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# **Risk Elements in Consumer Instalment Financing**

**By DAVID DURAND**

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*Technical Edition*

**Financial Research Program**

**Studies in Consumer Instalment Financing 8**

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**NATIONAL BUREAU OF ECONOMIC RESEARCH**

## **Risk Elements in Consumer Instalment Financing Technical Edition**

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This study presents a statistical approach to the analysis of certain pertinent risk elements in consumer instalment financing. It attempts to analyze the significance of some credit factors generally considered important by credit men, to discern which of these factors have been associated in the past with bad loans, and determine whether or not this information can be used to predict the course of future transactions. Highly refined statistical methods have been employed in order to assure precise results and also test the applicability of such methods to the problems involved. The study provides information on:

the characteristics of consumer instalment credit;

details of procedure to be followed in an analysis of borrower characteristics as factors in credit risk;

the relative importance of various credit factors in risk selection as revealed by the analysis;

credit-rating formulae developed by means of a specialized statistical procedure;

technical aspects of the statistical methods evolved;

the application of findings to credit policy and to a study of costs.

The basic data for the study were obtained from actual loan applications and were contributed by lending concerns operating in various phases of consumer instalment credit — commercial banks, industrial banking companies, personal finance companies, automobile finance companies, and appliance finance companies.

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FINANCIAL RESEARCH PROGRAM OF THE  
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*Studies in Consumer Instalment Financing:*  
Number Eight

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BY DAVID DURAND

Financial Research Program  
*Studies in Consumer Instalment Financing*

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## Preface

THIS study presents an analysis of certain factors which are relevant to the selection of credit risks and the determination of credit standards in the field of consumer instalment financing. It constitutes one phase of the investigation in this field, initiated in 1938 by the National Bureau of Economic Research and supported by special grants from the Association of Reserve City Bankers and the Rockefeller Foundation. A study of consumer instalment financing was originally recommended by the National Bureau's Exploratory Committee on Financial Research in its report submitted in 1937, and the broad purposes of such a study were set forth as follows:

"Instalment financing of consumer purchasers withstood the strain of the depression so well and showed such relatively small losses throughout the crisis as compared with many other types of credit instrument that banks and other financial agencies, pushed to find outlets for surplus funds, are now expanding rapidly in this field. This expansion, moreover, is assuming a competitive form, with respect not only to interest rates and other financial charges, but also to the down payment, the term of loan, the security, and the amount extended in relation to the income of the borrower. As a result, pressure is being brought to bear to relax the strictness of the procedures that tended to safeguard instalment financing during the depression. The Committee feels that, in view of its potentialities, this situation deserves careful analysis. At present, it is impossible to decide with any

confidence whether these modifications of procedure are justified or whether they constitute introduction of credit standards which are far too lax and which may have serious repercussions. In the present state of knowledge, such judgments cannot be based on data drawn from broad experience; they must be largely expressions of opinion. It is essential, the Committee holds, that an effort be made to gather all the available data on this type of financing for the purpose of identifying those credit standards which are sound and have stood the test of experience."

In the five institutional studies previously prepared and published under the consumer instalment financing project—dealing with personal finance companies, sales finance companies, industrial banking companies, consumer financing departments of commercial banks, and government agencies of consumer instalment credit—we presented separate analyses of credit experience in the several areas represented by these agencies. The present study brings together the findings of the individual studies, and makes an integrated analysis of risk factors in the entire field of consumer financing.

The raw materials for this study consisted of about 7,200 reports on loans actually made by 37 firms engaged in consumer instalment financing. These firms included 21 personal loan departments of commercial banks, 2 personal finance companies, 10 industrial banking companies, 3 automobile finance agencies and 1 appliance finance company. Although the basic data were supplied by a variety of firms in different areas, certain tendencies appeared consistently in most of the samples supplied.

Highly refined statistical methods were employed in this study, in order to assure precise results as well as to test the applicability of such methods to the problems involved. But since many companies may not find feasible the use of elaborate statistical methods, we have limited the discussion in the main text to procedures which are simpler, easier, and

less expensive, and which any company can apply to its own records in order to test its risk experience. The technical discussion of statistical theory and methods has been confined to three appendices. Since these appendices will be of interest chiefly to statisticians with specialized mathematical training, the study has been published in two editions, and the appendices have been eliminated from one of them. This is the technical edition, with appendices.

We welcome the opportunity to express indebtedness to the following firms, which cooperated, at considerable expense to themselves, in furnishing data or other assistance for this study:

Bank of the Manhattan Company  
The City National Bank and Trust Company, Columbus, Ohio  
The City National Bank and Trust Company, Kansas City, Missouri  
Corn Exchange National Bank and Trust Company, Philadelphia  
The Equitable Trust Company, Baltimore  
The First National Bank of Boston  
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 The National Shawmut Bank of Boston  
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Citizens Savings and Loan Corporation, Chattanooga,  
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 Louisiana  
 Royal Industrial Bank, Louisville, Kentucky  
 Thrift, Incorporated, Des Moines, Iowa  
 Thrift, Incorporated, Evansville, Indiana

The collection and analysis of the data presented many difficult technical problems, and much experimental statistical work was required to determine the most appropriate treatment of the material. Mr. Durand, who has been in charge of the analysis from its beginning, has resolved these problems with great skill, patience, and resourcefulness.

By pointing the way to a recurrent statistical testing of credit experience by institutions engaged in consumer instalment financing, Mr. Durand has made a unique contribution to credit practices in the field, and we hope that the completion of this study will stimulate further investigation into the problem of such credit standards. In modern interest theory, much emphasis is placed on credit risk as a factor affecting the gross charge to the borrower, but little attention is given to the elements that comprise or affect risk. By identifying and indicating the role of some of these elements in the field of consumer instalment credit, Mr. Durand's study affords an empirical basis for the elaboration of the risk problem in this single sphere of interest theory.

RALPH A. YOUNG

*Director, Financial Research Program*

April 1941

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DAVID DURAND,  
*Financial Research Staff*  
(*National Bureau of Economic Research*)



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## Summary of Findings

IN ANY credit transaction, an element of uncertainty necessarily enters; the creditor can never be sure whether the debtor will fulfill his obligations. Most prospective credit transactions therefore receive critical analysis designed to enable the creditor to reject the most unsound deals, which might entail ruinous losses. Even so, some uncertainty of repayment remains, and the creditor must impose a charge high enough to provide a reserve to cover losses.

In consumer instalment financing, which includes cash lending on the instalment basis as well as the instalment financing of automobile and other retail sales, the risk problem is affected by the peculiar nature of the business. Transactions are small and numerous, for instalment credit is primarily designed to serve the masses of employed consumers with low incomes. As in all types of credit transactions, consumer loans are carefully investigated; but owing to the small size of the typical loan, the investigation is usually a rather simple, inexpensive, and routine affair; furthermore, the standards of the business are liberal so that the rejection of an applicant is the exception rather than the rule. Nevertheless, collection difficulties are not sufficient to make the business unprofitable. Charges are high enough to permit generous loss reserves and to cover the costs of handling small accounts; and the large number of cases handled makes diversification of risk an easy matter.

We began this study of instalment risk by asking a number of commercial bankers and retail merchants engaged in consumer financing what credit factors they considered indic-

ative of good risk. From the large number of replies a fairly simple and consistent pattern was finally pieced together. By consensus of opinion the two most important credit considerations are the applicant's moral character, which is judged by his past payment record as well as by his general reputation, and the stability of his employment, which is a criterion of the permanence of his earning power. Of secondary importance are the applicant's current obligation to other creditors, his assets, the amount of the down payment in sales finance transactions, the length of the loan contract, and so on. The adjustment of the borrower's income to the amount of his monthly payments was also given secondary consideration—a fact that requires some interpretation. Creditors certainly insist, we believe, that an applicant's income shall be sufficient to permit him to repay his loan; in the course of the investigation, the amount of the income is almost invariably ascertained, usually from the applicant's employer, and then analyzed with a view to its sufficiency or insufficiency. Although lack of sufficient income would be a prime cause for rejection, the possession of a more-than-ample income does not seem to be regarded as a sign of particular merit.

After learning what credit factors are thought important by credit executives, we proceeded to test the factors statistically. The choice of an appropriate method for making the test was largely dictated by considerations of economy, since the difficulties of obtaining and tabulating data were serious. The method that offered the most promise was a sample analysis of two types of loans, those with satisfactory repayment experience and those entailing serious collection difficulties; and the samples were to consist of approximately equal numbers of each type of loan. The method has the advantage of great efficiency, probably assuring maximum efficiency with a minimum expenditure of labor; it has the disadvantage of not stating the risk problem in terms of costs.

A number of consumer financing institutions contributed

samples of loans representing their good and their bad experience. For each loan pertinent information was provided covering duration of borrower's employment, nature of occupation, borrower's income, and other items commonly found on loan applications; no information relating to moral character or past payment record was provided, however, because of the difficulty of acquiring significant statistics.

The process of analyzing these samples and these data is best illustrated concretely. A sample of good loans and a corresponding sample of bad loans are both broken down according to the factor to be analyzed—say number of years applicant had been employed in his present occupation when he applied for his loan. The result is almost always the same: the good loans contain a larger percentage of borrowers with long periods of employment than do the bad loans, and the average number of years of tenure of occupation among the good loans is longer than that among the bad. This fact implies that in the past there has been a causal relation between stability of employment and good-loan experience, and that in the future, applicants with stable employment records are more likely to turn out well than those with unstable records. Stability of occupation, it will be remembered, is one of the factors considered extremely important by lenders.

In addition to stability of occupation, a number of other pertinent relationships were uncovered. Stability of residence, measured by the number of years applicant had lived at his present address, is more frequently associated with good loans, but the relation is less pronounced than for stability of employment. Borrowers with bank accounts are much commoner among good loans than among bad, and the same is true, though to a lesser extent, of borrowers possessing life insurance and owning real estate. Type of occupation is definitely related to credit risk, but there are so many difficulties in making a satisfactory study of risk experience by occupation that some reservation is necessary;



in general, professional persons and clerical employees appear to be good risks, whereas traveling salesmen and unskilled or semiskilled laborers appear to be poor risks. Women appear to be better risks than men, a fact that seems puzzling to a number of credit executives.

In the field of sales finance, the down payment is very important; measured either in dollars and cents or as a percent of the cash selling price, large down payments are generally associated with the better risks. In used-car financing, the purchasers of high-priced cars are the better risks, apparently because it is customary to demand a larger down payment, in dollars and cents, from the purchaser of a high-priced car. In new-car financing, the length of the loan contract appears to be important; samples of repossessions contain much higher percentages of long-term contracts than do samples of paid out accounts. But in used-car financing, contract length does not seem to have special significance.

In respect to a number of factors, the available evidence gives little or no indication of any relation to risk. Age of borrower, for example, seems to be related to risk experience, but the relationship is not very marked; older applicants are only slightly better risks than younger ones. The industry in which the borrower is employed is probably related to risk, but the samples on hand are too inconsistent to permit any reliable judgment; the same is true of the use to which the borrower intends to put the proceeds of his loan, which is relevant only to the cash lending business. The evidence on the asset items of ownership of automobiles or household goods, and on the liability items of charge accounts or other instalment accounts, is extremely inconsistent and generally unreliable. No significant evidence was found to indicate that the number of a borrower's dependents is related to risk. The same is true of marital status.

One of the most noteworthy findings of the entire study concerns borrower's income. A genuine, though not very

pronounced relation between income and risk was found in the sales finance samples, but no relation whatsoever was found in most of the cash loan samples. This fact raises two questions: why is the relation not more pronounced—even in the sales finance samples; and why is there a difference in experience between sales finance and personal finance? A number of cogent explanations are possible, though none of them are verifiable by available statistics. The lack of an income-risk relation is partly explainable by the fact that samples of carefully selected loans do not contain paupers, unemployed persons, or cases of extreme overborrowing on a small income, so that the samples cannot reflect the influence of seriously inadequate income on loan experience; and partly by the supposition that the actual amount of the total income is much less significant than the stability of that income, the margin between income and expenses available to retire the indebtedness, and the probity and financial acumen of the applicant. The difference in experience between sales finance and personal finance companies may be due to two reasons: sales finance transactions are initiated by a merchant who expects his profit from the sale of the merchandise rather than from an interest charge; and the sales finance company usually has for security not only a chattel mortgage on the goods sold, but also the endorsement of the merchant who makes the sale.

In the course of the study, we introduce the "efficiency index," whose purpose is to show which of the credit factors studied are the most important, in view of the available evidence. This index permits comparison of the effectiveness of the different factors as indicators of risk; it does not measure the intrinsic importance of the factors, but rather their potential importance in the future selection of risks. A discussion of this index and its computation is presented at length in Chapter 2; in brief, a high index for a particular factor suggests that the factor is an effective measure for differentiat-

ing good risks from bad among loan applicants; a low index suggests that the factor is an ineffective measure for this particular purpose. Table 17 (Chapter 3, page 80) presents the more important factors investigated, with their efficiency indices as determined from the various institutional samples analyzed. The factor having on the whole the highest index is down payment in the sales finance samples; the most notable single instance is an index of 46 for percent down payment in the new-car sample. Length of loan contract has a high index of 36 in the new-car sample, but is otherwise unimpressive. Both bank account and tenure of occupation have indices that average over 20 for the four sample groups for which indices could be determined.

A review of the above findings is particularly interesting in comparison with the general opinions of the instalment financing business expressed by the commercial bankers and retail dealers whose views were obtained; a number of points of agreement and a number of points of divergence will be apparent. First, it is worth pointing out that our samples shed no light on the important questions of past payment record or character and reputation because of the difficulty of obtaining data. Agreement in the case of stability of occupation is almost complete: the consensus of opinion in the business is that this factor is of first-rate importance, and all our samples bear this out. There is disagreement, however, in the matter of down payment in sales finance transactions; according to our findings, down payment is a factor of primary importance, but the retail dealers whom we interrogated gave it only secondary emphasis. There is also disagreement in regard to assets and liabilities: our samples suggest that a borrower's assets, particularly a bank account, are more important than his liabilities, but the financing business lays more stress on liabilities than on assets. Finally, two factors, which were almost completely disregarded by the bankers questioned, stand out as fairly important in our

analysis. These are sex and stability of residence. Several credit executives have expressed surprise that the loan samples show women to be considerably better risks than men, and they suggest that this result may be due to the indirect effect of other factors rather than to a simple, direct relationship.

Several credit-rating formulae were developed by means of a specialized statistical procedure; they will certainly be of more interest to students of statistical theory, however, than to practical credit executives. These formulae are presented primarily for purposes of illustration, to show that the findings on the individual factors can be consolidated, and that the resulting composite is more effective as an indicator than any of its components. In the matter of practical risk selection, the formulae are subject to a number of shortcomings that seriously impair their usefulness: (1) they fail to include important factors like moral character and past payment record, for which no data are available; (2) since they are based on samples of loans from which undesirable risks have been culled out by a suitable selection process, they will be useful only for culling out additional undesirables after the first selection has been made; (3) the theoretical considerations upon which the formulae rest, as well as the methods by which they are determined, are too complex to be understandable to any but trained mathematicians.

The findings of this study indicate that more careful selection of risks, with greater emphasis on possession of a bank account, stability of employment, a large down payment, and other factors, is almost certain to improve the quality of borrowers; but they do not indicate how far the improvement can be carried advantageously. Successful credit policy must be nicely adjusted to perform two almost contradictory functions: it must keep credit losses and collection costs within reasonable limits, and yet it must be liberal enough to encourage business. Since the function of the consumer credit

business is to make credit available to the masses, the business is more inclined toward liberality for the sake of volume than it is toward restrictiveness for the sake of quality. If applicants were too carefully selected—if they were required to have bank accounts and stable employment records, and to make large down payments—a large share of the present borrowers would be excluded. There is practically no evidence to indicate that additional care in the selection of applicants would bring greater benefits to the business. For several decades the consumer credit business has been pursuing a liberal policy of serving the masses of consumers, and it has succeeded in avoiding undue losses.

The ultimate problem of credit analysis is not one of determining which classes of risks are good and which classes are poor, but rather of determining which of the poorer classes are so poor that they are unprofitable at the prevailing rates charged for credit. The method of analysis outlined in this study is not an entirely satisfactory approach to the question of profitability. In cases where precision is required, the only satisfactory method is a detailed and laborious analysis of the actual costs involved, but in many other cases the simplicity and inexpensiveness of our method will compensate for its lack of precision.

While it is not our purpose to discuss the social implications of credit policy, it is necessary to point out that the problem exists. The consumer credit business fills a real need by extending credit facilities to a large number of worthy borrowers who could not otherwise enjoy such facilities; but by extending credit to borrowers who are unable to repay the financial obligations thus assumed, the business provides an undesirable social influence. Although the social benefits of consumer credit cannot be enjoyed without some of the attendant ills, risk policy can be directed toward maximizing the benefits and minimizing the ills.

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## Scope and Purpose of the Study

SOME form of credit investigation is essential to any loan transaction, whether large or small, personal or business. When making an investigation, a lender does not attempt to predict the applicant's repayment record precisely, but he does undertake to distinguish the applicants who are likely to repay from those who are not. In this attempt, he obtains pertinent information on such matters as borrower's character and reputation, borrower's financial condition, intended use of the funds, and type and value of any collateral that may be offered as security. From an analysis of this information, the lender evaluates the proposed transaction; in doing this, he relies on his experience and intuition, and in addition he may weigh the available facts according to some mechanical routine.

In the present study, we are presenting a statistical approach to the analysis of certain pertinent risk elements in consumer instalment financing. The purpose of the study is twofold: first, to analyze the significance of some credit factors generally considered important by credit men, to discern which of these factors have been associated in the past with bad loans, and to determine whether or not this information can be used to predict the course of future transactions; second, to experiment with the use of statistical methods that may be applied to the problem of credit risk selection. Statistical methods, particularly small sample techniques, have not heretofore been used to any great extent in credit analysis, and their value in such analysis is not well known. This is regrettable, for the orderly recording of experience, which

is the essence of the statistical method, should aid considerably in solving risk problems.

The statistical method evolved in this study has been designed to permit analysis of loan experience without undue expenditure of labor, and its application is simple enough, we believe, to be of practical value to credit executives in solving some of their own particular problems. But the method has its shortcomings as well as its advantages. Although it may be effectively used for testing various general hypotheses and for discovering unsuspected relations between credit information and risk experience, it is an inferior method for determining what type of credit policy will produce lowest costs and highest profits. Detailed consideration of the proper approach to the questions of costs and credit policy will be given in a later chapter.

#### CHARACTERISTICS OF CONSUMER INSTALMENT CREDIT

Provision for periodic repayment is the most general characteristic of consumer instalment credit, but a number of others are fairly typical. Loans are for the most part small; nearly all are substantially less than a thousand dollars in size, and the majority are less than five hundred dollars. The proceeds are usually employed by ultimate consumers to purchase goods, to finance a current deficit, or to meet a personal emergency; but they are also used for business purposes.<sup>1</sup> The security for these loans does not ordinarily consist of stocks and bonds or mortgageable real estate, which would be acceptable collateral for a loan at almost any commercial bank. The usual forms are endorsements by comakers, con-

<sup>1</sup> Loans used for consumption purposes cannot always be distinguished easily from those used for business purposes. When a small business enterprise buys a truck on the instalment plan, a business loan is undeniably involved. On the other hand, while the purchase of a passenger automobile would usually be considered a consumer loan, many passenger cars are used partly for business purposes.

ditional sales contracts, and chattel mortgages on automobiles or household goods; in many cases there is no security at all. Interest rates on consumer loans are on the whole higher than on business loans, but the costs of doing business are also higher. A number of different types of institutions make consumer instalment loans; the main ones are industrial banking companies, commercial banks, personal finance companies, sales finance companies, retail dealers, and credit unions.

In general, consumer instalment credit transactions may be classified in two broad groups—sales finance transactions and personal finance transactions. The former are handled largely by sales finance companies or retail merchants, and to a lesser extent by commercial banks and industrial banking companies; cash loan transactions are usually handled by personal finance companies, commercial banks, industrial banking companies, credit unions, and a number of lesser agencies. In sales finance, some retail merchants handle the entire transaction themselves—the investigation of risk, the arrangement of terms, and the collection of payments; others investigate the risk, arrange the terms, and then dispose of the customer's obligations to one of several agencies that discount and collect such paper; and still others leave all the arrangements to their financing agencies. In personal finance, the borrower applies to one of the available lending agencies for a loan of cash, and this agency, if it approves the application, assumes the task of collecting the account. The borrower uses the loan for some specified purpose or purposes; he may use it to purchase goods, in which case it may be a substitute for a sales finance transaction, or he may use it to meet emergencies or to settle pre-existing obligations.

In legal discussions it is extremely important to distinguish sales finance transactions from personal finance transactions, for a debt arising out of a bona fide sale of goods on the deferred payment plan is not legally a loan and is not subject to the maximum interest statutes. For purposes of risk analy-



sis, however, the distinction is of little use. Although we shall occasionally find it convenient to consider sales credit separately from personal credit, we shall usually prefer to consider both together; we shall use the term *loan* to include both cash loans and instalment sales transactions, and the term *lender* to include sales finance companies and retail merchants as well as cash lending agencies.

On the whole, consumer instalment lending institutions tend to establish themselves in urban areas and to grant credit to urban and suburban dwellers with moderate and regular incomes. These facts are reflected in the vocational composition and income distribution of their clientele. Persons of all occupations are included, from unskilled laborers to the higher-paid business and professional classes. The number of farmers included, however, is relatively small in comparison with the general population.<sup>2</sup> Farmers tend to seek other forms of credit since on the whole they have seasonal incomes unsuited to meeting regular monthly payments; as entrepreneurs, they can usually satisfy their personal, as well as their business needs with non-instalment loans from commercial banks and from a number of other institutions specially set up to provide credit to farmers.

The highest and lowest income classes also are underrepresented. Although the income distribution covers a wide range, substantially more than half of all the cases in the samples on which this study is based represent borrowers with incomes between \$1200 and \$3000; and among purchasers of used cars and borrowers from personal finance companies, more than 75 percent of each group falls within this income range.<sup>3</sup> The proportion of the total borrowing public included in this income group is considerably higher than the analogous proportion of the country's total population; the

<sup>2</sup> No farmer group is given in the occupational distribution presented in Table 13, pp. 70-71, because the number of farmers was too small to justify a separate classification.

<sup>3</sup> See Table 4, pp. 46-47.

latter proportion is only about 47 percent.<sup>4</sup> The well-to-do are underrepresented because they have relatively less need for consumer loans than do other classes; when they do require financing, they can usually obtain lower interest rates on non-instalment bank loans either unsecured or secured by stocks and bonds or real estate; and in any event they rarely have to resort to the higher-rate loans secured by co-makers or chattel mortgages. The very poorest classes, the unemployed and the indigent and those with incomes substantially less than \$1200, are underrepresented among borrowers by necessity rather than by choice; they are excluded from credit facilities by lenders' credit standards. Instalment loans are intended to be repaid out of income, and the main concern of lenders is that their borrowers shall have a means of livelihood. Therefore, customers usually must be employed or engaged in business, and they must receive a remuneration sufficient for their support. Probably every lender operates on a set of minimum income standards. These standards are seldom precisely formulated, and are capable of being waived in special circumstances; nevertheless, they serve to prevent paupers and near paupers from availing themselves of loan facilities.<sup>5</sup>

<sup>4</sup> This percentage, which was estimated for 1935-36 by the National Resources Committee, refers to the income class of \$1000 to \$3000. It includes all single persons and non-relief families. See *Consumer Incomes in the United States* (1938) Table 8, p. 25.

The picture we have presented is based on the operations of sales finance companies, personal finance companies, commercial banks, and industrial banking companies. If we had had data for other lending agencies, particularly retail merchants, we might have shown that even lower-income classes make extensive use of instalment credit. Retail dealers extend credit to very low-income classes, particularly in communities where clothing, cheap radios, and other low-priced goods are sold on the instalment plan. Furthermore, mail-order houses extend considerable amounts of instalment credit to farmers.

The limits of the interval \$1200 to \$3000 are not particularly significant since we do not know the precise points at which the overrepresented middle group ends and the underrepresented extreme groups begin. However, the chosen limits are convenient for broad illustrative purposes.

<sup>5</sup> The records of most lenders show a few cases of borrowers with little or no income, but these cases can usually be explained in terms of family or

### RISK SELECTION

Because consumer credit is designed to be available to the general masses, and because small sums are involved, the detailed and exhaustive investigation of credit standing characteristic of most commercial loan transactions is not typical of consumer instalment credit transactions; a more routine and less individual procedure is necessary. The lender has to content himself with a rather limited amount of credit information. In essence, the process of risk selection is more one of rejecting a small number of undesirables from a large body of generally satisfactory applicants than one of selecting a limited number of high-grade risks. Despite this fact, the consumer credit business has grown rapidly, and consumer lenders usually succeed in avoiding undue losses.

Risk selection is effected not only by the interviewing of applicants but also by other methods. For instance, after deciding what class of customers it wishes to deal with, a lending firm can direct its advertising to that class; and by making known its general requirements for loans, it can dissuade a great number of unsatisfactory risks from applying for credit.

Standards of acceptability doubtless vary considerably from lender to lender, but certain broad principles appear fairly universal. The minimum income restriction, mentioned above, seems to be one of the fundamentals of risk selection. Another fundamental is the lender's insistence upon obtaining borrowers who are reasonably honest and fairly responsible in meeting their obligations. To assure this result, a good share of the credit investigation consists in checking

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other personal relationships. Examples are a wife who borrows on the co-signature of her husband, a son who succeeds in buying a car on credit because of his father's credit standing, or an unemployed person who meets his expenses while seeking employment with the proceeds of a loan secured by co-signatures of friends. These cases do not occur frequently, and when they do occur the reported income is misleading.

applications for false statements, consulting credit bureaus and previous creditors for signs of irresponsibility, and searching court records. Apparently some lenders reject a credit applicant if he has ever failed to meet financial obligations or if he falsifies his application; others, however, may be much more lenient.

In addition to minimum incomes and satisfactory past payment records, applicants are expected to possess other qualifications, and to supply on their applications information concerning these qualifications. This information, which concerns age, marital status, number of dependents, stability of residence and occupation, assets and liabilities, etc., is indicative of what credit officials generally consider important. The items collected for our analysis of risk elements are reasonably representative except for one item; no information is available on the important matter of past payment record.

Although a study of application forms demonstrates the items of information required, it does not even suggest the relative importance that credit officials attach to these items. Consequently, two sets of questionnaires were sent to credit officials, to determine how operating lenders evaluate credit factors. One set went to commercial bankers operating personal loan departments, and the other to retailers in several lines of business; 126 replies were received from the former and 688 replies from the latter.

The bankers, in their questionnaire, were requested to state what credit factors they considered important and to list them in order of importance. No hints were given concerning the answers expected except that reference to income was not to be included. Although the replies showed amazing variation, many of the differences seemed to be merely in terminology. The answers were classified into 15 convenient categories, such as character and reputation, stability of employment, borrower's liabilities, etc. These categories were then given ratings on a point system; a score of 5 was given

each category every time it was listed first in importance by a banker; a score of 4 was given every time it was listed second; 3 was given for third place; 2 for fourth place; and 1 for fifth place. These 15 categories were then consolidated into 5 broad groups; for example, the similar items of past payment record, character and reputation, and credit rating were combined to form the broad group, moral characteristics. A score for each broad group was then determined by computing a simple sum of the scores of the component items. All the scores, both single and combined, were then converted to index numbers, with the total score of the vocational characteristics as the base figure (i.e., 100). The results are presented in Table 1.

As the table stands, moral characteristics are most highly emphasized, financial characteristics are next, and vocational characteristics are a very close third. But this presentation of results may be extremely misleading, for the table could be rearranged to show a very different order of importance. The table was arranged in its present form because of certain resemblances among the grouped categories. Character and reputation, past payment record, and credit rating, all seemed to us to be virtually identical, and hence they were grouped together; but they may not have seemed identical to the bankers who filled in the questionnaires. Thus, although the present form of the table shows that moral characteristics are most important, with financial characteristics next, and vocational characteristics third, other interpretations are possible; for example, stability of occupation may be considered most important, with past payment record second, and character and reputation third.

The questionnaire for retail merchants was arranged differently. Six specific credit factors were listed on the questionnaire, and the merchants were requested to indicate the relative order of importance of these factors. The merchants were also requested to list any other factors that they con-

TABLE 1

INDEX OF RELATIVE IMPORTANCE ATTACHED TO VARIOUS CREDIT FACTORS OTHER THAN INCOME BY 126 COMMERCIAL BANKS<sup>a</sup>

<i>Credit Factor</i>	<i>Index<sup>b</sup></i>
<b>Vocational characteristics</b>	
Work performed	25
Industry and employer	4
Stability	71
	—
	100
<b>Financial characteristics</b>	
Assets	21
Liabilities	46
Income balance	36
	—
	103
<b>Moral characteristics</b>	
Past payment record	63
Character and reputation	59
Credit rating	40
	—
	162
<b>Personal characteristics</b>	
Age	5
Marital status	4
Number of dependents	18
Stability of residence	3
	—
	30
<b>Loan characteristics</b>	
Security	13
Duration	14
	—
	27

<sup>a</sup> Based on a questionnaire survey made by the National Bureau of Economic Research. A more detailed table, showing number of times each factor was given first or second or third place, is given in National Bureau of Economic Research (Financial Research Program), *Commercial Banks and Consumer Instalment Credit*, by John M. Chapman and Associates (1940) p. 138.

<sup>b</sup> For explanation see text, pp. 15-16.

sidered important, but few of them availed themselves of the opportunity. The replies were rated by the same point system used for the bank questionnaire; and the scores were converted to relatives, with occupation and permanence of employment equaling 100. The results are shown in Table 2.

In this table, item (1), occupation and permanence of employment, and item (2), past payment record, appear clearly as the two most important factors, with all others distinctly secondary. But items (3) and (4) could be combined to form a group similar to financial characteristics in Table 1, and then the combined score of 90 would bring this group

TABLE 2

INDEX OF RELATIVE IMPORTANCE ATTACHED TO VARIOUS CREDIT FACTORS BY 688 RETAIL ESTABLISHMENTS<sup>a</sup>

<i>Credit Factor</i>	<i>Index<sup>b</sup></i>
(1) Occupation and permanence of employment	100
(2) Past payment record	98
(3) Terms conveniently adjusted to customer's income	48
(4) Additional instalment obligations to other stores	42
(5) Terms that will secure largest down payment and fastest liquidation possible	33
(6) Length of loan contract	16

<sup>a</sup> Based on a questionnaire survey conducted by the National Retail Credit Association in cooperation with the National Bureau of Economic Research (Financial Research Program), July and August, 1939. Answers were received from 688 retail establishments situated in 157 cities in the United States and Canada. The answers were graded by giving 5 points to the credit factors ranked first in importance by the retail merchants, 4 to those ranked second, 3 to those ranked third, 2 to those ranked fourth, and 1 to those ranked fifth; the final scores were then converted to relatives with item (1) equal to 100. A more detailed table, showing replies by various types of stores, is to be found in National Bureau of Economic Research (Financial Research Program), *Sales Finance Companies and Their Credit Practices*, by Wilbur C. Plummer and Ralph A. Young (1940) p. 137.

