

Stochastic Dynamic Modeling: An Aid to Agricultural Lender Decision Making

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Factors affecting a lender's decision to grant farmers operating credit in North Dakota are quantified in an intertemporal loan profitability model using stochastic dynamic programming. Experimental data obtained from a panel of lenders demonstrates the sensitivity of an optimal policy to changes in a lender's discount rate, a borrower's repayment status, and patronage. The value of credit scoring models that appraise a borrower's credit worthiness also is determined.

Key words: credit, credit scoring, dynamic programming, experiment, simulation.

An apparent paradox exists in agricultural credit. Despite high levels of default and negative rates of return, lenders continue to grant operating credit to established farmers with whom they have no prior business experience. In North Dakota, 6.9% of all farmers change financial institutions annually (Leistriz et al.). A discontinued line of credit is not the sole reason farmers change lenders. Credit-worthy farmers may shift lenders to obtain more favorable terms, expanded financial services, and increased security.¹

Lenders have difficulty appraising the repayment potential of prospective borrowers because available financial records are often incomplete, nonstandard, based on accounting rather than economic principles, and fail to incorporate the operator's managerial and entrepreneurial abilities (Fisher and McGowan). Due to this informational asymmetry, lenders only obtain true knowledge of the borrower's operation through trial and experience.

Traditional loan profitability analyses are

static in nature and fail to value this educational process. After granting credit for one period, lenders obtain information that sufficiently improves decision making in subsequent periods. Therefore, extension of credit over a period of time may be profitable to the lender even though expected returns in the first period are negative.

The objective of this article is to formulate an intertemporal loan profitability model using stochastic dynamic programming (DP) and evaluate a lender's optimal credit granting policy in a dynamic rather than a static setting. The importance of the lender's time preference for money, a customer's repayment status, and patronage will be demonstrated. Organization of the paper is as follows: the first section briefly describes the extent and characteristics of the lender's management problem. This general discussion is followed by specification of a stochastic DP model. An experiment designed to collect data from a panel of lenders for purposes of model estimation is discussed in the third section. Statistical results and optimal decision rules are presented in the fourth section. The final section summarizes and discusses limitations of the study's findings.

The Lender's Dilemma

Lenders granted \$1.98 billion of nonreal-estate credit to North Dakota farmers in 1986 (U.S. Department of Agriculture). This total consists of both operating and intermediate debt. To reduce transaction costs and increase flexibil-

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¹ Melichar discusses risks associated with patronizing a weak financial institution. Problems faced by credit-worthy farm borrowers when their lender fails include inconvenience, lower credit availability, and capital losses (if the institution's stock was required to be purchased as part of the original loan agreement). Borrowers who are delinquent and in a weak financial condition face greater risks including possible foreclosure.

ity, lenders frequently combine both types of debt into a single, renewable "master note."² Hence, intermediate credit is often treated as operating credit. Each year lenders must decide whether to grant operating credit to new and existing customers who apply.

Lenders undertake a large risk when operating credit is granted to new farm customers with low probabilities of repayment. Loan losses, defined as the amount uncollected on a defaulted loan, are costly to a financial institution (Gustafson, Saxowsky, and Braaten; Lee and Baker). When a borrower defaults, lenders lose uncollected principal and acquisition and administrative costs.³ Due to recent periods of financial stress in the agricultural sector, large loan losses, declining loan volume, and deregulation, financial institutions in rural communities are especially vulnerable to failure. Since farmers of varying financial strengths apply for operating credit, lenders must evaluate each applicant's credit worthiness to avoid adverse selection.

Some lenders formally appraise borrowers. Credit scoring methods evaluate a borrower in terms of liquidity, leverage, profitability, collateral, tenure, repayment capacity and history, management ability, and other personal characteristics. However, as Lufburrow, Barry, and Dixon note, "In general, credit evaluations have mostly occurred through the personal observations and subjective judgments of loan officers, using what data farmers have supplied."

Static loan profitability models price loans in accordance with perceived risks. Loans are priced explicitly through the use of interest rates, fees, and service charges as well as implicitly by requiring compensating balances, loan limits, collateral, loan documentation, and supervision (Barry and Calvert).

