Pertanika J. Soc. Sci. & Hum. 11(1): 97-106 (2003)

ISSN: 0128-7702
© Universiti Putra Malaysia Press

Impact of Credit Risk on Farm Planning in Chiang Mai Valley, Thailand

ZAINAL ABIDIN MOHAMED[1], PICHIT THANI[2]
& EDDIE CHIEW FOOK CHONG[1]

[1] *Department of Agricultural Economics,*
Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[2] *Department of Agricultural Economics,*
Chiang Mai University, Chiang Mai Thailand

Keywords: Risk, credit, portfolio, risk-efficient, risk-programming, aversion and E-V frontier

ABSTRAK

Unsur risiko yang dihadapi di dalam usaha perladangan bukan sahaja mempengaruhi strategi pengeluaran tetapi juga melibatkan pembuatan keputusan oleh peminjam untuk melabur dan kesanggupan pemberi pinjaman memberikan kredit. Risiko yang dikaitkan dengan kos dan kemudahan kredit merupakan unsur tambahan di dalam portfolio risiko petani yang akan mempengaruhi penggunaan pinjaman dan struktur pengagihan kapital. Teori portfolio mencadangkan bahawa model risiko-cekap penyelesaian optimum tanpa risiko kredit mempunyai aktiviti pertanian campuran yang padat. Mengambil kira risiko akan menyebabkan anjakan yang tak selari akan gugusan yang cekap kepada satu tahap varians yang tinggi bagi setiap jangkaan nilai fungsi objektif. Kajian ini adalah bertujuan untuk mengukur keperluan kredit dalam keadaan berisiko di dalam operasi ladang dan kesannya terhadap petani pengelak risiko dengan mengguna model pemprograman risiko berbilang masa. Model ini menekankan kaitan di antara risiko kredit dan pendapatan perladangan dan digunakan untuk mengenal pasti perancangan perladangan yang cekap di Chiang Mai Valley. Keputusan pemprograman risiko mendapati ianya bertetapan dengan tindak balas yang dijangkakan. Memasukkan risiko kredit mecerminkan keseluruhan keadaan risiko petani. Apabila tahap pengelak risiko ditingkatkan mengikut peratusan jumlah pinjaman kapital dan operasi, tiada pinjaman kapital dibuat di tahap pengelakan-risiko yang tinggi, dan ini menyebabkan kesemua rizab kredit tidak digunakan. Satu gugusan yang merangkumi 13 portfolio yang cekap di atas bahagian pertengahan sempadan E-V juga diwujudkan daripada model pemprograman risiko.

ABSTRACT

The risk elements inherent in farming not only influence production strategies but also borrowers decision to invest capital and the willingness of lenders to supply capital. Risk associated with costs and availability of credit is an added element of farmers' portfolio risk, which can influence debt use and the resulting capital structure. Portfolio theory suggests that the model farm's risk-efficient optimal solutions, derived without credit risk, have a concentrated mix of activities. Incorporation of risk will cause a nonparallel shift of the efficient set towards higher variances for each expected value of the objective function. This study was undertaken to measure credit availability in response to risk in farm operations and its impact on risk-averse farmers by utilising a multiperiod risk-programming model. The model emphasises the relationships between credit risks and farm income risk and is used to generate risk-efficient farm plans for representative farms in Chiang Mai Valley. The risk-programming results obtained are consistent with anticipated responses. The inclusion of credit risk takes a fuller account of the overall risk positions of farmers. As risk-aversion increases as a percentage of total for both capital and operating loans, no capital loans occur at the highest risk-aversion level, leaving intact the entire reserve of capital credit. A set of 13 efficient portfolios in the intermediate portion of the E-V frontier was also generated from the risk-programming model.

INTRODUCTION

Thailand, being a developing country, has 63% of its population engaged in the agricultural sector. Agriculture not only serves as the major source of food and fibres, but is also the main source of foreign exchange earnings. Thus, in consideration of the strategic importance and strong contribution of agriculture to the well being of the country, the Royal Thai Government has given serious attention to agricultural development and production.

Like any other developing country, agricultural production in Thailand faces uncertainties in output namely yield and price risks. As such, risk-averse farmers have preferred to adopt less risky crop production strategies rather than optimise for a profit maximisation strategy.

