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Optimal Equity Recovery for a Cooperative Financial Institution

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A model is developed that shows the usefulness of dynamic optimization in deriving optimal equity recovery strategies for a cooperative lending institution. The objective is to minimize the cost of a member borrowing over time. An interest rate surcharge, above the cost of funds and operating cost, is the control variable to be determined. The financial position of the cooperative is described by equity and loan volume, which are the state variables. Applications show how the surcharge, loans, and equity change over time as model parameters are changed.

Farm Credit System (FCS) losses of $2.7 billion in 1985 and $1.9 billion in 1986 raised questions about the financial stability of this cooperative institution during 1987 (Freshwater; Lins; Webster). This represented a sharp contrast to the previous decade when FCS was viewed as one of the safest segments of the financial community. Rising asset values provided agricultural lenders with more than adequate security, and borrowers profited from the depreciating real value of their debt. This combination, in the midst of rising farm income expectations, led to a dramatic increase in the agricultural sector's level of debt. FCS was able to capture a larger share of this growing market primarily due to its lower rates, based on average cost loan pricing during a period of rising interest rates.

The prosperity of FCS and other agricultural lenders changed with the financial health of the sector they service. Farm income levels dropped, and, with the additional indebtedness assumed in the previous period, debt servicing problems were accentuated. Farm asset values consequently fell, providing insufficient security for the loans held against them. This process forced lenders to increase loan loss provisions and charge-offs, which in turn resulted in a reduction of their institutions' net worth.

The Farm Credit banks are funded principally through the sale of securities backed by the resources of all banks. They were not guaranteed against default by the government, and, as a result, equity erosion of FCS raised the risk perceived by bondholders.[1] In October 1985, this reaction culminated with an unprecedented basis spread of 110 points between FCS bonds and comparable U.S. Treasury bonds.

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The problems confronting FCS by the third quarter of 1985 led to the implementation of a new farm credit act. By giving the system a more central focus and providing the framework for a government line of credit, investor confidence was restored. The new legislation narrowed the basis point spread without requiring an increase in equity.

At the same time, troubled FCS districts raised interest rates to solvent borrowers to rebuild equity lost from loan losses to distressed borrowers. This surcharge was incorporated implicitly into the prevailing FCS rates, which remained relatively high despite a general decline in the level of other interest rates. The equity buildup, however, was tempered by the exodus of financially sound borrowers who obtained credit from competing institutions at a lower rate.

The loss of quality borrowers left the system with a smaller loan base and proportionately less equity capital. The loss of borrowers did not directly diminish system-earned equity, but their contributed equity (class A stock) was removed. The loss of loan volume did directly retard equity restoration. The system also was left with a riskier loan portfolio and higher default rate. The impact of these events was to reverse or negate the equity restoration process.

A more descriptive and explanatory discussion of the problems facing FCS during this period is contained in Dobson and Barnard. They provide a chronological list of FCS happenings during this time. A discussion of policy alternatives is in Harl.

Because the future outlook for farm income during 1987 still was uncertain, projections were made of a possible FCS equity deficit to occur during 1988. Again federal legislation to address the farm credit problem was drafted and debated during 1987, and the president signed the Agricultural Credit Act of 1987 on January 6, 1988. The act has a number of provisions for recapitalizing and restructuring FCS. It provides for up to $4 billion in federal financial assistance to troubled institutions within FCS. Given stabilizing, if not improving, farm incomes and asset values, the new legislation and changes within FCS may restore its viability.

The results of this article were completed before the Agricultural Credit Act of 1987. The article's purpose is to demonstrate how dynamic optimization can be utilized to determine an optimal strategy for restoring lost equity in a cooperative financial institution in view of the system's dynamics. The use of an interest surcharge to increase equity and thus the ability to sell securities in a bond market is balanced against the competitive ability to lend money to financially sound borrowers.