<sup>b</sup> For explanation, see text above.

into a position of importance with the first two items; similarly, the combining of groups (3), (5), and (6) would result in a total score of 97.

The two questionnaires together substantiate fairly well our views of the two fundamental requirements of risk selection. Lenders attach considerable importance to past payment record, which was one of our fundamentals. Although the questionnaires did not request information concerning minimum income, our other fundamental, its importance may be gauged in other ways. For all practical purposes the minimum income requirement means that borrowers must be employed and self-supporting; and since the questionnaires indicate emphatically that borrowers are expected to be employed in stable positions, the matter of minimum income adequate for self-support can almost be taken for granted. In addition to employment stability and repayment record, other factors such as borrower liabilities and the relation of income to obligation are important, but no attempt is made in this study to determine the relative importance placed upon these factors by credit executives.

#### NATURE OF PROBLEM

The specific problem undertaken in this study is the analysis, by use of statistical methods, of some credit factors generally considered important in consumer instalment financing. The data on which the study is based were transcribed from actual loan applications, and were contributed by 37 lending concerns operating in various phases of consumer instalment credit. About 7200 loans were represented, of which about 2700 cases were supplied by commercial banks operating personal loan departments, 1400 by personal finance companies, 1300 by industrial banking companies, 1400 by automobile finance companies, and 400 by appliance finance companies. The data obtained covered a number of bor-



rower characteristics: age, sex, marital status, number of dependents, income, occupation, number of years at occupation, number of years at present address, borrower's assets and liabilities. Information was also secured concerning the chief characteristics of the loan contract: the amount of the loan, number of months for repayment, intended use of funds in the case of cash loans, and the amount of down payment in instalment sales transactions. These data are readily available on most applications and are adaptable to statistical analysis. Information was not obtained on the important question of past payment record and similar considerations, since such data were difficult to obtain in a form suitable for analysis. No information could be secured on matters like physical and mental health, which are certainly germane to the risk problem, but which obviously do not lend themselves to analysis in a statistical study of credit risks.

The present report is concerned solely with the selection of risks and does not deal with the matter of collecting accounts. This qualification of the practical significance of the study is important, for leniency in selection may be partly offset by more rigorous collection policy, and vice versa. The cure for excessive delinquency and charge-off losses, among borrowers as a whole or in some particular class of borrowers, is not always a better selection of risks; in some cases it may be found in better collection methods.

Perhaps the most serious limitation of the present study is that it is based upon data derived from applications that were carefully investigated and finally accepted. The findings therefore pertain to high-grade, selected risks and not to risks in general. Since we have only meager data on the reasons for rejecting applicants and no data whatsoever that show how rejected applicants would have behaved if they had been granted loans, the opportunities for determining the effectiveness of existing methods of risk selection are few.

This limitation is no drawback, however, to lenders pri-

marily interested in reducing losses by further raising of credit restrictions. Even among the selected, high-grade risks, different degrees of excellence exist. On the basis of the findings presented here, or on the basis of a similar study of his own past loan experience, a lender may determine the characteristics of the most desirable of his present customers; he may then supplement his existing credit standards with others to obtain an even more highly selected group of customers.

On the other hand, if a lender is interested in increasing the volume of loans as far as possible, the value of this study—or of any study based on past loan experience—is distinctly limited. The lender's problem is to determine which of the borrowers hitherto excluded can be safely included in the acceptable class. One possible procedure is to make experimental loans, which amounts to a temporary lowering of standards, with a possible increase in losses, and a subsequent adjustment of standards on the basis of the newly gained experience. Another possible procedure is to follow the experience of some other lender who has already relaxed credit standards. Of course, the methods of analysis used in the present study are appropriate for evaluating experience with experimental loans or for evaluating the experience of another lender.

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## How Risks Can Be Studied

THE analysis of risk factors presented in this volume is the result of a statistical sampling procedure based on a categorical classification of all loans into two mutually exclusive classes, "good" loans and "bad" loans. Theoretically, a good loan is distinguished from a bad loan by the fact that the gross profit on a good loan is sufficient to cover all expenses including possible losses; but in practice the distinction is much less precise. Many, perhaps most loans are repaid in full and on time, and are therefore considered by lenders to be good loans. Some loan accounts become delinquent, however, and sooner or later the lender begins to take action; follow-up letters and calls by collectors usually come first; later comes legal action, which includes seizure and sale of collateral as well as the garnishment of wages; and finally, if all efforts appear fruitless, the loan may be charged off. Although no lender can determine precisely when a loan ceases to be profitable and begins to become unprofitable, many lenders draw some qualitative distinction between their worst loans and the others. Some lenders, for example, set up a Grade A class of borrowers, comprised of those who have repaid promptly and in full, a Grade B class consisting of those who have repaid but with occasional delinquency, and a Grade C class including those who have shown serious delinquency leading to court action, charge-off, or repossession. Such a distinction may be very useful in determining which borrowers merit additional loans in the future.

Since most lenders' files are arranged with some sort of separation between good and bad loans, separate analyses of

these two classifications, rather than a single analysis of all loans, are made in the present study. The characteristics of the borrowers in each class—average age, occupational distribution, percentage of persons having bank accounts, etc.—are compared. The analysis consists, then, of a study of the important differences in borrowers' characteristics between good loans and bad loans. Each lender who contributed material was requested to provide a sample of good loans and an approximately equal sample of bad loans. The process of making such a selection, while appearing simple, involves a number of serious complications, which are discussed later in this chapter.

#### ILLUSTRATIVE ANALYSIS

The procedure of analysis adopted for this study may be described by illustrating its use in a specific case—for example, in the analysis of samples of 100 good loans and 100 bad loans obtained from the personal loan department of a New England commercial bank. We know from the questionnaires described in Chapter 1 that lenders consider stability of occupation an important credit factor, and we wish to determine whether or not the samples bear this out. The data requested from the bank include the number of years the borrower had been engaged in the occupation in which he was employed at time of application. We have used this information as the basis for a measure of stability, although admittedly a measure based on previous employment as well as present employment would be more satisfactory. Among the cases submitted, the borrowers' present employment records were reported for all the bad loans and all but one of the good loans. This fact is important, for if the information had not been reported for a substantial number of cases, the results would have been questionable if not entirely invalid. In most of the tables accompanying this report,

the number of cases not reporting information requested is given in addition to the number of cases reporting; when the number not reporting seems sufficiently high to discredit the result, attention is called to this fact.

One possible method of showing whether stability is related to risk is to compute the means of the employment records of the two samples. In this illustrative case the mean of the good-loan sample is 10.76 years, and that of the bad is 7.16 years.<sup>1</sup> If these averages are reliable, they indicate that satisfactory borrowers in the past have been persons with occupations more stable than those of the unsatisfactory borrowers. Most people will be willing to infer that future applicants with stable employment records are likely to be better risks than those with unstable records.

The next point to consider is whether or not the averages are reliable. A skeptic might object: "I believe that if you took sufficiently large samples, you would find no difference between the means of the good loans and of the bad loans; I believe that the apparent difference in the stability of employment in these two groups of loans is a pure coincidence entirely attributable to sampling errors, which are bound to occur in inadequate samples." Such a coincidence is of course possible, but extremely unlikely. A standard test<sup>2</sup>

<sup>1</sup> After reading a preliminary draft of this study, one of our critics reported that these averages are considerably higher than his experience would indicate. Upon investigation, we discovered that the occupational tenures reported by this bank are among the longest reported by any of the contributing banks. This fact we attribute either to selection on the part of the bank officials or to the possibility that the community served by this bank may be a particularly stable one. In any case, the sample is satisfactory for illustrative purposes. Furthermore, it is typical of all other samples in that the average tenure for the good loans is greater than the average tenure for the bad loans.

<sup>2</sup> A description of this test, called the t-test, particularly its application to small samples, will be found in R. A. Fisher, *Statistical Methods for Research Workers* (London and Edinburgh, 6th edition, 1936) Chapter 5 (in particular sec. 25.1); G. Udny Yule and M. G. Kendall, *An Introduction to the Theory of Statistics* (London, 11th edition, 1937) Chapters 20 and 23; George W. Snedecor, *Statistical Methods Applied to Experiments in Agriculture and Biology* (Ames, Iowa, 1937) Chapters 2, 3, 4.

of statistical significance indicates that there is not one chance in a hundred that such a coincidence could have occurred. Some grounds therefore exist for believing that the results are reliable. If, however, the test of significance had indicated that the chance of a sampling coincidence was considerably more than one in a hundred—say 10 in 100, or 1 in 10—we should have dismissed the evidence as unreliable.

That tests of significance demonstrate reliability only in a limited sense should be emphasized. Such tests actually show whether or not the sample is large enough to be reliable. If the test of significance indicates that the sample is not large enough, no further evidence is necessary to demonstrate unreliability. But if the sample is large enough to be reliable, it may still be unreliable for a number of other reasons. For example, borrowers may have made false or misleading statements on their applications, and the prevalence of falsehood may be lower among the good loans than among the bad; errors of transcription or tabulation may have been made, and these may for some reason affect the good and bad loans differently. Errors of this sort, however, can only be eliminated at their source, by systematic credit investigation and by careful checking of statistical transcriptions and computations.

Table 3, giving percentage distributions of the good and bad loans according to the borrowers' stability of occupation, illustrates an alternative method of sample analysis, used as the standard throughout this report. In this type of analysis we are no longer interested in the average number of years of tenure of occupation for each sample, but in the difference between the percentage of good and the percentage of bad loans for any particular group of borrowers. In the example in Table 3, 30.0 percent of the bad loans show tenure of less than three years, but only 22.2 percent of the good loans are in this same class. Similar discrepancies for the other class intervals will be noted.

TABLE 3

THE RELATION BETWEEN BAD-LOAN EXPERIENCE AND STABILITY OF OCCUPATION, AS SHOWN BY THE GOOD-LOAN AND BAD-LOAN SAMPLES SUBMITTED BY ONE COMMERCIAL BANK<sup>a</sup>

Number of Years at Present Occupation <sup>b</sup>	Percentage Distribution		Ratio of Bad Loans to Good
	Good Loans	Bad Loans	
0- 3	22.2	30.0	1.4
3- 6	19.2	30.0	1.6
6-10	13.1	18.0	1.4
10 and over	45.5	22.0	.5

*Remarks:* The discrepancy between the samples is statistically significant. The efficiency index is 23.5; for description of efficiency index, see text, pp. 28-31.

<sup>a</sup> The good-loan sample consisted of 100 cases, of which 1 did not report information, and the bad-loan sample of 100 cases, all reporting.

<sup>b</sup> Upper limit of class interval excluded.

These distributional differences are not explainable as sampling coincidences any more than the average differences discussed above; an appropriate test for this arrangement<sup>3</sup> indicates that there is not one chance in a hundred that these results could have occurred as a sampling coincidence. This fact is indicated in Table 3 under "remarks," which include a statement to the effect that the results are significant. Most of the other tables accompanying this report also contain remarks indicating whether the evidence is significant, questionably significant, or not significant.<sup>4</sup> Significance refers, of course, to statistical significance, which only means that the sample is of sufficient size to justify drawing conclusions.

<sup>3</sup> The Chi-square test. Cf. R. A. Fisher, *op. cit.*, Chapter 4; Frederick C. Mills, *Statistical Methods* (New York, revised, 1938) pp. 618-36; George W. Snedecor, *op. cit.*, Chapters 1 and 9.

<sup>4</sup> Results are considered significant if they satisfy the 1 percent criterion; they are considered questionably significant if they meet only the 5 percent criterion; and otherwise they are considered not significant.

## INDEX OF BAD-LOAN EXPERIENCE

Table 3 also gives ratios of the percent of bad loans in any class interval to the percent of good loans in that class interval. This ratio, called the bad-loan relative, may be used as an index of bad-loan experience for the cases in that interval. Since the ratio or index for all classes combined is 1 (100 percent to 100 percent), a ratio of 1, when it occurs, indicates average experience; a ratio greater than 1 indicates worse-than-average risk; and a ratio smaller than 1 indicates better-than-average risk. Thus for the interval of fewer than three years in Table 3 the ratio of 30.0 percent to 22.2 percent, or 1.4, indicates worse-than-average experience; and for the interval of 10 years and over the ratio .5 indicates better-than-average experience. In samples of only 100 good and 100 bad loans, the bad-loan relative is subject to a large sampling error; about all the relative can indicate is whether a particular class interval, or group of borrowers, is better than average, roughly average, or worse than average. In much larger samples, however—samples of several thousand would be necessary—the relative takes on more precise significance.<sup>6</sup>

When a sufficiently large unselected sample is obtained—i.e., a sample that represents the true relative importance of the good and bad loans—the bad-loan relative can be supplanted by the ratio of the number of bad loans in any class interval to the number of all loans handled in that class interval, which is obviously preferable to the relative. Of course, the bad-loan relative can be used to estimate the desired ratio for a particular class interval if the over-all ratio of the number of bad loans in all classes to the number of all loans handled is known. The process may be illustrated by the following example. Suppose the banker who sub-

<sup>6</sup> See section on size of sample, pp. 35-37 below, and also Appendix C.



mitted the sample of Table 3 discovered from past experience that 2 percent of all loans made were bad loans. If he wanted to know the ratio for borrowers with less than 3 years' employment tenure, he could obtain an estimate by multiplying 2 percent by 1.4, i.e., by multiplying the over-all bad-loan ratio by the bad-loan relative for the class interval in question.

### THE EFFICIENCY INDEX

An abstract interpretation of the result of this sample experiment can be given easily. The questionnaire results reviewed in Chapter 1 show that lenders believe that stability of occupation is an important indicator of creditworthiness, and the sample data bear out this belief. This conclusion is not of much use, however, in the formulation of loan policy. Although loan policy can be satisfactorily discussed only in terms of operating cost—as we shall show later—a concrete example of the type of problem involved can be obtained immediately by reference to Table 3. In this table, three class intervals, comprising all borrowers with tenure of employment of less than 10 years, are worse than average. On the basis of this evidence, however, a loan officer is not likely to reject all future applications from applicants with occupation records of less than 10 years; Table 3 suggests that by setting up a 10-year minimum tenure standard a lender will lose more than half his present business, which he probably will not wish to lose even if it is worse than average. Before making any minimum requirements, a lender will want to make sure that the borrowers thus eliminated are so much worse than average that they are absolutely unprofitable.

A factor, to be really effective as a credit indicator, must provide some means whereby a substantial number of bad accounts can be eliminated without appreciable rejection of

good business. In this connection a simple though rough measure of the effectiveness of various factors can be computed. To illustrate: The three worse-than-average class intervals in Table 3, including all borrowers with tenures of less than 10 years, contain 78.0 percent of the bad loans but only 54.5 percent of the good; the difference between these two percentages is 23.5 percent. The one better-than-average class, that with tenures of 10 years and over, contains 45.5 percent of the good loans and only 22.0 percent of the bad; and again the difference is 23.5 percent. Conceivably this difference can vary all the way from 0 to 100. When it is 0, the distributions of good and bad loans are identical; therefore, if any class of borrower is rejected, the same percentages of good and bad loans will be eliminated. If the difference should ever be 100, the better-than-average classes would contain all the good loans, and the worse-than-average groups would contain all the bad loans; hence, all bad loans could be eliminated without the loss of any of the good loans. Thus, the larger differences between 0 and 100 generally indicate greater opportunities for eliminating bad risks without undue elimination of good risks. This difference, which we shall call the efficiency index, provides the desired measure of the usefulness of any factor (in our illustration, the particular factor is tenure of occupation) as a means of credit control.<sup>6</sup>

In the course of this report, the efficiency index will receive considerable emphasis; its function is to separate the more effective credit factors from the less effective. The highest

<sup>6</sup>The efficiency index for normal distributions is an easily determined function of the ratio of the mean difference between the two samples to the standard deviation. (See Appendix A, pp. 106-8.) In most technical discussions, this ratio is a more fundamental concept than the efficiency index. The efficiency index has the advantage, however, of being determinate for qualitative attributes, such as occupation, where there is no ratio of mean difference to standard deviation.

index discovered in the entire analysis is 46 for percent of down payment in the new-car sample.<sup>7</sup> From this maximum, the efficiency indices for other factors range down to almost zero, and most of them are below 20. Indices of less than 10 may usually be considered practically equivalent to zero; this matter will be amplified in Chapters 4 and 5. A tabulation of the efficiency indices for the more important credit factors appears in Table 17, Chapter 3.

Discussion of the efficiency index introduces a major problem in interpreting results. The index is offered as a measure of the effectiveness of a factor as a risk selector; what it really measures, however, is not the inherent effectiveness of a factor, but its effectiveness in future selection only. When the sample analysis of a factor shows no significant difference between good and bad loans, or when the efficiency index is small, the most natural interpretation is that the factor is unrelated to risk. This interpretation would be the only correct one if it were based on samples of totally unselected loans, but the fact that all loans have been carefully selected permits another interpretation. When, in the granting of loans, considerable emphasis is laid on a given factor, and when these loans are used as a basis for sample analysis, a low efficiency index for the factor—even an important factor—is likely to result. The low index merely means that further emphasis on this factor is undesirable; it does not mean that less emphasis is desirable.

Lenders who wish to make studies of their own loan experience should not consider results yielding an efficiency index of less than 15.0 as significant. This precaution, used along with two others to be recommended later<sup>8</sup> (a minimum sample of 200 good and 200 bad cases, and a minimum total of 30 good and bad cases in each class interval), may suffice

<sup>7</sup> See Table 9, p. 61.

<sup>8</sup> See pp. 35-36.

as a rule-of-thumb substitute for a precise test of statistical significance. This substitute rule, while not infallible, will aid in securing sample reliability. We recommend, however, that investigators acquaint themselves with the standard sampling methods, especially if they intend to make very extensive investigations.

### SELECTION OF SAMPLES

The specific case used for illustrative purposes above was based on an analysis of 100 good loans and 100 bad loans. The objection may be raised that an analysis based on samples of equal size gives undue weight to the bad loans, which are considerably less important numerically than the good loans. This objection can arise only from a misconception of the purpose of the equal sample method and of the principles of modern statistical sampling theory. The analysis of bad-loan experience may be considered in two distinct parts. The first part is the measurement of the relative importance of the two groups of loans—i.e., the ratio of bad loans to good, or of bad loans to total number of cases handled—and for this purpose equal samples are obviously useless. The second part is the portrayal of characteristic differences between the good and bad loans; and for this one purpose the equal sample approach is admirable, for it provides maximum reliability with a minimum number of cases. We have found that a total sample of 200 cases is often large enough to determine some of the differences between the two groups if the sample is equally divided between good and bad loans. But a sample of 190 good and 10 bad loans, which is the sort of distribution that would truly represent the relative importance of good and bad, would be inadequate because of the small number of bad loans. To obtain reliable results, a sample of some 2000 cases containing perhaps 1900 good

and 100 bad loans would be necessary. No one will deny that such a representative sample of 2000 cases is preferable to an equally divided, selected sample of 200 cases. But if the cost of obtaining 2000 cases is prohibitive, a sample of 100 good and 100 bad loans may be better than no sample at all. The essential point is to obtain a sufficiently large sample to be statistically reliable for each of the two categories.

Another objection to equal samples arises from the popular belief that the reliability of a sample is determined by its coverage, i.e., the percentage of all cases represented by the sample. Modern sampling theory rarely finds the concept of coverage very useful. Except in special cases—and the analysis of loan experience is not one of them—a sample is not thought of as a finite percentage of a finite population (i.e., the total group from which the sample is drawn), but rather as an infinitesimal part of an indefinitely large population—a hypothetical infinite universe, so called. Although this view of sampling may seem radical, it is actually the most conservative possible. For example, if a sample of 250 cases is large enough to represent reliably an infinite universe, it will represent better a finite population of 1000 cases, and still better, one of 300 cases. The important fact in sampling is not coverage but the attainment of a sample large enough to represent faithfully an infinite universe. This policy is followed in the present analysis.

#### RANDOM SAMPLING TECHNIQUE

In statistical investigations of the kind outlined in this volume, correct random sampling procedure is extremely important; it is also one of the most difficult problems encountered in loan sample analysis. A standard satisfactory method cannot be formulated because the design of a suitable method often depends upon the nature of the problem

at hand. All we can do in this study is illustrate good sampling procedure in the following rather simplified imaginary situation.

A lender has on record 237 particularly unsatisfactory loans made during 1938 and 1939. He also has some 15,000 other loans made during the same period; these other loans are generally satisfactory, containing nothing worse than cases of minor delinquency. For his study the lender decides that the 2-year period is sufficiently homogeneous and sufficiently short so that selection of cases by chronological distribution is not necessary. He also decides to take the entire 237 cases for a bad-loan sample and to draw a random sample of approximately 237 cases from the 15,000 satisfactory cases, believing that for his study the additional accuracy obtainable by using more than 237 good cases does not justify the additional work involved. The only difficulty is the problem of drawing the random sample of good cases.

Several simple methods of drawing are possible. One is to take 237 cases haphazardly from the filing cabinets; another is to take some letter in the alphabet that will provide about 237 cases; and a third is to count out the loans and take every 63rd one. All of these methods, however, are frowned on by some statisticians. A more acceptable method is to make out a control card for each loan and to shuffle the cards in a mechanical shuffler, but this procedure is extremely cumbersome. An acceptable and at the same time practical method, which can be used if the loans to be sampled are numbered consecutively, may be found in a table of random numbers.<sup>9</sup>

Suppose the 15,000 loans are numbered consecutively from 10,000 to 25,000. The loans are probably arranged in chronological order, but that is of no consequence. A sample of 237

<sup>9</sup> One table of random numbers appears in *Tracts for Computers, No. 15, Random Sampling Numbers*, compiled by L. H. C. Tippets (London, 1927). Another appears in R. A. Fisher and F. Yates, *Statistical Tables for Biological, Agricultural and Medical Research* (London and Edinburgh, 1938), Table XXXIII, pp. 82 ff.

cases can be drawn easily from a table consisting of columns of random digits as follows:

8091	9271	1473	....	....
0818	4452	0627	....	
2314	5748	3108		
0550	5465	9463		
1351	1788	2406		
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A column of five digits may be marked off, and from this column all numbers between 10,000 and 25,000 may be selected. In the above sample table we can take the first five-digit column (the first four-digit column plus the first digit in the second column); the third number in this column, 23145, is within the required range; so is the fifth, 13511. In this way 237 random numbers can be obtained, and the loans with the corresponding numbers can then be secured from the file. If a few of the numbers are missing, additional numbers can be drawn until the sample reaches the required size.

Usually, however, the sampling problem is not nearly so simple. The loans may not be filed consecutively by number, or a selected chronological distribution of loans may be considered necessary. In such cases proper random sampling can be accomplished by means of shuffling, or the loans can be specially numbered to permit the use of a table of random numbers, but the mechanical difficulty of either process will probably induce many to use less acceptable but simpler methods.

#### SIZE OF SAMPLE REQUIRED

We assume throughout this report that the best samples to use are approximately equal samples of good and bad loans. This assumption, of course, is true only when good and bad cases are equally easy to obtain and tabulate; when they are not, very unequal samples may be utilized. For example,

a lender with a good punch card system and with records available for 10,000 good loans and 200 bad loans may find the tabulation of the entire 10,000 good loans as simple as the drawing of a random sample of 200 good loans to match the 200 bad; he will probably decide that the small additional expenditure of effort is more than repaid by the additional precision inherent in the larger sample. But in many other cases little is gained by using unequal samples, and this study is primarily concerned with such cases.

The optimum size of sample depends upon a number of things: the cost or difficulty of obtaining cases, the degree of precision desired, the nature of the questions to be answered, and so on. The required number will be small if the problem at hand is merely to answer some such question as the following: Is there a significant difference between good and bad loans in respect to stability of occupation? One possible approach, already pointed out, is to determine the means and standard deviations of the two samples and then to apply an appropriate test of significance.<sup>10</sup> Our experience indicates that samples based on as small a number as 55 good loans and 55 bad loans may give significant results. The alternative method, that of making frequency distributions and then employing another test of significance,<sup>11</sup> probably requires a somewhat larger number of cases, but actual experience indicates that samples of 100 good and 100 bad loans are frequently large enough to demonstrate significance.

Although significant results can be obtained with samples of 100 good and 100 bad loans (or even fewer), we do not recommend that lenders wishing to make analyses of their own loans use such small samples. Those who understand the use of tests of significance can form their own judgment concerning the size of the sample, but those who do not understand these tests should use samples of at least 200 good

<sup>10</sup> See footnote 2, p. 24.

<sup>11</sup> See footnote 3, p. 26.



loans and 200 bad loans. Furthermore, they should arrange the distributions so that the minimum total of good and bad loans in any class interval is 30. This last restriction, which is important, will either limit the number of class intervals to a few, or it will necessitate samples larger than 200 of each type of loan. For example, if loans are to be classified into 20 occupational classes, a total of 30 good and bad loans in each class cannot be obtained with fewer than 300 good loans and 300 bad, and in all likelihood many more will be required.

The above estimates of sample size are all made on the supposition that no great degree of precision is required. We have already mentioned that the bad-loan relative (the percentage of bad loans in any class to the percentage of good loans in that class) is not very accurate for small samples; if the bad-loan relative is to be determined precisely, much larger samples will be required. A degree of precision can be defined, for illustration, as follows: suppose that for some class interval or group of loans the true, or so-called population value of the bad-loan relative is 1.0 (this is the value that would be approached if the sample were indefinitely large), and suppose that the sample must be large enough to insure, within reasonable likelihood, that the sample value of the bad-loan relative shall be between .9 and 1.1; then the minimum number of cases in each sample is about 7200 if there are to be 10 class intervals, and about 15,200 if there are to be 20 intervals.<sup>12</sup> Samples of this size would be appropriate in studies of bad-loan experience by occupation, for example. For such a study the relative merits of the different occupational groups would have to be accurately determined. Furthermore, to be satisfactory, the occupational classification would have to be fairly detailed; 20 different

<sup>12</sup> The range of error from .9 to 1.1 is taken to represent a sampling variation of two standard errors on either side of the true value, 1.0. Thus there is only one chance in twenty that any given sample estimate will lie outside the specified range. See Appendix C, pp. 151-53.

occupational groups would not be too many, and even 50 occupational groups might be desirable.

#### CONSOLIDATION AND CONSISTENCY OF INDIVIDUAL SAMPLES

Since many lenders contributed samples, a separate analysis of each contribution is not presented in this study, but all the available samples have been consolidated into six general groups, as follows: commercial banks, industrial banks, personal finance companies, appliance finance companies, new-car transactions, and used-car transactions. In the process of consolidation most samples were merely added together, but the commercial bank samples were specifically weighted to compensate for the effect of samples containing an unequal number of good and bad loans.<sup>18</sup> A consolidation of sam-

<sup>18</sup> For commercial banks, the distributions presented throughout this study are weighted averages of the percentage distributions of the 12 component samples. These averages were computed because different banks contributed different proportions of good and bad loans; some contributed twice as many good loans as bad, whereas others contributed an equal number. If all these available samples had been merely added together, the good-loan experience of the banks submitting twice as many good loans would have been overrepresented; and if any variation had existed in the loan experience of the different banks, a source of error would have been introduced. To avoid this source of error, a weight was given to each bank sample, and the same weight was applied to both the good- and the bad-loan distributions of that bank sample. The weight was determined by the total number of loans in the smaller of the two samples; if the bad-loan sample was the smaller, the number in that sample was taken as the weight, and conversely. The sum of the weights was, in most cases, 1294, which we have termed the effective number of cases. This is a fictitious number used for the purpose of making tests of significance, and does not refer to the actual number of loan schedules, which was 1468 good and 1297 bad loans. A measure of statistical significance based on 1294 will slightly underestimate the true significance.

In many of the distributions shown here, information was not reported for some of the cases. In such instances the effective number of cases was reduced in accordance with the number for which data were not reported. For all the other types of lending institutions submitting samples, the number of good and bad loans was approximately equal; consequently no process of weighting seemed necessary, and all component samples were merely added together.

ples, even samples from the same general type of institution, has serious drawbacks, however. When samples drawn independently from different lenders' loan portfolios are haphazardly collected and consolidated, the net result is not a sample of any particular homogeneous universe. The combined samples represent a diversity of influences: they represent no standard degree of goodness or badness; they represent lenders operating in different geographical locations and employing different credit policies; and they cover an undetermined period of time, during which lending conditions and credit experience may have varied considerably.

Although a serious attempt was made to secure uniformity in the goodness and badness of the loans submitted for analysis, the loan samples received were anything but uniform. For example, commercial bankers were requested to distinguish bad loans by one of the following criteria: loan was more than 90 days delinquent; comaker paid all or part of loan after demand by bank; legal action was taken; loan was charged off. But upon analysis, the samples submitted were found to vary surprisingly. In one sample the proportion of cases that were excessively delinquent without receiving further action by the bank was only 2 percent; in another sample, it was 90 percent.<sup>14</sup> The banker who submitted the second sample wrote by way of explanation that he had a dearth of really bad loans to choose from; that many of the cases submitted were delinquencies of less than the specified 90 days; and that in many cases these so-called bad loans were not bad enough to prevent the borrowers from obtaining other loans in the future. In the auto finance samples, bad loans were supposed to contain only repossessions, and

<sup>14</sup> For a description of the composition of the bad-loan samples submitted by the various contributing commercial banks, see National Bureau of Economic Research (Financial Research Program), *Commercial Banks and Consumer Instalment Credit*, by John M. Chapman and Associates (1940) Table B-1, p. 275.

good loans were to contain only paid out accounts; but one large contributor had trouble obtaining enough paid out accounts because lack of storage space prevented retention of the records. Consequently this company was forced to provide a good-loan sample consisting partly of paid out accounts and partly of current accounts that had not yet become bad. In short, neither bad loans nor good loans in the available samples are a clearly defined species. The selection of good or of bad loans depended largely upon the judgment of the contributing lender and upon the quality of the material he had readily available. In spite of these difficulties, we feel confident that the repayment experience represented by the good-loan samples is clearly and substantially superior to that represented by the bad-loan samples; and as long as this is true, these samples will suffice for the sort of analysis we are trying to make.