Credit rationing occurs when lenders are unable to price loans that meet profit goals, costs of funding, and administration as well as compensate for lending and liquidity risks (Stiglitz and Weiss). In 1984, 9.3% of all North Dakota farmers were refused credit, largely because of insufficient equity or farm income (Watt et al.).

² With a "master" loan, lenders have the option of denying credit and adjusting intermediate loan terms annually.

³ Even though crop insurance and collateral liens reduce the likelihood of operating loan losses, North Dakota statutory laws, such as confiscatory price, effectively prevent timely lender collections from delinquent borrowers. Thus, lenders frequently reduce interest rates, reschedule payments, and extend maturities in an attempt to avoid a borrower's default. As Gustafson, Saxowsky, and Braaten show, these actions are still very costly to lenders.

Ironically, lenders continue to grant credit to selected new applicants on a trial basis—fully expecting above average rates of default and negative returns. Although the decision appears irrational in light of pricing and credit rationing options available, granting credit for one period permits discrimination of borrowers in the future because some new borrowers will repay while others default. As lenders revise probabilities of loan repayment based on this new information, the initial credit granting decision becomes rational and profit maximizing when considered in a multiperiod framework. Hence, lenders are willing to incur a significant short-run cost in an effort to acquire long-term customers. Factors affecting these tradeoffs in the lender's decision are mathematically illustrated with a stochastic DP model.

Dynamic Loan Profitability Model

Stochastic DP is a convenient means of explicitly evaluating the expected present value of future credit extensions. Optimization problems with separable objective functions and discrete decision variables are readily solved by DP and yield optimal decision rules for decision makers (Dreyfus and Law; Taylor and Burt). The following model is similar to one formulated by Bierman and Hausman for commercial trade credit in the sense that it accounts for the dynamics of repayment but differs in the sense that it is applied empirically and accounts for greater detail including partial repayment. The model abstracts from the considerable detail involving compensating balances, alternative fund sources, and user costs embodied in traditional loan profitability models so the stochastic and dynamic relationships presented can be clearly illustrated. Further, the model does not consider the portfolio effects of granting additional credit. However, diversification opportunities for many rural lenders are limited.

Extending credit to unfamiliar farmers is a risky decision for lenders because repayment is uncertain. Assume the borrower is initially in one of the following mutually exclusive repayment states i : (a) full repayment of principal and interest, (b) repayment of interest only, and (c) default. Further, assume j represents the borrower's state one period later. A static, but stochastic, loan profitability mod-

el with expected profit $\pi(n, i)$ from a borrower in state i at period n can be defined as:

$$(1) \quad \pi(n, i) = \sum_{j=1}^J p(n, i, j) \cdot [REV(n, i, j) - CF(n) - AO(n, i, j) - LL(n, i, j)],$$

where the probability of transition from state (n, i) to state $(n + 1, j)$ is $p(n, i, j)$, $REV(n, i, j)$ is uncertain gross revenue from lending, $CF(n)$ is a lender's cost of funds which is known in advance, $AO(n, i, j)$ are administrative and overhead expenses, and $LL(n, i, j)$ is a loan loss charge for unrecovered principal. Gross revenue is obtained from borrowers who repay fully or repay interest only on outstanding debt and is zero from borrowers who default. Loan maturities are assumed to be extended and terms of the loan renegotiated when borrowers default on their principal payments. Administrative and operating expenses vary with repayment status. Loan losses arise when borrowers default.

Lenders are assumed to maximize expected monetary values. These values consist of both current returns and the present value of returns from future credit extensions. Initially, lenders must decide whether to extend or deny credit to a new applicant. If losses from credit extension are expected to exceed returns, credit is denied and the firm's return is zero.⁴ If expected returns are positive, credit is extended, and a likelihood exists that the customer will again apply for credit in future periods. One period later, lenders must again decide whether to extend or deny credit. As long as credit is granted, the problem recurs in subsequent periods, and returns from those future periods must be considered in solving the present decision. This recurrence relationship is the fundamental theorem of DP and can be used to specify an intertemporal loan profitability model as follows:

$$(2) \quad \begin{aligned} f(n, i) &= 0 \quad \text{for } n = N \\ f(n, i) &= \max[\text{profits from extending} \\ &\quad \text{credit, profits from} \\ &\quad \text{denying credit}] \\ &= \max \left[\pi(n, i) + \alpha \delta \sum_{j=1}^J p(n, i, j) \right. \end{aligned}$$

$$\left. \begin{aligned} &f(n + 1, i, j), 0 \right] \\ &\text{for } n < N, \end{aligned}$$

where $f(n, i)$ is the expected value of an optimum policy of credit extension from period n to the horizon, δ is a discount factor, and α is the probability a borrower chooses to patronize the financial institution again in $n + 1$ providing the loan is either fully or partially repaid in n .⁵ It is a borrower-choice variable, over which the lender has no control.