Although the motivation for this article was the problems of FCS, the mathematical model used to characterize the problem and demonstrate the technique is hypothetical. The model includes many of the components of FCS but excludes others for simplicity, and the parameters used are suppositional. For instance, only one lending interest rate is determined although FCS uses differentiated rates. The impact of that single lending interest rate on loan volume was assumed and not empirically estimated.

Mathematical programming models have been used previously to investigate management issues facing FCS. Ahmad, Duft, and Mittelhammer (1985) describe the use of a linear programming model for selecting Banks for Cooperatives optimum equity capital components. Their results suggest that equity programs can be structured to the advantage of the borrower while protecting the debt-to-equity positions of cooperative lenders. They used a similar approach in a later article (Ahmed, Duft, and Mittelhammer 1986). Tauer and Boehlje used a quadratic programming model to demonstrate how the FCS bond participation decision can be cast as a minimum expected cost subject to a variance of cost level decision. Their numerical examples showed there is a significant trade-off between expected cost and cost risk.

Dynamic Optimization Model

The mathematical solution technique for the problem is dynamic optimization using nonlinear mathematical programming. Other optimization techniques are available, but given that discrete results (quarterly or annual) would be preferred to continuous results, the following model is formulated in discrete form (Kamien and Schwartz). The time horizon can be altered, which, as demonstrated, will change the results. An implication is that a borrower with longer-term objectives may prefer his or her bank to be operated differently than a borrower with short-term objectives.

The model is:

$$\underset{S_i}{\text{Minimize}} \sum_{i=1}^{n} (c_i + s_i + r_i((l_i + \Delta l_i)/E_i)^2 + k_i/(l_i + \Delta l_i)) \qquad (1)$$

subject to:

$$\Delta E_i = s_i(l_i + \Delta l_i) - d_i l_i \qquad i=1,\ldots,n \quad (2)$$

$$E_{i+1} = E_i + \Delta E_i \qquad i=1,\ldots,n \quad (3)$$

$$\Delta l_i = w_i(b_i - c_i - s_i - r_i((l_i + \Delta l_i)/E_i)^2 - k_i/(l_i + \Delta l_i)) - d_i l_i + y_i \qquad i=1,\ldots,n \quad (4)$$

$$l_{i+1} = l_i + \Delta l_i \qquad i=1,\ldots,n \quad (5)$$

where:

c_i = fund cost (.08),
s_i = surcharge,
r_i = risk factor (.00004),
l_i = loans,
Δl_i = change in loans,
E_i = equity (retained earnings),
k_i = fixed cost ($0.90 billion),
ΔE_i = change in equity,
d_i = default rate (.015),
w_i = loan change due to rate difference ($500 billion),
b_i = competitors' rate (.115),
y_i = exogenous change in loan volume ($2 billion), and
n = number of years

and the initial conditions are:

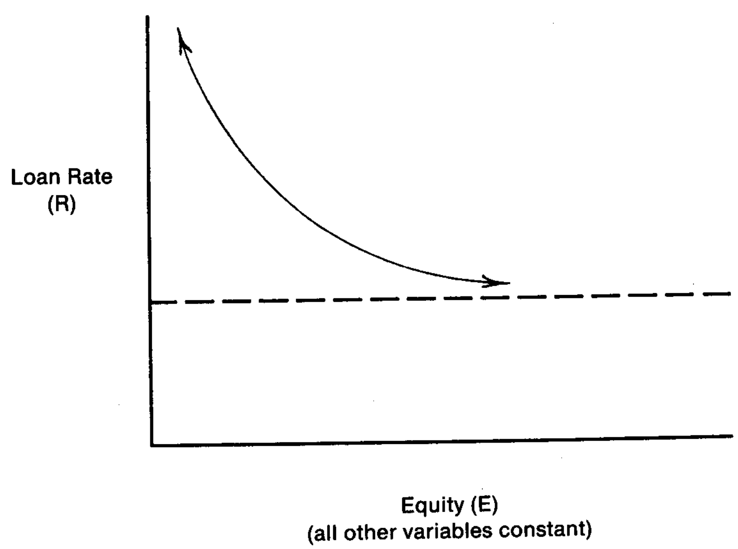
l_o = $60 billion
E_o = $3 billion.