Because of the possibility that bad-loan experience might vary considerably from lender to lender, the loan samples submitted by each contributor were analyzed separately if they were large enough to assure reliability; otherwise they were combined with other similar small samples until sufficiently large units were obtained. Thus 10 of the 21 commercial bank samples obtained were analyzed separately, and the other 11 were combined and analyzed as 2 separate units; 2 of the 10 industrial bank samples were treated separately, and the other 8 were combined into one unit; the 2 personal finance company samples and the one appliance finance company sample were each treated separately; and finally 2 of the 3 automobile finance company samples were analyzed separately, and the other was broken down into 2 units representing the operations of 2 branch offices of the same company. The individual tabulations are not reproduced in this study, but in most of the tables of composite experience, remarks will be found indicating the degree of consistency

observed among the components.<sup>15</sup> No objective test is used herein for judging consistency. While an objective test is undoubtedly desirable, the construction of one that would not entail an exorbitant expenditure of labor seems impossible. The only feasible procedure, therefore, is to examine each component superficially and subjectively to see whether or not it is consistent with the composite. Since consistency may be taken in more than one sense, its meaning should be clarified. A good-loan sample received from a New York City lender indicates that 16 percent of all cases report ownership of real estate, whereas a similar sample from Los Angeles indicates 40 percent. While there is no consistency between the 16 percent and the 40 percent reporting ownership, there is consistency of bad-loan experience because the real estate owners appear to be definitely good risks in both samples. The latter meaning of consistency—consistency of bad-loan experience—is the only one used in this report.

Since the time element may cause considerable variation in risk experience, some method of control is desirable. One possible method is to select a number of short, homogeneous time periods, and to make separate analyses of the loans made in each of these periods; a sample of good loans made in the first half of 1936 could be compared with a similar sample of bad loans. Carried far enough, this process might eventually result in a description of secular and cyclical changes in risk experience. An alternative method is to choose a longer period of time and to select the chronological distribution of the good and bad loans so that they are approximately identical; that is, if 25 percent of the good sample is selected from loans made in the first half of 1936, about the same propor-

<sup>15</sup> The results of some of these analyses have appeared elsewhere. For actual tabulation of the component commercial bank samples see John M. Chapman and Associates, *op. cit.*, Appendix B. A tabulation of the industrial bank components will be found in National Bureau of Economic Research (Financial Research Program), *Industrial Banking Companies and Their Credit Practices*, by Raymond J. Saulnier (1940) Chapter 6.

tion of the bad sample should cover the same period. Lenders who contributed to this study were asked to select their samples by the latter method; they were requested to select their bad-loan sample first, and then to select the good-loan sample, with approximately the same distribution. On the whole, we do not have information concerning either the accuracy with which they were able to follow this procedure or the sort of chronological distribution that resulted, but we presume that most of the loans in the samples were made during the period from 1935 through 1938. One of the industrial banking company samples, it is true, was carefully broken down to show experience in three successive years; in this form the sample failed to show any significant variation, but this failure may well be attributable to the fact that the number of cases in the sample was smaller than one would wish. Obviously this study does not throw any light on the effect of time on risk experience, and the results should be considered as averages related to a rather undefined period of about 4 years' duration in the near past.

#### SUMMARY OF PROCEDURE

The following summary lists the more important steps to be taken and the more serious difficulties likely to be encountered in an analysis of risk experience based upon sampling procedure.

Determination of the quality of loans to be included in both the good-loan sample and the bad-loan sample is the first problem of risk analysis. The bad-loan cases should, if feasible, contain all types of clearly unsatisfactory repayment experience, and nothing else. In some cases, however, the mechanical process of selecting loans from the files will be greatly simplified if the bad loans are limited to some specific class, such as repossessions or charge-offs; in other cases, the number of clearly bad loans may be so small that the inclu-

sion of borderline cases may be necessary to obtain a sample of adequate size, i.e., a sample that includes at least 200 cases. Good loans can be variously defined, depending on the desires of the analyst and the type of filing system from which the loans are drawn; they can be defined as clearly exemplary cases, or as cases not classified as bad loans.

The number of cases chosen will depend on several considerations: for example, the nature of the specific task to be performed, the amount of labor time available, and the degree of precision desired. In general, 200 good loans and 200 bad loans represent the absolute minimum on which a sample should be based, although trained statisticians may frequently see opportunities for solving special problems with considerably smaller numbers. Even 200 cases, however, will probably be insufficient for a satisfactory study of occupation or other factors requiring detailed analysis; a thousand cases is probably desirable here, and even more may be required if particular detail or great accuracy is necessary.

The mechanical process of drawing cases out of the loan file is one that must be devised to fit the individual case. The first requisite is that the drawing should be properly random in order to eliminate all conscious or unconscious personal bias as well as other undesirable biases that sometimes result from non-random sampling; the use of a table of random numbers is definitely advantageous. The second requisite is economy of effort, and in this connection, a little ingenuity on the part of the analyst may save considerable work.

The effect of changes in time on risk experience can be avoided in three ways: the study can be limited to a short and rather homogeneous period; the selection of loans can be so arranged that the chronological distribution of the good loans is approximately identical with that of the bad; and a number of separate studies can be made of several short, homogeneous periods.

An illustration of the method by which samples can be

tabulated appears in Table 3. Limitation of the number of class intervals is important in making such a tabulation; moreover, no class interval should contain fewer than 30 loans, good and bad combined. As soon as the percentage distributions among the various class intervals have been computed, the bad-loan relatives and the efficiency index can be computed. The bad-loan relative, which is the percentage of bad loans in any class interval divided by the percentage of good loans, will indicate the classes that represent particularly good or particularly bad risks; and the efficiency index, which has been described above, will permit comparison of the effectiveness of different factors as indicators. The differences observed between the good- and bad-loan distributions based on a sample of only 200 cases, however, may not be genuine. While the reliability of the results should be examined by use of one of the standard tests (see footnotes 2 and 3, pages 24 and 26), the efficiency index can be used as a poor substitute. If all results yielding an efficiency index of 15 are rejected, a number of false conclusions will be avoided. Of course, if a result obtained by the procedure outlined above is rejected as unreliable, further evidence may be sought to establish reliability. Whether to discard a result or to seek additional information is usually a question that must be decided in relation to circumstances.



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## Findings of Risk Factor Studies

IN CREDIT studies the essential elements of risk are usually grouped into a few broad categories. Some writers speak of the three C's of credit—character, capacity, and capital; others refer to moral risk, financial risk, and cyclical risk. In the consumer financing studies of the National Bureau of Economic Research, risk elements in instalment credit have been segregated into such groups as personal characteristics, moral characteristics, vocational characteristics, etc.<sup>1</sup> Although such groupings are generally accepted, some ambiguities and misunderstandings of terminology are usually involved. For example, there is no standard notion of the meaning of moral risk. To some people the concept appears narrow, referring only to personal integrity and social respectability; to others it has much broader meaning and includes the notion of ability—ability to earn a livelihood, ability to meet problems and make decisions, ability to handle financial matters. On the whole, however, the terms are used to create general impressions; when more specific delineation is needed, other terms are ordinarily employed.

In this chapter we present statistical information relevant to a number of credit factors, and in the presentation we draw a tentative distinction between financial and non-financial characteristics. Some of the factors that we present

<sup>1</sup> See National Bureau of Economic Research (Financial Research Program), *Commercial Banks and Consumer Instalment Credit*, by John M. Chapman and Associates (1940) Chapter 6; *Industrial Banking Companies and Their Credit Practices*, by Raymond J. Saulnier (1940) Chapter 6.

as financial, however, may reflect indirectly non-financial qualities, and vice versa.

### FINANCIAL FACTORS

In commercial lending, a borrower is usually requested to submit a balance sheet and income statement, which the lender uses as a basis for judging whether or not the borrower may be a good financial risk. Analysis of the financial statements is detailed and systematic, with emphasis on a number of crucial ratios such as the current ratio, sales to inventory, and gross profit to sales. The consumer borrower, on the other hand, is rarely asked to provide a comprehensive, formal financial statement but instead is requested merely to list a few asset and liability items or a few items of income and expense. The lender, in his analysis of these data, examines the ratio of the amount of the loan to income, of monthly payment to income, or some other measure of the burden of debt upon the borrower's current purchasing power. The ratio of the amount of down payment to the amount of the total sale is important in sales finance transactions. Ratios other than these are conceivable in consumer instalment lending, and may be used occasionally, but not frequently.

#### *Income*

Perhaps the most surprising findings of the entire study are those concerning borrower's income and its relation to the amount borrowed. None of the income distributions of borrowers in Table 4 shows more than a moderate tendency for the higher incomes to be the better risks. In the new and used-car distributions, the tendency is clear but not pronounced; the efficiency indices of about 17 in both cases are not notably high, and the component samples are not entirely

TABLE 4  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY INCOME OF  
 BORROWER

<i>Source and Composition of Data</i>	<i>Monthly Income</i>							<i>Number of Cases</i>		<i>Effi- ciency Index</i>	<i>Remarks</i>
	<i>\$0- 99</i>	<i>\$100- 149</i>	<i>\$150- 199</i>	<i>\$200- 249</i>	<i>\$250- 299</i>	<i>\$300- 399</i>	<i>\$400 and Over</i>	<i>Re- porting</i>	<i>Not Re- porting</i>		
<b>21 Commercial banks<sup>a</sup></b>											
12 Samples											
Good loans	11.9	28.4	28.1	13.7	7.7	5.5	4.7	1,260	34		Not significant. Very inconsistent indications in component sam- ples.
Bad loans	11.0	32.8	28.1	14.2	6.2	4.5	3.2	1,240	54		
Bad-loan relative	.9	1.2	1.0	1.0	.8	.8	.7			4.9	
<b>10 Industrial banking companies</b>											
3 Samples											
Good loans	16.1	24.8	27.7	11.2	8.6	5.2	6.4	614	49		Not significant. Component sam- ples fairly con- sistent.
Bad loans	17.3	28.2	25.1	12.7	6.7	5.6	4.4	585	74		
Bad-loan relative	1.1	1.1	.9	1.1	.8	1.1	.7			6.5	

TABLE 4 (concluded)

Source and Composition of Data	Monthly Income							Number of Cases		Efficiency Index	Remarks	
	\$0-99	\$100-149	\$150-199	\$200-249	\$250-299	\$300-399	\$400 and Over	Re-reporting	Not Re-reporting			
<b>2 Personal finance companies</b>												
<b>2 Samples</b>												
Good loans	13.8	39.3	29.2	11.0	4.7	2.0 <sup>b</sup>	...	698	13	7.6	Questionably significant. No consistency.	
Bad loans	17.7	42.6	25.5	8.0	3.8	2.4 <sup>b</sup>	...	713	19			
Bad-loan relative	1.3	1.1	.9	.7	.8	1.2	...					
<b>3 Automobile finance companies</b>												
<b>4 Samples</b>												
New cars	Not repossessed	...	15.8 <sup>a</sup>	18.2	20.4	10.0	14.7	20.9	368	55	17.6	Significant. 3 of 4 samples consistent.
	Repossessed	...	27.0 <sup>a</sup>	20.6	24.4	7.4	8.2	12.4	340	48		
	Bad-loan relative	...	1.7	1.1	1.2	.7	.6	.6				
Used cars	Not repossessed	10.1	30.0	29.8	19.1	7.2 <sup>d</sup>	...	3.8	446	38	16.5	Significant. No consistency.
	Repossessed	15.3	41.3	24.9	10.5	6.4 <sup>d</sup>	...	1.6	450	35		
	Bad-loan relative	1.5	1.4	.8	.5	.9	...	.4				

<sup>a</sup> See footnote 13, p. 37.

<sup>b</sup> Includes all cases with incomes of \$300 and over.

<sup>c</sup> Includes all cases with incomes of less than \$150.

<sup>d</sup> Includes all cases with incomes of \$250-399.

consistent. In the cash loan distributions, however, the tendency for good risk to go with high income is virtually non-existent; only in the personal finance company samples is any tendency apparent, and even here the evidence is of doubtful significance.

These findings on the income-risk relation are so confusing that additional data are welcome. Analysis of some two million loans made by a large personal finance company from 1934-37 indicates a significant, though small tendency for risk to improve with income; the efficiency index is only 9.6.<sup>2</sup> A sample of appliance finance deals insured by the Electric Home and Farm Authority shows a more pronounced relation; the repossession ratio rises sharply as income decreases.<sup>3</sup> This and the evidence presented above point toward one conclusion—that income is distinctly more important in sales finance than in cash lending; the evidence, however, is not conclusive, but only suggestive.

### *Amount of Loan*

Table 5, showing amount of loan, does not include the automobile finance companies' samples, which are analyzed separately later. Very little concerning the relation between risk and the amount of loan is learned from the commercial bank and industrial banking company samples, where the variation is small and of questionable significance; loans of less than \$100, however, appear somewhat worse than average. In the personal finance company samples, the bad loans are on the

<sup>2</sup> Data supplied by the Household Finance Corporation. The distribution of loans and charge-offs, and the bad-loan relatives are as follows:

	<i>Monthly Income of Borrower</i>					
	\$1-50	\$51-100	\$101-150	\$151-200	\$201-250	Over \$250
All loans	.7	16.1	34.0	27.0	11.6	10.6
Charge-offs	1.6	22.2	36.6	23.9	8.4	7.3
Bad-loan relative	2.3	1.4	1.1	.9	.7	.7

<sup>3</sup> See National Bureau of Economic Research (Financial Research Program), *Government Agencies of Consumer Instalment Credit*, by Joseph D. Coppock (1940) Table 41, p. 144.

TABLE 5  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY AMOUNT OF  
 LOAN

Source and Composition of Data	Amount of Loan							Number of Cases		Efficiency Index	Remarks
	\$0-99	\$100-199	\$200-299	\$300-399	\$400-499	\$500-999	\$1000 and Over	Re-porting	Not Re-porting		
21 Commercial banks*											
12 Samples											
Good loans	6.8	42.2	19.4	15.7	5.2	9.2	1.5	1,289	5	4.2	Questionably significant. No consistency.
Bad loans	10.8	40.2	19.5	15.3	4.8	7.8	1.6	1,294	0		
Bad-loan relative	1.6	1.0	1.0	1.0	.9	.8	1.1				
10 Industrial banking companies											
3 Samples											
Good loans	9.4	40.5	19.2	14.8	3.3	9.5	3.3	662	1	7.7	Questionably significant.
Bad loans	14.8	36.9	20.5	13.5	4.3	8.8	1.2	654	5		
Bad-loan relative	1.6	.9	1.1	.9	1.3	.9	.4				
	\$0-49	\$50-99	\$100-149	\$150-199	\$200-249	\$250-299	\$300 and Over <sup>b</sup>				
2 Personal finance companies											
2 Samples											
Good loans	4.1	23.0	28.5	14.4	10.7	18.6	.7	709	2	13.4	Significant. No consistency.
Bad loans	3.0	16.9	22.3	16.3	15.2	24.7	1.6	732	0		
Bad-loan relative	.7	.7	.8	1.1	1.4	1.3	2.3				

\* See footnote 13, p. 37.

<sup>b</sup> One of the contributing companies operates branches in states permitting loans over \$300.

whole the larger ones. Similar results for this type of company are obtained from the sample of some two million loans referred to above; but the efficiency index of 3.3 is so low that the observed results are considered inconsequential.<sup>4</sup>

The ratio of the amount of the obligation to the amount of the income is one possible measure of the burden of the debt on the borrower's purchasing power. Since we have found no significant relation between risk and income or between risk and amount of loan in the commercial bank and the industrial banking company samples, we can reasonably infer a similar lack of relation between risk and the ratio of amount of obligation to income. Likewise, for the personal finance companies, where good risks show a slight tendency to be associated with large incomes and small loans, we can infer that good risks will also be associated with a low ratio of amount of loan to income. Inferences of this sort are not absolutely infallible, but they are usually fairly reliable; in this case they were actually confirmed by detailed tabulations, which are not presented here.<sup>5</sup>

Since the opinion is rather widely held that income and the relation of the amount borrowed to income ought to be important risk indices, the fact that they do not appear important in any of the cash loan samples calls for comment. The explanations offered here are only conjectures; to arrive at any more definite conclusions we should have more data—particularly on the reasons behind delinquency and charge-off. In general, cash loan agencies, and also sales finance com-

<sup>4</sup> Data supplied by the Household Finance Corporation. The distribution of loans and charge-offs, and bad-loan relatives are as follows:

	Amount of Note						
	\$0-49	\$50-99	\$100-149	\$150-199	\$200-249	\$250-299	\$300
All loans	3.5	16.7	27.0	13.6	14.9	3.8	20.5
Charge-offs	2.4	14.5	27.3	14.3	15.9	4.6	21.0
Bad-loan relative	.7	.9	1.0	1.1	1.1	1.2	1.0

<sup>5</sup> Information concerning the ratio of the amount of note to income may be found for commercial banks in John M. Chapman and Associates, *op. cit.*, Table 35, p. 130, and for industrial banking companies in Raymond J. Saulnier, *op. cit.*, Table 35, p. 140.

panies, insist that their customers shall be employed and have a certain regular minimum income; certain standard relationships between amount borrowed and income also must be met. In spite of numerous exceptions, these restrictions undoubtedly serve to eliminate most of the poorest risks, including paupers with no ability to pay and others with grandiose ideas of their abilities to repay large sums out of small incomes. Therefore a sample giving no evidence of an income-risk relation, or of relation between risk and the ratio of the amount of the note to income, undoubtedly indicates that standards are sufficiently restrictive to eliminate most of these particularly undesirable lower strata. Yet one important point requires explanation. Within normally acceptable limits, why is there no observable risk variation by income or amount borrowed? Why are not persons with incomes of \$4000 appreciably better risks than persons with incomes of \$1500, and why are not persons who borrow only 5 percent of their annual incomes appreciably better risks than those who borrow 20 percent?

Ability to pay is not measured by the amount of income alone, particularly not by the amount of income at the time of application for funds. Stability of income and the likelihood of increases rather than decreases are also important. They depend upon a number of characteristics: the borrower's age, health, character, experience, his general employability, the nature of his occupation, the stability of his employer's business, and so on. No less important than stability of income is the borrower's ability to live within his income, his ability to budget, to save, and to adjust his expenditures to unusual strains. Some credit men are of the opinion that most consumer-borrowers tend to spend to the very limit of their incomes; that higher incomes are offset by higher expenditures for luxury goods, which the borrower soon learns to consider necessities. If this reasoning is correct, the larger incomes will not carry with them any greater



flexibility, or any additional margin of safety between income and the so-called minimum necessary expenses. This discussion implies that lack of character and the inability to handle finances are more likely to be causes of default than lack of income. In the last analysis, ability to pay may be as much a result of personal attributes as of financial condition.

The fact that income appears important in the automobile finance business but not in the cash loan business suggests fundamental differences between the two types of lending. A significant difference seems to exist between the dealer-customer relation in sales finance and the analogous relation in cash lending. In an instalment sale the dealer is interested in selling merchandise, and the extension of credit is usually a secondary matter. The dealer, however, obtains the necessary credit information, and the customer rarely deals directly with the financing agency. The dealer frequently endorses the note so that the financing agency is covered in case of default. The result of the dealer's desire to make a sale and his subsequent endorsing of the customer's note may be a lowering of standards; the dealer may be inclined to sacrifice standards for the sake of the sale; and the sales finance company may either be willing to accept poor risks because of the dealer's endorsement, or may feel compelled to do so in order to continue its relations with the dealer. Therefore, the sales finance company samples, which are all from recourse companies,<sup>9</sup> may contain a larger proportion of low-grade, low-income risks than the cash loan samples.

Certain authorities are of the opinion that the economic and financial status of instalment purchasers of automobiles is distinctly different from the status of customers of cash lending agencies. Those who share this opinion believe that the instalment purchaser of an automobile buys something

<sup>9</sup> A recourse company is one that discounts a dealer's paper only on condition that the dealer guarantees it. Then if the customer defaults, the financing agency attempts to collect and, if necessary, repossesses; if a loss is entailed, the dealer must assume the burden.

presumably not essential to his living, and therefore that his financial position is good. The cash borrower, on the other hand, is borrowing to meet an emergency, which indicates a poor financial position. This differentiation, while probably relevant, is clearly open to criticism since a sizable proportion of cash loan borrowers do not borrow to meet an emergency; many borrow to purchase merchandise which they might otherwise have financed through a sales finance company.

The automobile represents an almost unique position in American life; it is not only a means of transportation but also of ostentation. The loss of an automobile through repossession might be considered a serious blow to a person's prestige, and this blow would be more serious for the higher-income than for the lower-income purchasers.

The fact that income and the ratio of amount of loan to income do not appear particularly important as risk factors does not mean that lenders should accommodate paupers or persons wishing to borrow exorbitant sums; nor does it mean that lenders should relax their existing standards of income and amount of loan. It merely suggests that lenders in the cash loan business are giving adequate attention to the matter of minimum income and maximum loan—roughly determined by the amount of the income—and that further restrictions would probably not improve the quality of the borrowers. This conclusion is based on combined samples from a number of individual contributions, some of which showed quite contradictory tendencies. Possibly the risk experience of some individual contributors is significantly related to income, in contrast to the combined experience.

### *Length of Loan Contract*

Distribution of samples according to length of loan contract is given in Table 6, where length of contract indicates the number of equal monthly payments the borrower agrees to

TABLE 6  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY LENGTH OF  
 LOAN CONTRACT

Source and Composition of Data	Number of Equal Monthly Payments					Number of Cases		Efficiency Index	Remarks	
	0-6	7-11	12	13-17	18 and Over	Re-reporting	Not Re-reporting <sup>a</sup>			
<b>21 Commercial banks<sup>b</sup></b>										
12 Samples	Good loans	3.8	7.3	78.2	3.6	7.1	1,278	16	3.6	Not significant.
	Bad loans	2.4	5.8	80.8	4.6	6.4	1,275	19		
	Bad-loan relative	.6	.8	1.0	1.3	.9				
<b>10 Industrial banking companies</b>										
3 Samples	Good loans	3.7	9.6	75.7	3.2	7.8	655	8	3.5	Not significant.
	Bad loans	4.7	7.5	74.3	4.4	9.1	637	22		
	Bad-loan relative	1.3	.8	1.0	1.4	1.2				
<b>2 Personal finance companies</b>										
2 Samples	Good loans	14.2	32.5	20.2	33.1		703	8	9.8	Significant. Both samples consistent.
	Bad loans	7.9	29.6	19.6	42.9		643	89		
	Bad-loan relative	.6	.9	1.0	1.3					
<b>3 Automobile finance companies</b>										
4 Samples										
New cars	Not repossessed	6.2	43.5	36.3	14.0		421	2	36.0	Significant. 3 of 4 samples consistent.
	Repossessed	2.1	11.6	53.8	32.5		379	9		
	Bad-loan relative	.3	.3	1.5	2.3					
<b>Used cars</b>										
Used cars	Not repossessed	11.0	50.6	11.6	26.8		482	2	2.8	Not significant.
	Repossessed	12.2	49.3	13.2	25.3		483	2		
	Bad-loan relative	1.1	1.0	1.1	.9					

<sup>a</sup> Includes cases of irregular repayment.

<sup>b</sup> See footnote 13, p. 37.

make in order to repay his loan. The new-car samples indicate a striking tendency for good risks to be associated with short-term contracts; the efficiency index is 36, which is high. The personal finance companies, with an efficiency index of slightly less than 10, show a similar though much less pronounced tendency; but here the import of the data is obscure, for in the personal finance business loans are frequently renewed before their contractual maturity. For the other samples the variation between risk and length of contract is not significant. The negative results for the commercial bank and industrial banking company samples may be explained by the fact that most of the loans—about 75 percent of them, in fact—mature in exactly 12 months. In the case of used cars, however, a very interesting situation is well worth pointing out as an example of the necessity of using caution in analysis.

On the basis of other data for used cars, two pertinent facts were brought to light.<sup>7</sup> First, low-priced used cars are much more likely to be repossessed than high-priced used cars (see Table 7, page 58), a difference probably due partly to the higher down payments on the high-priced cars and partly to the greater age of the low-priced cars. Second, only the high-priced used cars are financed with loans of long duration. Thus long duration, indicating bad risk, apparently goes hand in hand with high price, indicating good risk; the two opposing tendencies ought to counteract each other, and the available data suggest that they actually do. If the used-car data of Table 6 were presented to show experience by price levels, they would undoubtedly show that for each price level the long-term contracts were the poorer risks.

Lenders seem to believe rather generally that short-term contracts are better than long. One reason for this opinion is that a short contract offers less time for a catastrophe to

<sup>7</sup> See National Bureau of Economic Research (Financial Research Program), *Sales Finance Companies and Their Credit Practices*, by Wilbur C. Plummer and Ralph A. Young (1940) pp. 164-68.

occur and to prevent repayment. Another aspect, however, should not be overlooked. Many short contracts are voluntarily sought by applicants who prefer to repay in less than the standard time. Presumably, such persons do not like to be in debt, and their financial condition must be reasonably good to permit quick retirement; these persons are undoubtedly good risks. But there may be a difference in risk experience between voluntary and involuntary short-term contracts; if a lender forces a short contract on a borrower who wishes a long contract, he should not suppose that the borrower's risk status will be greatly improved.

### *Security of Loan*

Various types of security are common in personal lending. In sales financing the collateral for the loan is the article purchased; and if the lender is a financing agency and not a dealer, the additional security of the dealer's endorsement may be required. In cash lending, commercial banks and industrial banking companies frequently require comaker signatures, and personal finance companies often take chattel mortgages and single-name notes; but there is no standard policy, and numerous other forms of security are commonly used. Acceptable collateral for commercial loans—such as securities, real estate, life insurance policies, and savings bank passbooks—may be used as security for consumer loans,<sup>8</sup> but the practice is probably not very common. Contributing commercial banks and industrial banking companies were requested to exclude all such loans from the samples submitted for this study.

A number of sources indicate that the likelihood of repayment is not so much determined by the kind of security, as

<sup>8</sup> Tables showing this information were not considered sufficiently interesting to publish here. For commercial bank and industrial banking company experience see John M. Chapman and Associates, *op. cit.*, Table 38, p. 134, and Raymond J. Saulnier, *op. cit.*, Table 37, p. 142.

that the kind of security is determined by the lender's appraisal of the likelihood of repayment. Thus persons with three or more comakers are found to be poor risks in both the commercial bank and industrial banking company samples.<sup>9</sup> This fact merely means that banks do not require an additional comaker unless they consider the risk poor, and that the additional security is not enough to make the loan good. Contrariwise, some of the commercial bank and industrial banking company component samples show single-name notes to be as good as or better than comaker notes,<sup>10</sup> which merely indicates that these particular banks have been successful in limiting their single-name loans to their best grade of applicants. An analogous situation occurs in the one appliance finance company sample. Non-recourse deals contain relatively fewer repossessions than recourse deals; undoubtedly the finance company is more cautious in selecting non-recourse paper, and is less likely to repossess a delinquent account that has no dealer's endorsement behind it.

### *Cash Price*

For the automobile finance and appliance finance company samples, the distributions of good and bad loans according to the cash price of the article purchased are presented in Table 7. In the new-car samples the price seems to be unimportant; for used cars, however, the higher-priced cars appear to be less frequently repossessed. Since the price of a car varies with the make, a study was also made of repossession experience by make; no satisfactory evidence of variation for either the new cars or the old was discovered. The samples from the appliance finance company, like those for the used cars, indicate that the higher-priced articles are less frequently repossessed.

<sup>9</sup> *Loc. cit.*

<sup>10</sup> See John M. Chapman and Associates, *op. cit.*, Appendix B, Table B-13, p. 303.

TABLE 7  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY CASH PRICE  
 OF ARTICLE PURCHASED

<i>Source and Composition of Data</i>	<i>Cash Price</i>					<i>Number of Cases</i>		<i>Efficiency Index</i>	<i>Remarks</i>
	<i>Under \$800</i>	<i>\$800-999</i>	<i>\$1000-1199</i>	<i>\$1200-1499</i>	<i>\$1500 and Over</i>	<i>Re-reporting</i>	<i>Not Re-reporting</i>		
<b>3 Automobile finance companies</b>									
<b>4 Samples</b>									
New cars	Not repossessed	22.2	35.9	25.8	12.3	3.8	423	0	4.0 Not significant.
	Repossessed	23.5	37.5	26.9	10.8	1.3	387	1	
	Bad-loan relative	1.1	1.0	1.0	.9	.3			
Used cars		<i>Under \$200</i>	<i>\$200-399</i>	<i>\$400-599</i>	<i>\$600 and Over</i>				
	Not repossessed	13.0	35.8	34.5	16.7	484	0	17.8 Significant. 3 of 4 samples consistent.	
	Repossessed	26.8	39.8	20.8	12.6	485	0		
	Bad-loan relative	2.1	1.1	.6	.8				
	<i>Under \$100</i>	<i>\$100-199</i>	<i>\$200 and Over</i>						
<b>1 Appliance finance company</b>									
Not repossessed	37.5	40.1	22.4			237	0	20.6 Significant.	
Repossessed	58.1	31.0	10.9			184	0		
Bad-loan relative	1.5	.8	.5						

### *Down Payment*

In sales finance transactions, the ultimate security is the purchased article, and the value of this article as coverage is usually considerably enhanced by the practice of requiring a down payment. That the likelihood of default and repossession decreases as the amount of the down payment increases is almost axiomatic in sales finance. Repossession experience according to the amount of down payment is shown in Table 8. Here the actual down payment, the dollar amount of trade-in plus cash, is given in place of percent of cash selling price, which is the factor usually considered. In all of the samples shown, those for new cars, used cars, and appliances, the purchases with the higher down payments are less frequently repossessed. This tendency is not difficult to understand, for the purchaser's ability to make a large down payment is likely to reflect financial strength; furthermore, a purchaser who has a substantial equity in an article will be less likely to allow his payments to lapse out of sheer indifference. The evidence presented suggests that down payment is the most effective risk indicator among all the factors considered in this study; the efficiency indices for the new-car and appliance samples are both above 30, and that for used cars is above 20. This conclusion does not conform entirely to the consensus of opinion of the retail merchants who replied to the questionnaire and laid only secondary emphasis on down payment (see Table 2, page 18).

The reason for discussing actual down payment instead of percent down payment is by way of illustration. Percent down payment is the ratio of two credit factors, actual down payment and price; as such it may be either more or less significant than its components. Therefore, whether the proper approach is to analyze the ratio alone, to analyze the components, or to analyze all three cannot always be determined. To analyze all three is the most methodical procedure, but



TABLE 8  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY AMOUNT OF  
 DOWN PAYMENT

Source and Composition of Data	Amount of Down Payment							Number of Cases		Efficiency Index	Remarks	
	\$100-199	\$200-299	\$300-399	\$400-499	\$500-599	\$600-799	\$800 and Over	Re-reporting	Not Re-reporting			
3 Automobile finance companies												
4 Samples												
New cars	Not repossessed	.9	19.0	18.5	18.2	19.2	14.0	10.2	422	1	35.8	Significant. All 4 samples consistent.
	Repossessed	6.4	32.7	35.1	16.8	5.2	2.8	1.0	388	0		
	Bad-loan relative	7.1	1.7	1.9	.9	.3	.2	.1				
Used cars	Not repossessed	5.6	17.5	24.5	20.6	18.5	8.9	4.4	481	3	22.9	Significant. 3 of 4 samples consistent.
	Repossessed	8.3	37.7	23.0	15.1	13.0	2.5	.4	483	2		
	Bad-loan relative	1.5	2.2	.9	.7	.7	.3	.1				
1 Appliance finance company	Not repossessed	17.4	29.4	19.2	10.6	7.7	13.6	2.1	235	2	34.6	Significant.
	Repossessed	52.0	28.4	9.8	4.9	1.7	2.7	.5	183	1		
	Bad-loan relative	3.0	1.0	.5	.5	.2	.2	.2				

also the most laborious, and in some cases it is virtually a waste of time.

