53	.3136	136.24	42.72			
	.0106	128.96	1.37	.1232	135.03	16.64			
	.0961	131.19	12.61	.0484	134.86	6.52			
	.0271	129.90	3.52	.1232	133.66	16.47			
	.0690	129.70	8.95	.0484	132.57	6.42			
	.1756	128.43	22.55						
	.0690	127.29	8.78						
	.0271	127.11	3.44						
	.0690	125.98	8.69						
	.0271	124.95	3.39						
	.0106	128.18	1.36						
	.0271	126.92	3.34						
	.0106	125.79	1.33						
	.0271	125.62	3.40						
	.0690	124.50	8.59						
	.0271	123.48	3.35						
	.0106	123.33	1.31						
	.0271	122.32	3.32						
	.0106	121.43	1.29						
Sum of probabilities	*.9997			1.00			1.00		
Sum of expected loan balances			128.26			135.97			143.45

* Error due to rounding.

First Passage Times

First passage time (Hillier and Lieberman, 1980) calculates the length of time it takes interest rates to drop low enough for refinancing to occur. The expected length of time or number of transitions to move from state i to state j are calculated. The expected first passage time was calculated for three different interest rates utilizing the modified transition probability matrix for eight nominal interest rates. The results are tabulated in Table 10, U_{ij} is used to represent the expected number of years or stages that will pass before the nominal interest rate or initial state represented by i; transits through to the j^{th} state. When j = i, the first passage time or recurrence time is the number of transitions until the process returns to the initial state i.

Column 1 features the number of stages that will be passed through before the first occurrence of a nominal interest equal to 7.03 percent. For example, if the interest rate is 11.59 percent, the expected time period for interest rates to decline to 7.03 percent is 74.4 years. Looking at column 2, a borrower will first encounter an interest rate of 8.58 percent in 27.55 years. If the borrower secures a loan at a contract rate of 9.49 percent, and wishes to refinance his loan under the optimal refinancing policy (with a two percent refinancing charge), he would not be able to refinance his loan to a 9.49 percent contract rate for an expected period of 12.66 years. If, in turn, he wishes to refinance a second time at an interest rate of 7.03 percent, he would have to wait an additional 59.78 years. Thus the borrower would wait an expected period of 73.45 years to refinance his loan twice.

Table 10. First passage times for selected interest rates.

Column 1		Column 2		Column 3	
u_{ij}	Years (stages)	u_{ij}	Years (stages)	u_{ij}	Years (stages)
u 5.75, 7.03	13.63	u 5.75, 8.58	45.45	u 5.75, 9.49	68.21
u 6.36, 7.03	9.09	u 6.36, 8.58	40.91	u 6.36, 9.49	63.67
u 7.03, 7.03	8.40	u 7.03, 8.58	31.82	u 7.03, 9.49	54.58
u 7.77, 7.03	24.54	u 7.77, 8.58	18.18	u 7.77, 9.49	40.94
u 8.58, 7.03	44.56	u 8.58, 8.58	8.02	u 8.58, 9.49	22.76
u 9.49, 7.03	59.78	u 9.49, 8.58	13.75	u 9.49, 9.49	7.79
u 10.49, 7.03	69.58	u 10.49, 8.58	22.96	u 10.49, 9.49	8.12
u 11.59, 7.03	74.40	u 11.59, 8.58	27.55	u 11.59, 9.49	12.66

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to develop an optimal refinancing decision rule to minimize the cost level of loans for farm operators who are financed or are considering financing. DP was used to develop this optimal policy. The objective of the model was to minimize the loan balance at the end of the specified planning period. The state variables were original loan levels, contract rates and variable nominal interest rates. A time series analysis of FLB internal rates indicated that nominal interest rates may follow a "random walk" time path. A transition probability matrix was developed and expected values of loan balances in future stages were calculated using an interpolation function. A farm budget was constructed for a representative Montana dryland wheat farmer to establish the amount of after tax cash available for loan repayment. The optimal policy was that a borrower would refinance, regardless of loan level, so long as the sum of the nominal interest rate and the transaction cost was less than his current contract rate. A sensitivity analysis was performed to test the stability of the optimal policy on the following parameters:

1. Alteration of the origination fee.
2. Discounting and amortizing outstanding terminal loan balances whenever the current contract rate was less than the nominal interest rate.

3. Deletion of three lowest interest rates and a reduction in the level of loan increments.

Lastly, a probabilistic flowchart was developed for five stages to develop a probability distribution of further loan levels. Since it is a common perception that if a farm can survive the initial years, it will likely survive in the future years. Also, calculations beyond five stages become cumbersome. Another flowchart was developed for three stages to contrast the difference in the probability distribution of future loan balances of fixed interest rates versus flexible interest rates. First passage time of interest rates calculated the expected time periods before refinancing.

Conclusions

The optimal refinancing policy developed was that a borrower will refinance whenever the current interest rates plus the refinancing charge are less than the borrower's present contract rate. The probability of refinancing during the first five years, assuming a two percent origination fee, is only 4.91%. The expected period for refinancing is lengthy. For example, the expected number of years for interest rates to decrease from 9.49% to 7.03% is 69.58 years.

The first passage times were calculated from a truncated transition probability matrix which was constructed for a specific time series. Consequently, some bias involving the upper interest rates will occur. However, the expected time before conditions are conducive to refinancing is quite long. The probability distributions of interest rates and lengthy first passage times indicates that borrowers will tend to retain their contract rate. Fixed contract rates lower risk to borrowers when nominal interest rates are increasing, but increase risk when nominal interest rates are decreasing. From the point of view of lenders, fixed contract rates are a higher risk when interest rates are climbing, but are appealing when interest rates are falling. Flexible interest rates are preferred by lenders when interest rates are increasing since some of the risk is transferred to the borrowers. Borrowers may also prefer variable interest rates to circumvent possible future transaction cost of refinancing if interest rates decline.

Recommendations

The time series analysis of nominal interest rates was based on the sample which included the years 1950 to 1982. No evidence of a statistically significant relationship, for this sample period, between net farm income of the representative Montana dryland wheat farmer and interest rates could be formed, although other researchers (Melichar, 1979; and Tweeten, 1980) have developed relationships between farmland values, inflation and farm income. If significance could be determined between farm net income and interest rates, then a joint probability distribution could be integrated into the DP model. However, the optimal refinancing policy would be unaffected.

The data sample of interest rates used for the time series analysis may have economic influences that should be investigated. During portions of the sample period, the U.S. was in conflict with North Korea, a period of fixed prices existed, and the influence of government programs was not isolated and examined.

The transition probability matrix may be modified by using smaller probability categories. For example, the tail probability of .22 could accurately be broken into two probabilities of .21 and .01. This modification could be attempted, however, the resultant transition probability matrix could be difficult to work with, particularly when examining the probabilistic flowchart. It is doubtful if the optimal policy will be altered.

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APPENDIX
PROBABILISTIC FLOWCHARTS