The objective function in equation (1) seeks to minimize the cost of a member borrowing from the bank over time. Because the financial institution is a cooperative, this objective is consistent with its prescribed mandate. Alternative objectives could be specified, including multivalued functions. The interest rate charge on a dollar loan consists of the cost of funds c_i, a surcharge to be determined each year s_i, a risk cost of funds factor based on capitalization, and a fixed operating cost spread over the volume of loans.[2]

The risk cost capitalization factor is written as the square of the ratio of loans to equity (retained earnings) multiplied by r_i, which is set at .00004 for all years. If the bank has $60 billion in loans and $3 billion in equity, the ratio is 20. Twenty squared and multiplied by .00004 is 160 basis points. If equity was $6 billion rather than $3 billion, the risk cost factor would be only 40 basis points, which is about normal for agency debt.[3]

This relationship between equity and the rate charged is depicted by the hyperbolic curve in figure 1. Holding all other variables constant, if equity approaches zero, the risk cost of funds approaches infinity, and consequently so does the rate charged to borrowers. As equity increases, the perceived risk of bondholders falls and the associated risk premium required by investors declines. In this situation, the institution loan rate gradually approaches a level consisting of the cost of risk-free funds and the operating cost, plus any surcharge assessed.

Figure 1.—Effect of Equity on Institution Loan Rate



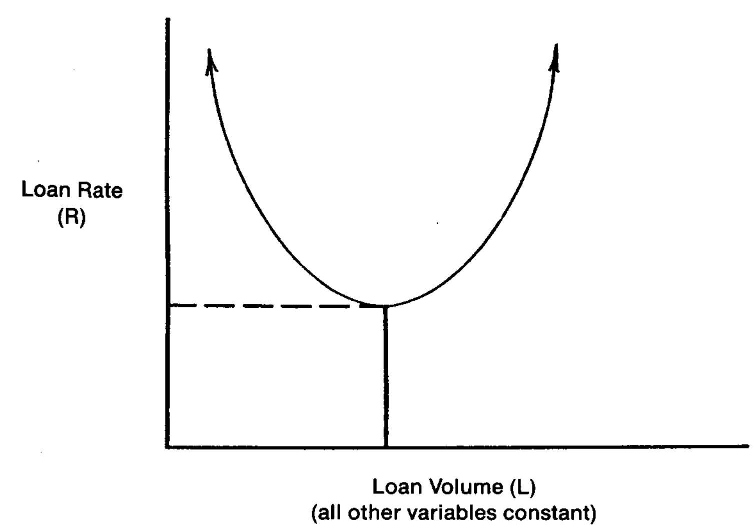
Besides equity, the other variable affecting the risk cost of funds is loan volume for the year as computed by $l_i + \Delta l_i$, or loans at the beginning of the year plus the change in loans during the year. The assumption is made that any loan change will occur instantaneously at the beginning of the year after a new interest rate is announced although a more gradual change can be modeled.

It is assumed that a loan volume decrease has a negative effect on the risk cost factor of funds. In the preceding example where equity was $3 billion, a decline in loan volume from the current $60 billion to $45 billion would lower the risk premium 70 basis points to 90. However, it should be noted that the impact of loan volume is dependent on the equity level or, in other words, the institution's capitalization rate. If equity were to increase to $6 billion but loan volume were to double at the same time, the risk cost factor would remain at 160 points rather than the 40 points that would be predicted if loans were constant.

Loan volume also affects the cost of operations (o_i) through the linear functional form: $o_i = k_i + a_i (l_i + \Delta l_i)$. Dividing through by $l_i + \Delta l_i$ produces $k_i / (l_i + \Delta l_i) + a_i$. For simplicity a_i is added to the cost of funds c_i whereas k_i is set at $0.90 billion. Thus the fixed cost per dollar of loan is 150 basis points if loan volume is $60 billion. By increasing the loan volume to $90 billion, the fixed cost would decrease to 100 basis points.