From the behavior of the components of a ratio, the behavior of the ratio itself may sometimes be predicted easily, as illustrated by the new-car samples. Here we have found that price is not important as a credit factor; and the variation in price, if expressed in percentage form, is relatively small, with more than half of all cars priced between \$800 and \$1200. We may therefore safely infer that high percentage down payment as well as high actual down payment indicates small likelihood of repossession; furthermore, the inference is adequately justified by facts, as shown by the tabulations in Table 9. The efficiency index for percent down payment is 46, ten points higher than that for actual down payment; in this case the ratio approach seems to have distinct merit.

For used cars and appliances, however, the behavior of percent down payment cannot be predicted so simply, owing to the fact that price as well as down payment is related to repossession experience, and to the greater range, if expressed

**TABLE 9**  
**PERCENTAGE DISTRIBUTION OF REPOSSESSED AND NON-REPOSSESSED NEW-CAR SAMPLES, BY AMOUNT OF DOWN PAYMENT IN PERCENT OF CASH SELLING PRICE**

<i>3 Automobile Finance Companies 4 Samples</i>	<i>Ratio of Down Payment to Cash Selling Price</i>						
	<i>Less than 30%</i>	<i>30- 34%</i>	<i>35- 39%</i>	<i>40- 44%</i>	<i>45- 49%</i>	<i>50- 59%</i>	<i>60% and Over</i>
Not repossessed	4.3	17.5	13.7	11.3	9.4	19.9	23.9
Repossessed	16.8	45.2	19.4	8.3	5.2	3.6	1.5
Bad-loan relative	3.9	2.6	1.4	.7	.6	.2	.1
Efficiency Index: 45.9							

in percentage form, of the price of used cars. Actual tabulations, not reproduced here, indicate that repossessions decrease as percent down payment increases. The efficiency indices are 21 for used cars, which is just slightly less than the index for actual down payment, and 26 for appliances, which is considerably less. Here the ratio approach not only has little to offer, but appears to be actually detrimental.

In sales finance transactions, the amount of the obligation, which is equal to the cash price less the down payment plus a relatively small finance charge, is affected by both its main constituent parts, price and down payment. As a credit factor it appears to be a poor indicator. For new cars, where price is not related to repossession experience, amount of note behaves conversely with down payment; a large down payment, resulting in a small note, means a good risk; but in respect to efficiency, amount of note is inferior to down payment. For used cars, where price is an important factor, no relation appears between amount of note and repossession experience.

### *Borrower Assets and Liabilities*

The possession by a borrower of such assets as life insurance, a bank account,<sup>11</sup> or real estate indicates both financial strength and personal stability. Financial strength is indicated because these assets usually represent reserves of purchasing or borrowing power. The indication of personal stability arises from the fact that possession of life insurance or a bank account connotes the willingness and ability to save and provide for the future, and further that the ownership

<sup>11</sup> One of our critics points out that there are several types of bank accounts; he refers particularly to special checking accounts (those not requiring a minimum balance), which have been introduced by many banks in recent years, and suggests that these accounts are less indicative of good risk than the traditional commercial checking account with a minimum balance. We may add that the available data did not show which type of checking account was reported. The data did list savings accounts and checking accounts separately, but, for simplicity, cases with either or both types were all tabulated together.

of real estate, particularly an unmortgaged home, suggests domestic solidity, although it must be admitted that the ownership of heavily mortgaged speculative real estate may suggest the precise opposite.

Table 10, which shows the relation between risk experience and the possession of assets, gives no indication of the value of the assets held; it merely indicates whether or not assets were held. Further information on value would be extremely pertinent, but it is not generally available.<sup>12</sup> Even without this information, however, Table 10 is significant. The mere ownership of life insurance or a bank account or real estate, without regard to its value, suggests better-than-average risk. This relation occurs consistently in the combined samples from all types of reporting institutions and in all but one of the available component samples. Of the three asset items, life insurance is the most widely held by borrowers; bank accounts are next; and real estate last. The bank account item has by far the highest efficiency index, averaging about 22 for the reporting institutions as against 10 or so for life insurance and real estate.

A few of the contributing commercial banks reported information on three additional asset items—ownership of stocks and bonds, ownership of automobiles, and ownership of household goods—and two liability items—charge accounts and other instalment accounts. Information relevant to these items is not shown in Table 10.<sup>13</sup> Of these five items, ownership of securities alone appears to have any reliable relation to risk. The available evidence suggests that security ownership is relatively rare among personal loan borrowers, probably occurring in less than 10 percent of the cases, but that the few who do have securities are better risks. The other

<sup>12</sup> Data were obtained on the value of real estate and the amount of liens against it, but the number of cases reporting was too small for a significant analysis.

<sup>13</sup> For tabulations see John M. Chapman and Associates, *op. cit.*, Table 36, p. 131, and Table B-11, pp. 293-300.

TABLE 10  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY SELECTED  
 ASSET ITEMS OF BORROWER

Asset Items	21 Commercial Banks <sup>a</sup>			10 Industrial Banking Companies			3 Automobile Finance Companies					
							New Cars			Used Cars		
	Good	Bad	Bad-Loan Relative	Good	Bad	Bad-Loan Relative	Not Rep.	Rep.	Bad-Loan Relative	Not Rep.	Rep.	Bad-Loan Relative
Bank account	44.6	21.5	.5	34.0	19.6	.6	70.9	45.5	.6	51.0	25.5	.5
No bank account <sup>b</sup>	55.4	78.5	1.4	66.0	80.4	1.2	29.1	54.5	1.9	49.0	74.5	1.5
Efficiency index	23.1			14.4			25.4			25.5		
Number of cases	1,294	1,294		318	318		323	288		384	385	
Remarks	Significant. 11 of 12 samples consistent.			Significant. Both available samples consistent.			Significant. 3 available samples consistent.			Significant. 3 available samples consistent.		
Life insurance	81.8	71.4	.9	81.1	72.8	.9	Information not available					
No life insurance <sup>b</sup>	18.2	28.6	1.6	18.9	27.2	1.4						
Efficiency index	10.4			8.3								
Number of cases	1,294	1,294		350	342							
Remarks	Significant. 11 of 12 samples consistent.			Significant. Both available samples consistent.								
Real estate	27.3	13.3	.5	23.7	14.0	.6	26.1	15.5	.6	18.9	8.9	.5
No real estate <sup>b</sup>	72.7	86.7	1.2	76.3	86.0	1.1	73.9	84.5	1.1	81.1	91.1	1.1
Efficiency index	14.0			9.7			10.6			10.0		
Number of cases	1,294	1,294		663	659		249	220		238	248	
Remarks	Significant. 11 of 12 samples consistent.			Significant. 3 available samples consistent.			Significant.			Significant.		

<sup>a</sup> See footnote 13, p. 37.

<sup>b</sup> Includes cases not reporting information.

four items occur much more frequently than ownership of securities, but provide most unsatisfactory evidence concerning risk experience. In many instances, the number of cases not reporting information is altogether too high for reliability; furthermore, the variation in experience between samples is sufficiently pronounced to discredit any conclusions.

A comparison of these findings with the opinions expressed by bankers and retail merchants is of interest. Table 1 shows that the bankers who replied to our questionnaire laid considerably more stress on liabilities than on assets; Table 2 shows that the retail merchants—who were not asked to express themselves concerning assets—laid some stress on liabilities. Our findings suggest that the general opinion of the business lays too much stress on liabilities and not enough on assets.

#### NON-FINANCIAL FACTORS

The factors considered thus far—income, amount of loan, length of loan contract, security, cash price, down payment, assets, and liabilities—are all used to measure financial characteristics of borrowers. To be sure, a borrower's income, or the amount of his down payment, indicates his general ability as well as his spending power, but by and large these factors represent financial risk. The factors next to be considered are more personal, although some of them reflect financial as well as non-financial status.

##### *Stability of Occupation*

Stability of occupation, measured by the number of years an applicant has been at his present position, has been mentioned in Chapter 2. Further information is presented in Table 11. The tendency for long periods of employment to

TABLE 11

PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY DURATION OF BORROWER'S PRESENT EMPLOYMENT

Source and Composition of Data	Number of Years <sup>a</sup>						Number of Cases		Efficiency Index	Remarks
	0-1	1-2	2-3	3-6	6-10	10 and Over	Re-reporting	Not Re-reporting		
<b>21 Commercial banks<sup>b</sup></b>										
<b>12 Samples</b>										
Good loans	5.7	7.4	9.5	18.5	19.3	39.6	1,226	68	19.8	Significant. All 12 samples consistent.
Bad loans	13.0	11.1	12.4	24.4	15.7	23.4	1,216	78		
Bad-loan relative	2.3	1.5	1.3	1.3	.8	.6				
<b>10 Industrial banking companies</b>										
<b>3 Samples</b>										
Good loans	5.1	7.5	5.3	17.8	18.8	45.5	547	116	21.2	Significant. All 3 samples consistent.
Bad loans	11.4	13.5	9.5	22.2	19.1	24.3	555	104		
Bad-loan relative	2.2	1.8	1.8	1.2	1.0	.5				
<b>3 Automobile finance companies</b>										
<b>4 Samples</b>										
New cars	Not repossessed	9.2	20.2	28.0	42.6		357	66	23.9	Significant. All 4 samples consistent.
	Repossessed	23.8	29.5	22.6	24.1		319	69		
	Bad-loan relative	2.6	1.5	.8	.6					
Used cars	Not repossessed	16.9	29.0	22.3	31.8		421	63	15.6	Significant. 3 of 4 samples consistent.
	Repossessed	27.0	33.8	23.0	16.2		444	41		
	Bad-loan relative	1.6	1.2	1.0	.5					

<sup>a</sup> Each class interval includes the lower and excludes the upper limit.

<sup>b</sup> See footnote, 13, p. 37.

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denote good risk is shown consistently by all but one of the available sample components. Furthermore, in the one used-car unit that is the exception, evidence of this tendency is merely lacking; it is not contradicted. The efficiency index for stability of occupation is high; the average of the indices for the samples of lending institutions is about 20, which is only slightly lower than that for bank account. In this case, however, the efficiency index is not a satisfactory index of the importance of a credit factor. Few lenders would deny loans to all persons without bank accounts, for if they did so they might be turning away roughly half of their good business. They might, however, deny loans to persons with less than one year's employment tenure, since then they would be turning away only about a twentieth of their good business. For this reason, stability of occupation is probably a more useful means of credit control than is bank account. The importance attached to stability of occupation by credit executives has already been pointed out.

### *Stability of Residence*

Like stability of occupation, stability of residence appears to be associated with good risks (Table 12). This general tendency is typical of the 3 reporting industrial banking company components and 10 of the 12 commercial bank components; the 2 exceptions, moreover, are negative and show no contradictory tendencies. The information reported by the industrial banking companies is open to question, however, for some of them reported number of years at present address, and some reported number of years in the same city, and a large number of cases did not report any information. The efficiency indices of 14.7 for commercial banks and 20.1 for industrial banking companies are reasonably high, though they average slightly lower than those for stability of occupation. The importance of stability of resi-



TABLE 12

PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY DURATION OF RESIDENCE AT BORROWER'S PRESENT ADDRESS

<i>Source and Composition of Data</i>	<i>Number of Years<sup>a</sup></i>						<i>Number of Cases</i>		<i>Efficiency Index</i>	<i>Remarks</i>
	0-1	1-2	2-3	3-6	6-10	10 and Over	Re-reporting	Not Re-reporting		
<b>21 Commercial banks<sup>b</sup></b>										
<b>12 Samples</b>										
Good loans	13.5	14.5	13.7	21.1	10.1	27.1	1,249	45		Significant.
Bad loans	21.6	18.8	16.0	20.2	7.2	16.2	1,240	54		10 of 12 samples
Bad-loan relative	1.6	1.3	1.2	1.0	.7	.6			14.7	consistent.
<b>10 Industrial banking companies<sup>c</sup></b>										
<b>3 Samples</b>										
Good loans	3.4	2.8	5.7	15.9	14.0	58.2	435	228		Significant.
Bad loans	3.1	8.6	8.9	21.4	19.6	38.4	383	276		All 3 samples
Bad-loan relative	.9	3.1	1.6	1.3	1.4	.7			20.1	consistent.

<sup>a</sup> Each class interval includes the lower and excludes the upper limit.

<sup>b</sup> See footnote 13, p. 37.

<sup>c</sup> Some industrial banking companies reported the number of years at present address; some reported the number of years in the same city; and, as indicated above, some did not report any information on this point.

dence as a credit factor seems to have been overlooked by most credit executives; it received virtually no recognition by the bankers whose replies are tabulated in Table 1.

### *Occupation and Industry*

A word of warning must precede a discussion of the occupational classification of Table 13, which is subject to a number of shortcomings. The main difficulties with making an occupational classification are that hundreds, perhaps even thousands of different occupations must be consolidated into a few broad groups, and that the number of occupations that can be classified separately is limited by the number of cases available for analysis. Numerous systems of consolidation are possible, and almost any one of them, including that in Table 13, is open to serious criticism. A system of classification will not be satisfactory if a number of occupations with widely different characteristics are grouped together; but decisions concerning similarity of occupation and the grouping of these occupations depend upon a detailed study based on a larger number of cases—perhaps 25,000. We may safely conclude that samples of the size used in this study are not large enough to supply all the desired information about occupation.

The construction of an acceptable scheme of classification is not the only problem; the fitting of any particular borrower's occupation into that scheme is also difficult. Frequently the borrower's description of his occupation, which appears on his application blank, is so inadequate or ambiguous that a clear picture of the borrower's duties cannot possibly be obtained.<sup>14</sup> In such instances, which probably occur in nearly a fifth of all the cases handled here, the am-

<sup>14</sup> This judgment is based entirely on the transcribed statements of occupation made available to the National Bureau of Economic Research. The credit investigators of the contributing institutions undoubtedly have a much better picture than we can form of the applicant's duties.

TABLE 13

PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY OCCUPATION OF BORROWER

Occupation	21 Commercial Banks <sup>a</sup>			10 Industrial Banking Companies		
	Good	Bad	Bad-Loan Relative	Good	Bad	Bad-Loan Relative
1. Professions	11.2	6.5	.6	9.3	6.4	.7
a. Teachers, nurses, doctors, technicians, lawyers	8.0	3.6	.4			
b. Artists, actors, musicians, misc.	3.2	2.9	.9			
2. Clerical	42.8	34.1	.8	30.0	30.5	1.0
a. Typists, stenographers, accts., etc.	24.2	10.6	.4	13.1	9.1	.7
b. Salespersons behind retail counters	4.0	3.7	.9	3.3	3.9	1.2
c. Outside salesmen, commercial representatives	6.6	11.2	1.7	4.7	9.6	2.0
d. Other clerical: agents, messengers, etc.	8.0	8.6	1.1	8.9	7.9	.9
3. Policemen, firemen, etc.	2.4	2.0	.8		<sup>b</sup>	
4. Proprietors	13.0	13.2	1.0	11.8	12.4	1.1
5. Managers and officials	8.0	10.2	1.3	9.3	10.2	1.1
6. Wage-earners	19.6	29.8	1.5	27.8	32.9	1.2
a. Skilled labor	8.7	11.5	1.3	14.2	12.9	.9
b. Semiskilled and unskilled	8.2	14.7	1.8	11.0	17.7	1.6
c. Service trades	2.7	3.6	1.3	2.6	2.3	.9
7. Miscellaneous	3.0	4.2	1.4	11.8	7.6	.6
Number of cases	1,294	1,294		663	659	
Efficiency index <sup>c</sup>	19.0			13.7		
Remarks	Significant			Significant		

<sup>a</sup> See footnote 13, p. 37.

<sup>b</sup> Because of the small number of cases available policemen and firemen are included with skilled labor.

<sup>c</sup> Whenever subgroupings appear in this table, the efficiency index is computed from the subgroupings without reference to the main groups.

(concluded on next page)

TABLE 13

PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY OCCUPATION OF BORROWER (*concluded*)

Occupation	2 Personal Finance Companies			3 Automobile Finance Companies					
	Good	Bad	Bad-Loan Rel.	New Cars			Used Cars		
				Not Rep.	Rep.	Bad-Loan Rel.	Not Rep.	Rep.	Bad-Loan Rel.
1. Professions	5.9	4.0	.7	13.5	8.5	.6	11.6	4.3	.4
a. Teachers, nurses, doctors, technicians, lawyers									
b. Artists, actors, musicians, misc.									
2. Clerical	24.7	22.3	.9	23.4	23.0	1.0	22.1	18.7	.8
a. Typists, stenographers, accts., etc.	9.6	8.0	.8	5.2	3.9	.8	5.2	3.1	.6
b. Salespersons behind retail counters	3.4	4.8	1.4	1.2	1.5	1.3	3.9	4.9	1.3
c. Outside salesmen, commercial representatives	1.3	1.5	1.2	9.4	15.0	1.6	8.5	6.2	.7
d. Other clerical: agents, messengers, etc.	10.4	8.0	.8	7.6	2.6	.3	4.5	4.5	1.0
3. Policemen, firemen, etc.	3.4	1.1	.3						
4. Proprietors	3.9	6.0	1.5	19.9	25.8	1.3	14.7	18.4	1.3
5. Managers and officials	6.3	6.7	1.1	12.5	8.2	.7	3.9	4.8	1.2
6. Wage-earners	48.2	53.3	1.1	21.0	25.5	1.2	39.4	49.9	1.3
a. Skilled labor	24.9	25.4	1.0	13.7	11.8	.9	20.0	19.4	1.0
b. Semiskilled and unskilled	15.7	21.3	1.4	5.9	10.3	1.7	15.3	24.8	1.6
c. Service trades	7.6	6.6	.9	1.4	3.4	2.4	4.1	5.7	1.4
7. Miscellaneous	7.6	6.6	.9	9.7	9.0	.9	8.3	3.9	.5
Number of cases	711	732		423	388		484	485	
Efficiency index <sup>a</sup>	10.2			18.2			16.7		
Remarks	Significant			Significant			Significant		

<sup>a</sup> For footnotes, see p. 70.

biguous occupation either must be classified as miscellaneous or must be arbitrarily placed in some class that seems not too inappropriate. Neither procedure is entirely satisfactory.

An analysis of the occupational groupings of Table 13 reveals that certain groups appear to be consistently good risks and other groups consistently poor. For all the samples shown, the professional group as a whole is above average. From this evidence, however, the inference that all professional classes are good risks does not follow. Some lenders consider clergymen and lawyers poor risks, but separate indices for these two groups could not be computed because of an insufficient number of cases among the samples submitted. For the commercial bank classification, the professional group was broken down into two subgroups; a group containing teachers, doctors, and the like was formed, and another containing musicians and actors. Both these groups appear to be better-than-average risks; the doctor group, with a bad-loan relative of .4, is well above average, whereas the actor group, with a bad-loan relative of .9, is only slightly above.

A number of very diverse occupations have been classified as clerical. One of these, a group containing typists, accountants, etc., appears to be a good-risk group; the evidence is particularly strong in the commercial bank sample where such persons comprise a large portion of the total. Another of the clerical subgroups, consisting of outside salesmen and commercial representatives, perhaps does not even belong under the heading of clerical. With one exception, the used-car sample, it appears to be one of the worst risk groups shown.

Another bad-risk group contains semiskilled and unskilled workers whose record is consistent for all the samples. Skilled workers and service trade workers, who are classed as wage-earners along with the unskilled and semiskilled, show no reliable indications one way or the other. Two groups, managers and officials, and proprietors, are fairly close to average.

This fact is understandable from the wide diversity of persons found in these groups. Proprietors include all those from the owners of newsstands to the owners of large hotels; managers and officials include officers of companies ranging from the smallest to the largest.

Separate examination of the component samples was not considered feasible, for the number of cases in many of the classes was too small to give reliable results. Hence no statements are made concerning the extent to which the combined samples are typical of the individual samples. Even in the combined samples some of the groups are too poorly represented to be reliable. The service trade group is probably one such example; the fact that indices for this group are above average for the automobile finance and commercial bank samples but below average for the industrial banking company and personal finance samples is probably a point of no consequence.

Judged by the efficiency index, averaging about 16 for the five available samples, occupation is a fairly important credit factor. Its importance, however, may be somewhat discounted because of difficulties already mentioned, and may be further discounted because the efficiency index is open to bias; when there is a relatively large number of classes containing a small number of cases each, the index is likely to be larger than it would otherwise have been.

The classification of borrowers by industry is subject to all the shortcomings of the occupational classification, and the results are even less definite. The industrial classification is not tabulated here, but the average efficiency index for industrial banking companies, commercial banks, new cars, and used cars, has been found to be 14. Judged by the bad-loan relatives computed, borrowers in government service appear to be somewhat better-than-average risks, and those in miscellaneous transportation industries—including trucking, the

garage and service station business, etc.—apparently are worse-than-average risks.

### *Personal Characteristics*

The classification of borrowers by sex and marital status (Table 14) indicates that women are better risks than men; and the superiority appears to be statistically significant. No significant difference, however, is evident between the risk characteristics of married and single persons. The superiority of women is not well confirmed in the component samples. Four of the twelve commercial bank samples, one of the three industrial banking company samples, and one of the two personal finance company samples, fail to show such a tendency. This failure may indicate a genuine inconsistency. It may, on the other hand, merely reflect the effects of sampling error; a considerable sampling error could have been expected in the component samples, for the number of women in some of them was very small.

Some credit men have expressed surprise that women should appear to be the better risks, and they have suggested that these results may be due to the indirect effect of other factors. Little can be offered in the way of amplification except that a very simple cross-classification of the commercial bank loans by sex and occupation showed that in the better-than-average occupations women are still the better risks.

The age distribution of borrowers in the commercial bank and industrial banking company samples is shown in Table 15. While some tendency is apparent for the older borrowers to be the better risks, the tendency is slight. In the component commercial bank samples the consistency of the result is very poor.

The number of a borrower's dependents is virtually unimportant. This conclusion is based on both the commercial

TABLE 14  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY MARITAL  
 STATUS AND SEX OF BORROWER

<i>Source and Composition of Data</i>	<i>Married</i>		<i>Single</i>		<i>Other<sup>a</sup></i>	<i>Number of Cases</i>		<i>Efficiency Index</i>	<i>Remarks</i>
	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>		<i>Re- porting</i>	<i>Not Re- porting</i>		
<b>21 Commercial banks<sup>b</sup></b>									
<b>12 Samples</b>									
Good loans	61.4	5.0	16.1	11.6	5.9	1,294	0	10.9	Significant. 8 of 12 samples con- sistent.
Bad loans	66.3	2.2	22.1	5.0	4.4	1,294	0		
Bad-loan relative	1.1	.4	1.4	.4	.7				
<b>10 Industrial banking companies</b>									
<b>3 Samples</b>									
Good loans	60.0	7.5	10.9	9.7	11.9	663	0	9.0	Significant. 2 of 3 samples con- sistent.
Bad loans	62.4	4.2	16.5	4.0	12.9	659	0		
Bad-loan relative	1.0	.6	1.5	.4	1.1				
<b>2 Personal finance companies</b>									
<b>2 Samples</b>									
Good loans		71.6	21.0	6.6	.8	711	0	11.0	Significant. No consistency.
Bad loans		63.1	31.4	4.1	1.4	732	0		
Bad-loan relative		.9	1.5	.6	1.8				

<sup>a</sup> Includes divorced, separated, widowed persons, and persons not reporting information.

<sup>b</sup> See footnote 13, p. 87.



TABLE 15  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY AGE OF  
 BORROWER

<i>Source and Composition of Data</i>	<i>Age of Borrower in Years</i>							<i>Number of Cases</i>		<i>Efficiency Index</i>	<i>Remarks</i>
	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50	Over 50	Re- porting	Not Re- porting		
<b>21 Commercial banks*</b>											
<b>12 Samples</b>											
Good loans	12.4	19.8	17.1	15.3	13.2	9.6	12.6	1,267	27		
Bad loans	14.2	20.2	20.8	18.1	11.8	7.9	7.0	1,250	44		Significant.
Bad-loan relative	1.1	1.0	1.2	1.2	.9	.8	.6			8.7	Poor consistency.
<b>10 Industrial banking companies</b>											
<b>3 Samples</b>											
Good loans	9.6	16.4	16.7	13.7	12.8	10.3	20.5	604	59		Significant. All
Bad loans	13.6	20.7	19.7	17.1	12.1	7.9	8.9	609	50		3 samples con-
Bad-loan relative	1.4	1.3	1.2	1.2	.9	.8	.4			14.7	sistent.

\* See footnote 13, p. 37.

bank and industrial banking company samples, where no significant relation between risk and number of dependents is observable. The tabulations are not considered worth reproducing here.<sup>15</sup>

### *Purpose of Loan*

Consumer-borrowers undoubtedly seek loans for a variety of reasons. In sales finance the problem is simple; the purchaser buys merchandise and thus contracts a debt. In cash lending, however, the reasons for borrowing vary remarkably from one lender to another; thus one commercial bank makes 5 percent, and another makes 50 percent, of its loans to persons who wish to buy cars. Despite the variations, most of the reasons for borrowing may be classified into three broad groups: to meet emergencies; to purchase merchandise, usually durable consumer goods, or to finance improvements on property; and to refinance pre-existing indebtedness. Table 16 presents the distribution of good and bad loans for the commercial bank and industrial banking company samples by reported reason for borrowing. The results are puzzling. The variations seemed to be statistically significant, but little uniformity among individual institutions is apparent; hence the results should be considered negative. Furthermore, the problem of classification offered serious difficulties: too many cases were ambiguous concerning the purpose of borrowing; too many cases indicated that loans were desired for miscellaneous uses; and a number of cases reported several uses without indicating the main one.

### SUMMARY

One of the most striking indications of the reliability of the findings of this chapter has been the consistency with which

<sup>15</sup> Cf. John M. Chapman, *op. cit.*, Table 29, p. 122, and Raymond J. Saulnier, *op. cit.*, Table 28, p. 128.

TABLE 16  
 PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY INTENDED  
 USE OF FUNDS

Source and Composition of Data	Intended Use of Funds										Total No. of Cases Reporting and Not Reporting
	Taxes	Vaca- tion	House- hold	Help for Rela- tive	Pur- chase Auto- mobile	Medi- cal and Dental	Busi- ness	Cloth- ing	Consoli- dation of Debts	Miscella- neous <sup>a</sup>	
<b>21 Commercial banks<sup>b</sup></b>											
<b>12 Samples</b>											
Good loans	3.5	3.8	11.7	2.8	12.0	13.3	6.6	1.7	24.2	20.4	1,294
Bad loans	1.1	2.2	7.0	1.8	9.9	15.6	8.0	2.2	32.4	19.8	1,294
Bad-loan relative	.3	.6	.6	.6	.8	1.2	1.2	1.3	1.3	1.0	
Remarks	Efficiency index: 12.4			Significant.		No consistency.					
<b>10 Industrial banking companies</b>											
<b>3 Samples</b>											
Good loans	4.7	1.8	8.2	4.1	1.4	6.6	7.7	.9	32.4	32.2	663
Bad loans	1.7	1.4	4.9	3.6	2.1	12.3	8.6	2.7	35.2	27.5	659
Bad-loan relative	.4	.8	.6	.9	1.5	1.9	1.1	3.0	1.1	.9	
Remarks	Efficiency index: 11.2			Significant.		No consistency.					

<sup>a</sup> Includes a considerable number of cases not reporting information.

<sup>b</sup> See footnote 13, p. 37.

certain relations occur repeatedly in samples obtained from very diverse sources; bank account and stability of occupation are two cases in point. If only three or four samples had exhibited a pronounced relation between, say, stability of occupation and bad-loan experience, the result might have been attributed to sectional peculiarities, to institutional differences, or to some personal sampling bias on the part of the contributing lenders; but when the same tendency occurs in 22 out of 23 available samples, as it actually did, the evidence supporting a universal, fundamental relationship between stability and bad-loan experience is almost incontrovertible. The relation between down payment and repossession experience is supported not only by all the samples available for the present study but also by many other statistical studies made by other investigators; and the fact that our results agree substantially with those of others helps justify the use of our special sampling techniques.

The efficiency index was introduced in this study as a means of appraising the relative importance of the various credit factors studied. But since computation of the efficiency index is based on samples of loans actually made, the index does not measure the intrinsic importance of the factors; what it measures is their potential importance in the future selection of risks. A summary of the efficiency indices for the more important factors analyzed appears in Table 17. The most striking of all the indices are those for down payment, a factor peculiar to sales finance; and the highest single index is that for percent down payment in the new-car sample. Length of loan contract is not strictly limited to the sales finance business, but it appears to be an important factor only in this field; the index of 36 for the new-car sample is impressive, while for all the other samples the indices are either small or negligible. Since this factor tends to be related to other factors, as shown above, a simple statement of its true importance cannot be made.

TABLE 17

EFFICIENCY INDICES FOR THE MORE IMPORTANT CREDIT FACTORS, BY FIVE TYPES OF FINANCING INSTITUTIONS

<i>Credit Factor</i>	<i>21 Commercial Banks</i>	<i>10 Industrial Banking Companies</i>	<i>3 Automobile Finance Companies</i>		<i>2 Personal Finance Companies</i>	<i>1 Appliance Finance Company</i>
			<i>New Cars</i>	<i>Used Cars</i>		
Down payment in percent of cash selling price	..	..	46	21	..	26
Down payment in dollars	..	..	36	23	..	35
Length of loan contract, in months	4	4	36	3	10	..
Tenure of occupation	20	21	24	16	..	..
Bank account	23	14	25	26	..	..
Tenure of residence	15	20	..	..	..	..
Nature of occupation	19	14	18	17	10	..
Borrower's income	5	7	18	17	8	..
Real estate	14	10	11	10	..	..
Cash purchase price	..	..	4	18	..	21
Sex and marital status	11	9	..	..	11	..
Life insurance	10	8	..	..	..	..
Amount of loan	4	8	..	..	13	..
First credit-rating formula (see p. 85)	31	..	..	..	..	..
Second credit-rating formula (see pp. 86-87.)	32	30	..	..	..	..

Of the factors germane to all fields of lending, stability of occupation and possession of a bank account stand out as primarily important in the selection of risks; for each of these

factors the efficiency indices for all the samples average a little over 20. Stability of residence, nature of occupation, and borrower's income in sales finance only, are probably next in importance, although their proper order cannot be determined easily; after them comes ownership of real estate. The least important factors are possession of life insurance, sex of borrower, cash price in sales finance, and amount of note.