The risk elements inherent in farming not only influence the production strategies but also influence the decision of borrowers to invest capital and the willingness of lenders to supply capital. Other things being equal, the greater the degree of risk and uncertainty involved in a given investment, the greater the degree of risk and uncertainty to the person who advances credit.

A study by Barry *et. al* (1981) concluded that risks associated with costs and availability of credit are an added element of farmers' portfolio risk that influence debt use and the capital structure for risk- averse farmers. Hence, it is appropriate to include the effects of credit risk in farm firm analysis in order to evaluate its effects on farmers' portfolios.

Portfolio theory led us to anticipate that the model farm's risk-efficient set, derived without credit risk, should have a concentrated mix of activities at the peak of the frontier. This results in maximum resource utilization and farm growth. The risk will also be the highest among the risk-efficient solutions. Movements to lower risk on the efficient set should show slower growth, less use of production capacity, greater diversification, lower leverage, larger credit reserves and other risk response factors.

Including credit risk will cause a non-parallel shift of the risk-efficient set toward higher variance for each expected value of the objective function. The effects on an optimal portfolio will depend on how the decision maker's risk aversion (t) remains constant and the optimal portfolio will have a lower expected value and variance (Robison and Barry 1977). Still lower risk and returns would occur for decreasing absolute risk aversion. Solution should have some combination of slower growth of net wealth, less use of production capacity, greater diversification, or greater reserves compared to the absence of credit risks. Most of the differences should occur in rates of investment and firm growth and in holding of credit reserves.

Thus, the objectives of this paper are twofold: first to develop a procedure to measure credit availability in response to risk in farm operations, and second to analyse the results and draw implications of behaviour for risk averse farmers by utilizing a multiperiod risk-programming model which emphasises the relationships between credit risks and farm income risk, to come up with risk efficient farm plans for a representative farm in the Chiang Mai Valley. In general, farmers in Chiang Mai Valley are conservative due not only to the losses, which they may have to incur if losses occur, but also by the higher price, which they have to pay for the loans. In view of the above, problems faced by both farmers and lenders in financing are closely associated with the risks and uncertainties in agriculture.

THE THEORETICAL FRAMEWORK AND METHODOLOGY

The mean-variance approach or portfolio theory is well known and much debated, especially about the limited generality of its assumptions. However, its widespread use (Robison and Brake 1979), its explicit measures of risk, and rigorous demonstration of its usefulness as an approximate method for portfolio selection help make it an acceptable model for showing the portfolio effects of credit risk (Tsiang 1972; Levy and Markowitz 1979). Portfolio theory defines a risk-efficient set as the combinations of risky assets that minimize variance for expected returns. In empirical analysis, the risk coefficient set is subject to other specific resource constraints and business requirements.

Barry *et al.* (1983) consider a risk-averse farmer as those who must choose a level of debt (D) with which to leverage equity (E) in financing risky production with total farm assets (A). Expected returns before interest and consumption and variance from investment in risky farm assets are designated r and σ_r^2 respectively. When credit is specified only in deterministic terms, cost of

using credit in borrowing is expressed as rate $i = i_b + i_r$, with both components having zero variance. Component i_b is the interest rate paid to the lender, and liquidity premium i_r is the farmer's value of credit reserve. When credit is treated as a random variable, the cost of using credit in borrowing is expressed as expected rate i, with variance σ_i^2, and covariance σ_{ri} with return from risky farm assets. Hence, risk is treated in probabilistic terms with variance used to measure likelihood of events occurring that produce less than expected results.

To show a closed-form solution, let the farmer's utility function be approximated by the negative exponential,

$$U(\pi) = 1 - e^{2\tau\pi}, \tag{1}$$

where π is the degree of risk aversion ($\tau > 0$), and t is the level of income. Freund (1956) has shown that maximizing the expected value of a negative exponential integrated over a normal density function, as is assumed for r and i, is equivalent to maximizing

$$E[U(\pi)] = E(\pi) - \tau\sigma_\pi^2. \tag{2}$$

Notation $E(\pi)$ and σ^2_π now represent the expected profits and variance, respectively, of the farmer's portfolio. Expected profits are defined as the returns to assets (rA) less the cost of borrowing (iD)

