Financial Institution Regulations, Redlining and Mortgage Markets

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Part I: Introduction

Government regulations of market transactions have increased in recent years. The objectives of these new regulations are at least as noteworthy as their proliferation. Traditional forms of government regulation, such as antitrust and utility regulation, have sought either to reduce market power or to prevent its abuse. By comparison, many recently enacted regulations attempt to deal with various perceived failures of the market to achieve certain social goals.[1]

Government regulation of financial institutions is no exception. Prior to the 1970s, these institutions were subject to regulations governing entry into markets and mergers as well as numerous restrictions on interest rates that could be paid to depositors or charged to borrowers. Recent major new regulations include: (1) the Equal Credit Opportunity Act; (2) the Fair Housing Act; (3) the Home Mortgage Disclosure Act; and (4) the Community Reinvestment Act. All of these new regulations are administered by organizations already established to enforce earlier statutes. But regulatory objectives of recent legislation differ substantially from previous ones.

This new generation of legislation governing financial institutions attempts to address a perceived failure of private markets to provide "equal" access to credit. The Equal Credit Opportunity Act attempts to provide individuals with equal access to both consumer and mortgage credit. The Fair Housing, Home Mortgage Disclosure, and Community Reinvestment Acts are intended to improve the availability of mortgage credit to certain individual borrowers, and/or to certain neighborhoods.

This paper focuses on those regulations enacted to deal specifically with the perceived social problem of "redlining." These regulations impose and/or suggest limits on criteria that may be used in granting mortgages and hence may limit

[1] For a recent discussion of the evolution of regulations see Joskow and Knoll (1978).

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the ability of firms to make economically efficient lending decisions. Any loss in economic efficiency would be a cost of the regulation that must be weighed against any benefits it generated. In the case of redlining regulation, if property location is important in determining default risk on home mortgages, limitations on use of location in the lending decision may impair efficient mortgage market operation. Empirical tests of the effect of location on mortgage default risk are developed here to determine if significant costs are associated with failure to consider property location. We begin our analysis with three sections discussing the relationship between legal and economic definitions of redlining. Readers only interested in economic analysis may skip much of this material but we feel that it is important to understand both legal and economic approaches to redlining. Part IV examines some empirical studies of redlining and Part V develops our own empirical model of the determinants of default probabilities. Some implications of this study for measuring the costs of redlining regulation are drawn in the concluding section.

Part II: Definitions of Redlining

Concern about redlining is virtually synonymous with concern about the behavior of lenders in mortgage markets. Indeed, redlining may be defined as lender behavior that, without justification, denies or limits credit to specific neighborhoods.[2]

Although this broad definition is generally agreed upon, considerable controversy exists about which neighborhood characteristics lenders are justified in using to limit credit. Two definitions of redlining may be distinguished. Lender behavior towards neighborhoods which is designated unjustified by statute constitutes the *legal definition* of redlining. Behavior which is inconsistent with certain forms of economic rationality represents an *economic definition* of redlining.

Both the legal and economic definitions of redlining emphasize similar phenomena in mortgage markets. However, legal definitions of redlining generally designate fewer market factors as justifiable, either implicitly or explicitly, than do economic definitions of redlining. Consequently, more forms of lender behavior will be classified as redlining under the legal than under the economic definition.

A. *Legal Definitions of Redlining*

Access to credit may be denied or restricted in several ways. First, individuals seeking credit may be discouraged from applying. Second, individuals may be encouraged to withdraw an application for credit. Third, individuals who apply for a loan may be rejected. Fourth, individuals may be granted credit, but on relatively onerous terms. Such terms would include higher interest rates, higher required downpayments, higher closing costs, and shorter loan maturities.

[2] See, for example, Dennis (1979), Guttentag and Wachter (1978), King (1979), and Van Order (1979).

The examination procedures established by federal regulatory agencies in response to both Fair Housing and Community Reinvestment Acts emphasize the detection of such occurrences. For example, any of the following practices would be subject to scrutiny under the Fair Housing Act:

(1) rejection of mortgage applications

(2) imposition of onerous interest rates, terms, conditions, or requirements for borrowers;

(3) imposition of onerous penalties on borrowers in the event of delinquency or default;

(4) prescreening of potential borrowers with the intent of discouraging some from applying for loans.