In some respects Table 17 is at variance with the opinions of credit executives tabulated in Tables 1 and 2 of Chapter 1. The first striking difference is in the importance of down payment; the efficiency indices presented in Table 17 give primary emphasis to this factor, while the replies listed in Table 2 rate it fifth among six factors. Both possession of a bank account and stability of residence, particularly bank account, are important in Table 17; but the replies of Table 1 indicate that bank accounts and other assets are secondary in importance, and that stability of residence is almost entirely overlooked. Lenders attach considerable significance to character and past payment record, which are not analyzed in this study; they also attach importance to the borrower's other obligations, upon which we have obtained only inconclusive evidence. Our findings and the opinions of the financing business agree on the importance of stability of occupation as an indicator of credit risk.

The findings of this chapter must be broadly interpreted, for they are only general tendencies; furthermore, they are subject to exceptions, which are often readily apparent to a critical eye. Thus, an unstable employment record usually indicates a poor risk, but instability due to frequent promotions is almost certainly a sign of good risk; likewise, a large down payment on an automobile is a good indication in general, but not if it represents a grossly overvalued trade-in. In fact, all of the objective credit indicators here shown to be important are probably not important in themselves; their

real significance lies in their ability to reflect the intangible qualities of the applicant. A satisfactory borrower does not need to have a stable employment record, or a bank account, or cash to make a large down payment. What he needs is the ability to earn a livelihood, the capacity to exercise prudence and judgment, and regard for his financial and social reputation; but these qualities are often apparent only indirectly through more objective criteria like stability of occupation or the possession of a bank account.

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## Credit-Rating Formulae

IN THE last chapter we presented a series of individual analyses, each of which treated the relation of an isolated credit factor to bad-loan experience. We shall now attempt to bring these isolated findings together and to consider the problem of credit analysis as a whole. One common way of meeting this problem is to select a number of the more important factors, to determine the relative importance—or weight—of each factor, and to combine these factors and weights to obtain a credit-rating score, which may then be used as a basis for accepting or rejecting applications for loans. For example, one bank officer has advanced a rating scheme based on five groups of items: he allots 20 percent of the total rating to the applicant's employment record and 25 percent to the income statement, 10 percent to the financial statement (including data on assets, liabilities, income, expense, and similar items appearing on a borrower's application), 20 percent to the type of security, and 25 percent to the past payment record; a score of 70 or better is necessary to indicate a satisfactory risk.<sup>1</sup> A sales finance officer has a substantially similar scheme; on the whole he treats the same fundamental concepts, but he treats them in more detail, and he gives more weight to occupation.<sup>2</sup> A "credit quotient" scheme for evaluating automobile transactions also has been devised.<sup>3</sup>

<sup>1</sup> H. L. Dunham, "A Simple Credit Rating for Small Loans," *Bankers Monthly*, vol. 55, no. 6 (June 1938) pp. 332, 333, 361.

<sup>2</sup> Joseph M. Greenberg, "A Formula for Judging Risks Accurately," *The Credit World*, vol. 28, no. 9 (June 1940) pp. 20-22.

<sup>3</sup> Owen L. Coon, *An Analysis of Automobile Repossessions and the Credit Quotient Method of Credit Analysis*, American Finance Conference, Special



Finally, a very systematic procedure for evaluating mortgage risks has been worked out by the Federal Housing Administration and described in their *Underwriting Manual*.

A credit formula is ordinarily regarded as a supplement to, rather than a substitute for, judgment and experience. It may enable a loan officer to appraise an ordinary applicant fairly quickly and easily; and in large-scale operations, it may be of service in standardizing procedure, thus enabling most of the routine work of investigation to be handled by rather inexperienced and relatively low-salaried personnel. A credit formula may not be satisfactory, however, in the investigation of extraordinary cases.

The credit-rating schemes or formulae in common use are generally, if not always, derived from a combination of experience and intuition. To devise a satisfactory formula, a credit officer usually draws first on his own experience, which he then supplements with the experience of others; he next employs his imagination to incorporate this information into a mechanical rating scheme; and finally he puts the scheme into practice, finds flaws in it, and modifies it accordingly.

In this study we have experimented with deriving purely objective credit formulae by statistical methods. Three of the formulae thus derived are presented in this chapter to show how the individual findings of the previous chapter can be combined into a single result. Unfortunately, these formulae are subject to a number of limitations that seriously restrict their usefulness in practical risk selection. First, since the samples on which the analysis was based are composed entirely of loans that were made only after the applicants had been carefully investigated and the poorest risks culled out, the resulting formulae will be suitable only as a supple-

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Bulletin no. 27 (February 7, 1938) pp. 21 ff. A brief description will be found also in National Bureau of Economic Research (Financial Research Program), *Sales Finance Companies and Their Credit Practices*, by Wilbur C. Plummer and Ralph A. Young (1940) p. 138.

mentary means of risk control; after the original selection has been made, the formulae may be used for a further weeding out of undesirables. Second, our formulae are seriously handicapped by the non-inclusion of important factors like past payment record and moral character, on which no data were available. Finally, the statistical methods by which the formulae are derived—which are similar to the methods used in multiple correlation analysis—are not readily understood by any but trained statisticians or mathematicians; therefore, all details of the procedure and all discussion of its theoretical aspects are omitted here, and only a brief summary of the results is given.

#### SPECIFIC FORMULAE

For the commercial bank sample, two sets of formulae were determined. The first of these, which includes nine factors, provides a means of computing a credit-rating score for any applicant as follows:

*Age:* Give a credit of .01 for each year of age over 20, with a maximum of .30 for 50 years or more.

*Sex:* Credit of .40 if applicant is a woman.

*Stability of Residence:* Credit of .042 for each year at present residence, with a maximum of .42 for 10 years or more.

*Occupation:* Credit of .55 for either of two good-risk occupations of Table 13 (1a and 2a); nothing for either of two bad-risk occupations (2c and all of 6); credit of .16 for all others.

*Industry:* Credit of .21 for those employed in utility industries, government service, and banking or brokerage business.

*Stability of Employment:* Credit of .059 for each year at present employment, with a maximum of .59 for 10 years or more.

*Three Asset Items:* Credit of .45 for bank account, .35 for real estate, .19 for life insurance.

A score of 0 is the minimum that any borrower could receive, and a score of 3.46 is the maximum.

After the formula had been worked out, each loan included in the commercial bank sample was given a credit-rating score. The distribution of loans by this formula rating appears in the top section of Table 18; a marked divergence between good and bad loans is apparent. The good-loan scores on the whole are distinctly higher than those for bad loans; the dividing line between better-than-average loans and worse-than-average is about 1.25. The efficiency index for this credit-rating formula is 31, which is higher than that for any one of the component factors; bank account, for example, which is the highest single component, has an efficiency index of 23.

A second credit formula was determined by another method, which has the advantage of taking account of inter-relationships between factors. If, for example, longer employment records are more characteristic of the older borrowers than the younger—as is actually the case—the second method automatically takes account of the relation. This advantage is probably not great in cash-loan experience, where relationships between factors are not pronounced; but it may be great in sales finance, where the relationships are closer. The method has the disadvantage of being laborious and complex. In the actual application of the method, two factors considered in the first formula, age and industry, were discarded, and the calculation was limited to a subsample of 191 good loans and 190 bad loans.

By the second formula the credit rating of an applicant may be determined as follows:

*Sex:* Give a credit of 2.63 if applicant is a woman.

*Stability of Residence:* Deduct .025 for each year applicant has lived at present address, with a maximum deduction of .25 for 10 years or more. (The negative weight for this factor, which implies that stable residence signifies poor risk, probably is faulty; it is at least partly due to the size of the subsample from which the

TABLE 18

## PERCENTAGE DISTRIBUTION OF GOOD-LOAN AND BAD-LOAN SAMPLES, BY TWO CREDIT-RATING FORMULAE

Source and Composition of Data	Rating According to Formula <sup>a</sup>										Number of Cases		Efficiency Index
	.00- .49	.50- .74	.75- .99	1.00- 1.24	1.25- 1.49	1.50- 1.74	1.75- 1.99	2.00- 2.24	2.25- 2.49	2.50 and Over	Re- porting	Not Re- porting	
<b>First credit-rating formula</b>													
<b>20 Commercial banks<sup>b</sup></b>													
Good loans	3.3	7.2	8.9	11.6	16.6	13.2	13.4	10.3	8.6	6.9	1,020	210 <sup>c</sup>	31.2
Bad loans	13.2	16.7	17.0	15.3	13.8	11.1	6.5	3.6	1.4	1.4	961	238 <sup>c</sup>	
Bad-loan relative	4.0	2.3	1.9	1.3	.8	.8	.5	.3	.2	.2			
			Less than 0	0-1	1-2	2-3	3-4	4-5	5-7	7 and Over			
<b>Second credit-rating formula</b>													
<b>21 Commercial banks</b>													
Good loans			4.2	9.7	12.9	12.5	14.3	13.8	20.0	12.6	1,157	137	32.3
Bad loans			12.1	23.7	23.3	11.8	10.1	9.0	7.9	2.1	1,110	184	
Bad-loan relative			2.9	2.4	1.8	.9	.7	.7	.4	.2			
<b>9 Industrial banking companies<sup>d</sup></b>													
Good loans			2.9	12.2	15.9	11.8	14.4	15.1	17.7	10.0	271	151	29.9
Bad loans			11.8	26.2	22.9	11.8	8.6	7.9	8.3	2.5	279	143	
Bad-loan relative			4.1	2.1	1.4	1.0	.6	.5	.5	.3			

<sup>a</sup> Each class according to the second credit-rating formula includes the lower and excludes the upper limit.

<sup>b</sup> One sample containing 109 good and 106 bad loans was eliminated from this tabulation because the reported information was inadequate. For this tabulation the weights used to obtain the average differ slightly from those used in all the other commercial bank tabulations.

<sup>c</sup> Actual number of cases not reporting. In the other commercial bank tabulations, the number given is fictitious, as explained in footnote 13, p. 37.

<sup>d</sup> One sample containing 241 good and 237 bad loans was eliminated from this tabulation because the reported information was inadequate.

formula was determined.<sup>4</sup> The fact that it is faulty apparently does not seriously affect the results. The limitation of the maximum deduction to .25 was made arbitrarily.)

*Occupation:* For either of two good-risk occupations (items 1a and 2a) of Table 13 give a credit of 1.19; for either of two bad-risk occupations (2c and all of 6) deduct 1.19; for all others make no adjustment.

*Stability of Employment:* Credit of .077 for each year applicant has been at present employment.

*Three Asset Items:* Credit of 1.87 for real estate, 2.72 for bank account, 1.19 for life insurance.

A score of minus 1.44 is the absolute minimum that any applicant could receive. Although there is no absolute maximum, a score of more than plus 10 would be extremely high, and one of more than plus 14 would be virtually impossible.

By use of this second formula, scores were computed for all the commercial bank loans reporting sufficient information. The distribution of these scores is shown in the lower section of Table 18. The ratings obtained by this formula, like those secured by the first, are substantially higher for the good loans than for the bad. The efficiency indices are virtually the same—32 for the second formula and 31 for the first; the difference is altogether too small to be significant in a sample of this size. Thus, in spite of the fact that it contains seven factors instead of nine, and a negative weight for stability of residence, the second formula appears to be quite as good a risk indicator as the first.

The second formula was also applied to the industrial banking sample, with two minor variations: stability of residence was eliminated altogether because of the unreliability of the evidence, and all professional persons (both 1a and 1b in Table 13) were given the highest occupational rating. These changes tend to make the scores obtainable by

<sup>4</sup> See Appendix B, pp. 130-31.

the formula slightly higher: the absolute minimum is  $-1.19$  instead of  $-1.44$ . The distribution of the scores is also shown in Table 18. The efficiency index of 30 is again substantially higher than that for any of the components; the highest component index is 21 for stability of occupation. Here it is interesting to note that a formula derived from commercial bank experience may also be applied to industrial banking companies.

A third formula, determined for the sample of used cars, was based on only four factors—price, down payment, length of contract, and purchaser's income, as follows:

$$\begin{array}{r}
 \text{down payment (in dollars)} \\
 \textit{less} \quad .174 \times \text{cash price (in dollars)} \\
 \textit{plus} \quad .124 \times \text{monthly income (in dollars)} \\
 \textit{less} \quad 6.45 \times \text{length of contract (in months)}
 \end{array}$$

This formula was never actually used to determine ratings for the various cases. An estimate of the efficiency index, based on theoretical considerations, was 25. This index was such a slight improvement over 23, the efficiency index for the down payment component, that it seemed hardly worth while to compute and tabulate all the scores.

This formula was derived by the second method mentioned above, which takes account of the interrelationships between factors; as a result, the formula does not conform with the individual analyses of cash purchase price and duration of contract described in Chapter 3. The analysis of cash price showed that high-priced used cars are less frequently repossessed than the low-priced cars; yet the negative weight for price in the formula implies the opposite. The reason for this discrepancy may be found in the relation between price and down payment. When a high price is accompanied by a high down payment—as it usually is—it connotes a good risk; but when a high price is accompanied by a low down payment—which is the exception—it connotes a poor risk.

The individual analyses showed no relation between re-possession experience and contract length, but the negative weight in the formula implies that short contracts are better risks. Here the reason for the discrepancy is that low-priced used cars are apt to be financed with short-term contracts. In any particular price level, the short-term contracts are the good risks; but when all price levels are combined, the short-term contracts are no longer noticeably good because they tend to be associated with low-price deals, which are poor.

#### EVALUATION OF FORMULAE

There is probably no such thing as a unique, ideal credit formula, for different formulae are probably appropriate for different phases of business cycles, for different types of consumer financing agencies, and perhaps even for different firms in the same type of financing. Yet when we consider that the first and second credit formulae above were, despite their differences, about equally effective as risk indicators, we are likely to conclude that the form of a credit formula can be chosen with some latitude. Perhaps a formula designed for depressions will be nearly as useful during prosperity as another especially designed for prosperity; a formula derived for California may work fairly well in New York; and a formula determined by an industrial banking company may even serve for a personal finance company. These questions, however, cannot be answered without recourse to more data than have been available for this study.

The formulae have been presented here only for the purpose of illustrating how individual factors may be combined to obtain credit-rating scores for borrowers; it is not suggested that lenders use these formulae to select risks. Each formula has the not-so-surprising quality of being a better indicator than any of its component factors. But even so, the combination is not substantially better than its com-

ponents. For example, as pointed out above, the first formula has an efficiency index of 31 as against 23 for bank account, its highest component. Although this difference represents an appreciable increase, we do not believe it sufficient to make the first formula a revolutionary discovery. The practical credit executive is primarily interested in a formula that will promise a substantial reduction in credit losses and a substantial increase in profits. Such a formula might have an efficiency index of 62 instead of 31, as we shall show in the next chapter.



## Appraisal of Results

THIS study has examined a number of credit factors and has found that some of them are definite indices of risk. For example, stability of occupation and residence, possession of certain assets, and a relatively large down payment in sales finance transactions, are more frequently characteristic of good loans than of bad. These findings are interesting from the point of view of credit theory. They provide support for some of the widely held opinions of practical credit executives; they also contradict other widely held opinions; and they furnish evidence of some unsuspected relationships, thus suggesting further study. But from the practical point of view, from the point of view of improving credit policy, what is the value of these findings?

A rough analogy can be drawn between the insurance business and the consumer financing business. In the former, the premiums charged different types of risks vary in accordance with the actuarially determined costs of underwriting these risks; thus in group life insurance, the premium depends on the industrial classification and the average age of the insured group. Conceivably the consumer finance business could follow the same policy; it could accumulate extensive experience tables showing the costs of handling various types of risks, and it could charge accordingly. Actually, however, the consumer financing business is not likely to pursue this policy closely because of the difficulty, if not the impossibility, of obtaining the necessary experience tables, and because of the unpracticality of discriminating between borrowers.

And yet in a limited sense, the consumer finance business does pursue this policy. Different individual lending firms cater to somewhat different types of borrowers and charge different fees. A commercial banker, for example, may decide to make low-rate loans to low-cost, good-risk applicants. The banker will attempt to determine a rough dividing line that will enable him to separate the high-cost, unprofitable applicants from the low-cost, profitable ones. The high-cost applicants, although unacceptable to this particular banker, will probably be able to obtain loans from other sources at higher rates. Although the banker will realize that some of the profitable risks are much more profitable than others, he will probably charge the same fees to all. Nevertheless, some individual institutions do vary their charges with the risk; for example, some personal finance companies make special rates to teachers.

Each lender has the problem of determining what types of borrowers he can accommodate at his prevailing rates. He will probably decide that some part of his business can represent marginal, and even slightly submarginal borrowers, who do not completely pay their own way, as long as the greater part of the business consists of supermarginal borrowers, who more than pay their own way. For this reason he does not have to determine precisely where the margin lies between the profitable and the unprofitable applicants; he does not have to emulate the experience tables of the insurance actuary; but he must attempt to arrive at some sort of solution, however rough, for without it credit policy cannot be formulated.

#### REVISION OF CREDIT POLICY

Any lender who wishes to revise his credit policy may obviously proceed in one of two general directions: he may inaugurate more rigid standards, which will probably result

in decreased collection troubles, decreased losses, and also decreased volume of business; or he may relax his standards, which will result in an increase in both volume of business and collection problems. When credit policy is to be altered, all possible results must be considered—particularly the effect on net income. If standards are to be raised, how much will the volume of business be reduced; can this loss be recovered by an increase in advertising addressed to the more desirable classes of risks; how much will credit losses and collection difficulties be reduced; and what will be the final effect on profits? If, on the other hand, standards are to be relaxed, what will be the increase in volume and gross revenue; will additional advertising be necessary to attract the new borrowers; will the present collection department be able to keep losses within reasonable bounds; and what will be the effect on profits?

In deciding whether he will relax standards, restrict standards, or continue his present policy, a lender may find that the data compiled in this study give him valuable clues, and he may be able to gain supplementary similar data of his own by using the methods illustrated here; but probably he will also require other data only obtainable by other methods. The ensuing discussion is an attempt to illustrate how a lender may proceed toward a rational decision. If some of the suggestions border on the impracticable, they will serve to show that a completely rational and scientific approach to risk selection is not possible.

#### STUDY OF COSTS

Probably the first step that any lender should take is to make a simple analysis of his costs. Total gross income can be broken down into three general parts: a part necessary to cover collection costs, which include collectors' salaries, court fees, and other expenses incidental to handling delinquencies,

as well as actual losses charged off; a part necessary to cover non-collection costs, which include all costs not incidental to handling delinquent accounts; and a third part representing net profit. If the first part is very small, the lender will not be particularly interested in trying to reduce it further by means of greater restrictiveness; he will be more interested in reducing his non-collection costs by increasing efficiency of operation, or in finding ways to bring in new business. If collection costs are high, however, an attempt to reduce them is certainly in order; but the success of the attempt depends upon the possibility of culling out from among present borrowers a group of particularly unsatisfactory ones.

Evidence of the sort presented in this study is designed to distinguish the more satisfactory borrowers from the less satisfactory, but the distinction is primarily qualitative. Our evidence has shown that a young mechanic with employment and residence tenure of less than three years, and without bank account, life insurance, or real estate, is one of the poorer risks; but since the fact that the risk is poor does not mean that it is necessarily unprofitable, an estimate of the cost of granting loans to borrowers of this general type is essential. The only clue provided by this study is the bad-loan relative, which may be used as a rough measure of the comparative collection costs of different classes of borrowers. Consider the first credit-rating formula of Chapter 4, for example. The class of borrowers with ratings of less than .50, which includes the above mechanic, has a bad-loan relative of 4.0, and that with ratings of 2.25 and over has a relative of .2. One possible inference is that the collection costs (though not the non-collection costs) of the first class are twenty times those of the second class and four times as much as the average for all classes.

The bad-loan relative, however, is no more than an approximation. There are two reasons. First, the relative is subject to sampling error, which is large in samples of 200 loans

and is still appreciable in samples of 1000. Second, the bad-loan relative may be an intrinsically poor method of estimating actual costs, for the mere fact that bad loans are four times more numerous among borrowers with ratings of less than .50 than among all borrowers does not prove that collection costs are also four times as high; they may be either more or less than four times. A much more reliable, but at the same time more onerous method is to make a study of the actual collection costs incurred. For each delinquent account in the questioned class, an estimate would be made of the cost of follow-up letters sent out, of the portion of collectors' or attorneys' salaries allocable to the account, and of any other expenses or credit losses that might have been incurred. The proper allocation of expenses between collection costs and non-collection costs is a serious cost accounting problem; nevertheless, it is necessary if the study is to be comprehensive.

If the collection costs for borrowers with ratings of less than .50 are four times as high as the average for all borrowers—as the bad-loan relative suggests—does this indicate that the group in question is unprofitable? If not, how high would the relative have to be in order to suggest unprofitability? The dividing line between profitability and unprofitability, the breakeven point, can be roughly estimated from the following simple formula:

$$\frac{\text{Net profit} + \text{Collection costs} + K \times \text{Non-collection costs}}{\text{Collection costs}}$$

The cost and profit items in this formula refer to the totals for an individual enterprise, which may be expressed in actual dollars, or as a percentage of gross revenue, or in a number of other ways; the constant  $K$  depends upon overhead costs.

By rejecting an applicant, a lender can avoid a number of expenses that he would otherwise have to incur in carrying

the loan to maturity, but he cannot recover any of the expenses already incurred in investigating the applicant; there is, therefore, a strong incentive to accept an applicant once he has been investigated, and the incentive is particularly strong if these sunk or overhead costs form a large part of the total non-collection costs. The constant  $K$  in the above formula is the ratio of overhead costs to total non-collection costs, so that it can conceivably vary from 0 to 1. Obviously, as  $K$  becomes larger, the breakeven point determined by the formula will increase. To determine  $K$  accurately is a difficult, if not impossible cost accounting problem, but to make a satisfactory rough estimate is probably within the power of most lenders.

This formula may be illustrated as follows. Suppose non-collection costs account for 60 percent of the total gross receipts; that collection costs account for 15 percent; and that the remainder, 25 percent, represents net profit. If there are no overhead costs—so that  $K$  is zero—the breakeven point is  $2\frac{2}{3}$ ; if all non-collection costs are overhead—so that  $K$  is one—it is  $6\frac{2}{3}$ . Actually, the true value of the breakeven point lies somewhere between these two extremes; if  $K$  is  $\frac{1}{3}$ , indicating that one-third of non-collection costs are overhead, the breakeven point will be exactly 4, which is the same as the bad-loan relative for borrowers with ratings of less than .50; if  $K$  is  $\frac{2}{3}$ , the breakeven point will be  $5\frac{1}{3}$ .

If the simple assumptions in the foregoing illustration are realistic, the class of borrowers with ratings of less than .50 is approximately marginal, and an attempt to exclude this class from loan service is not likely to have a pronounced effect on net profits. As we pointed out when presenting the efficiency index, the raising of credit standards naturally results in the elimination of a portion of the bad loans; but it almost invariably results in the elimination of a somewhat smaller portion of the good loans. This principle can be extended to include considerations of cost. The raising of

credit standards will reduce bad-debt losses and collection expenses, but it will also reduce the volume of business and gross income; and if high overhead costs are involved, it may even raise the average operating cost per loan. A real increase in net profits can only be accomplished by isolating and eliminating some class of borrowers that contains a much larger percentage of bad loans than of good loans, a class that contributes little to the company's income while contributing much to its expenses. In our analysis such a class can be identified by a high bad-loan relative which is likely to be found only in conjunction with a factor having a high efficiency index.

An example of the sort of situation that would permit profitable restriction of risks appears in the following purely hypothetical distribution of loans (figures indicating percents):

	Class					
	A	B	C	D	E	F
Good loans	1	2	5	22	40	30
Bad loans	16	22	32	16	10	4
Bad-loan relative	16.0	11.0	6.4	.7	.3	.1

Here the efficiency index of 62 is just twice that of the first credit-rating formula in Chapter 4. Class A and Class B are probably both submarginal; Class C is doubtful. Elimination of Classes A and B would not have an appreciable effect on the volume of satisfactory business—but it would have a very pronounced effect on the unsatisfactory business; the good business would be decreased by 3 percent, and the bad business by 38 percent. Unfortunately, our researches have not yet succeeded in uncovering a situation even approaching this, or a single clearly submarginal bad-loan relative. From this fact follows the tentative conclusion that the organizations submitting samples have been sufficiently careful in selecting risks so that further selection is hardly necessary. Of course, this conclusion is founded on rather meager

evidence. A detailed examination of the costs involved might indicate otherwise; and if we could obtain additional data—such as information on moral character, past payment record, and other considerations not available at present—we might be able to construct a much more effective credit formula, which would permit profitable restriction of borrowers. But the inherent nature of the consumer financing business argues against restriction. The instalment financing business does not aim at exclusiveness, for its function is to reach out and extend facilities to the general public. To deny facilities to all but the elite among risks is to defeat the fundamental purpose of consumer credit as well as to forego an opportunity for profit. Over the past two decades the trend has been toward more liberal credit terms and better collection procedure; and the business has prospered.

#### VALUE OF CREDIT ANALYSIS

Owing to the fact that the analysis of credit experience is expensive and that the practical value of the results appears to be limited, many lenders may conclude that analysis is not worth while. They may be willing to admit that empirical studies will point the way to greater efficiency of operation, and yet very justifiably contend that the improvement in operating experience will not pay for the research necessary to achieve it. They may feel that the search for efficiency in the particular begets inefficiency in the whole. They may point out, and rightly, that risk selection entails a margin of uncertainty that defies solution, and that regardless of research no lender can ever expect to perfect his selection technique to the point of no losses. They may argue that, after two decades of experience, lenders have learned enough to identify and reject the few impossible risks, and to collect from the others. In short, they will prefer to trust their own judgment and let good enough alone. This view, however,



is probably extreme. Most large lenders carry on research programs, and they presumably feel that continual critical analysis of their operating policies is justified because it tends to keep the organizations alert even though the results may not lead to revolutionary improvements in technique. For these lenders, the problem is to keep the cost of the research program within reasonable limits.

The actuarial analysis of risk along the lines used in insurance is the goal toward which credit research should strive. The efficient design of a research program consists in proceeding as far as possible in that direction without incurring undue expenses. The method of risk analysis that we have illustrated has the prime advantage of being inexpensive; and it is particularly inexpensive when lenders' files are arranged to permit quick random sampling. A lender might easily manage a sample analysis of four or five hundred loans a year—particularly if the work could be done in periods of slack business. After several years the accumulation of evidence should be impressive. The reliability of findings will be enhanced by repeated confirmation; questionable results obtained in the earlier years will be amplified and explained by the results of subsequent years; and any pronounced cyclical or secular changes will become apparent. But the sample method, though inexpensive, has the disadvantage of lacking precision, particularly in its failure to relate risk experience to costs and profits. This method is primarily a preliminary method; it suffices to test intuitive hypotheses and to formulate new problems. As the preliminary evidence accumulates, issues will crystalize—issues that can, perhaps, be solved only by the more precise, and more costly, methods.

The fact that the risk problem has been discussed here in pecuniary terms should not obscure its broader social as-

pects. An unwise loan may become a disaster to the borrower. The borrower who succeeds in repaying an unwise loan may undergo great hardship in doing so. The borrower who does not succeed may find his credit standing impaired; if he signed a chattel mortgage, his furniture or automobile may be seized; if his friends acted as comakers, they may be embarrassed by legal proceedings; he may even lose his job; and in any case, he is bound to lose a measure of his self-respect, his self-confidence, and his social position. The lender who is sensitive about his public relations faces two serious dilemmas. In selecting applicants, he may refuse all loans that seem questionable or unwise, but if he does so, he will divert considerable business to his competitors. In collecting delinquent accounts, he cannot afford to be over-lenient, for he may encourage further delinquencies; and he cannot afford to be over-aggressive, for he may suffer a serious loss of good will.

The social appraisal of consumer credit faces the same sort of dilemma. Consumer credit fills a social function in making credit available to those who would otherwise not be able to obtain it; but at the same time it has unfortunate effects on the minority who have difficulty in repaying their loans. Strictly speaking, social gain and social loss are intangibles that cannot be measured. Nevertheless, it is impossible to entirely suppress the question: how should risk selection be organized to obtain the maximum social gain at the expense of the minimum social loss?

**APPENDIX A**

**A Note on the Theory of  
Discriminant Functions**

# Appendix A

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## A Note on the Theory of Discriminant Functions

VIEWED in the abstract, the present problem of statistical analysis is one of differentiating two species by means of a set of measurements; it is analogous to some of the problems of biology in which two varieties of plants or other organisms are differentiated on the basis of length of leaf, breadth of stem, etc. The two species under consideration in this study are the good and bad loans of consumer instalment lending, or rather the borrowers who repay their loans and those who fail to repay. This twofold classification, as we have pointed out, is somewhat artificial because loans or borrowers vary considerably in quality; but the distinction is useful and, roughly speaking, reasonably valid. The set of measurements includes information concerning borrower's income, occupation, sex, stability of residence, and the like. Again, to speak of measuring characteristics such as occupation, which is classified qualitatively and not quantitatively, may not be strictly correct, but in a broad sense the concept is satisfactory.

Statistical theorists have given considerable attention to the problem of differentiating two species by a set of measurements, and they have advanced the method of discriminant functions to solve it. This method permits an investigator to weight several credit factors according to their relative importance, and to allow for interrelationships between factors, which are extremely hard to account for by other approaches. A brief discussion of the theory underlying the method will be useful background for the study of good- and bad-loan samples.

Unfortunately, discriminant functions are usually determined

on the rather restrictive assumptions that each species considered has the multivariate normal distribution, and that the two species differ only in the average values of the measurements or variates—in other words, that the standard deviation of the variates and the coefficients of correlation between them are the same for each species. These conditions are not met in the good- and bad-loan samples; hence the method in question is not strictly applicable. Nevertheless, for illustrative purposes, its value is sufficiently great to warrant detailed attention.

The problem of differentiating two species by a set of measurements may be introduced by a discussion of the one-variate case. Assume the two species are normally distributed with respect to the distinguishing criterion. Each distribution has variance  $\sigma^2$ ; but the means are different—say  $+\frac{a}{2}$  and  $-\frac{a}{2}$ , so that the difference between them is  $a$ . The two species then have the probability distributions

$$P(A) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\frac{a}{2})^2}{2\sigma^2}} dx, \quad P(B) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x+\frac{a}{2})^2}{2\sigma^2}} dx.$$

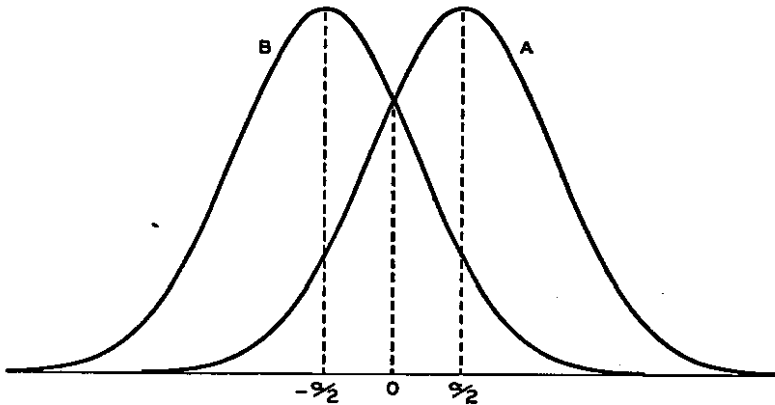
If species A and species B are equally numerous, the distributions may be represented by two congruent curves, as in Figure 1. To make the example concrete, imagine that A represents good loans, that B represents bad loans, and that the distinguishing criterion is number of years at present occupation.