$$\pi = r\bar{A} - i\bar{D}. \tag{3}$$

Portfolio variance is

$$\sigma_\pi^2 = \sigma_r^2 A^2 \tag{4a}$$

where cost of borrowing is deterministic and a random variable

$$\sigma_\pi^2 = \sigma_r^2 A^2 + \sigma_i^2 D^2 - 2AD\sigma_{ri}, \tag{4b}$$

Thus, expression (4b) is variance of the difference between two random variables. Hence, the covariance term has a negative sign preceding it, indicating that the lower (higher) is the correlation between r and i, the greater is the increase (reduction) in total portfolio variance (Fama 1976).

For the deterministic credit case, substituting the expressions in equation (3) and (4a) into equation (2) yields

$$E(U(\pi)) = E(r\bar{A} - i\bar{D}) - (\sigma_r^2 A^2) \tag{5}$$

Substituting $D + E = A$ and considering the level of debt (D) as a decision variable, the first-order condition for an expected utility-maximizing level D^* is

$$dU(\pi)/dD = \bar{r} - \bar{i} - 2\tau\sigma_r^2 D - 2\tau\sigma_r^2 E = 0, \tag{6}$$

which gives optimal debt of

$$D^* = (\bar{r} - \bar{i} - 2\tau\sigma_r^2 E)/(2\sigma_r^2) \tag{7}$$

Differentiating (7) with respect to r, i, τ, σ_r^2, and E shows the following comparative statistic properties;

$$dD^*/dr = 1/(2\tau\sigma_r^2) > 0, \tag{8a}$$
$$dD^*/di = -1/(2\tau\sigma_r^2) < 0, \tag{8b}$$
$$dD^*/dE = -1 < 0, \tag{8c}$$
$$dD^*/d\tau = (-\bar{r} - \bar{i}) / (2\tau^2\sigma_r^2) < 0, \tag{8d}$$
$$dD^*/d\sigma_r^2 = (-r + i) / (2\tau\sigma_r^4) < 0. \tag{8e}$$

Optimum debt is positively related to changes in expected returns on farm assets and inversely related to changes in costs of borrowing, equity, variance of returns, and risk aversion. In the latter two cases, the inverse relationships hold as long as expected return on farm assets is greater than the cost of borrowing.

When credit risks are introduced, the expression for the expected utility maximization becomes

$$E(U(\pi)) = E(r\bar{A} - i\bar{D}) - \tau(\sigma_r^2 A^2 + \sigma_i^2 D^2 - 2AD\sigma_{ri}). \tag{9}$$

Again, substituting $D + E = A$ and considering the level of credit as the decision variable, the first-order condition for an expected utility-maximizing level D^* is

$$dU(\pi)/dD = r - i - 2\tau\sigma_r^2 D - 2\tau\sigma_r^2 E - 2\tau\sigma_i^2 D + 4\tau D\sigma_{ri} + 2\tau E\sigma_{ri} = 0, \tag{10}$$

which gives optimal debt D^{**} of

$$D^{**} = \frac{\left(\bar{r} - \bar{i} - 2\tau E\left(\sigma_r^2 - \sigma_{ri}\right)\right)}{2\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)} \tag{11}$$

Comparison of expressions for optimal debt in equations (7) and (11) indicates that the addition of risk measures for credit will mostly warrant lower use of debt, although the result depends strongly on the level of covariance σ_{ri}. If, for example, the covariance is zero, then the optimal debt is clearly less in expression (11). However, if covariance is strongly positive, then optimal debt could be higher in expression (11). This is shown by setting equations (7) and (11) equal to each other and solving for σ_{ri}. The result is

$$\sigma_{ri} = \frac{\sigma_i^2\left(2\tau\sigma_r^2 E - r + i\right)}{2\left(\tau\sigma_r^2 E - \bar{r} + \bar{i}\right)} \tag{12}$$