The term $\alpha \delta \sum_{j=1}^J p(n, i, j) f(n + 1, i, j)$ represents the value of future credit extensions. The present value of these extensions approaches zero as n increases because of discounting and the possibility of borrower patronage ceasing. These conditions thereby permit a finite analysis and define ending conditions. Horizon year N is the point where the value of the recursive function is zero. Terminating before this date could change the initial decision, although any change is likely to be insignificant for most practical problems.

The dynamic loan model above has a number of desirable characteristics. It allows for prior probabilities of payment, includes the potential for future profit, and permits systematic revision of repayment probabilities based on past experience (Bierman and Hausman).

Transition probabilities from one state to another can be either estimated with historical data or subjectively specified. Bierman and Hausman did not consider partial repayment and conveniently modeled the transition function as a Bernoulli trial. Cumulative outcomes (probabilities of repayment) over time formed a binomial process with unknown parameter p , a random variable distributed according to a beta probability density function. Revision of prior probabilities is remarkably simple (Raiffa and Schlaifer), but requires that (a) an applicant desires a constant dollar amount of credit each period, and (b) probabilities of repayment are stationary over the decision horizon. Such assumptions are difficult to make if granting operating credit alters a farmer's leverage or wealth positions over time.

To keep the above DP model manageable,

⁵ The model assumes loanable funds are unconstrained. Even though fund shortages have occurred historically, overall deregulation of financial institutions and elimination of interest rate ceilings in particular reduce the likelihood of shortages in the future. In addition, partial granting of the loan request and other credit responses are not permitted.

⁴ Costs associated with credit analysis are considered sunk costs because they are incurred regardless of the lending decision.

a traditional Markovian relationship for repayment is postulated:

$$(3) \quad p(n, i, j) = \text{Prob}(x_{n+1} = j | x_n = i),$$

indicating the probability of transition to state j is conditional upon the current state i . Transition probabilities $p(n, i, j)$ have the usual statistical properties:

$$(4) \quad 0 \leq p(n, i, j) \leq 1, \quad n, i;$$

$$(5) \quad \sum_{j=1}^J p(n, i, j) = 1, \quad n, i.$$

Experimental Method and Data Collection Procedures

Data to parameterize the model were collected in an experimental setting during which lenders' responses to a simulated borrowing situation were elicited. Lenders were able to learn the borrower's true performance with the passage of time. Their credit responses were then evaluated in light of the educational process.

The experimental method was selected over other survey methods because it (a) provided the necessary quantitative and probabilistic information for model estimation, (b) obtained lenders' responses to a specific management problem, and (c) minimized the possibility of extraneous variables influencing the lender's decision. Arrow and Simon advocate using experimental methods when investigating decision-making behavior. In addition, the method has been successfully used in the study of Illinois cash grain farmers' investment behavior (Gustafson, Barry, and Sonka).

Two representative farm situations, one located in the Red River Valley and the other in the East Central region of North Dakota, were constructed to reflect diverse areas of cash grain production in the state. Data were obtained from adult vocational agriculture farm business summaries (Watt, Johnson, and Ali). The Valley farm consisted of 1,385 acres, and the East Central farm involved 2,855 acres. Crops representative of each region (continuous and fallow wheat, barley, and sunflowers on the East Central farm and continuous and fallow wheat, barley, and sugarbeets on the Valley farm) were raised; no livestock was produced, and crop sales were assumed to occur at harvest. Participation in government programs was permitted, and no off-farm income was available. The Valley farm cash rented 290

acres, whereas the East Central farm share rented 1,640 acres. Financial statements for each farm were prepared with the aid of a simulation model.⁶

Financial characteristics of the farms were structured to represent an established borrower who was seeking a lender with lower cost financing. Debt-to-asset ratios were set to .40 for each farm. A panel of farm lenders located outside each region considered these ratios representative and served as a pretest mechanism for the study.