The ratio  $\frac{P(A)}{P(B)} = e^{\frac{ax}{\sigma^2}}$  is the ratio of the relative frequency of A's to B's in a small region around  $x$ . The ratio is an increasing function, approaching 0 as  $x$  approaches negative infinity, and approaching positive infinity as  $x$  approaches positive infinity. When  $x$  equals 0, the ratio equals one, indicating that in this region A's and B's are equally numerous. Because the ratio is an increasing function, all regions to the right of 0

contain more A's than B's, and conversely for all regions to the left of 0.

If species A and species B are to be differentiated on the basis of the value of  $x$ , several schemes are possible. One common scheme is to use the point 0, the midpoint between the means, as a criterion; values greater than 0 are classified as probably belonging to group A, and vice versa. Under this scheme the probability of misclassifying either an A or a B,  $P(\text{Mis})$ , is the ratio of the area of the portion of the A curve

Figure 1



left of 0 to the total A area, which is the same as the area of the B portion right of 0 to the total B area.  $P(\text{Mis})$  is therefore equal to one-half the probability that the absolute value of a normal variate will exceed the absolute value of the ratio  $a/2\sigma$ . The ratio  $a/\sigma$ , or  $v$ , will be used in the future as a measure of the effectiveness of a criterion as a means of differentiating the two species.  $P(\text{Mis}) = \frac{1}{2}$  when  $v$  is 0; it decreases as  $v$  becomes larger, approaching 0 as  $v$  becomes infinite. The quantity  $1 - P(\text{Mis})$ , the probability of classifying correctly, varies from  $\frac{1}{2}$  to 1 as  $v$  varies from 0 to infinity. Earlier in this study we have used the quantity  $1 - 2P(\text{Mis})$ , which we have called the

efficiency index, to measure the effectiveness of the variate  $x$  as a means of distinction. This index, which varies from 0 to 1, can be expressed in terms of the ratio  $v$  by the following integral:

$$\text{Index} = \frac{1}{\sqrt{2\pi}} \int_{-v/2}^{v/2} e^{-\frac{t^2}{2}} dt$$

Equally numerous species differentiated by the midpoint between the means are a special case of a much more general situation. In credit analysis the generalization is desirable, for the special case is far from realistic. Good loans and bad loans are not equally numerous. If the ratio of good to bad—i.e., A to B—is  $k$ , then the relative frequency ratio

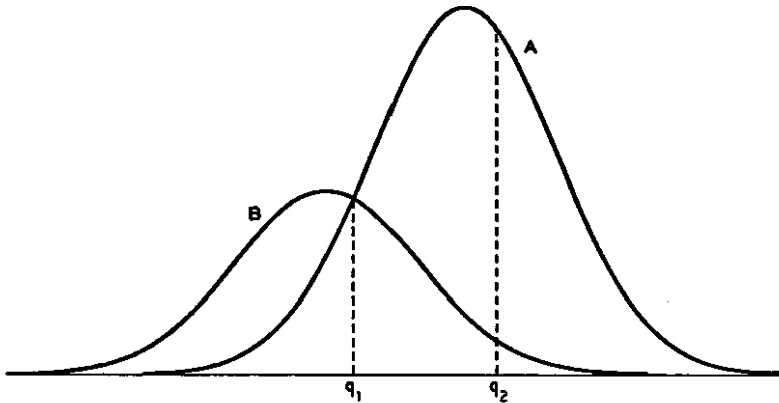
$$\frac{P(A)}{P(B)} = ke^{\frac{\alpha x}{\sigma^2}}$$

is no longer equal to unity when  $x$  is zero; it is equal to unity at some other point  $q_1$ , which depends on  $k$ ,  $\alpha$ , and  $\sigma$ . But the point  $q_1$ , where  $\frac{P(A)}{P(B)}$  is unity, is not a satisfactory point of demarcation because the net loss on a bad loan is likely to be considerably greater than the net profit on a good loan; the suitable point,  $q_2$ , is determined by equating  $\frac{P(A)}{P(B)}$  to the ratio of the average profit on good loans to the average loss on bad loans. In risk selection, two points of demarcation,  $q_2'' > q_2'$ , may be required in place of only one. For example, applicants to the right of  $q_2''$  could be accepted unconditionally; applicants to the left of  $q_2'$  could be rejected unconditionally; and those between  $q_2''$  and  $q_2'$  could be given a more rigorous investigation and be required to furnish additional collateral.

For the general case, the concept of the probability of misclassification is substantially altered. Instead of one simple quantity, there are now four as follows: (I) the probability that species A will be misclassified; (II) the probability that species B will be misclassified; (III) the probability that an observation

with a value of  $x$  greater than the critical value ( $q_2$ ) will be misclassified; (IV) the probability that an observation with a value less than  $q_2$  will be misclassified. In Figure 2, (I) is represented by the fraction of curve A to the left of the critical value  $q_2$ ; (II) by the fraction of B to the right of  $q_2$ ; (III) by the ratio of the tail of B (to the right of  $q_2$ ) to the sum of the tails of A and B; and (IV) by the ratio of the main portion of A (to the left of  $q_2$ ) to the sum of the main portion of A and the main portion of B.

Figure 2



In practice, all these values can be determined from tables of the normal curve. These four quantities are not entirely independent; they can be reduced to two quantities. For example,

$$(III) = \frac{(II)}{K[1 - (I)] + (II)}$$

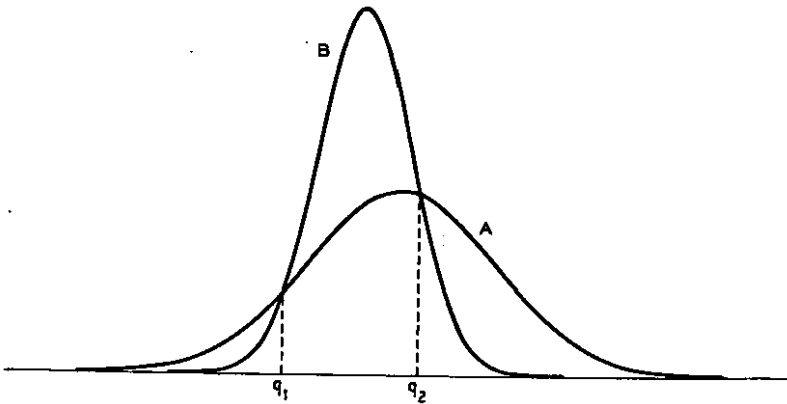
$$(IV) = \frac{K(I)}{1 - (II) + K(I)}$$

where  $K$  is the ratio of A's to B's. In the special case, where the two species are equally numerous and where 0 is the point of demarcation,  $P(\text{Mis}) = (I) = (II) = (III) = (IV)$ .



A new set of complications is introduced when the two species have different variances as well as different means. The situation is illustrated in Figure 3, where the A variance is larger than the B variance. For the case of equal variances, the logarithm of the ratio  $\frac{P(A)}{P(B)}$  (equal to  $\frac{\alpha x}{\sigma^2}$ ) is the equation of an upward sloping straight line through the origin; all values are possible from negative infinity to positive infinity. This means that the ratio of A's to B's can be increased indefinitely

Figure 3



by taking a region to the right of a sufficiently large value of  $x$ , and conversely. With unequal variances, however, the situation is entirely changed. The logarithm of the probability ratio represents a second degree parabola. In general, the relative frequency ratio is unity at two points,  $q_1$  and  $q_2$ . In all regions between these two points, B's are preponderant, but the ratio of B's to A's is everywhere bounded. In the two external regions, the A's are preponderant, and the ratio of A's to B's can be increased indefinitely by taking sufficiently large or sufficiently small values of  $x$ .

When several variates or criteria are available for differenti-



where  $|s_{ij}|$  is the determinant of the  $s_{ij}$ 's and  $s^{ij}$  is the cofactor of  $s_{ij}$  in that determinant.

A somewhat different approach, which yields the same results with the proper assumptions, is to investigate the relative frequency of species A to species B in various regions of the  $p$ -dimensional variate space. Assume two multivariate normal distributions

$$\begin{aligned} P(A) &= Ce^{-1/2 \sum \sum Q_{ij} \left(x_i - \frac{\alpha_i}{2}\right) \left(x_j - \frac{\alpha_j}{2}\right)} dx_1 \dots dx_p \quad (2) \\ P(B) &= Ce^{-1/2 \sum \sum Q_{ij} \left(x_i + \frac{\alpha_i}{2}\right) \left(x_j + \frac{\alpha_j}{2}\right)} dx_1 \dots dx_p, \end{aligned}$$

which are identical except for the mean values of the variates. The  $Q_{ij}$ 's and the  $\alpha_i$ 's are supposed to be true population parameters and not sample estimates. In this particular form, which entails no loss of generality,  $\alpha_i$  is the difference between the  $i$ -mean of the A's and the  $i$ -mean of the B's, and 0 is the midpoint between those means; but other forms in which the midpoints are not 0 are sometimes convenient. The ratio  $\frac{P(A)}{P(B)}$  has the form  $e^{\sum \sum Q_{ij} x_i x_j}$ , which may also be written  $e^{\sum x_i \lambda_i}$  where  $\lambda_i = \sum_j Q_{ij} \alpha_j$ .

The equation  $\frac{P(A)}{P(B)} = e^{\sum x_i \lambda_i} = K$  is the locus of all points in the vicinity of which the ratio of A's to B's is  $K$ . This can be transformed into

$$\sum x_i \lambda_i = \log_e K,$$

which is the equation of a hyperplane. In particular  $\sum x_i \lambda_i = 0$  is the equation of a hyperplane through the origin, which is the locus of all points in whose vicinity A's and B's are equally numerous. Since the matrix of  $Q_{ij}$  is the inverse of that of  $\sigma_{ij}$ , the covariances of the  $x$ 's,

$$\lambda_i = \sum_j \alpha_j \frac{\sigma^{ij}}{|\sigma_{ij}|}$$

This is the same as the solution of (1) if  $s_{ij} = \sigma_{ij}$  and  $a_j = \alpha_j$ .

The function  $Z = \sum x_i \lambda_i$  provides a unique means of differentiating the two species. According to (2), the function  $Z$  is nor-

mally distributed with variance  $\sigma_i^2 = \sum \lambda_i \sigma_{ij}$ ; it has a mean for the A species of  $\bar{Z}_A = \sum_{i=1}^p \frac{\lambda_i \alpha_i}{2}$  and for the B species  $\bar{Z}_B = - \sum_{i=1}^p \frac{\lambda_i \alpha_i}{2}$ , where  $\frac{\alpha_i}{2}$  is the A-mean of  $x_i$  and  $-\frac{\alpha_i}{2}$  is the B-mean. The function Z therefore transforms the multivariate problem into a one-variate problem exactly analogous to that considered earlier.

If A and B are equally numerous, all regions for which Z is greater than 0, which is the midpoint between  $\bar{Z}_A$  and  $\bar{Z}_B$ , contain a preponderance of A's, and conversely. If A's are K times as numerous as B's, and if some adjustment must be made to equate the average loss on bad loans to the average profit on good loans, then an alternative point of demarcation  $Z_q$  can be determined.

In the one-variate case with normal distributions and equal variances, the ratio  $\nu$  was advanced as a measure of the effectiveness of the variate as a differentiator. Two other measures, the probability of misclassification and the efficiency index, were also introduced, but for the case in point these measures depend only on  $\nu$  and are merely supplementary to it. For the multivariate case, the ratio T is exactly analogous to  $\nu$  in the one variate case; it serves as a measure of the effectiveness of the discriminant function as a differentiator. The probability of misclassification and the efficiency index for a discriminant function are determined by T just as they were determined by  $\nu$  for one variate. It is interesting to note that U, the sample estimate of T, is related to Hotelling's generalized  $T^2$  and to the  $D^2$ -statistic of Bose and Roy by the following:

$$U = T \sqrt{\frac{n + n' + 2}{(n + 1)(n' + 1)}} = \sqrt{pD^2}^3$$

<sup>3</sup> By definition  $U = \frac{\sum I_i a_i}{\sqrt{\sum I_i s_{ii}}}$ . The numerator of this fraction can be rewritten  $\frac{\sum \sum a_i a_j s_{ij}}{|a_{ii}|}$  since  $a_i I_i = a_i \sum_j \frac{s_{ij}}{|s_{ii}|}$ ; moreover, the quadratic form in the denomi-

(where  $n + 1$  is the number of cases in one sample;  $n' + 1$  is the number in the other samples; and  $p$  is the number of variates).

The ratio  $T$  cannot be smaller than any of the individual ratios  $v_i$ , and in general it will be larger. It may be considerably or only slightly larger; and if it is only slightly larger, the necessary labor of computing the discriminant function may be hardly worthwhile. Consideration of the conditions that make for a larger ratio and those that make for a small one is therefore pertinent.

In general, the computation of the discriminant function and of the ratio  $T$  is a difficult task, which grows more difficult as the number of variates increases; but for the special case of complete independence of variates, the computation is almost simple. For the case of complete independence  $\sigma_{ij} = 0$  except when  $i = j$ ; therefore,  $\lambda_i = \frac{\alpha_i}{\sigma_i^2}$ . This means that the discriminant function can be computed as soon as the  $\alpha$ 's and  $\sigma$ 's are known. The ratio  $T$ , equal to

$$\frac{\sum \lambda_i \alpha_i}{\sqrt{\sum \sum \lambda_i \lambda_j \sigma_{ij}}}$$

simplifies to

$$\frac{\sum \frac{\alpha_i^2}{\sigma_i^2}}{\sqrt{\sum \frac{\alpha_i^2}{\sigma_i^2}}}$$

and thence to

$$\sqrt{\sum \frac{\alpha_i^2}{\sigma_i^2}}$$

nator,  $1/|s_{ij}|$ , is equal to its inverse,  $\sum \sum a_{ia} \frac{s^{ij}}{|s_{ij}|}$ , for the same reason (Cf. Bôcher,

*Introduction to Higher Algebra*, 1936, p. 160). Therefore,  $U = \sqrt{\frac{\sum \sum a_{ia} s^{ij}}{|s_{ij}|}}$ .

Since  $T^2 = \frac{\sum \sum a_{ia} s^{ij}}{|s_{ij}|} \cdot \frac{n' + n + 2}{(n' + 1)(n + 1)}$ , and since  $D^2 = \frac{1}{p} \sum \sum a_{ia} \frac{s^{ij}}{|s_{ij}|}$  (cf. Appendix C, pp. 146, 148, 150-51) the relation of  $U$  to  $T^2$  and  $D^2$  follows easily.

which will be written hereafter  $\sqrt{\sum v_i^2}$ . This also is extremely easy to compute when the ratios  $\frac{\alpha_i}{\sigma_i} = v_i$  are known.

It would be very convenient if the expression  $\sqrt{\sum v_i^2}$  could be used as a first approximation for the true value of  $T$ . One might be able to predict whether the actual computation of a discriminant function would be justified by the results obtainable. The following pertinent relation has been worked out for the case of two variates; but a simple generalization for more than two variates appears to be impossible.

The true ratio  $T$  is equal to  $\sqrt{v_1^2 + v_2^2}$  at two points,  $\rho = 0$  and  $\frac{2}{\frac{v_1}{v_2} + \frac{v_2}{v_1}}$  (where  $\rho$  is the correlation coefficient between  $x_1$  and  $x_2$ ). The ratio reaches a minimum value of  $v_1$  or  $v_2$ , whichever is larger, at the point  $\rho = \frac{v_1}{v_2}$  or  $\frac{v_2}{v_1}$ , whichever is less than one in absolute value. Naturally the minimum point lies between 0 and  $\frac{2}{\frac{v_1}{v_2} + \frac{v_2}{v_1}}$ . On either side of the minimum point,

the ratio increases steadily, approaching infinity as  $\rho$  approaches  $\pm 1$ .<sup>4</sup>

<sup>4</sup> For two variates  $T = \left[ \frac{\alpha_1^2 \sigma_{22} - 2\alpha_1 \alpha_2 \sigma_{12} + \alpha_2^2 \sigma_{11}}{\sigma_{11} \sigma_{22} - \sigma_{12}^2} \right]^{\frac{1}{2}}$  (see footnote 3). Dividing both numerator and denominator by  $\sigma_{11} \sigma_{22}$ , and writing  $\rho = \sigma_{12} / \sqrt{\sigma_{11} \sigma_{22}}$ ,  $v_1 = \alpha_1 / \sqrt{\sigma_{11}}$ ,  $v_2 = \alpha_2 / \sqrt{\sigma_{22}}$ , we get

$$T = \left[ \frac{v_1^2 - 2v_1 v_2 \rho + v_2^2}{1 - \rho^2} \right]^{\frac{1}{2}}$$

When  $|\rho|$  approaches unity,  $T$  becomes infinite except in two special cases: when  $v_1 = v_2$  and  $\rho$  approaches one, or when  $v_1 = -v_2$  and  $\rho$  approaches minus one, then  $|T|$  approaches  $|v_1| = |v_2|$ . The derivative of  $T^2$  with respect to  $\rho$ , which is

$$\frac{2\rho(v_1^2 + v_2^2) - 2v_1 v_2(1 + \rho^2)}{(1 - \rho^2)^2}$$

is equal to zero at the point  $v_1/v_2$  or  $v_2/v_1$ , whichever is less than one in absolute value. At this point  $T$  has a minimum value of  $v_1$  or  $v_2$ , whichever is larger.

We now inquire: At what values of  $\rho$  will  $T = \sqrt{v_1^2 + v_2^2}$ ? We get  $v_1^2 - 2v_1 v_2 \rho + v_2^2 = (1 - \rho^2)(v_1^2 + v_2^2)$ , whence  $\rho = 0$  or  $\frac{2}{v_1/v_2 + v_2/v_1}$ .

There are, then, four different types of cases, which are illustrated in Figure 4. To make the example concrete, imagine that A represents good loans, that B represents bad loans, and the two correlated criteria for differentiation are number of years at present address and number of years at present occupation. In the first two of these (4a and 4b), the true ratio is higher than  $\sqrt{v_1^2 + v_2^2}$ ; in the second two it may be higher or lower depending on the value of  $\rho$ .

A few concrete applications of this theory may be in order. Suppose that for stability of occupation  $v = .5$ , which corresponds to an efficiency index of about 20; and that for stability of residence  $v = .4$ , which corresponds to an efficiency index of 16. (These are approximately the efficiency indices actually obtained in the commercial bank samples.) If there is no correlation between stability of residence and stability of employment, the ratio  $\bar{r}$  will be .64, which corresponds to an efficiency index of 25. But actually a positive correlation is to be expected. The situation is like that of Figure 4c below; if the correlation lies between 0 and .976 =  $\frac{2}{\frac{.4}{.5} + \frac{.5}{.4}}$ , the actual ratio will be

less than .64. Furthermore, since the actual correlation is very likely to lie between 0 and .976, it is a fairly safe prediction that  $\bar{r}$  will actually be less than .64. In the commercial bank samples an estimate of the correlation between stability of residence and stability of occupation was made from a small number of cases. The result, .15, was well within the limits of 0 and .976. (See Table B-3, p. 132.)

In the commercial bank samples no appreciable difference was found between the good- and bad-loan samples in connection with either borrower's income or amount borrowed. What then can be inferred about the ratio of amount borrowed to income? Under the assumptions of normality and of equal standard deviations and correlation coefficients, two definite conclusions are possible: (1) as a means of differentiating good

and bad loans, the ratio of the amount of the loan to borrower's income, which is just one possible way of combining amount and income, will be inferior to a linear discriminant function; (2) the discriminant function will not show any appreciable difference between good and bad loans. Under the assumed conditions, an independent study of the amount/income ratio, or any other combination of income and amount, would not be warranted. Actually, the distribution of loans according to the amount/income ratio was determined, and the results were negative.

Conclusions such as the above rest on the assumption of normality and the equality of standard deviations and correlation coefficients. Since these assumed conditions do not exist in the loan samples, any of the foregoing conclusions may be invalid. Situations that will upset almost any conclusions based on the theory of this chapter are easily invented. No standardized procedure can be worked out for handling such cases, for each one presents its own problem. A few examples will be shown.

Although a linear discriminant function is entirely appropriate for multivariate normal distributions with equal variances and covariances, it is not so appropriate for most other forms of distributions. For example, when the logarithms of the variates are distributed normally with equal variances and covariances, the appropriate discriminant function has the form

$$Z = \lambda_1 \log x_1 + \lambda_2 \log x_2 + \dots,$$

for which we may conveniently substitute

$$Z' = e^Z = x_1^{\lambda_1} x_2^{\lambda_2} \dots$$

A very interesting case occurs when there are only two variates. If  $\lambda_1 = \pm \lambda_2$ , as will be the case when  $\alpha_1(\sigma_{22} \pm \sigma_{12}) = \alpha_2(\sigma_{12} \pm \sigma_{11})$ , then the appropriate discriminant function will be  $x_1 x_2$  or  $\frac{x_1}{x_2}$ .

When the distributions are normal but with the variances and covariances of A unequal to those of B, the appropriate



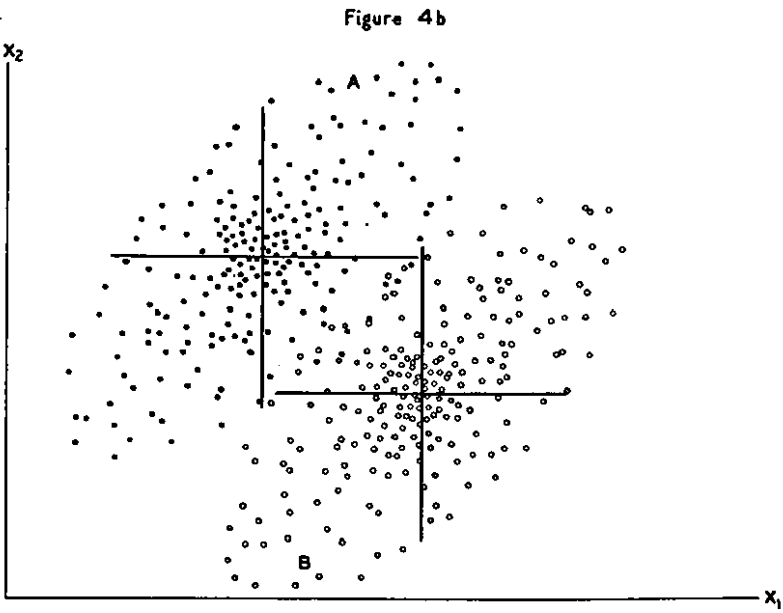
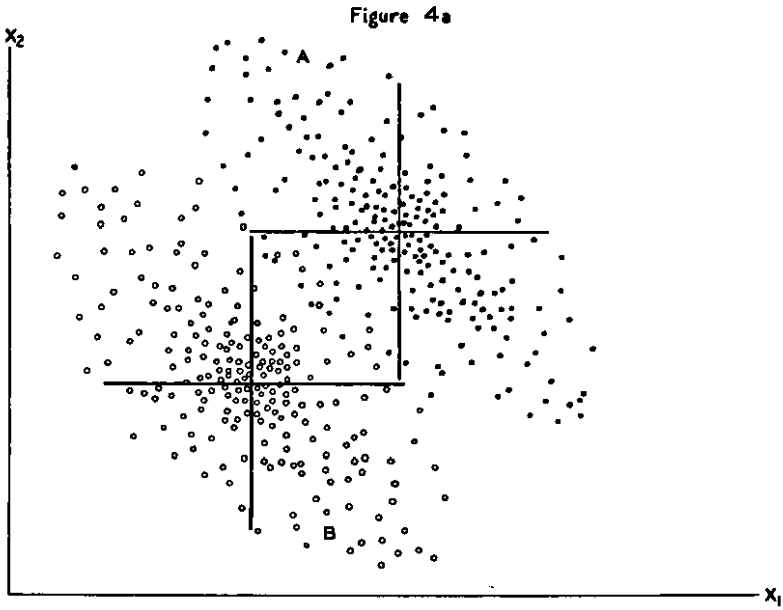


Figure 4c

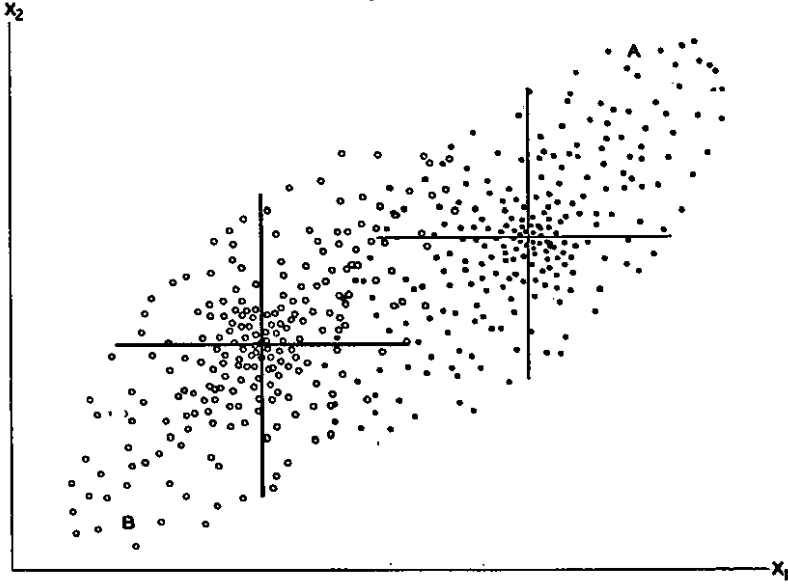
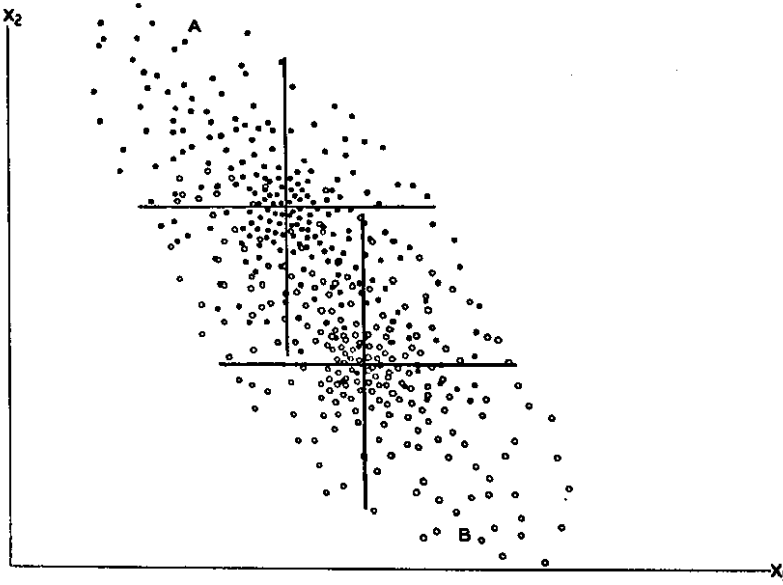


Figure 4d



discriminant function is a general second degree function. We have

$$\frac{P(A)}{P(B)} = \frac{C_A}{C_B} \frac{e^{-\sum \sum A_{ij}(x_i - \alpha_i)(x_j - \alpha_j)}}{e^{-\sum \sum B_{ij}(x_i - \beta_i)(x_j - \beta_j)}} = \frac{C_A}{C_B} e^{-\sum \sum \{(A_{ij} - B_{ij})x_i x_j - 2x_i(\alpha_i A_{ij} - \beta_i B_{ij}) + A_{ij}\alpha_i \alpha_j - B_{ij}\beta_i \beta_j\}},$$

which indicates a discriminant function of the form

$$\sum \sum \lambda_{ij} x_i x_j + \sum \lambda_i x_i.$$

Such a function will not be normally distributed.

It is even conceivable that the means of the sample may be equal and that the only differences may be in the variances or covariances. A single example is cited by way of illustration. Assume only two variables, and assume the distributions are given by

$$P(A) = C e^{-\frac{1}{2(1-\rho^2)}(x_1^2 - 2\rho x_1 x_2 + x_2^2)} dx_1 dx_2$$

$$P(B) = C e^{-\frac{1}{2(1-\rho^2)}(x_1^2 + 2\rho x_1 x_2 + x_2^2)} dx_1 dx_2;$$

in other words, the means are equal; the variances are both unity; and the correlation coefficients are equal in absolute magnitude but opposite in sign, the A correlation being positive. (See Figure 5.) The probability ratio is

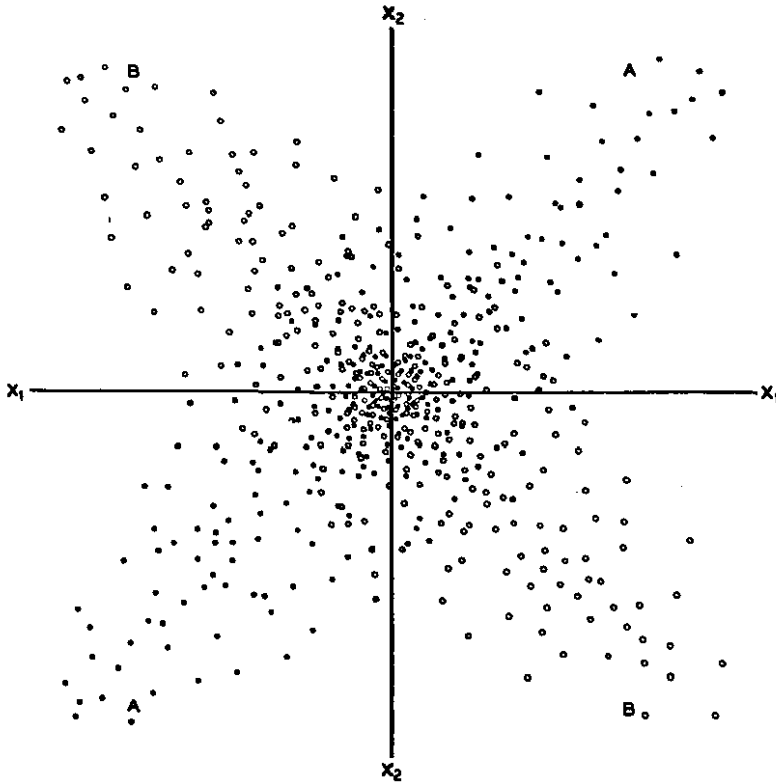
$$K = e^{\frac{2\rho x_1 x_2}{(1-\rho^2)}}, \text{ whence } \log K = \frac{2\rho x_1 x_2}{(1-\rho^2)}.$$

When K is greater (less) than one, the above equation represents a pair of hyperbolas lying in the lower right (left) and upper left (right) quadrants; and as K approaches  $\pm 1$ , the hyperbolas approximate the coordinate axis. Thus, when A's and B's are equally numerous, all regions in the upper right and lower left quadrants contain a preponderance of A's.