Any of these practices would also be critically evaluated under the Community Reinvestment Act.[3] In addition, considerable attention is given to the placement of loans as compared to the source of deposits. This reflects the concern of anti-redlining groups about "disinvestment" in urban neighborhoods. "Disinvestment" is presumed to occur when local lenders "withdraw" funds from particular neighborhoods through deposits and "export" these funds through loans made elsewhere. This particular type of activity is viewed by some as a denial or restriction of credit to neighborhoods as a whole.

There are, of course, sound economic reasons for denying or limiting credit to certain borrowers. The redlining controversy arises largely from divergent views about when lenders are justified in using neighborhood as a criterion for denial or limitation of credit.

The Fair Housing Act permits lenders to take some neighborhood characteristics into account, but not others. Characteristics that are permissible include:

(1) the condition or design of the proposed security property, or of nearby properties which clearly affect the value of that property;

(2) the availability of neighborhood amenities or city services;

(3) the need of the bank to hold a balanced real estate portfolio, with a reasonable distribution of loans in various neighborhoods, types of property, and loan amounts.

However, lenders are enjoined from:

(1) denying or restricting mortgage credit in certain neighborhoods in the lender's service area because of race, color, religion, or national origin of the residents;

(2) relying on appraisals that assign a lower value to a neighborhood because of a mix of races and national origins;

(3) equating a racially mixed neighborhood with a deteriorating neighborhood;

[3] See Federal Reserve press release of November 22, 1978.

(4) incorporating the idea that deterioration of a neighborhood is inevitable;

(5) equating age of the property with the value of the property;

(6) prescreening of loan applicants.

Lenders deemed in violation of the Fair Housing Act are assumed, *a priori*, to violate performance standards of the Community Reinvestment Act. Consequently, the forms of lender behavior described above are also proscribed under the Community Reinvestment Act. However, the range of lender behavior subject to scrutiny is wider under the Community Reinvestment Act than the Fair Housing Act.

In particular, emphasis is given in the Community Reinvestment Act to possible "errors of omission" that discourage potential borrowers from applying for loans. This is in contrast to the Fair Housing Act which singles out errors of commission in the form of prescreening. Prescreening is also viewed with suspicion under the Community Reinvestment Act. However, lenders are also judged on whether they make affirmative efforts to encourage applications for credit. Specific assessment factors are:

(1) activities conducted by the institution to ascertain the credit needs of its community, including the extent of the institution's efforts to communicate with members of its community regarding the credit services being provided by the institution;

(2) the extent of the institution's marketing and special credit-related programs to make members of the community aware of the credit services offered by the institution;

(3) the institution's record of opening and closing offices and providing services at offices.

By implication lenders that devote more resources to identification of community needs in some neighborhoods than others, or that open (close) offices in some neighborhoods but not in others, could violate the standards of the Community Reinvestment Act.

The various definitions of redlining identified in both the Fair Housing and Community Reinvestment Acts are summarized in Table 1. In principle, a variety of market outcomes may be classified as "redlining" according to the legal definitions of the term.

B. *Economic Definitions of Redlining*

Differential treatment of neighborhoods by mortgage lenders could be an economic problem for two reasons. It would clearly be a problem if such differential treatment *did not* correspond to differences in costs and risks of making loans. However, even if differential treatment did reflect costs and risks, it might still be a problem if the more stringent mortgage terms were faced by those least able to pay. In the former case "redlining" would reflect imperfections in the mortgage market. That is, redlining would be a form of economic *inefficiency*. In the latter instance redlining would be the result of interactions between a