The first situation was presented to five randomly selected lenders who granted farmers credit in the geographic region surrounding Wahpeton, North Dakota, and Breckenridge, Minnesota, and the second situation was introduced to six farm lenders in the Jamestown and Valley City, North Dakota, areas.⁷ Each lender was from a unique commercial bank or Farm Credit Services' office. These two areas were selected because of the high concentration of financial institutions in predominately rural areas of homogeneous farm production.

During the experiment, lenders were provided with a biographical sketch of the borrower and with historical and projected financial statements from the simulation model. Lenders described the characteristics of their institution and were asked if they would grant the operating loan request (figure 1). If the initial request was denied, the experiment was terminated.

If operating credit was granted, lenders were asked to specify credit terms, to subjectively estimate the likelihood the case farm borrower would transit to one of the three possible repayment states and future customer patronage, and to estimate the administrative, operating, and loan loss expenses associated with each state. After these data were elicited, the financial performance of the case farm was simulated again for each resulting repayment state.⁸ One at a time, updated financial statements (illustrating the case farm's possible financial position and credit application one year hence)

⁶ The selected model was the Farm Financial Simulation Model (FFSM) developed by Schnitkey, Barry, and Ellinger. FFSM is a multiyear spreadsheet of a farm's financial performance that reports results in terms of a set of coordinated financial statements.

⁷ One additional lender in the Wahpeton area and two in the Valley City-Jamestown area were contacted but removed from the sample, because they did not grant operating credit to farmers.

⁸ As in Gustafson, Barry, and Sonka, yields, commodity prices, farm income, and asset values of the case farms were randomly varied between the first- and second-year decision situations in order to add an element of uncertainty to the simulation.

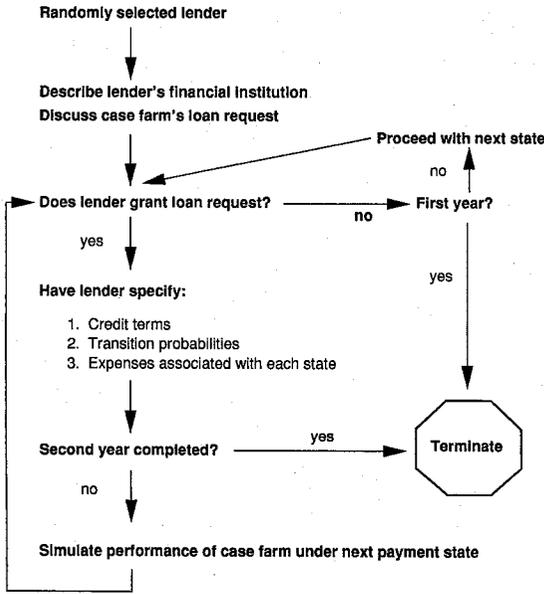


Figure 1. Experimental procedure

were provided to the lender and the experimental process repeated.

To minimize the respondent's burden, the experiment was only conducted for two consecutive periods. After the second session was completed, lenders were informally asked if third-period expectations would significantly differ from those of the second period, given that additional information (more trials) would be available. All of the surveyed lenders stated additional information would not alter their expectations.

The main disadvantage of the experimental method is the abstraction from actual decision situations. In an effort to validate the experimental approach, a research assistant made an incognito formal application for operating credit to one of the financial institutions selected for pretest. The loan officer's supervisor (who was informed of the trial) was instructed

to elicit the loan officer's subjective estimate of the applicant's probability of full, partial, and no repayment if the loan application were forwarded for review and processing. Similar data to that of the case farm were used to complete the loan application.

One week later, the same loan officer was asked to participate in the experiment. In both instances, the loan officer granted the operating loan request and provided identical probability estimates. Although the loan officer may have offered rote responses, he did so in both real-world and experimental settings.