As long as the actual σ_{ri} is less than σ_r^2, optimal debt in equation (11) will be less than optimal debt in equation (7). Comparative statistic properties for equation (11) are:-

$$dD^*/d\bar{r} = \frac{1}{2\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)} > 0, \tag{13a}$$

$$dD^*/di = \frac{-1}{2\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)} < 0, \tag{13b}$$

$$dD^*/d\tau = \frac{\left(-\bar{r} + \bar{i}\right)}{2\tau^2\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)} < 0, \tag{13c}$$

$$dD^*/d\sigma_r^2 = \frac{-\bar{r} + \bar{i} - 2\tau E\left(\sigma_i^2 - 2\sigma_{ri}\right)}{2\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)^2}, \tag{13d}$$

$$dD^*/dE = \frac{-\left(\sigma_r^2 - \sigma_{ri}\right)}{\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)}, \tag{13e}$$

$$dD^*/d\sigma_i^2 = \frac{-\bar{r} + \bar{i} + 2\tau E\left(\sigma_i^2 - 2\sigma_{ri}\right)}{2\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)^2}, \tag{13f}$$

$$dD^*/d\sigma_{ri} = \frac{\bar{r} + \bar{i} + \tau E\left(\sigma_i^2 - \sigma_r^2\right)}{\tau\left(\sigma_r^2 + \sigma_i^2 - 2\sigma_{ri}\right)^2}, \tag{13g}$$

These results are more ambiguous than in expression (8a) through (8e). In all cases, the denominator values are nonnegative. However, only (13a) and (13b) have definitive numerator value. Debt use is positively related to changes in farm asset returns and inversely related to borrowing costs. The relationship between debt and risk aversion is also inverse if expected farm asset returns exceed borrowing costs. Debt responses to changes in other parameters cannot be fully evaluated without knowing their values.

It is important to recall that although the results obtained in the comparative statistic analysis appear consistent with intuitive judgement about financial structure and credit use, they depend on the assumption of expected utility maximization, normality about r and i, and the choice of utility function. However, these assumptions will be kept throughout the analysis. These are maximization of expected utility with an exponential utility function, a linear profit function, and normally distributed profits. This is equivalent to minimizing the exponent of the expected utility function, which is a quadratic expression (Freund 1956). The exponential utility function has the advantage over the quadratic utility function of not implying increasing absolute risk aversion (Buccolar and French 1978).

A better understanding of the effect of stochastic credit on expected utility maximizing level of debt is needed for effective liquidity management. The importance of credit is clear in the growth process, but the existence of stochastic environmental variables causes credit to be a random variable. Hence an additional element of risk enters the decision process that may further influence farmers' production, marketing and financial decisions.

However, the task of measuring credit risk is hampered by the lack of explicit risk pricing on loans by lenders to reflect their judgements about farmer's credit worthiness and availability of credit funds. Lenders' risk responses are reflected in non-price results that include differing loan limits among borrowers, and differences in security requirements, loan maturities, loan supervision and documentation, and other means of credit administration (Robison and Barry 1977).

In order to measure credit risk, estimates are needed on how the lender's non-price responses are related to farm income risks and

farm loan demands. Those estimators must then relate to the farmer's cost of borrowing. Some approaches that account for the liquidity premium on a credit reserve (Barry *et al.* 1981) show the relationship between the farmer's cost of borrowing and lender's non-price credit responses to risk. The liquidity premium on maintaining the credit reserve signifies the liquidity risk component of the farmer's total portfolio risk and is determined by the level of risk aversion. Variations in lenders' non-price responses in the form of variations of credit limits, for example, are directly related to a farmer's cost of credit.

MATERIALS AND METHODS

Risk Programming Analysis

The effects of credit risk are evaluated with a multi-period quadratic-programming model, which derives risk-efficient growth plans for various levels of risk aversion. Risk-efficient plans are first derived without including credit risk. Then credit risks, based on the lender survey, are introduced to evaluate their effects on selected risk-efficient plans. The decision criterion reflects the farmer's preferences as a negative exponential function with normal probability distributions and a linear profit function.

The model used here is a general decision model based on the Markowitz E-V or mean-variance efficiency criterion. It is a modified version of the model employed earlier by Baker *et al.* (1983). Crop diversification is added to the original version. It is a multiperiod (four-year), quadratic (QP) model of portfolio selection. The optimization procedure uses the algorithm "GINO (General Interative Optimizer)" software, developed by Liebman *et al.* (1986).