TABLE 1

Definitions of Redlining under Fair Housing Act and Community Reinvestment Act

Manner in Which Credit is Denied or Limited	Fair Housing Act	Community Reinvestment Act
Applicant discouraged from applying for credit to purchase dwelling in a particular neighborhood.	Prescreening of applicants.	(1) Prescreening of applicants; (2) failure to ascertain credit needs of the community; (3) failure to communicate with community members regarding credit services offered; (4) limiting marketing efforts and special credit-related programs; (5) closing offices, particularly in low and moderate income neighborhoods.
Applicant rejected for credit to purchase dwelling in a particular neighborhood.	Higher standards applied for acceptance of a loan application based on: (1) racial, religious, and/or ethnic composition of the neighborhood; (2) appraisals based on racial, religious, or ethnic mix or neighborhood; (3) age of property; (4) prejudicial belief that racially mixed neighborhoods must inevitably deteriorate.	Arbitrary exclusion, based on criteria such as those proscribed under the Fair Housing Act, of certain neighborhoods from the lending area of institutions.
Credit granted but on relatively onerous terms or in smaller amounts.	More onerous terms required for loans made in certain neighborhoods based on four factors listed immediately above.	Same as under Fair Housing Act; also limiting amount of credit granted in some neighborhoods when such limitations are based on unjustified neighborhood characteristics described above.
Disinvestment in certain neighborhoods caused by net outflows of loanable funds.	Not applicable.	Refusal of institutions to make loans in communities from which their deposits originate when such refusals are based on unjustified neighborhood characteristics.

well-functioning mortgage market and an unequal income distribution. Redlining would reflect distributional *inequity.*

Restriction of credit to various neighborhoods may, therefore, be economically undesirable for two distinct reasons. However, it is only the first form of "redlining" that is directly attributable to imperfections in the mortgage market. By contrast, the second form of "redlining" is a problem of income distribution rather than market performance. With one notable exception, Guttentag and Wachter (1978), the economics literature has defined redlining as a problem of market performance rather than income distributional equity. Consequently, economic definitions of redlining typically include the first, but not the second form of "redlining". This convention will be followed here. That is, the economic definition of redlining will focus on differential treatment of neighborhoods not based on differences in costs and risks of making loans.

When mortgage lenders engage in this type of redlining, they fail to make loans that would be profitable. As a result, some economists have tended to view redlining as irrational behavior. We do not subscribe to this view. Redlining may imply nonprofit maximizing behavior by lenders. However, this may be rational if lenders strive to maximize a broadly defined utility function that includes profit as just one of several arguments. This concept of redlining is analogous to models of discrimination in product and factor markets. For example, models of labor market discrimination assume that employers maximize a utility function consisting of profits as well as the ethnic and racial characteristics of their employees. Of course, this type of behavior, though rational, may still be deemed socially undesirable.

Consider first how redlining would be defined if there were no possibility of default or delinquency on the part of borrowers. Maximization of lender's utility would require that mortgage funds be allocated among properties so as to equalize utility per dollar lent. For any property j, the utility per mortgage loan would be determined by equation (1).

(1) $U_j = U[R_j - C_j, N_j] = U[R(i_j, T_j, L_j, F_j) - C(\lambda, L_j, X_j, N_j), N_j]$,

where

U_j = utility per mortgage loan
R_j = revenue per mortgage loan
C_j = cost per mortgage loan
i_j = interest rate charged on mortgage for property j
T_j = term of mortgage
L_j = amount of mortgage
F_j = mortgage fees and charges
λ = opportunity cost of lender's funds (assumed equal for all properties)
X_j = a vector of borrower and/or property characteristics which affect the per dollar costs of servicing and processing the loan
N_j = a vector of characteristics of the neighborhood in which property j is located.

In equation (1) neighborhood characteristics may affect lender utility in two distinct ways. First, property location would affect utility by affecting profits whenever $\partial C/\partial N_j \neq 0$.[4] For example, the costs of processing and servicing loans might be lower in some neighborhoods than in others.[5] Lenders would, *ceteris paribus*, earn relatively high profits in neighborhoods requiring relatively low processing and service costs. Utility maximization by lenders would favor such neighborhoods. However, in such cases, *utility maximization* would be equivalent to *profit maximization*. No redlining would be present in the economic sense of the term.

Second, property location could affect lender's utility directly, whenever $\partial U/\partial N_j \neq 0$. Presumably such effects would be due to lenders' subjective attitudes toward lending in different neighborhoods. Utility maximization by lenders would cause them to "value" loans made on some properties more highly than loans on others solely because of neighborhood location. In these cases, utility maximization would not be equivalent to profit maximization and redlining of some form would be present.