Results

Data collected during the experiment are summarized in table 1. All institutions surveyed had assets of less than \$100 million. The average number of agricultural operating loans granted annually per institution ranged from 42 to 250. The size of these operating loans averaged \$84,636. Loan size was the only variable that differed statistically by region. Operating loans in the Red River Valley averaged \$120,400, while operating loans granted to farmers in the East Central region averaged \$54,833. This difference reflects the varying capital requirements of farms in each region. Assets of the representative Valley farm totaled \$1.362 million versus \$.566 million for the East Central farm. Profit margins on lender's operating loans averaged .77% after cost of funds, administrative costs, and loan loss charges were deducted.

Farmers with operating loans at these institutions were expected to remain customers for nearly 20 years. Lenders explained that even in light of the recent financial crisis, farmers still used available profits to purchase additional assets and expand the size of their businesses as opposed to reducing existing debt levels.

Table 1. Characteristics of Financial Institutions Surveyed

Item	Mean	Standard Deviation
Number of operating loans outstanding	120	55
Average operating loan size (dollars)	84,636	60,858
Current interest charged on operating loans (%)	11.71	1.02
Average cost of funds (%)	7.85	.92
Administrative costs and loan losses (%)	3.09	.72
Average length of time farmers remain customers of institution (years)	19.5	6.9

Table 2. Conditional Operating Loan Repayment Probabilities Elicited from Survey Lenders^a

Status of Case Farm Borrower	Probability of:		
	Full Repayment	Partial Repayment	No Repayment
	%		
New Customer	87.82 (5.27)	5.45 (2.58)	6.73 (3.85)
Existing Customer who Repaid Previous Operating Loan:			
Fully	96.36 (1.92)	2.64 (1.57)	1.00 (1.04)
Partially	69.82 (19.71)	23.36 (15.98)	6.82 (7.40)
No Repayment	20.00 (22.58)	25.55 (19.93)	54.45 (28.83)

^a Standard deviations are shown in parentheses.

Elicited Repayment Probabilities

Subjectively estimated conditional probabilities of repayment elicited from the lenders are shown in table 2. After evaluating the representative new customer, all of the lenders decided to grant the case farm's operating loan request. On average, lenders expected full repayment with 87.8% probability, payment of interest only with 5.5% probability, and default with 6.7% probability.

After granting operating credit for one period, lenders had more information to appraise the case farm's credit worthiness. Lenders believed that if the case farm borrower repaid the first period operating loan, the farm was more likely to do so in the future as the expected probability of default dropped from 6.73% to 1%. Similarly, if the farm defaulted, it was expected to do so again in the future. The probability of default, conditional on the borrower paying only interest on the first period loan, is not statistically different from that of a new borrower—although probability of full repayment is less. Unlike the uniform expectations lenders have for a case farm borrower who fully repays past loans, lenders' estimates of future repayment status are highly variable for a borrower who either partially repaid or defaulted on previous loans.

The probabilities elicited are stationary with respect to time. This is consistent with lenders' statements that a farmer's leverage positions and susceptibility to financial risks remain sta-

Table 3. Present Value of Optimal Credit Granting Policy at Each Decision Stage

Year	Borrower's Repayment Status, Last Period		
	Full	Partial	Default
	\$		
1		1,190 ^a	
2	1,882	1,178	-4,585 ^b
3	1,881	1,177	-4,585 ^b
4	1,880	1,176	-4,585 ^b
5	1,878	1,174	-4,585 ^b
6	1,875	1,172	-4,585 ^b
7	1,871	1,168	-4,585 ^b
8	1,865	1,163	-4,584 ^b
9	1,857	1,156	-4,584 ^b
10	1,846	1,146	-4,584 ^b
11	1,829	1,131	-4,583 ^b
12	1,806	1,110	-4,583 ^b
13	1,772	1,081	-4,582 ^b
14	1,723	1,038	-4,580 ^b
15	1,657	978	-4,578 ^b
16	1,561	893	-4,575 ^b
17	1,424	771	-4,571 ^b
18	1,229	598	-4,566 ^b
19	952	352	-4,557 ^b
20	557	-19.66 ^b	-4,739 ^b

^a Because borrower is a new customer, previous repayment status is unknown.

^b Credit denied because present value of optimal policy is less than zero.

ble over time. Expected probabilities of full, partial, and no repayment in the second period are 89.8%, 5.3%, and 4.9%, respectively—not statistically different from first-period expectations.