Enough examples have been presented to show that for departures from ideal conditions a linear discriminant function is less appropriate than some other form, the precise nature of

which depends on the nature of the distribution. For special cases like the above, the task of determining the appropriate function would not be unduly onerous; but for more general cases the task would be next to impossible. Most practical

Figure 5



investigators will probably prefer to determine a linear function, even when the ideal conditions do not exist; and in many instances the resulting approximations will probably be satisfactory.

**APPENDIX B**

**Application of the Method  
of Discriminant Functions  
to the Good- and Bad-Loan  
Samples**

# Appendix B

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## Application of the Method of Discriminant Functions to the Good- and Bad-Loan Samples

CONSIDERING the fundamental assumption of a dichotomous classification of loans, the problem of analysis is to discover differences between the good-loan and bad-loan distributions. The factors analyzed in this report fall into two rough categories: the qualitative attributes like occupation and marital status, and the quantitatively measurable variates like income and number of years at present address. Analysis of the qualitative attributes may be made by comparing the proportion of good loans in a given occupational group, for example, with the proportion of bad loans. Analysis of the quantitatively measurable factors can, of course, be carried out by the same process. The proportion of good loans in any income class can be compared with the proportion of bad loans; but one further step in the analysis is generally desirable and possible. A difference between the income distributions of the good and bad loans usually can be translated into a difference in mean or average income, a difference in the standard deviation about the mean, a difference in skewness, a difference in kurtosis, etc.

In the non-technical sections of this report, the distributions of all factors, quantitative and qualitative alike, are shown on the same basis; in all cases the percentage of good and bad loans in each of a small number of class intervals is determined; and for the quantitative factors no attempt is made to measure mean value, variance, skewness, kurtosis, etc. Nevertheless, a differ-

ence in mean values is frequently obvious. For example, the good-loan samples in Table 11 undoubtedly have a longer average tenure of employment than the bad-loan samples, although the amount of the difference is not readily apparent. Differences in other measures, such as variance or skewness or kurtosis, are much more obscure; and the difficulty of analyzing these differences is often great. On the whole, the analysis of the quantitative factors thus far has consisted of a rough attempt to determine differences between the means of the good and bad loans.

The analysis in Chapter 3 consists of a set of individual treatments of separate factors. The differences that were discovered between the samples of good and bad loans related only to separate factors—income distribution, occupational distribution, etc. This individualistic approach has its shortcomings, however. A more satisfactory approach would be to consider each of the samples as a single distribution in a number of variates. Any difference between two distributions could be used for the purpose of differentiation; for example, the correlation coefficient between tenure of residence and tenure of occupation might be one value for the good loans and another for the bad. In practice, however, differences between means are the most obvious and by far the easiest to handle, i.e., when quantitatively measurable factors are concerned. For this purpose the use of discriminant functions, described in Appendix A, has two distinct advantages; it provides a means by which a number of credit factors can be weighted and combined into an index of credit risk; and it helps to indicate when individual analyses may be specious because of correlation between factors.

The method of linear discriminant functions is the ideal method of analysis when the two populations have multivariate normal distributions with equal variances and covariances but differing means. In the good- and bad-loan samples, where the assumed conditions are not actually met, this method is no longer ideal, but it may be a useful approximation.

An experiment with discriminant functions was carried out for the used-car sample. Four factors were singled out for analysis: cash price, actual down payment in dollars, purchaser's monthly income, and length of contract. These factors were chosen because they are fundamentals from which a number of other factors can be derived. From the ratio of down payment to price, the percent down payment is derived. The difference between price and down payment is the unpaid balance, which is usually a fair approximation to the amount of the note; the ratio of the unpaid balance to contract length is an approximation of the amount of the monthly payment; and the ratio of this last factor to income is an index of the burden of the debt upon the borrower's purchasing power. Instead of a separate investigation of all these derivative factors, a single discriminant function analysis of the four basic factors appears to be more systematic and more expedient.

The four selected factors have already received separate analysis. The distribution of cases was presented in Tables 4, 6, 7, and 8. A summary of these analyses is presented in Table B-1,

TABLE B-1

MEANS AND STANDARD DEVIATIONS OF NON-REPOSSESSED AND REPOSSESSED USED-CAR SAMPLE, BY PRICE, DOWN PAYMENT, INCOME, AND MATURITY

	<i>Price</i>	<i>Down Payment</i>	<i>Income</i>	<i>Maturity</i>
Mean (non-repossessions)	\$410	\$166	\$172	13½ mos.
Mean (repossessions)	\$344	\$119	\$148	13½ mos.
Difference	\$66	\$47	\$24	0 mos.
Standard deviation (both samples)	\$195	\$89	\$93	3.4 mos.
Ratio $\frac{\text{mean difference}}{\text{standard deviation}}$	.34	.53	.26	.00
Theoretical efficiency index*	13	21	10	0

\* This index was not determined from the actual distribution of loans; it was computed from the ratio of mean difference to standard deviations by means of a table of the normal curve.



which presents means and standard deviations instead of percentage distributions. These values have been determined from the entire used-car sample of 484 non-repossessions and 485 repossessions of which 439 of the non-repossessions and 448 of the repossessions reported full data on price, contract length, down payment, and income.

This tabulation suggests that the first three variates are related to risk; that the order of importance is down payment, price, income; and that the last variate, contract length, is not related. As we have pointed out before, these conclusions may be specious if the correlation between the variates is high; and the correlation coefficients in Table B-2 indicate considerable correlation between some of the variates.

TABLE B-2  
CORRELATION COEFFICIENTS FOR SELECTED FACTORS

<i>Factor</i>	<i>Price</i>	<i>Down Payment</i>	<i>Income</i>
Down payment	.87		
Income	.33	.29	
Length of contract	.62	.47	.05*

\* Does not differ significantly from zero.

The discriminant function for these four factors was found to be  $Z = d - .174p + .124i - 6.45m$ , where  $d$  is the down payment in dollars,  $p$  is the price in dollars,  $i$  is the monthly income in dollars, and  $m$  is the length of contract in months.

The effectiveness of the function  $Z$  can be measured by the ratio of the difference between its two means (the mean for the good sample and the mean for the bad sample) to its standard deviation. The value of this ratio can be estimated without the actual computation and tabulation of the value of  $Z$  for each loan. The ratio is .63, which is an appreciable though not startling increase over the value of .53 for down payment alone; the corresponding efficiency indices computed from a table of the normal curve are 25 and 21. This increase is not striking;

if the factors had been independent, the ratio would have been .68, and the efficiency index would have been 27.

On the basis of these data we can now show that the individual analyses and their indications of the relative importance of factors are sometimes misleading. In the individual analysis, length of contract does not appear to be related to risk, for the good- and bad-loan samples have the same mean value. In the discriminant function  $Z$ , however, relation between contract length and risk does appear. Owing to the correlation between factors, the coefficient for length of contract is  $-6.45$ , which indicates that risks tend to improve as length becomes shorter. This inconsistency, as we have explained earlier, is attributable to the fact that few of the lower-priced used cars are financed on contracts of more than 12 months; for cars of the same price, the short terms are distinctly superior.

In the individual analysis, a high price appears to indicate good risk; but in the discriminant function, the price coefficient,  $-.174$ , indicates exactly the opposite. This apparent inconsistency can be explained by the high correlation between price and down payment. High price indicates good risk as long as it is accompanied by a high down payment, which is usually the case; but when down payments remain constant, the higher prices indicate poorer risks.

Nevertheless, the coefficients of the various factors are not entirely reliable as indices of the relative importance of the various factors. If the function  $Z$  is transformed to express the measurement of each variate in units of one standard deviation—a process analogous to the computation of the Beta-coefficients in multiple correlation—the transformed coefficients are somewhat more reliable, but they are not yet ideal. Transformed to units of one standard deviation, the discriminant function found above becomes  $Z' = d - .382p + .131i - .246m$ .

One possible way of measuring the relative importance of the factors is to determine discriminant functions for a number of combinations based on fewer than four factors. For combina-

TABLE B-3

CORRELATION COEFFICIENTS, MEAN DIFFERENCES, AND STANDARD DEVIATIONS, FOR SEVEN RISK FACTORS, COMPUTED FROM A COMMERCIAL BANK SUBSAMPLE OF 191 GOOD LOANS AND 190 BAD LOANS<sup>a</sup>

	<i>Sex<sup>b</sup></i>	<i>Real Estate<sup>c</sup></i>	<i>Number of Years at Present Address</i>	<i>Nature of Occupation<sup>d</sup></i>	<i>Number of Years at Occupation</i>	<i>Bank Account<sup>e</sup></i>	<i>Life Insurance<sup>f</sup></i>
<i>Correlation coefficients</i>							
Real estate	-.09*						
	.03*						
Number of years at present address	.17	.16					
	-.03*	.30					
Nature of occupation	.56	.09*	.08*				
	.11*	.05*	-.01*				
Number of years at occupation	.00*	.24	.12*	.09*			
	.03*	.22	.15	.07*			
Bank account	-.04*	.26	.09*	.21	.25		
	.11*	.21	.02*	.15	.01*		
Life insurance	.20	.05*	-.04*	.11*	.13*	-.13*	
	.03*	-.13*	-.12*	.06*	-.20	.12*	
<i>Mean</i>	.241	.241	5.937	1.094	8.785	.492	.235
	.090	.090	5.160	.695	5.884	.205	.305
<i>Difference</i>	.151	.151	.777	.399	2.901	.287	.070
<i>Standard Deviation</i>	.303	.303	5.15	.562	5.81	.353	.300
	.202	.202	5.40	.503	4.88	.285	.326

Footnotes will be found on page 133.

tions of down payment with each of the other factors, the results are as follows:

$$\begin{aligned}Z_1 &= d + .214i \\Z_2 &= d - .232p \\Z_3 &= d - 12.5m\end{aligned}$$

The theoretical ratios of mean difference to standard deviation were determined; they are .54, .58, and .60, respectively, and naturally enough, they lie between .53 for down payment alone and .63 for all four factors. Of these three combinations, that containing contract length has the highest ratio, but it is not strikingly better than the one containing price.

A second attempt with discriminant functions was made with the commercial bank sample. Here the number of available cases was so large that the drawing of a random subsample of 191 good loans and 190 bad seemed expedient. The computations were made entirely on the basis of this subsample.

Seven factors were selected for analysis: sex, stability of residence, stability of occupation, nature of occupation, bank account, life insurance, and real estate. Five of these factors are merely qualitative attributes incapable of quantitative measurement. As such, they are not directly subject to the discriminant function analysis; however, by assigning arbitrary numerical values to the qualitative categories the mechanical process of computing a discriminant function can still be followed. Thus women were given a value of 1, and men a value of 0; occupations were divided into three groups, with the poorest risk group having a value of 0, the middle group a value of 1, and the best a value of 2; cases with bank account were given a value of 1 compared with 0 for those with no bank account; and a similar process was used for life insurance and real estate. The means of the two samples, the standard deviations, and the correlation coefficients, are shown in Table B-3.

The form of the discriminant function obtained has been shown on page 86. This formula agrees well with the result

of the individual analyses except in regard to stability of residence; the negative weight given to stability of residence suggests that risk increases as residence becomes more stable, which is a direct contradiction of the individual analysis. This discrepancy seems to be traceable, however, to a substantial sampling error in the subsample.<sup>1</sup>

Values of Z were computed and tabulated for all loans in the commercial bank sample; and with slight modifications, the process was then extended to the industrial banking company sample. The efficiency index based on combined factors was in each case noticeably higher than that for any one of the individual factors. Since these efficiency indices were obtained from actual distributions and not from theoretical estimates, they are particularly important. The assumptions underlying the classical discriminant function approach were sadly lacking, and the function itself was determined from a relatively small subsample of the total available cases. Despite these serious drawbacks, the method produced concrete results.

#### SHORT-CUT METHODS FOR COMPUTATION, ON THE ASSUMPTION OF INDEPENDENCE

Ordinarily the process of computing a discriminant function is arduous; but when the factors in question are independent, the process is simplified. If the distributions are normal or approxi-

<sup>1</sup> The following percentage distribution of loans in the subsample, with an efficiency index of 8.3, is distinctly at variance with the corresponding distribution in the total sample, with an index of 13.8. The difference, which is not excessive in a sample of this size, is large enough to affect the discriminant function considerably.

	0-2 years	2-6 years	6-10 years	10 years and over
<i>Subsample</i>				
Good	29.8	34.0	7.9	28.3
Bad	32.6	36.9	10.5	20.0
<i>Total sample</i>				
Good	28.0	34.8	10.1	27.1
Bad	40.4	36.2	7.2	16.2

mately normal, a mere simplification of the standard procedure is appropriate. The equations (see p. 111)

$$\begin{aligned} s_{11}l_1 + s_{12}l_2 + \dots &= a_1 \\ s_{12}l_1 + s_{22}l_2 + \dots &= a_2 \\ \dots & \dots \end{aligned}$$

become

$$\begin{aligned} s_{11}l_1 &= a_1 \\ s_{22}l_2 &= a_2 \\ \dots & \dots \end{aligned}$$

in case of complete mutual independence. If a state approaching independence is suspected, the l's can be computed directly from the mean differences and the variances; and the resulting function will probably be a good approximation. If, however, the distributions depart markedly from normality, an alternative procedure may be preferable. This second short-cut method is based on the simple principle that the probability of two or more events may be computed, in the case of independence, merely by multiplying together the individual probabilities of the occurrence of the events.

Suppose that as far as factor A is concerned, the good and bad loans are distributed among p discrete classes. Let  $a'_i$  represent the percentage of good loans in the  $A_i$  class ( $i = 1 \dots p$ ); let  $a''_i$  represent the percentage of bad loans; then  $\frac{a''_i}{a'_i}$  is the bad-loan relative. Similarly for factor B with q discrete classes,  $b'_j$  and  $b''_j$  represent the percentage of good and bad loans in

*Footnotes for Table B-3 on page 130*

- \* The upper figure of each pair refers to the good-loan sample; the lower figure refers to the bad-loan sample. The correlation coefficients and standard deviations can be appropriately averaged by pairs to obtain a pooled estimate of the supposedly equal value for both distributions. Since the numbers of cases in each sample are virtually equal, an unweighted arithmetic average will suffice.
- <sup>b</sup> Males given a value of 0, females of 1.
- <sup>c</sup> Non-owners of real estate given a value of 0, owners of 1.
- <sup>d</sup> Better than average given a value of 2, average of 1, worse than average of 0.
- <sup>e</sup> Those with bank accounts given a value of 1, those without of 0.
- <sup>f</sup> Those with life insurance given a value of 1, those without of 0.
- <sup>g</sup> Does not differ significantly from 0. See also footnote 3, p. 135.

class  $B_i$ , and  $\frac{b''_j}{b'_j}$  is the bad-loan relative. On the assumption of independence, the expected percentages of loans belonging to both class  $A_i$  and class  $B_j$  are  $a'_i b'_j$  and  $a''_i b''_j$ , with a bad-loan relative of  $\frac{a''_i b''_j}{a'_i b'_j}$ . The result can be generalized to any number of factors.

The generalized bad-loan relative  $\frac{a''_i b''_j c''_k \dots}{a'_i b'_j c'_k \dots}$  will serve as a sort of discriminant function; if it is greater than one, it signifies a worse-than-average loan, and conversely. In actual practice, modifications of this procedure will be found convenient. The logarithm of the reciprocal of the bad-loan relative, which equals

$$\log \frac{a''_i}{a'_i} + \log \frac{a''_j}{a'_j} + \log \frac{a''_k}{a'_k} + \dots$$

is probably the most fundamental. This function is positive for better-than-average loans and negative for worse-than-average.

This short-cut method may be combined with the classical method of discriminant functions. Suppose three variates  $a$ ,  $b$ ,  $c$  are normally distributed and highly correlated. A discriminant function

$$z = L_a a + L_b b + L_c c$$

would be determined. There would be two normal distributions, one for the good loans and one for the bad. A transformation<sup>2</sup> can be made so that these distributions take the form

<sup>2</sup> Probably the most convenient transformation is of the form

$$A = a - \frac{\bar{a}' + \bar{a}''}{2}, B = b - \frac{\bar{b}' + \bar{b}''}{2}, \text{ etc.}$$

where  $\bar{a}'$  is the  $a$ -mean of the good loans and  $\bar{a}''$  is the  $a$ -mean of the bad loans, etc. The effect is to make the origin the midpoint between the means. Any transformation, however, that makes

$$L_a \bar{A}' + L_b \bar{B}' + L_c \bar{C}' = \frac{Dz}{2}$$

$$\frac{1}{\sigma_z \sqrt{2\pi}} e^{-\frac{(z+Dz/2)^2}{2\sigma_z^2}} dz, \frac{1}{\sigma_z \sqrt{2\pi}} e^{-\frac{(z-Dz/2)^2}{2\sigma_z^2}} dz$$

where Dz is the mean difference and 0 is the dividing line between better-than-average and worse-than-average cases. The bad-loan relative for any particular case is the ratio of the two

$$\frac{e^{-\frac{z^2+zDz+Dz^2/4}{2\sigma_z^2}}}{e^{-\frac{z^2-zDz+Dz^2/4}{2\sigma_z^2}}} = e^{-\frac{zDz}{\sigma_z^2}}$$

The natural logarithm of the reciprocal of this is  $\frac{zDz}{\sigma_z^2}$ ; it will be positive for better-than-average and negative for worse-than-average loans. If some additional factors D, E, . . . are not correlated, the discriminant function for all factors will be

$$\frac{zDz}{\sigma_z^2} + \log_e \frac{d'_1}{d''_1} + \log_e \frac{e'_1}{e''_1} + \dots$$

APPLICATION OF THE SECOND SHORT-CUT METHOD TO COMMERCIAL BANK SAMPLE

The evidence obtained from the available samples indicates that the factors under investigation are not entirely independent, but the degree of interdependence is surprisingly small. In Table B-3, which refers to the subsample of 191 good and 190 bad loans, the highest correlation coefficient (.56) is between occupation and sex in the good-loan sample, and the next highest (.30) is between stability of address and ownership of real estate in the bad-loan sample. These particular coefficients are more than large enough to be statistically significant, but most of the others are not.<sup>3</sup> Even the significant coefficients, however,

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and

$$L_a \bar{A}'' + L_b \bar{B}'' + L_c \bar{C}'' = -\frac{Dz}{2}$$

will suffice.

<sup>3</sup> On the assumption of true independence in the parent universe, the standard error of the correlation coefficient is  $\frac{1}{\sqrt{189}} = .073$  in a sample of 190 cases.

Since the 5 percent significance level is .143 (.073 × 1.96, where 1.96 is the 5 percent value of t for the normal curve), all values of .14 or less for the coefficient may be considered non-significant.



are not sufficiently high to suggest a particularly close relationship; hence a situation approximating independence may, perhaps, be indicated.

Further evidence on independence is obtained from a series of 21  $2 \times 2$  breakdowns of the commercial bank loans, one for each of the 21 possible pairs of the seven factors shown in Table B-3. For each of these factors the entire sample may be divided into two parts. In the case of some factors, like ownership of bank account, only two classifications are possible; for others like occupation, an arbitrary division is made so that the better risks are included in one classification and all the rest in another. For each pair of factors a two-way distribution may then be arranged by distributing all loans among four classes. Table B-4, which presents these data, will require some explanation. The first column is a percentage distribution of both good and bad loans by sex and real estate. The top figure (4.14) is the percent of females owning real estate among the good loans; beneath this figure is a similar percent (1.52) for the bad loans, followed by the bad-loan relative (.37). The next group of three figures (14.85; 6.99; .47) gives the percent of females not owning real estate and the bad-loan relative; the third group refers to males owning real estate; and the fourth refers to males not owning real estate. The second column gives the situation that would exist in a state of complete independence. The top figure (5.20) represents the expected proportion of females owning real estate among the good loans. This figure is determined by multiplying the total proportion of females among the good loans ( $4.14 + 14.85 = 18.99$ ) by the total proportion of all persons owning real estate ( $4.14 + 23.23 = 27.37$ ). Below this top figure is the expected proportion of females owning real estate among the bad loans (1.21), followed by the expected bad-loan relative ( $1.21 \div 5.20 = .23$ ). All these expected figures can be calculated easily from the summary totals at the end of Table B-4.

This table permits comparison of the actual proportion of good or bad loans in any class with the proportion that would

be expected in case of complete independence; it also permits comparison of the actual bad-loan relative with the expected bad-loan relative. This last comparison is important; for as long as the actual and expected relatives are approximately equal, the second short-cut method of computing the discriminant function can be used with assurance.

In Table B-4 the expected and actual values of the bad-loan relatives are surprisingly similar in most cases. The four most noticeable exceptions are for females owning real estate, females in the bad occupations, owners of real estate not owning life insurance, and persons having both bank account and real estate. Interestingly enough, the first three of these four cases include only a small proportion of all borrowers.

Although the evidence indicates that complete independence does not exist in the good- and bad-loan samples, we feel that the use of the second short-cut method is amply warranted in the case of the commercial bank sample. The standard discriminant function approach, which accounts for correlations between variates, is based on assumptions of normality that are not supported by the available evidence. The second short-cut method, which assumes independence but makes no assumption of normality, may be quite as realistic as the standard approach.

When the second short-cut method was tried for the commercial bank sample, the two factors age and income were added to the seven used in the previous experiment. The formula resulting from the experiment appears on page 85; and the distribution of loans is shown in Table 18. To illustrate the computation procedure, we shall show how some of the terms of this formula were computed.

The bad-loan relative for persons having bank accounts is .5 (see summary of Table B-4); the reciprocal is 2.0; and the common logarithm of the reciprocal is .30. For persons not having bank accounts, the relative is 1.4; the reciprocal, .715; the logarithm,  $\bar{1}.85$  or  $-.15$ . At this point two alternative proce-

TABLE B-4

PERCENTAGE DISTRIBUTIONS FOR THE COMMERCIAL BANK SAMPLE, SHOWING INTERDEPENDENCE AMONG THE FOLLOWING SEVEN CREDIT FACTORS: SEX, POSSESSION OF LIFE INSURANCE, OWNERSHIP OF REAL ESTATE, POSSESSION OF BANK ACCOUNT, STABILITY OF RESIDENCE, STABILITY OF OCCUPATION, AND NATURE OF OCCUPATION<sup>a</sup>

Classifica- tion <sup>b</sup>	SEX: FEMALE+, MALE-						LIFE INSURANCE: OWNED+, NOT OWNED-							
	Real Estate		Occupation <sup>c</sup>		Bank Account		Real Estate		Occupation <sup>c</sup>		Sex		Stab. of Res.	
	Owned	X	Good	X	Owned	X	Owned	X	Good	X	Female	X	3 Yrs-Up	X
	Not Owned	O	Bad	O	Not Owned	O	Not Owned	O	Bad	O	Male	O	0-3 Yrs <sup>d</sup>	O
	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.
+X														
Good loans	4.14	5.20	16.92	12.28	8.29	8.51	23.61	22.40	53.34	52.92	14.07	15.54	49.63	47.48
Bad loans	1.52	1.21	6.08	3.82	2.43	1.91	12.47	10.64	32.42	33.42	4.46	6.34	33.84	33.20
Relative	.37	.23	.36	.31	.29	.22	.53	.48	.61	.63	.32	.41	.68	.70
+O														
Good loans	14.85	13.79	2.07	6.71	10.70	10.48	58.22	59.43	28.49	28.91	67.76	66.29	32.20	34.35
Bad loans	6.99	7.30	2.43	4.69	6.08	6.60	62.00	63.83	42.05	41.05	70.01	68.13	40.63	41.27
Relative	.47	.53	1.17	.70	.57	.63	1.06	1.07	1.48	1.42	1.03	1.03	1.26	1.20
-X														
Good loans	23.23	22.17	47.75	52.39	36.53	36.31	3.76	4.97	11.33	11.75	4.92	3.45	8.39	10.54
Bad loans	12.77	13.08	38.80	41.06	20.06	20.58	1.82	3.65	12.46	11.46	4.05	2.17	10.74	11.38
Relative	.55	.59	.81	.78	.55	.57	.48	.73	1.10	.98	.82	.63	1.28	1.08
-O														
Good loans	57.78	58.84	33.26	28.62	44.48	44.70	14.41	13.20	6.84	6.42	13.25	14.72	9.78	7.63
Bad loans	78.72	78.41	52.69	50.43	71.43	70.91	23.71	21.88	13.07	14.07	21.48	23.36	14.79	14.15
Relative	1.36	1.33	1.58	1.76	1.61	1.59	1.65	1.66	1.91	2.19	1.62	1.59	1.51	1.85

(continued on next page)

TABLE B-4  
 PERCENTAGE DISTRIBUTIONS FOR THE COMMERCIAL BANK SAMPLE<sup>a</sup> (continued)

Classifica- tion <sup>b</sup>	REAL ESTATE: OWNED+, NOT OWNED-						BANK ACCOUNT: OWNED+, NOT OWNED-							
	Stab. of Res.		Occupation <sup>c</sup>		Stab. of Occup.		Real Estate		Stab. of Res.		Occupation <sup>c</sup>		Life Insurance	
	3 Yrs-Up 0-3 Yrs <sup>d</sup>	X O	Good Bad	X O	6 Yrs-Up 0-6 Yrs <sup>d</sup>	X O	Owned Not Owned	X O	3 Yrs-Up 0-3 Yrs <sup>d</sup>	X O	Good Bad	X O	Owned Not Owned	X O
	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.	Actual	Exptd.
<b>+X</b>														
Good loans	19.81	15.88	17.16	17.70	19.90	16.30	15.66	12.27	28.14	26.00	30.07	28.99	39.04	36.68
Bad loans	9.73	6.37	7.80	6.41	8.21	5.76	5.47	3.21	10.74	10.03	12.77	10.09	18.34	16.75
Relative	.49	.40	.45	.36	.41	.35	.35	.26	.38	.39	.42	.35	.47	.46
<b>+O</b>														
Good loans	7.56	11.49	10.21	9.67	7.47	11.07	29.16	32.55	16.68	18.82	14.75	15.83	5.78	8.14
Bad loans	4.56	7.92	6.49	7.88	6.08	8.53	17.02	19.28	11.75	12.46	9.72	12.40	4.15	5.74
Relative	.60	.69	.64	.81	.81	.77	.58	.59	.70	.66	.66	.78	.72	.71
<b>-X</b>														
Good loans	38.21	42.14	47.51	46.97	39.67	43.27	11.71	15.10	29.88	32.02	34.60	35.68	42.79	45.15
Bad loans	34.85	38.21	37.08	38.47	32.11	34.56	8.82	11.08	33.84	34.55	32.11	34.79	56.13	57.72
Relative	.91	.91	.78	.82	.81	.80	.75	.73	1.13	1.08	.93	.98	1.31	1.28
<b>-O</b>														
Good loans	34.42	30.49	25.12	25.66	32.96	29.36	43.47	40.08	25.30	23.16	20.58	19.50	12.39	10.03
Bad loans	50.86	47.50	48.63	47.24	53.60	51.15	68.69	66.43	43.67	42.96	45.40	42.72	21.38	19.79
Relative	1.48	1.56	1.94	1.84	1.63	1.74	1.58	1.66	1.73	1.85	2.21	2.19	1.73	1.97

(continued on next page)

TABLE B-4  
 PERCENTAGE DISTRIBUTIONS FOR THE COMMERCIAL BANK SAMPLE<sup>a</sup> (continued)

Classifica- tion <sup>b</sup>	STAB. OF RES.: 3 YRS-UP+, 0-3 YRS--						STABILITY OF OCCUPATION: 6 YRS-UP+, 0-6 YRS--							
	Occupation <sup>c</sup>		Stab. of Occup.		Sex		Occupation <sup>c</sup>		Sex		Life Insurance		Bank Account	
	Good Bad	X O	6 Yrs-Up 0-6 Yrs <sup>d</sup>	X O	Female Male	X O	Good Bad	X O	Female Male	X O	Owned Not Owned	X O	Owned Not Owned	X O
Actual Exptd.		Actual Exptd.		Actual Exptd.		Actual Exptd.		Actual Exptd.		Actual Exptd.		Actual Exptd.		
+X														
Good loans	38.50	37.52	37.40	34.56	11.42	11.02	39.27	38.52	11.76	11.31	51.04	48.75	27.86	26.70
Bad loans	21.58	20.01	21.38	17.97	4.46	3.79	19.45	18.09	3.75	3.43	32.11	30.03	9.02	9.07
Relative	.56	.53	.57	.52	.39	.34	.50	.47	.32	.30	.63	.62	.32	.34
+O														
Good loans	19.52	20.50	20.62	23.46	46.60	47.00	20.30	21.05	47.81	48.26	8.53	10.82	31.71	32.87
Bad loans	23.00	24.57	23.20	26.61	40.12	40.79	20.87	22.23	36.57	36.89	8.21	10.29	31.30	31.25
Relative	1.18	1.20	1.13	1.13	.86	.87	1.03	1.06	.76	.76	.96	.95	.99	.95
-X														
Good loans	26.17	27.15	22.17	25.01	7.57	7.97	25.40	26.15	7.23	7.68	30.79	33.08	16.96	18.12
Bad loans	23.30	24.87	18.94	22.35	4.05	4.72	25.43	26.79	4.76	5.08	42.36	44.44	13.47	13.42
Relative	.89	.92	.85	.89	.54	.59	1.00	1.02	.66	.66	1.38	1.34	.79	.74
-O														
Good loans	15.81	14.83	19.81	16.97	34.41	34.01	15.03	14.28	33.20	32.75	9.64	7.35	23.47	22.31
Bad loans	32.12	30.55	36.48	33.07	51.37	50.70	34.25	32.89	54.92	54.60	17.32	15.24	46.21	46.26
Relative	2.03	2.06	1.84	1.95	1.49	1.49	2.28	2.30	1.65	1.67	1.80	2.07	1.97	2.07

(concluded on next page)

TABLE B-4  
 PERCENTAGE DISTRIBUTIONS FOR THE COMMERCIAL BANK SAMPLE<sup>a</sup> (continued)

Classification	SUMMARY													
	Sex		Life Insurance		Real Estate		Bank Account		Stab. of Res.		Stab. of Occup.		Occupation <sup>e</sup>	
	Male	Female	Owned	Not Owned	Owned	Not Owned	Owned	Not Owned	3 Yrs -Up	0-3 Years <sup>d</sup>	6 Yrs -Up	0-6 Years <sup>d</sup>	Good	Bad
Good loans	81.01	18.99	81.83	18.17	27.37	72.63	44.82	55.18	58.02	41.98	59.57	40.43	64.67	35.33
Bad loans	91.49	8.51	74.47	25.53	14.29	85.71	22.49	77.51	44.58	55.42	40.32	59.68	44.88	55.12
Relative	1.13	.45	.91	1.41	.52	1.18	.50	1.40	.77	1.32	.68	1.48	.69	1.56

<sup>a</sup> This table is based on 1,179 good loans and 987 bad loans, all of which reported complete information for all seven factors. For explanation of table, see text, p. 136.