The analysis is complicated somewhat by introducing uncertainty about the repayment of loans. If such uncertainty were present, the revenue term in equation (1) would be a random variable whose value would depend on the terms of the loan (particularly owner's equity), property characteristics, borrower attributes, and location of the property. If lenders were assumed to be *risk-neutral*, equation (1) would be rewritten as

$$(2)\quad U_j = U[E(R_j - C_j), N_j] = U\{E[R(i_j, T_j, L_j, F_j, E_j, X_j, N_j)] - C_j(\lambda, L_j, X_j, N_j), N_j\},$$

where

E_j = owner's equity in property j
E = expectation operator
and all other variables are defined as in equation (1).

[4] It should be noted that lenders who have market power can charge prices above marginal cost, or offer loans on terms which produce relatively high expected returns. If lenders have different degrees of market power across neighborhoods, or if the elasticity of demand varies by neighborhood, expected returns may also vary by neighborhood. Guttentag and Wachter (1978) have observed, however, that the market power hypothesis is unlikely to be appropriate for mortgage lenders, given the large number of lenders.

[5] Note also that with nonconstant returns to scale, mortgage terms depend on the number of mortgages written in a neighborhood. If mortgage demand is larger in area A, then some lenders would specialize in lending in this area. If not, then each lender makes the same ratio of mortgages in area A and B and, given returns to scale, there will either be unexploited returns to scale in lending to area B (lenders on the falling portion of their average cost curve) or lenders in area A will be operating on the rising portion of their average cost curve. This makes it difficult to identify unwarranted *lender* price discrimination because firms specializing in area A will have more stringent terms for mortgages in area B than in area A, while their terms for area B will be stricter than those of other lenders who are lending in area B. However, observed differences in "market" mortgage terms across neighborhoods will still constitute price discrimination. If the "technology" for "producing" loans differed systematically by neighborhood, each neighborhood would, in effect be a distinct market, and loans in different neighborhoods would be heterogeneous products. There would, therefore, be no reason for even "market" mortgage terms to be the same across neighborhoods. Detecting price discrimination would require that mortgage terms be compared only after adjustments were made for the legitimate impact of neighborhood characteristics on the "production" of loans.

In equation (2) neighborhood characteristics also affect lender utility through their impact on expected revenue. It is quite plausible to expect default probabilities and, hence, expected default losses to vary systematically by neighborhood. Other things equal, expected profits would be relatively high in neighborhoods with relatively low expected default losses. Lender behavior that favored such neighborhoods through more lenient credit terms would not be redlining because maximization of expected utility would be tantamount to maximization of expected profits.[6]

In the case described by equation (2), redlining would occur in two ways. Redlining would occur if property location affected lender's utility directly. Redlining could also occur if lenders made use of "systematically biased" information in assessing the impact of neighborhood on expected revenue. For example, appraisers might systematically undervalue property in some locations because of class and/or racial prejudice.[7] If lenders relied on such appraisals, they would form a biased estimate of $\partial R/\partial N_j$. Differential treatment of borrowers on the basis of neighborhood would result in the maximization of a biased measure of profits. Unless lenders willingly cooperate, the profit incentive should eliminate any reliance upon such biased information. However, it may take time for this type of bias to be eliminated.

Thus, under the assumptions of certainty or risk-neutrality, redlining, in the economic sense, occurs whenever utility maximization of lenders is not consistent with maximization of an unbiased measure of profits. However, if lenders are assumed to be risk averse, the link between redlining and nonprofit maximizing behavior is broken. This is illustrated in equation (3), in which lender-utility depends upon expected profits, risk, and property location.

$$(3)\quad U_j = U[E(R_j - C_j), \sigma_j, N_j],$$

where σ_j is the "risk" associated with a loan on property j.

Risk-averse lenders would forego the maximization of expected profits in order to reduce "risk." Other things equal, lenders would favor "low risk" relative to "high risk" neighborhoods. Lender behavior of this sort would maximize lenders' expected utility, but not their expected profits. However, if aversion to risk were viewed as a "permissible" preference, differential treatment of loans

[6] A complete theoretical development of the supply of and demand for mortgage loans is presented in the Appendix.