Optimal Decision Rules

Given the case farm's expected probability of repayment, an average operating loan size of \$84,636, and profit margins described above, a myopic decision rule that does not consider the value of future credit extensions is to deny the loan request. Single-period expected gross returns are \$612 but expected costs including those of default are \$623 resulting in an expected payoff of -\$11.

Optimal decision rules for granting operating credit over a finite horizon are obtained when the DP credit granting model is estimated (table 3). The expected payoff of following such a policy and granting operating credit to the case farm borrower is \$1,190. This value includes the present value of all future credit extensions as well as the possibility that borrower patronage ceases.

At the end of the first period, expected future

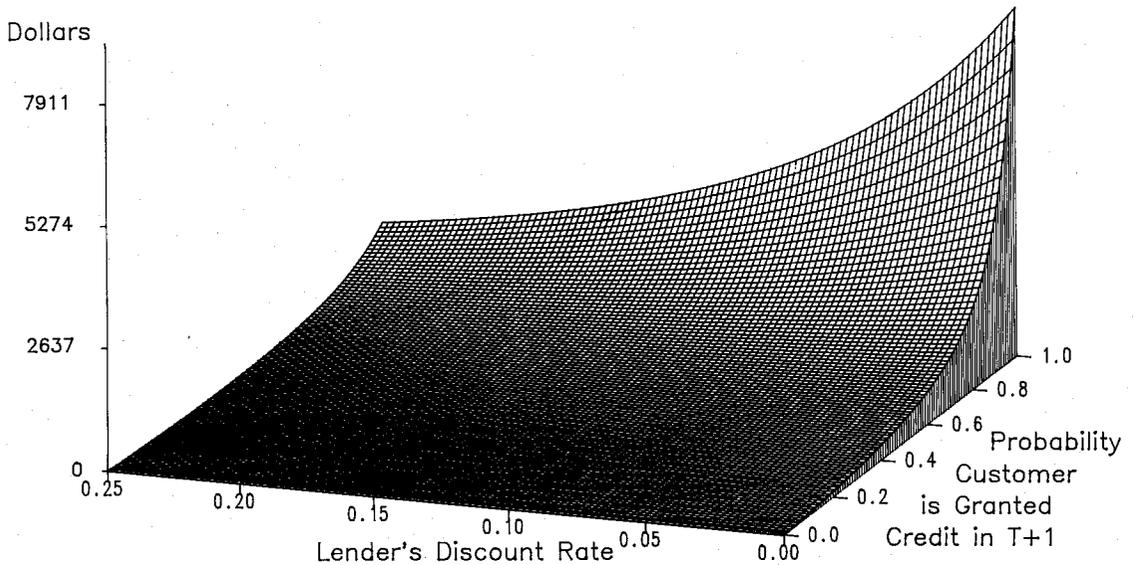


Figure 2. Value of optimal credit policy when lender's discount rate and customer patronage vary

payoffs of granting operating credit another period to case farm borrowers that fully repaid, partially repaid, and did not repay credit in the last period are \$1,882, \$1,178, and -\$4,585, respectively. Hence, an optimal policy at this stage is to deny credit if the borrower defaulted on previous operating loans. Because operating margins are small and costs of default high, defaulting borrowers are not given a second chance.

Lenders continue to grant the case farm credit until year 20 as long as farmers fully or partially repay. At that time, credit will only be granted if full repayment occurred in year 19. Future payoffs from extending credit to borrowers who only partially repaid are insufficient to warrant credit extension during the last period.

The repetitive utilization of credit affects the initial credit granting decision. One reason the myopic and optimal decision rules could differ is if probabilities of repayment were not stationary with respect to time. However, as noted above, this is not the case. Granting credit to the case farm is only profitable if the borrower continues to patronize the institution in the future. Borrowers could demand more favorable credit terms and reap a portion of the lender's profits at the time of loan origination if assurances of future patronage could be guaranteed. Likewise, lenders may rationally deny credit to borrowers who are over an age threshold because future patronage is uncertain.