The effect through the preceding relationships of loan volume on the interest rate charged to borrowers is illustrated in figure 2. Holding all other variables constant, a strictly convex function results. An initial increase

Figure 2.—Effect of Loan Volume on Institution Loan Rate



in volume from a small base will lower fixed cost per dollar loan, but it will have little impact on the risk factor due to the strong capitalization rate. However, as loan volume increases, so does the risk premium required by investors. The initial decline in loan interest reverses itself as the increase in the risk factor is no longer offset by the smaller declines in the fixed cost component.

Equity and loan volume are the variables used to describe the financial position of the cooperative institution and are referred to as state variables. These variables are altered through the imposition of a surcharge on the loan rate assessed borrowers. Because the institution can freely choose the level of surcharge and thereby its financial status, it can minimize the objective function in equation (1) by the proper selection of this control variable. If the surcharge had no impact on the state variables, the borrower interest rate would be minimized by selecting a surcharge equal to zero.[4] However, this is not the case, and the objective function is minimized subject to the constraint equations (2) through (5), which describe the transition of the state variables over time. For n years, there are n equations of each type that are influenced by the selection of the control variable in that period.

Equation (2) states that the change in equity during a year is equal to the surcharge times the loan volume minus the default rate (.015) times beginning loan volume. The increase in retained earnings is partially offset by the proportion of loans that are not recovered because of default. A linear functional form is assumed, so the increase in equity resulting from a surcharge may be slightly overstated because the relationship does not account for the deteriorating loan portfolio resulting from the imposition of a surcharge, as discussed earlier. It also is assumed that Δl_i, either lost loans or new loans added, are not subject to default so that the default rate chosen is applicable to beginning loans only. Members who receive loans from competitors are assumed to leave with good credit ratings. Similarly, the cooperative does not assume unsound new loans.

Again, any loan change is assumed to occur instantaneously, and the surcharge is collected only on the loan volume during the year. All other interest rate charge components go to bondholders and for operating costs and thus are not available to rebuild equity. Equation (3) simply states that equity at the end of a year is equal to its initial level plus the change during the year.

The change in net loans outstanding for any year is given by equation (4). It is equal to the loans applied for in the year, which is a function of the institution's competitive position, minus the loans lost through default. An exogenous loan change y_i is added to reflect a general increase or decline in loan demand for all lenders. It is set here at $2 billion.

However, the key force in the equation is the spread between the competitors' rate b_i and the rate charged members. As discussed earlier, the imposition of a surcharge effectively raises the interest rate assessed the institution's borrowers. The predicted exodus of financially sound members is tempered if the institution enjoys a competitive advantage over competing lenders. The interest rate spread is multiplied by a factor w_i, which is set at $500 billion, to determine the net change in loans. For example, if competitors' rates are 200 basis points greater than the bank's rate, $10 billion in loans will be gained. On the other hand, if the situation is reversed and the competitors' rate is 100 points less, for example, $5 billion in loans will be lost.

The factor w_i is used to represent the price sensitivity of the cooperative's members. If loyalty to the cooperative is based largely on a low cost of borrowed funds, the factor w_i will be larger. If w_i was raised to $700 billion, $7 billion in loans would be lost if competitors had a 100 basis point advantage over the cooperative financial institution. Finally, equation (5) states that the loan volume at the end of a year is equal to the beginning loan value plus the change in loans.

Results

The dynamic model formulated in the previous section was solved by a nonlinear programming technique (Murtagh and Saunders).[5] The optimal surcharge was determined for each year over the horizon of n years as were the resulting values of the state variables, equity and loan volume. The solution values are summarized in tables 1 through 5, which represent five different possible dynamic and competitive conditions facing the cooperative institution. Unless otherwise specified, the parameters used in the derivations are those expressed in the original statement of the model.