[7] Lenders may also have biased information on the relationship between neighborhood characteristics and mortgage default losses. Such biased perceptions are likely because the data requirements needed to validate a model of default behavior are quite extensive compared to the limited portfolio of any particular lender. Biased information is potentially a cause of both lender price discrimination and spatial mortgage market price discrimination. However, because of the difficulty in measuring default risk and the substantial lags between endorsement of a mortgage portfolio and full observation of the pattern of default on that portfolio, this process could easily require several years.

based on location would not be considered as redlining, provided that differential treatment corresponded to differences in risk.[8]

There is another situation in which the link between redlining and nonprofit maximizing behavior might be broken. Government regulation of usury rates and maximum risk exposure levels serve as constraints when lenders maximize expected utility. When these constraints are binding, lenders achieve lower expected utility and lower profits than in the unconstrained case. For example, low usury rate ceilings may preclude lenders from making potentially profitable high risk loans. Any differential treatment of borrowers on the basis of neighborhood, directly due to these regulations, would not be defined as redlining.

C. *Role of Prejudice and Discrimination*

In all the cases considered, it is evident that economic notions of redlining are ultimately based on the concept of prejudice. It is therefore appropriate to define this term more precisely, as well as the related, yet distinct concept of discrimination.

In the neoclassical model of discrimination, *prejudice* is an inflexible attitude of prejudgment on the part of economic agents. In spatial mortgage markets, prejudice would exist whenever attitudes were formed about the desirability of making a mortgage in a particular neighborhood that were independent of the profitability and risk on the mortgage. More formally, prejudice would exist whenever neighborhood characteristics appeared in lenders' utility functions for reasons other than those related to revenue, cost, and/or risk.

Discrimination occurs whenever prejudicial attitudes lead to differential treatment of economic agents. However, it is important to distinguish between firm discrimination and market discrimination.

Firm or lender discrimination exists when individual lenders treat borrowers differently because of prejudicial attitudes about neighborhood location. Government regulations of lenders are primarily aimed at detecting *firm* discrimination. Spatial mortgage market discrimination would occur if such differential treatment were present in the market as a whole. In general, discrimination at the firm level is a necessary but not a sufficient condition for market discrimination. That is, even if *some* firms discriminate, the class discriminated against may be able to participate in a separate nondiscriminatory market. Such an outcome

[8] Risk-aversion raises several difficulties with respect to economic definitions of redlining. If lenders are risk-averse, the detection of redlining requires that differential treatment of neighborhoods due to risk-aversion be distinguished from differential treatment due to prejudice. Since both risk-aversion and prejudice imply that lenders would not maximize expected profits, such distinctions may be difficult to make, unless one is able to measure "risk" across neighborhoods. Unfortunately, the relevant measure of risk would not be the variance of expected profits. Rather, the relevant notion of risk would be the marginal contribution of a loan made on property j to the lender's portfolio risk. This, in turn, depends on the covariance between the return to a loan on property j and that of the lender's portfolio. Furthermore, one would need information about a lender's preference toward risk. Differences in risk preference may also explain why some lenders are willing to make loans in some areas, while others refuse to do so.

would be termed market segregation. Thus, lender discrimination against mortgages made in certain neighborhoods need not affect the terms of mortgages written in those areas if there is a segregated market in which other nondiscriminatory lenders participate.

D. *Legal and Economic Concepts of Neighborhood*

Like the concepts of prejudice and discrimination, the concept of neighborhood plays an important role in legislation and in economic studies of redlining. Indeed, determining whether redlining has occurred depends crucially on how neighborhood boundaries are drawn.

When defined explicitly in government regulations, neighborhood boundaries are based either on official units, such as census tracts and zip codes, or on the judgment of the regulatory examiner. For example, the Home Mortgage Disclosure Act requires lenders to provide information on loans granted or purchased by census tract, or by zip code if census tract information is not available. Under the Community Reinvestment Act, examiners are advised to identify low- and moderate-income neighborhoods by identifying census tracts in SMSAs where median family income is less than 80 percent of median family income for the entire SMSA. When such data are not available, examiners are advised to rely on "personal knowledge of the area, physical inspection as necessary, discussion with institutional personnel, or a combination of these."[9]

Though the concept of neighborhood appears frequently in the urban economics literature, there is no precise economic definition of the term. The closest approximation to such a definition is the identification of neighborhood with homogeneity of characteristics such as housing or socioeconomic status. Empirical studies, both of housing market discrimination and redlining, have used operational concepts of redlining similar to those appearing in government regulations – namely census tracts, zip codes, and intuitive judgment. In addition, some studies have relied on larger geographical units such as central city-suburb, and county.[10]