<sup>b</sup> The meanings of the symbols in this column are indicated by corresponding symbols in the captions over the columns of percentages.

<sup>c</sup> The following occupational groups of Table 13, pp. 70-71, were considered good: professional (1a and 1b); clerical, except outside salesmen and commercial representatives (2a, 2b, 2d); policemen and firemen (3); and proprietors (4). All others were classed as bad.

<sup>d</sup> Upper limit excluded from this class interval.

dures are possible. One is to add .30 to the score of all cases with bank account and to subtract .15 from those without; the other is to add the difference, .45, to those having bank accounts and to subtract nothing from the others. With the first scheme, the point 0 is the dividing line between the better-than-average and worse-than-average cases; with the second, the point .15 is the dividing line. The second scheme, which may be a little easier for computing actual scores, was used here. The dividing line for the entire scoring system was 1.25, the sum of .15 for bank account plus eight similar quantities for the other factors.

A rough job of curve fitting was done in the case of stability of residence. The bad-loan relative is 1.6 for the class of less than one year; and it decreases more or less regularly to .6 for the class of 10 years or over (Table 12). The common logarithm or the reciprocals increase from  $-.20$  to  $.22$  so that the difference between the extremes is  $.42$ . For each year up to 10 at present address the loan was rated one-tenth of  $.42$  or  $.042$ . Since the class of 10 years and over was not subdivided, we have no evidence to show whether the bad-loan relatives continue to fall as the length of residence increases above 10 years. For this reason the total score was limited to  $.42$  no matter how long the tenure of residence. Some readers may take exception to this conservative policy; they may feel that an additional score of  $.042$  should be added for each year over 10. While this point of view may be justified, we merely suggest that such a policy may give too high a rating to the young person of 25 who has never been away from home.

**APPENDIX C**

**Tests of Significance  
and Sampling Errors**



# Appendix C

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## Tests of Significance and Sampling Errors

IN THIS study, problems of sampling error may arise in at least three different connections: two samples drawn from the same population may erroneously appear to be different (an error of Type I);<sup>1</sup> two samples drawn from different populations may erroneously appear to be identical (an error of Type II); and finally the sample estimates of some of the special measures introduced here, such as the efficiency index and the bad-loan relative, may deviate considerably from the true values. In Chapter 2 the Chi-square test and the t-test were mentioned in connection with the first of these sampling problems. These tests, which are adequately described in standard treatises,<sup>1</sup> need little further discussion. It is only necessary to point out that special procedures for calculating Chi-square may be appropriate when frequency distributions are presented in percentages, as they are in this study. (See pages 157-58.)

Both the Chi-square test and the t-test, if used as previously suggested, have the great disadvantage of testing the significance of only one variate at a time. This is unsatisfactory for two reasons. First, two samples may not differ significantly in respect to any one of  $p$  variates, and yet the combined difference for all  $p$  variates may be highly significant. Second, a significant difference may appear in one or two isolated variates when the combined difference for all  $p$  variates is not significant; for if 100 tests of significance were applied to 100 independent factors, five of these tests could exceed the 5 percent significance

<sup>1</sup> See footnotes 2 and 3, Chapter 2.

level, and one of them could exceed the one percent level, without discrediting the null hypothesis;<sup>2</sup> hence the singling out of the particular variates that happened to meet the specifications would be entirely erroneous. In a case entailing several factors, the ideal procedure is simultaneously to test the significance of all the factors under consideration; and the findings of the individual tests should then be reviewed in the light of the findings of the combined test.

A simultaneous test of significance can be accomplished in two ways. In the first place, an n-way cross classification may be made—if there are n factors—and the Chi-square test can be used to test the difference between the two n-way distributions just as it would be used to test the difference between two one-way distributions. This process requires considerable labor and rather large samples if the number of factors considered is more than four.<sup>3</sup> An alternative approach is the generalized t-test, which simultaneously tests the differences between a number of means. This test, which has been discussed by several writers, is extremely pertinent to some of the sampling problems encountered in this study.

The  $T^2$ -statistic, introduced by Hotelling,<sup>4</sup> is appropriate for determining whether an apparent difference between two samples is attributable to sampling error only (an error of Type I).  $T^2$  is defined by

$$T^2 = \sum \sum A_{ij} (\bar{x}_i - \bar{x}'_i) (\bar{x}_j - \bar{x}'_j) \frac{(n+1)(n'+1)}{n+n'+2},$$

where  $\bar{x}_i$  is the mean value of the i-th variate for one sample

<sup>2</sup> Here the null hypothesis is that both samples are drawn from the same population.

<sup>3</sup> If only two classification cells are used for each factor—with and without bank account, and more or less than six years of employment tenure, for example—the number of classification cells for n factors is  $2^n$ . Thus five factors would entail 32 cells; and if the number of good plus bad-loan cases in each cell is to be at least 20, a sample of 320 good loans and 320 bad is the minimum, and probably a much larger sample will be required.

<sup>4</sup> Harold Hotelling, "The Generalization of 'Student's' Ratio," *Annals of Mathematical Statistics*, vol. 2, no. 3 (1931) pp. 360-78.

and  $\bar{x}'_i$  is the mean value for the other. Moreover, the matrix  $A_{ij}$  is the inverse of the matrix of the covariances; i.e.,

$$A_{ij} = \frac{s^{ij}}{|s_{ij}|},$$

where  $|s_{ij}|$  is the determinant of the  $s_{ij}$ 's and  $s^{ij}$  is the cofactor of  $s_{ij}$  in that determinant. For two samples  $s_{ij}$  is defined by

$$s_{ij} = \frac{1}{n+n'} [\Sigma(x_i - \bar{x}_i)(x_j - \bar{x}_j) + \Sigma(x'_i - \bar{x}'_i)(x'_j - \bar{x}'_j)],$$

where  $n$  is the number of degrees of freedom in one sample and  $n'$  is the number in the other. On the assumption that the two samples to be tested are drawn from the same multivariate normal population,  $T$  has the distribution

$$d(f) = \frac{2\Gamma\left(\frac{n+n'+1}{2}\right)}{\Gamma\left(\frac{p}{2}\right)\Gamma\left(\frac{n+n'+1-p}{2}\right)(n+n')^{\frac{p}{2}}} \times \frac{T^{p-1}dT}{\left(1 + \frac{T^2}{n+n'}\right)^{\frac{n+n'+1}{2}}} \quad (1)$$

This is obviously equal to "Student's" ratio,  $t$ , for  $p$  equal to one. For large values of  $n$  or  $n'$   $d(f)$  approaches

$$\frac{(T^2)^{\frac{p-1}{2}} e^{-\frac{T^2}{2}} dT}{2^{\frac{p-2}{2}} \Gamma\left(\frac{p}{2}\right)},$$

which indicates that  $T$  is normally distributed for  $p$  equal to one if both positive and negative values of  $T$  are considered, and that  $T^2$  has the Chi-square distribution for all values of  $p$ . For small values of  $n$  and  $n'$ , the significance of  $T^2$  can be determined from the  $z$ -distribution by means of the transformation

$$z = \frac{1}{2} \log_e \frac{n+n'+1-p}{p(n+n')} T^2, \quad (2)$$

where there are  $n_1 = p$  and  $n_2 = n+n'+1-p$  degrees of freedom.

The amount of clerical labor necessary to compute  $T$  increases rapidly as the number of variates considered increases.

This difficulty is not serious if the data can be punched on cards, so that the sums of squares and products can be computed by automatic multiplying punches, and if the necessary determinants can be solved mechanically; otherwise, it is serious. In this study we have frequently been able to economize labor by determining  $T$  for a small number of variates and by using this value as a test of significance for a larger number. The reason is that the samples used here are large enough to give very significant results for some of the individual factors. The generalized  $t$ -test is not needed to establish combined significance when individual significance is lacking; it is only necessary to confirm individual significance. Since the value of  $T$  for  $p$  variates cannot be less than the value of  $T$  for any  $p-h$  of the same variates,<sup>5</sup> a large value of  $T$  (or  $t$ ) for a single variate may suffice to establish significance for all  $p$  variates; this value of  $t$  can be used in (2) in place of the true value of  $T$ , and if the resulting value of  $z$  is significant, the true value of  $z$  must also be significant. To establish significance in this way, the value of  $t$  would have to be distinctly higher than the value necessary to establish significance for one variate. If a single

<sup>5</sup>To prove this, it is only necessary to show that  $T_p \geq T_{p-h}$ , where  $T_p$  is determined for  $p$  variates and  $T_{p-h}$  is determined for  $p-h$  of the original  $p$  variates. In Appendix A we mentioned (see footnote 3) that

$$T_p \sqrt{\frac{n+n'+2}{(n+1)(n'+1)}} = \frac{\sum l_{ja_1}}{\sqrt{\sum \sum l_{ij} s_{ij}}} = U_p \quad (i, j = 1 \dots p),$$

where the fact that  $l_{j1} = \sum_i a_{ij} \frac{s^{ij}}{|s_{ij}|}$  (i, j = 1 . . . . p), makes  $U_p$  the maximum of all ratios having the form (see page 111)

$$\frac{\sum l'_{ja_1}}{\sqrt{\sum \sum l'_{ij} s_{ij}}} \quad (i, j = 1 \dots p).$$

$U_{p-h}$  can be written in the same form, i.e.,

$$U_{p-h} = \frac{\sum l''_{ja_1}}{\sqrt{\sum \sum l''_{ij} s_{ij}}} \quad (i, j = 1 \dots p-h)$$

where  $l''_{j1} = \sum_i a_{ij} \frac{s^{ij}}{|s_{ij}|}$  for  $i, j = 1 \dots p-h$

and  $l''_{j1} = 0$  for  $i, j = p-h+1 \dots p$ .

Therefore  $U_p \geq U_{p-h}$ , and  $T_p \geq T_{p-h}$ .

variate does not yield a sufficient value of  $t$ , a combination of two or three of the most likely variates may give a generalized  $T$  large enough for all other variates.

The generalized  $t$ -test was used in practice to establish significance for the four factors singled out for special analysis in connection with the used-car sample—down payment, cash purchase price, borrower's income, and length of contract. The value of  $T^2$  obtained was 86.76. This is more than large enough to establish significance for the four factors in question; the value of  $z$  was 1.54 against the 1 percent value of less than .65. In fact, 86.76 for  $T^2$  is large enough to establish significance for many more than four factors. The corresponding value of  $z$  for 24 factors ( $n_1 = p = 24$ ), which is the largest finite number tabulated for  $n_1$  by R. A. Fisher,<sup>6</sup> is .63; it is more than significant by the 1 percent criterion.

A similar determination of  $T^2$  can be made for the seven factors included in the second credit-rating formula. This formula was originally determined from a subsample of 191 good loans and 190 bad loans; and the first problem is to establish significance within the subsample. The value of  $t$  in the subsample for stability of occupation is 5.29, which is more than sufficient to establish significance for one degree of freedom. Since  $t^2$  (27.9) is necessarily less than  $T^2$ , and since the corresponding value of  $z$  (.682) is significant for seven factors ( $n_1 = p = 7$ ), it follows that the seven factors are conjointly significant for the original subsample. Furthermore, after the formula had been determined for the subsample, it was tested on the entire commercial bank sample; then it was tested, with slight modifications, on the industrial bank sample. In both cases, an extremely significant difference between good and bad loans can be shown by means of the Chi-square test.

The sampling distribution of  $T$  in (1) is based on the assumption that the population value,  $\tau$ , is 0. This distribution is appropriate only to determine the probability that two samples

<sup>6</sup> *Statistical Methods for Research Workers* (London and Edinburgh, 6th edition, 1936) Table VI.

showing an apparent discrepancy could have been drawn from a single universe (an error of Type I). Sometimes, however, it is desirable to determine the probability that no significant discrepancy will be observed between two samples drawn from different universes (an error of Type II). For this purpose the distribution of  $T$  must be determined on the assumption that  $\tau$  is not 0. This problem has been investigated by Bose and Roy, Hsu, and Tang.<sup>7</sup> Tang has prepared tables of the distribution to permit the calculation of the probability of a Type II error.

When a discriminant function,

$$Z = I_1x_1 + I_2x_2 + \dots,$$

is determined for several factors, the  $I$ -coefficients are naturally subject to sampling error. The problem of finding their sampling distribution, however, can be reduced to a more fundamental one—that of finding the sampling distribution of the ratio  $U$ . The  $I$ -coefficients are not unique. Although a unique set of constants will be determined from the solution of equation (1) (see Appendix A, p. 111), any other set of constants proportional to them will produce an equally effective discriminant function with the same value of  $U$ ; that is, the  $I$ 's will be uniquely determined only after one of them has been arbitrarily chosen. As a result it is meaningless to speak of the sampling error of one single  $I$ -coefficient, for an error in one coefficient implies an error in all the others. For most purposes a set of  $I$ 's will be erroneous only if they jointly produce an unsatisfactory estimate of  $U$ ; if  $U$  can be determined precisely, possible variations in the  $I$ 's can usually be overlooked.<sup>8</sup>

The sampling distribution of  $U$  follows directly from the dis-

<sup>7</sup> R. C. Bose and S. N. Roy, "The Distribution of the Studentised  $D^2$ -Statistic," *Sankhya*, vol. 4, no. 1 (Dec. 1938) pp. 19–38; S. N. Roy, "A Note on the Distribution of the Studentised  $D^2$ -Statistic," *Sankhya*, vol. 4, no. 3 (Sept. 1939) pp. 373–80; P. L. Hsu, "Notes on Hotelling's Generalized  $T$ ," *Annals of Mathematical Statistics*, vol. 9, no. 4 (Dec. 1938) pp. 231–43; P. C. Tang, "The Power Function of the Analysis of Variance Tests with Tables and Illustrations of their Use," *Statistical Research Memoirs*, vol. 2 (1938) pp. 126–49.

<sup>8</sup> Occasionally the problem will arise of determining how much the  $I$ 's can

tribution of Hotelling's generalized  $T$  or from the distribution of the  $D^2$ -statistic of Bose and Roy. These distributions are admirably adapted to determining the probability of a Type I or a Type II error in a small sample, but sometimes another sampling problem presents itself. In a large sample, the value of  $U$  may be so large and its standard error may be so small that an error of either Type I or Type II is unthinkable. Here we are not interested in determining whether  $U$  departs significantly from 0; we want to know how reliable  $U$  is as an estimate of the population value  $T$ . If, for example,  $T$  is equal to one, is a value of  $U$  less than .9 or greater than 1.1 likely to occur? For problems like this the limiting value of the distribution of  $U$  will usually be a satisfactory approximation.

In the one-variate case, two populations have a standard deviation of  $\sigma$  and a mean difference of  $\alpha$ . Two samples drawn from these populations will have a standard deviation of  $s$  and a mean difference of  $a$ . We require the limiting distribution of  $a/s$  for large samples. The difference  $a$  is normally distributed with variance  $\sigma^2(n + n')/nn'$  where  $n$  is the number of cases in one sample and  $n'$  is the number in the other. The standard deviation  $s$  has the Chi distribution with  $n + n' - 2$  degrees of freedom, but for large values of either  $n$  or  $n'$  the distribution approaches normal, with variance of  $\sigma^2/2(n + n')$ . The problem therefore reduces to the distribution of the quotient of two normal independent variates.

Geary has shown that if  $x$  and  $y$  are uncorrelated normal variates with 0 means, and if  $z$  is defined by

$$z = \frac{Y + y}{X + x} -$$

where  $Y$  and  $X$  are constants, and  $X \geq 3\sigma_x -$

then

$$t = \frac{Xz - Y}{\sqrt{\sigma_x^2 z^2 + \sigma_y^2}}$$

---

vary without unduly affecting  $U$ . We illustrated this sort of problem in Appendix A, where we investigated the effect of the arbitrary assumption that all correlation coefficients are 0.

will be approximately normally distributed with unit variance.<sup>9</sup> It can be shown that as  $\sigma_x$  and  $\sigma_y$  both approach 0,

$$t = \frac{X^2(z - Y/X)}{\sqrt{\sigma_x^2 Y^2 + \sigma_y^2 X^2}}$$

also approaches normal with unit variance.<sup>10</sup> From this it follows that the limiting distribution of  $a/s$  is normal with a variance of

$$\frac{n + n'}{nn'} + \frac{\alpha^2}{\sigma^2} \frac{1}{2(n + n')} = \frac{n + n'}{nn'} \left( 1 + \frac{\alpha^2}{\sigma^2} \frac{nn'}{2(n + n')^2} \right),$$

where  $\frac{\alpha^2}{\sigma^2}$  can be replaced by  $v^2$ . This result, moreover, can be generalized to any finite number of variates: in the limit the distribution of  $U$  is normal with variance of

$$\frac{n + n'}{nn'} + v^2 \frac{1}{2(n + n')} = \frac{n + n'}{nn'} \left( 1 + v^2 \frac{nn'}{2(n + n')^2} \right)^{11}$$

<sup>9</sup> R. C. Geary, "The Frequency Distribution of the Quotient of Two Normal Variates," *Journal of the Royal Statistical Society*, vol. XCIII, part III (1930) pp. 442-46. The notation used here is not Geary's.

<sup>10</sup> To prove this, we have only to prove that

$$\frac{\sqrt{\sigma_x^2 z^2 + \sigma_y^2}}{\sqrt{\sigma_x^2 \frac{Y^2}{X^2} + \sigma_y^2}}$$

approaches 1 as  $\sigma_x$  and  $\sigma_y$  approach 0. Squaring, we get

$$\frac{\sigma_x^2 z^2 + \sigma_y^2}{\sigma_x^2 \frac{Y^2}{X^2} + \sigma_y^2} = 1 - \frac{\left( \frac{Y^2}{X^2} - z^2 \right) \sigma_x^2}{\sigma_x^2 \frac{Y^2}{X^2} + \sigma_y^2} = 1 - \frac{\frac{Y^2}{X^2} - z^2}{\frac{Y^2}{X^2} + \frac{\sigma_y^2}{\sigma_x^2}}$$

which clearly approaches 1 because  $\frac{Y^2}{X^2} - z^2$  approaches 0, and  $\frac{Y^2}{X^2} + \frac{\sigma_y^2}{\sigma_x^2}$  does not.

<sup>11</sup> Let  $U = T + U$ ,  $s_{ij} = \sigma_{ij} + \theta_{ij}$ , and  $a_i = \alpha_i + u_i$ , where the Greek letters represent population parameters, and the German letters represent random variations about them; as the size of sample increases, the random variations grow smaller and eventually approach zero. By definition

$$U^2 = (T + U)^2 = \frac{\sum \sum (\alpha_i + u_i)(\alpha_j + u_j) \text{ cofactor } (\sigma_{ij} + \theta_{ij})}{|(\sigma_{ij} + \theta_{ij})|}$$

Since  $U$  remains invariant for all non-singular linear transformations, we can



A single example will serve to illustrate the size of the errors to be expected in our good- and bad-loan samples. In a sample of about 825 good and 825 bad loans, the approximate standard error of  $U$  is  $.049\sqrt{1 + T^2/8}$ . For a value of .5 for  $T$ , the standard error is .050, which suggests that there is about one chance in twenty that  $U$  will lie outside the range of .4 to .6.

STANDARD ERROR OF THE EFFICIENCY INDEX

Since the efficiency index is related to  $T$  by the relation

$$\text{Index} = \int_{-T/2}^{T/2} e^{-t^2/2} dt$$

assume without loss of generality that  $\sigma_{ij} = 0$  whenever  $i \neq j$ . We wish to reduce this to a linear function in the  $\alpha_{ij}$ 's and  $\theta_{ij}$ 's, which is possible because second order terms in  $\alpha_{ij}$  and  $\theta_{ij}$  can be neglected as infinitesimals of higher order. We may therefore write:

$$\begin{aligned} & \frac{(\alpha_1 + a_1)(\alpha_j + a_j) \text{ cofactor } (\sigma_{ij} + \theta_{ij})}{|(\sigma_{11} + \theta_{11})|} \quad [i \neq j] \\ & \quad \frac{(\alpha_1 + a_1)(\alpha_j + a_j)\theta_{ij}(\sigma_{11} + \theta_{11})(\sigma_{22} + \theta_{22}) \dots (\sigma_{pp} + \theta_{pp})}{(\sigma_{11} + \theta_{11})(\sigma_{jj} + \theta_{jj})} \\ & = \frac{(\alpha_1 + a_1)(\alpha_j + a_j)\theta_{ij}}{(\sigma_{11} + \theta_{11})(\sigma_{jj} + \theta_{jj})} = (v_1 + u_1)(v_j + u_j)r_{ij}, \end{aligned}$$

where  $u_i = v_i + u_i = \frac{\alpha_i + a_i}{\sqrt{\sigma_{11} + \theta_{11}}}$  and  $r_{ij} = \frac{\theta_{ij}}{\sqrt{(\sigma_{11} + \theta_{11})(\sigma_{jj} + \theta_{jj})}}$ ; more-

over,  $\frac{(\alpha_1 + a_1)^2 \text{ cofactor } (\sigma_{11} + \theta_{11})}{|(\sigma_{11} + \theta_{11})|} = \frac{(\alpha_1 + a_1)^2}{\sigma_{11} + \theta_{11}} = (v_1 + u_1)^2$ .

Therefore,  $(T + U)^2 = \sum \sum (v_i + u_i)(v_j + u_j)r_{ij}$ , where  $r_{11} = 1$ . Omitting all second-order terms in  $u_i$  and  $r_{ij}$  gives  $T^2 + 2UT = \sum \sum v_i v_j r_{ij} + 2 \sum v_i u_i$ ,

whence  $U = \frac{\sum v_i u_i + \frac{1}{2} \sum_{i \neq j} \sum v_i v_j r_{ij}}{T}$

since  $T^2 = \sum v_i^2$ .

This last is a linear function in  $u_i$  and  $r_{ij}$ ; it is therefore normally distributed in the limit.

Since  $\sigma_{2U1} = \frac{n + n'}{nn'} + \frac{u_i^2}{2(n + n')}$  and since  $\sigma_{T11} = \frac{1}{n + n'}$ , the variance of  $U$  is equal to

$$\begin{aligned} & \frac{1}{T^2} \left[ \sum \left( \frac{n + n'}{nn'} v_i^2 + \frac{v_i^4}{2(n + n')} \right) + \sum_{i \neq j} \sum v_i^2 v_j^2 \frac{1}{n + n'} \right] \\ & = \frac{1}{T^2} \left[ \frac{n + n'}{nn'} \sum v_i^2 + \frac{1}{2(n + n')} \sum \sum v_i^2 v_j^2 \right] \\ & = \frac{n + n'}{nn'} + \frac{T^2}{2(n + n')} = \frac{n + n'}{nn'} \left( 1 + \frac{T^2 nn'}{2(n + n')^2} \right) \end{aligned}$$

for a normal population, sampling errors of the efficiency index can be estimated from the standard error of  $U$ . In the above example, a value of .5 for  $T$  corresponds to an efficiency index of about 20, and the sampling range of .4 to .6 for  $U$  corresponds to a range of approximately 16 to 24 for the efficiency index.

An alternative approach to the standard error of the efficiency index is worth pointing out. Consider the 2x2 contingency table

	<i>Class A</i>	<i>Class B</i>
Good loans	$\beta$	$100 - \beta$
Bad loans	$\beta'$	$100 - \beta'$

where  $\beta$  represents the population probability in percentage form that a good loan will belong to Class A, etc. The efficiency index is equal to the absolute value of  $\beta - \beta'$ . Since the standard error of  $b$ , the sampling estimate of  $\beta$  in a sample of

$N$  cases, is  $\sqrt{\frac{\beta(100 - \beta)}{N}}$ , and since the standard error of  $b'$  is  $\sqrt{\frac{\beta'(100 - \beta')}{N'}}$ , the standard error of the difference is

$$\sqrt{\frac{\beta(100 - \beta)}{N} + \frac{\beta'(100 - \beta')}{N'}}$$

This formula, derived for a 2x2 table, can also be used for a 2xp table, for a 2xp table can be reduced to a 2x2 table by the simple expedient of consolidating all better-than-average classes into one class, and all worse-than-average classes into another. When the formula is used, the sample estimates must be used in place of the population parameters. This is particularly unfortunate when a 2xp table is to be consolidated, for some better-than-average classes may be erroneously classed as worse than average, and vice versa.

#### STANDARD ERROR OF THE BAD-LOAN RELATIVE

The bad-loan relative, the ratio of the percent of bad loans in a particular class to the percent of good loans in that class, has

been used as a means of comparing the risk merits of any class with those of any other class or with the average. This relative is, of course, subject to sampling error, and comparisons should be modified accordingly. An approximate expression for the standard error of this ratio is derived here.

Let  $\alpha$  be the probability that a loan drawn at random from the good-loan population will belong to class A; let  $\alpha'$  be the probability that a loan drawn from the bad-loan population will belong to class A; then  $\frac{\alpha'}{\alpha}$  is the true bad-loan relative for class A. Let  $a$ ,  $a'$ , and  $\frac{a'}{a}$  be the estimates of  $\alpha$ ,  $\alpha'$ , and  $\frac{\alpha'}{\alpha}$  derived from samples of  $n$  good loans and  $n'$  bad ones. If  $n$  and  $n'$  are large,  $a$  and  $a'$  are both normally and independently distributed with variance

$$\frac{\alpha(1-\alpha)}{n} \quad \text{and} \quad \frac{\alpha'(1-\alpha')}{n'}$$

From the previous discussion of the sampling error of a quotient, it will be seen that the limiting distribution of  $a'/a$  is normal with variance of

$$\frac{\sigma_a'^2}{\alpha^2} + \frac{\sigma_a^2 \alpha'^2}{\alpha^4}, \text{ which equals} \\ \frac{1}{\alpha^3} \left[ \frac{\alpha \alpha' (1 - \alpha')}{n'} + \frac{\alpha'^2 (1 - \alpha)}{n} \right] \quad (3)$$

The square root of (3) is the approximate expression for the standard error of the bad-loan relative.

To give some idea of the amount of error to be expected, the standard errors shown in Table C-1 were computed for sixteen assumed class intervals and two assumed sample sizes. In samples of this size the distribution of  $a'/a$  is not normal, but distinctly skewed. These standard errors are computed for a sufficient range of values to indicate fairly well the amount of error possible in the bad-loan relatives computed from the available samples. The standard errors quoted are probably not

TABLE C-1

STANDARD ERRORS FOR ASSUMED SET OF CASES

$\alpha$ (percent)	$\alpha'$ (percent)	$\frac{\alpha'}{\alpha}$	$\sigma \alpha'/a$	
			1,000 cases in each sample	500 cases in each sample
5	5	1.0	.195	.276
10	10	1.0	.134	.190
20	20	1.0	.089	.127
40	40	1.0	.055	.078
3	6	2.0	.438	.620
5	10	2.0	.334	.473
10	20	2.0	.228	.322
20	40	2.0	.148	.210
5	15	3.0	.471	.667
5	20	4.0	.606	.858
15	5	.33	.052	.074
20	5	.25	.038	.054
6	3	.50	.110	.155
10	5	.50	.084	.118
20	10	.50	.057	.081
40	20	.50	.037	.052

adequate to represent a satisfactory margin of error; twice the above standard errors is probably a better estimate, and even then about 5 percent of the sample estimates can be expected to differ from the true value by more than this margin. Since roughly 300 bad-loan relatives are quoted in the tables accompanying this report, some 15 of them are probably erroneous by more than two standard errors.

This discussion of error throws more light on the limitations of small samples in risk analysis. The samples used here are large enough—in many cases much larger than necessary—to demonstrate bona fide relations between bad-loan experience and certain credit factors; stability of employment is a prime example. Although the available samples are adequate to show that persons who have been engaged in the same employment

for 10 years or more are better-than-average risks, and much better than those employed for less than two years, they are not adequate to estimate precisely the degree of difference. To obtain a high degree of precision in estimating bad-loan relatives, much larger samples are necessary; for a sample containing as many as 10,000 good and 10,000 bad loans, the standard errors amount to about 31 percent of the errors for 1,000 cases, which are shown in the set of hypothetical errors presented above.

#### COMPUTATION OF CHI-SQUARE FOR PERCENTAGE DISTRIBUTIONS

The numerous common methods for computing Chi-square presuppose that the distribution of cases is given in actual frequencies and not in percentages. In the present study, where all distributions have been reduced to percentages, an alternative method designed for percentage distributions was found convenient. To apply this method, only the total number of cases in the samples need be known. The following formula is appropriate:

$$\chi^2 = \frac{n'n''}{10,000} \sum_{i=1}^m \frac{(a_i' - a_i'')^2}{\frac{a_i'n'}{100} + \frac{a_i''n''}{100}}$$

where  $n'$  and  $n''$  are the total number of cases in the good and bad samples,  $m$  is the number of classes into which each sample is divided, and  $a_i'$  and  $a_i''$  are the percentages of cases in the  $i^{\text{th}}$  class for the good and bad samples. The quantity  $\frac{a_i'n'}{100} + \frac{a_i''n''}{100}$  is the total actual number of cases of both samples in class  $i$ . When  $n'$  and  $n''$  are equal, or approximately equal, the above formula takes the very simple and convenient form

$$\chi^2 = \frac{n}{100} \sum_{i=1}^m \frac{(a_i' - a_i'')^2}{a_i' + a_i''}$$

where  $n$  is the number of cases in either sample.

Where  $n'$  and  $n''$  are only approximately equal, this second formula is still useful. If a significant value of  $\chi^2$  is obtained when the smaller of the two  $n$ 's is substituted, the true  $\chi^2$  is obviously greater and also significant; and if a non-significant value is obtained with the larger of the two  $n$ 's, the true value is also non-significant. An example may prove enlightening. The following is the percentage distribution of loans by sex and marital status in the sample submitted by one bank:

	<i>Single Females</i>	<i>Single Males</i>	<i>Married Females</i>	<i>Married Males</i>	<i>Others</i>
150 Good loans	30.0	9.3	12.7	40.7	7.3
100 Bad loans	5.0	24.0	2.0	59.0	10.0

In the first class the quantity  $\frac{(30.0 - 5.0)^2}{(30.0 + 5.0)}$  is 17.86; the sum of this and four similar quantities for the other four classes is 35.89.<sup>12</sup> If we substitute 100, the smaller of the two  $n$ 's, we still have 35.89, which is an underestimate of the true  $\chi^2$ . Since the 1 percent value of  $\chi^2$  is only 13.28, 35.89 is clearly significant. Since the contribution of the first class to the total  $\chi^2$ , 17.86, is itself greater than the 1 percent value of 13.28, the significance can be demonstrated from the first class alone, and additional computation is unnecessary.

<sup>12</sup> With the aid of a table of squares and a calculating machine, the calculation of  $\chi^2$  by this process is reasonably easy.

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## Studies in Consumer Instalment Financing

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