The results in both tables 1 and 2 are based on these original parameters. The only difference is the length of time over which the interest rate was minimized. In table 1, the minimization period was six years. The results show that a surcharge of .031 should be applied per dollar of loan in the first year of the six-year period. Equity is expanded by $589 million the first year as a result of the surcharge, which also causes loan volume to drop by $12.6 billion. The changes are not proportional, however, and the improved capitalization rate allows the risk cost to fall, which in turn lowers the overall interest rate. After the first year, the level of the surcharge drops successively until 1991, the second to last year of the horizon, when no surcharge is applied. Up to that time, the decrease in the surcharge slows the reduction in loan level until it is eventually reversed. Equity erodes sharply in the last year, which in turn forces up the interest rate. This myopic result occurs because the member does not care what happens beyond the last year and is content to let the financial situation of the cooperative institution deteriorate.

Table 1.—Optimal Values for Minimizing the Cost of Borrowing $1 from 1988 through 1993

Year	Loans	Equity	Cost of $1 of Loan: Fund Cost	Risk Cost	Fixed Cost	Surcharge Cost	Total Cost
	-- Billion Dollars --		*Dollars*				
1988	60.000	3.000	.08	.0160	.0150	.031	.1420
1989	47.389	3.589	.08	.0070	.0190	.018	.1240
1990	44.314	3.665	.08	.0058	.0203	.013	.1192
1991	43.688	3.558	.08	.0060	.0206	.005	.1116
1992	46.487	3.157	.08	.0087	.0194	.000	.1080
1993	51.273	2.460	.08	.0174	.0176	.000	.1149

This pattern of results compares closely with table 2, where the parameters are identical except the minimization is over nine years instead of six. After an initial surcharge is levied to rebuild equity, it is lowered gradually until it becomes nonexistent in the eighth year, which is the second to last year in the minimization. At that time, loan volume starts to increase after successive years of decline. The results in tables 1 and 2 are similar although not identical because the time horizon is different. However, it is interesting to note that the optimal conditions are nearly identical during the first two years when the surcharges are .031 and .018 (or .019). This demonstrates the robustness of the results generated by this model for the critical first few years.[6]

Table 3 shows the results if competitors charge a rate of .13 instead of .115. With this improved competitive position, the cooperative is able to impose a higher initial surcharge and keep it at a relatively high level throughout much of the minimization. The surcharge is used to build up

Table 2.—Optimal Values for Minimizing the Cost of Borrowing $1 from 1988 through 1996

			Cost of $1 of Loan				
Year	Loans	Equity	Fund Cost	Risk Cost	Fixed Cost	Surcharge Cost	Total Cost
	-- *Billion Dollars* --		-------- *Dollars* --------				
1988	60.000	3.000	.08	.0160	.0150	.031	.1420
1989	47.437	3.586	.08	.0070	.0190	.019	.1250
1990	43.891	3.695	.08	.0056	.0205	.015	.1211
1991	42.254	3.662	.08	.0053	.0213	.013	.1196
1992	41.207	3.573	.08	.0053	.0218	.012	.1192
1993	40.449	3.445	.08	.0055	.0223	.010	.1178
1994	40.265	3.256	.08	.0061	.0224	.004	.1125
1995	42.750	2.838	.08	.0091	.0211	.000	.1101
1996	46.545	2.197	.08	.0180	.0193	.000	.1173

Table 3.—Optimal Values for Minimizing the Cost of Borrowing $1 from 1988 through 1996 if Competitors' Rate Is 13 Percent