The conventional notation for the QP model can be writtten as follows:

$$Max: r' x - 1/2\ \tau\ X'\ Q\ X \qquad (14)$$

subject to

$$A\ X \leq b \qquad (15)$$

$$X,\ \tau \leq 0 \qquad (16)$$

where $X' = (X_1,.....,X_n)$; $b' = (b_1,.....,b_n)$;
$r' = (r_1,.....,r_n)$;

$$\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \text{ and } Q = \begin{bmatrix} \sigma_{11} & \cdots & \sigma_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_{n1} & \cdots & \sigma_{nn} \end{bmatrix}$$

where r is a n x 1 vector of net income assigned to the n x 1 vector of activities X, to evaluate final net wealth, which is presented by the linear portion of the objective function. Q, variance-covariance matrix, provides an estimate of the potential variation of outcomes around the expected value of the portfolio. The matrix A is an (m x n) matrix of technical coefficients equivalent to the input of a linear programming model. There are m linear constraints (AX) which may be equalities or inequalities, and which are restricted by m right-hand side vector b.

The linear portion of the objective function measures the farm's terminal net worth plus the sum of annual consumption expenditures. The objective function entries are equally weighted and expressed in end of horizon baths. The opportunity cost of money is modelled as a non-farm investment having a risk-free annual yield. This formulation is a future value model with the opportunity rate of reinvestment on earnings represented by the yield on the non-farm investment.

The quadratic entries in the objective function are the annual variance of gross margin on the production activities and, the variance and covariance of operating and capital credit when credit risk is included. The expected gross margins and variance-covariance matrix were estimated from time-series data of yields, prices and production costs.

Table 1 summarizes the relationships among borrowing activities, credit constraints, risk measures, and other model components. The measures of credit availability and risk came from Thani's (1988) results. They are briefly reviewed here. The historical data series of farmer's income and supply of credit were elicited from individual borrower record keeping and approved loan request forms. Farmers were classified into the following six groups: severe loss, moderate loss, average conditions, moderate gain, and favourable gain, based on their farm income experienced by the farmer in the preceding year. The percentage of loan requests actually granted was then correlated with the corresponding levels of farm income. Results indicated that the supply of available credit is

TABLE 1
Summary of production and financial components for year one of the programming model

Constraint	Produce and sell	Borrow operating	Borrow capital	Lease land	Purchase machines	Hired labour	Non-farm investment	Consume and tax	Transfer cash 1	Transfer cash 2	Relation-ship	Level
Objective			$-C_n$		C_n			C_n			=	Max
Beginning cash	A	-1	A_{dp}				1	A_c	1		<=	B
Ending cash	-A	$1+i_0$	A_{ic}	A			-(1+I)	A_{ct}	-1	1	=	0
Finance requirement			A		-A						=	0
Operating credit	-A	A									<=	B
Capital credit		A		-A							<=	B
Land	1			-1							<=	B
Lease limit				1							<=	B
Family labour	A					-1					<=	B
Hired labour						1					<=	B
Machinery	A			A	-1						<=	B
Accounting equality	-A	I_0	i_c	A	A_{dep}		-i	1			=	0
Variance-covariance												
Produce and sell	r^2_r											
Operating credit	r_{rio}	r^2_{rio}										
Capital credit	r_{ric}	r^2_{ric}										

positively correlated with changes in farm income. The correlation was stronger for capital credit than operating credit. A positive correlation between supply of credit and farm income implies negative correlation between borrowing cost and farm income. This adds to the model farm's total risk.

Data, Farm Resources and Constraint

The model and data needs are based on a farm representative in the Chiang Mai Valley (Thani 1988). The data used in this study were obtained from both primary and secondary sources. The historical data series of farmers' income and supply of credit were elicited from lender's record keeping.

The design of the model is similar to other risk analysis models (Barry and Willmann 1976), except that it is modified to include credit risk. Financial components are emphasised, with production and post-harvest sales combined into a single annual activity over the model's horizon. Product diversification and marketing responses to risk are also considered.