The value of the optimal policy is sensitive to changes in a lender's discount rate and assessment of a borrower's patronage (figure 2). As a lender's discount rate increases or expectations of customer patronage decrease, the value of the optimal policy declines. These variables likely differ by lender. Hence, a lender's characteristics, in addition to those of a borrower, determine whether operating credit is granted.

Value of Credit Scoring

There is a second application of the DP credit granting model. The recursive relationship $f(n, i)$ provides the present value of an optimal credit granting policy from year n to the end of the planning horizon, given repayment probabilities $p(n, i, j)$. The value of techniques employed by lenders when evaluating a borrower's credit worthiness, such as credit scoring and discriminate analysis, which lead to improved estimation of $p(n, i, j)$, can be ascertained with the recursive relationship.

After evaluating the representative new borrower, lenders in the survey expected default on the first-year operating loan with 6.7% probability. During the experiment, some lenders systematically evaluated borrowers, while others did not. Figure 3 illustrates how improved credit scoring techniques can influence the present value of an optimal credit granting policy. Such methods would further

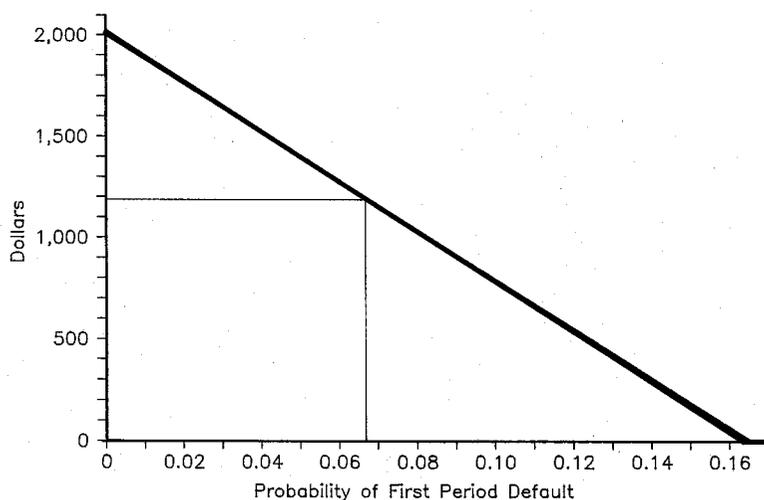


Figure 3. Value of optimal credit granting policy given varying probabilities of default

allow lenders to identify and deny credit to marginal borrowers—increasing the odds remaining customers will repay.

If improved evaluation techniques had led lenders to expect half the default rate, 3.4% rather than 6.7%, the value of the optimal policy would have risen \$414 (from \$1,190 to \$1,604). This value would increase further if probability estimates of repayment beyond the first period were also revised upward. Given these payoffs, lenders, either individually or cooperatively with peer institutions, could devote more resources to the development of improved credit scoring models and place less emphasis on the ad hoc methods of evaluation noted by Lufburrow, Barry, and Dixon.

Development of the DP model alters the role of scoring models in lenders' credit granting decisions. With subjective interpretation, lenders previously translated credit scores directly into lending decisions. If a borrower's score was above (below) some threshold level, credit was granted (denied). Now the role of scoring models becomes more narrowly focused and objective—integrating knowledge of a borrower's production, financial, marketing, management, and personal characteristics into the specification of transition probabilities. Once formulated, the transition probabilities, revenue, and costs of extending credit can be explicitly evaluated in a dynamic setting and optimal credit granting decisions determined.

Conclusion

Optimal credit granting policy requires balancing the expected gains from extension

against possible losses associated with default. Gains from extending credit not only include those of the current period but also the present value of all future returns. Presented in this article is a dynamic loan profitability model that quantifies the importance of those future returns in the lender's decision. Overall results demonstrate the sensitivity of an optimal policy's value to changes in a lender's discount rate, a borrower's future repayment status, and patronage.

A major limitation of this study relates to estimating the transition probabilities $p(n, i, j)$. When solving any dynamic programming model for a nontrivial number of states, the number of parameters to be estimated soon exceeds available data. In this study, parameters could only be estimated for the first two stages of the problem. Thus, the greatest potential for improving the model would be collecting additional data that test whether repayment probabilities beyond the second period are constant. The findings of this study also could be broadened by replicating the study in other geographic areas and periods and by including the level of detail currently embodied in static loan profitability models.

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