			Cost of $1 of Loan				
Year	Loans	Equity	Fund Cost	Risk Cost	Fixed Cost	Surcharge Cost	Total Cost
	-- *Billion Dollars* ---		-------- *Dollars* --------				
1988	60.000	3.000	.08	.0160	.0150	.034	.1450
1989	53.486	3.931	.08	.0074	.0168	.024	.1282
1990	55.719	4.449	.08	.0063	.0162	.022	.1244
1991	59.613	4.931	.08	.0058	.0151	.022	.1229
1992	64.272	5.448	.08	.0056	.0140	.022	.1216
1993	69.603	6.004	.08	.0054	.0129	.021	.1193
1994	76.070	6.532	.08	.0054	.0118	.013	.1103
1995	86.672	6.540	.08	.0070	.0104	.000	.0974
1996	103.668	5.240	.08	.0157	.0087	.000	.1043

equity to support the higher loan volume. Loan volume increases every year because the interest rate charged members is below other lenders' rate of .13 except for the first year. Total interest cost is lowest in the eighth year when it is .0974, which is below the rates in tables 1 and 2. By enjoying a comparative advantage, the cooperative is able to build up equity through the surcharge, yet remain competitive. The resulting strong financial position allows the cooperative to offer the borrower low interest rates in later years.

Table 4 shows the impacts that increasing competitiveness has on loan volume and consequently the performance of the cooperative. By increasing the spread factor w_i from $500 billion to $700 billion, current and future cooperative members become more price sensitive. The result is a smaller surcharge during the first year and a rapid decline in the surcharge in succeeding years. Loan volume responds differently than under previous parameter sets and falls throughout the minimization period. Total interest cost is lower during the early years in comparison with table 2, but is higher in later years, and the cooperative is never quite able to match the competitors' rate of .115. The final result is that the cooperative has approximately half the market share with which it started. Due to the price sensitivity of its members, the cooperative is able to rebuild its financial position only through liquidation of loans and downsizing, and not through the imposition of a surcharge.

Table 5 demonstrates the situation of a well-capitalized financial cooperative. Starting with an equity position of $6 billion instead of $3 billion (perhaps by a government infusion), the institution starts off with a total interest cost that matches the competitive rate of .115. The total interest cost falls throughout the minimization period, which allows loan volume to rise correspondingly. The initial surcharge rate of .016 is lower than under any other parameter set. It is kept at approximately that level both to pay for defaults and to increase equity.

Table 4.—Optimal Values for Minimizing the Cost of Borrowing $1 from 1988 through 1996 if the Spread Factor w_i Is 700

			Cost of $1 of Loan				
Year	Loans	Equity	Fund Cost	Risk Cost	Fixed Cost	Surcharge Cost	Total Cost
	-- *Billion Dollars* --		-------- *Dollars* --------				
1988	60.000	3.000	.08	.0160	.0150	.026	.1370
1989	45.573	3.293	.08	.0077	.0197	.016	.1234
1990	40.858	3.272	.08	.0062	.0220	.013	.1213
1991	38.197	3.137	.08	.0059	.0236	.011	.1205
1992	36.066	2.946	.08	.0060	.0250	.009	.1199
1993	34.101	2.710	.08	.0063	.0264	.007	.1197
1994	32.564	2.413	.08	.0073	.0276	.000	.1149
1995	33.489	1.955	.08	.0117	.0269	.000	.1186
1996	32.463	1.453	.08	.0200	.0277	.000	.1277

Table 5.—Optimal Values for Minimizing the Cost of Borrowing $1 from 1988 through 1996 if Beginning Equity Is $6 Billion

Year	Loans	Equity	Cost of $1 of Loan: Fund Cost	Risk Cost	Fixed Cost	Surcharge Cost	Total Cost
	-- Billion Dollars --		Dollars				
1988	60.000	6.000	.08	.0040	.0150	.016	.1150
1989	61.251	6.062	.08	.0041	.0147	.016	.1148
1990	62.364	6.152	.08	.0041	.0144	.016	.1145
1991	63.458	6.256	.08	.0041	.0142	.016	.1143
1992	64.723	6.357	.08	.0041	.0139	.016	.1141
1993	66.418	6.423	.08	.0043	.0136	.013	.1108
1994	69.411	6.342	.08	.0048	.0130	.003	.1008
1995	77.660	5.508	.08	.0080	.0116	.000	.0095
1996	86.224	4.343	.08	.0158	.0104	.000	.1062

Model Extensions

Models are used to help reason through a problem and obtain plausible solutions. A model only needs to be sufficiently complex to accomplish that and does not need to be a complete representation of reality. Even if numerical results are obtained, they often must be evaluated qualitatively, cognizant of the model's limitations.