The beginning farm has 10 rais (1 rai = 0.16 hectare) of cropland. A land leasing activity allows expansion beyond 10rai. The model summary in Table 1 shows that leasing land requires additional machinery purchase with cash or credit financing. Borrowing activities for machinery have four and five year maturities. Short-term borrowing to supplement the annual cash flow is for one year. Average propensities to consume, tax, and save from net income are 0.50, 0.25, and 0.25, respectively. Each year has two cash sub-periods. Maximums are set for leasing in any year, credit for operating and capital loans, and machinery capacity. Accounting equalities assure that depreciation charges, cash transfers between periods, and tax and consumption requirement are met.

The model used in this study requires estimates of the variances and covariance's of gross margins of production activities and borrowing cost of credit activities. This part is the quadratic portion of the objective function of the model.

The measures of covariance of production activities and borrowing cost are derived from from the method of Baker *et al.* (1983). They hypothesised that farmers' credit is positively correlated with farm income. The use of average loan granted as percentages of original loan requested is preferred over the use of absolute value of loan granted. According to Thani(1993), analysis of variance (ANOVA) is conducted to find out how the amounts of credit granted by a particular lender vary with changes in farm income. The variation in credit responses attributable to the block variable "lenders" is subtracted from the total sum of squares. The proportion of the remaining total variance that is due to income treatments is then the partial coefficient of determination, and the square root of that coefficient is a proxy for the partial correlation of credit on past income. We are unable to reject the hypothesis tested at the five percent level. The results of the ANOVA test imply that credit availability is a source of risk in farm plans, and that it is related to past farm income. In other words, credit risk contributes to the total portfolio risk in a significant manner. Table 2 shows the variance-covariance matrix of gross returns for crop activities, while Table 3 shows the covariance of gross margins of production activities.

TABLE 2
Variance-govariance matrix of gross returns for crop activities

	Rice (X1)	Soybean (X2)	Mung Bean (X3)	Peanut (X4)	Garlic (X5)	Second Rice (X6)
Rice (X1)	8.638E04*	7.84E04	1.509E04	5.49E04	4.68E05	7.82E04
Soybean (X2)		1.30E03	1.85E04	3.34E04	1.41E05	5.16E04
Mungbean (X3)			5.200E03	1.23E04	6.205E04	4.70E04
Peanut (X4)				5.70E04	2.67E05	4.70E04
Garlic (X5)					5.73E06	6.32E05
Second Rice (X6)						1.81E05

*E04 – Indicates 4 decimal points to the right similarly, E03,E05 and E06 are 3,5 and 6 decimal points to the right respectively.

TABLE 3
Covariance of gross margins of production activities and borrowing cost of credit activities

	Year 1			Year 2			Year3			Year4		
	STB	IB4	IB5	STB	IB4	IB5	STB	IB4	IB5	STB	IB4	IB5
X1	2.44	6.37	6.37	2.56	6.69	6.69	2.68	7.01	7.01	2.81	7.33	7.33
X2	0.94	2.47	2.47	0.99	2.59	2.59	1.04	2.71	2.71	1.08	2.84	2.84
X3	.059	1.56	1.56	0.62	1.64	1.64	0.65	1.71	1.71	0.68	1.79	1.79
X4	1.98	5.17	5.17	2.08	5.43	5.43	2.18	5.69	5.69	2.28	5.95	5.95
X5	9.91	51.92	51.92	20.9	54.51	54.51	21.89	57.1	57.1	22.89	59.7	59.7
X6	2.85	7.45	7.45	3	7.82	7.82	3.14	8.19	8.19	3.28	8.56	8.56
STB	0.12			0.12			0.12			0.12		
IB4		.363			.363			.363			.363	
IB5			.363			.363			.363			.363

STB = short term borrowing activity
IB4 = Intermediate term borrowing, at 4th year
IB5 = Intermediate term borrowing, at 5th year

RESULTS AND DISCUSSION

Portfolio theory leads us to anticipate that the model farm's risk-efficient set, derived without credit risk, should have a concentrated mix of activities at the peak of the frontier. This results in maximum resource utilization and farm growth. The risk will also be the highest among the risk- efficient solutions. Movements to lower risk on the efficient set should show slower growth, less use of production capacity, greater diversification, lower leverage, larger credit reserves, and more use of other risk responses.