In its current form, this model has shown the impact of various scenarios but has limited applicability to FCS without additional development. Further development would fall into two categories: (1) specifying variables and functional relationships that describe the environment of the bank and (2) then empirically estimating the values of the model coefficients. Computer software and computers are available that can derive solutions to models much more complex and extensive than specified here. It may be more difficult, however, to obtain the data needed to estimate the coefficients of a more extensive model.

The model presented here used retained earnings as the only type of equity, but financial cooperatives also use advance capitalization and revolved retained earnings. Although only one member quality and one interest rate were specified, it is common to group members and charge differential interest rates. Loss loan volume may differ significantly between groups and may affect the quality of the loan portfolio. However, in this model, loans were dichotomously classified as performing or lost. In reality, loans are often placed into various categories of nonperformance before they are written off. These and other model extensions may be necessary to ensure the results are more applicable to FCS. Although data may be a limitation in determining relevant coefficients and parameters, it is possible to perform sensitivity analyses by varying coefficient values about which the user is not very confident. Often results are robust to extreme values in coefficients.

Conclusions

This model demonstrates the usefulness of dynamic optimization in deriving optimal equity recovery strategies. Although the problems of the Farm Credit System were the basis for this article, the dynamic model was formulated for a hypothetical cooperative financial institution. Applications of the model show that an interest rate surcharge to restore equity should be imposed immediately and be decreased as equity is restored. The initial surcharge is lower, however, if the cooperative's cost of funds causes it to be less competitive with other lenders. Results also show that the infusion of outside equity can restore an otherwise deteriorating financial condition.

With modifications and extensions, the technique could be used to help answer some of the questions currently facing FCS. After mergers occur under the 1987 act, districts will be reducing overhead or fixed costs. Although some of these costs may be from duplications, elimination of many costs will reduce services to members or reduce loan monitoring. The result may be loan volume reduction with lower quality. If these relationships can be specified, it may be possible to explore optimal levels of overhead services. To meet capitalization requirements, banks will be able to use retained earnings and issue stock at risk. Which source of equity to use depends on initial bank conditions and the lending environment. A dynamic model would be appropriate to determine optimal capitalization strategies. Where government financial assistance is required, FCS eventually must repay the government for its interest outlays although no repayment schedule is specified in the 1987 act. The model could be used to derive an optimal payment schedule. Other applications are undoubtedly possible.

Notes

1. Many would argue that a nondefault guarantee was implicit as evidenced by passage of the Agricultural Credit Act of 1987.
2. Interest costs are not discounted to the present so that the cost of member borrowing in period j has the same weight in the objective as the cost of member borrowing in period k. Discounting would reduce the value of future costs relative to current costs and would shift more of the recapitalization burden from current to future members. Use of a high discount rate may be appropriate if farmers currently are facing financial difficulty.
3. Equity defined here is strictly retained earnings. Borrower contributed equity could be included, but its impact on lowering risk cost probably would be insignificant because many view it as "soft" equity.
4. We prevent the surcharge from becoming negative, which would imply the institution is giving a subsidy.
5. Although all specified constraints are equalities, some variables are constrained to be nonnegative. The objective function is convex, and the constraints are concave. The constraint qualification is satisfied. Thus the Kuhn-Tucker conditions are necessary and sufficient for a minimum.
6. If the model is used for management purposes, it should be solved before the start of each period using revised parameters to obtain optimal conditions for the next period.

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