The risk-programming results obtained are consistent with those anticipated responses. A thirteen risk-aversion level for risk-efficient set was derived with and without credit risks. Model results with and without credit risk are contrasted. Including credit, risk takes fuller account of the overall risk position of farmers. As risk aversion increases, the principal responses involve greater liquid reserves and slower growth. Credit reserves generally increase as a percentage of total credit for both capital and operating loans. No capital loans occur at the highest risk-aversion level, leaving intact the entire reserve of capital credit. Land leasing declines with increasing risk aversion until no more acerage is leased and part of the original land is idled. Taxable income, objective function values, and standard deviations also increase as risk aversion increases.

A set of 13 efficient portfolios in the intermediate portion of the E-V frontier was generated from the QP model for the case of with credit risk. These portfolios are expected utility maximizing solutions for risk aversion coefficient within the range of $0.20 > \tau > 0.0001$. When the risk coefficient is higher than 0.20, the initial point of the E-V frontier maximizes utility. When τ is equal or lower then 0.0001, the linear programming solution is the expected utility maximizing solution (see Table 4).

The results show that for risk coefficients in the range $0.20 > \tau > 0.0001$, including credit risk to the analysis is likely to imply a more conservative strategy in order to maximize expected utility than the one adopted when credit risk is ignored.

Including credit risk in the multi-period QP model produces a shift of the E-V frontier and possible changes in the composition of the risk efficient portfolios. *Fig. 1* shows the E-V frontiers corresponding to each one of the two cases. That shift may imply changes in the optimal plans for risk adverse decision-makers.

Similarly, a set of 13 efficient portfolios in the intermediate portion of the E-V frontier that was provided by the model contain optimal solution for values of risk aversion coefficient that range from $0.4 > \tau > 0.001$ generated from the QP model for the case of without credit risk. Values of risk aversion above 0.40 imply that a decision maker would maximize expected utility at the lowest feasible point of the E-V frontier (the one with lowest E and lowest V). Values of the risk aversion coefficients under 0.001 imply that wealth maximizing (or linear programming) solution maxamizes expected utility. This solution is also the optimal one for a risk neutral investor.

TABLE 4
Composition of the objective function for expected utility maximizing plans on the E-V frontier under selected risk aversion coefficients

Risk Aversion	Without Credit Risk		With Credit Risk	
	Standard Deviation	Final Wealth	Standard Deviation	Final Wealth
0.0001	79769	118869*	98637	118869*
0.0005	79769	118869*	87428	114754
0.001	79769	118869*	71505	110453
0.01	68986	114927	63829	104219
0.015	57625	113763	55473	100467
0.02	48297	112764	45513	98497
0.04	42128	104367	39614	90246
0.045	30472	92328	31573	81235
0.05	26136	83748	26695	77245
0.10	20581	64436	19927	61886
0.15	15883	52789	16134	51221
0.2	10155	34426	10022	33226**
0.4	9668	33226**	11235	33226**

*LP solution
** Initial Solution

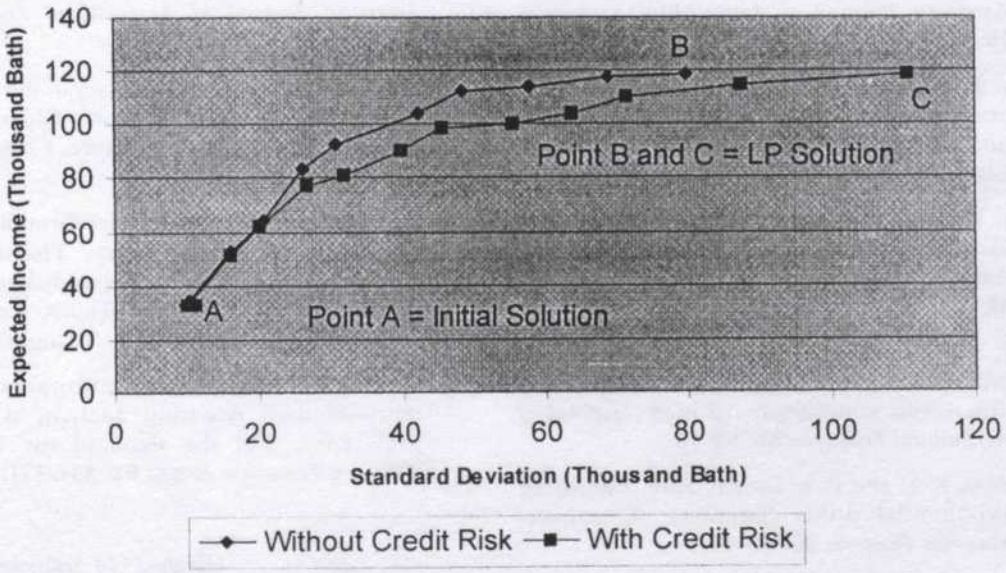

Fig. 1: Efficient mean variance frontier for a farmer operator without and with credit risk

CONCLUSION

When credit risks are included in the model and the solution compared at the same levels of risk aversion, the growth measures and performance decline and credit reserves increase. Solution with high-risk aversion shows little growth in farms size and partial idling of production capacity. Moreover, the effects of greater reliability for capital credit relative to operating credit are evident as risk aversion increases; the solutions show a stronger tendency to conserve riskier capital credit by restricting investment and firm growth, at least until capital loans no longer occur. Then, further building of credit resolve requires fewer operating loans, which can cause idle production capacity.

The stronger portfolio responses by farmers with increasing absolute risk aversion are

illustrated by comparing solutions obtained without credit risks to solutions with credit risks for higher risk aversion coefficients.

To conclude, when credit risk is included in the analysis: (i) the average level of the credit reserve increases faster, and the use of capital credit and expansion and expansion of farm growth are more rapidly eliminated from optimal plans as the risk aversion coefficient increases, and (ii) for a given level of risk aversion, the average level of the credit reserves for both credit lines are generally much higher. Hence, these results are consistent with the hypothesis that more credit risk brings slower growth, greater credit reserves, and some idling of resources. These results support that credit risk should be taken into account in farm management decisions.

REFERENCES

BAKER, C. B., P. J. BARRY and L. R. SANINT. 1983. Programming analysis of farmers' credit risk. *American Journal of Agricultural Economics* **65**: 321–325.

BARRY, P. J. and C. B. BAKER. 1971. Reservation prices on credit uses: a measure of response to uncertainty. *American Journal of Agricultural Economics* **53**: 222–227.

BARRY, P. J., C. B. BAKER and L. R. SANINT. 1981. Farmers' credit risks and liquidity management. *American Journal of Agricultural Economics* **63**: 216–227.

BARRY, P. J. and D. R. WILLMANN. 1976. A risk programming analysis of forward contracting with credit constraints. *American Journal of Agricultural Economics* **58**: 62–70.

BUCCOLAR, S. T. and B. L. FRENCH. 1978. Estimating exponential utility functions. *Agricultural Economic Research.* **30**: 37–43.

FAMA, E. F. 1976. *Foundation of Finance.* New York: Basic Books.

FREUND, R. J. 1956. Introduction of risk in to a risk programming model. *Econometrica* **24**: 253–263.

LEVY, H. and H. M. MARKOWITZ. 1979. Approximating expected utility by a function of mean and variance. *American Economics Review* **69**: 158–164.

LIEBMAN, J., L. LASDOM, L. SCHRAGE and A. WAREN. 1986. *Modeling and Optimization with GINO.* New York: The Scientific Press.

MARKOWITZ, H. M. 1959. *Portfolio Selection-Efficient Diversification of Investments.* New York: John Wiley and Sons, Inc.

ROBISON, L. J. and J. R. BRAKE. 1979. Application of portfolio theory to farmer and lender behavior. *American Journal of Agricultural Economics* February: 158–164.

ROBISON, L. J. and P. J. BARRY. 1977. Portfolio adjustments: An application to rural banking. *American Journal of Agricultural Economics* **59**: 311–320.

THANI, P. 1988. Socio-economic survey in the Chiang Mai Valley. Research Report. Chiang Mai Thailand: Faculty of Agriculture, Chiang Mai University.

THANI, P. 1993. Impact of credit risk farm planning in the Chiang Mai Valley, Thailand: a multiperiod risk programming analysis of credit reserve. Unpublished Ph.D Thesis, Universiti Pertanian Malaysia, Serdang, Selangor.

TSIANG, S. C. 1972. The rational of the mean-standard deviation analysis, skewness preference, and the demand for money. *American Economics Review* **62**: 354–371.

(Received: 14 September 1996)