None of the operational delineations of neighborhood appearing in regulations or in empirical studies is sufficiently homogenous to be a true neighborhood. Census tracts are probably the best approximation because their boundaries are drawn to reflect uniformity of characteristics such as housing and income. However, since roughly 4000 persons reside in each census tract, considerable heterogeneity is likely within each tract. Like census tracts, zip codes are relatively small geographical areas. However, zip code boundaries are based on mail volume and natural boundaries. Similarity of housing and other characteristics is not explicitly used as a factor in determining zip codes. Larger geographical units such as counties, suburbs, central cities, and so forth, bear still less relation to the concept of neighborhood. Consequently, such geographical units are less satisfactory for purposes of defining and detecting redlining.

[9] See Federal Reserve press release of November 22, 1978, page 12.
[10] These empirical studies are discussed in more detail in Section IV.

E. *Comparison of Legal and Economic Definitions of Redlining*

It is clear from the above discussion that important similarities and differences exist between the legal and economic definitions of redlining. In this section we compare and contrast some main features of each conception of redlining.

In contrast to economic definitions, legal views are ambiguous as to whether redlining is a problem of market performance or distributional inequity. This is particularly true in the case of the Community Reinvestment Act where lenders are explicitly and repeatedly admonished to pay special attention to the mortgage credit needs of *low* and *moderate* income neighborhoods. Indeed, portions of the Act are easily interpreted as proscribing lender actions that reduce the flow of credit to "low and moderate income" communities, even though such actions might be based on legitimate cost and risk considerations.

Economic definitions of redlining based on the concept of *price discrimination* differ from legal views of discrimination in several respects. Of the four types of actions viewed with suspicion under the law, two correspond quite naturally to the notion of price discrimination. These are the rejection of applicants and the imposition of "onerous" terms as a condition for mortgage acceptance. As noted above, discouraging individuals from applying for credit would not necessarily be reflected in *price* discrimination among those actually applying for loans. Such prescreening could constitute redlining under the legal definition even though no price discrimination was observed.

The legal notion that redlining occurs when "local" lenders "export" deposit funds may be interpreted in several ways. Net outflows of deposits may be viewed by some as proxies for price-discrimination and/or prescreening. If so, disinvestment definitions of redlining would be equivalent to price-discrimination and prescreening definitions. However, price-discrimination neither implies nor is implied by net outflows of deposits. This is also true for prescreening. Consequently, if "disinvestment" is to be a meaningful concept, it should describe a phenomenon not included under the notions of either price discrimination or prescreening. It is, however, difficult to discern such a phenomenon apart from the vague notion that neighborhoods, as well as individuals, have some form of entitlement to mortgage credit. This view has some support among anti-redlining activists, but not among economists, who regard the individual as the correct "unit of analysis."

Perhaps the most important distinction to be made between the legal and economic definitions of redlining is that the economic definition provides a standard for comparison of actual lender behavior. Only in this way is it possible to distinguish between redlining and nonredlining behavior.

Part III: Other Possible Causes of Spatial Mortgage Market Price Discrimination

Several potential causes of "redlining" have been cited in the literature which do not cause the type of price discrimination discussed in the previous section. In many cases these other causes of "redlining" reflect the failure of urban *housing* markets rather than a failure of spatial *mortgage* markets.

Because rehabilitation and maintenance of existing housing generate spillover benefits for other units in the neighborhood, landlords making the investment may not capture the full benefits of their efforts. Rothenberg (1967) and others have noted that this situation may lead to underinvestment in some neighborhoods. Such market failure in housing markets should not be confused with price discrimination in spatial urban mortgage markets. Lower rates of investment in particular neighborhoods may contribute to differences in mortgage lending terms by affecting the expected default probability and expected return of some mortgages. However, if lenders react to this situation by making mortgage loans on the same terms (adjusted for differences in expected return), there is no redlining given the economic definition adopted here. It might be argued that the prisoner's dilemma facing landlords also affects lenders. That is, if some lenders believe that other lenders redline a neighborhood, they may also restrict their lending in that area. This argument ignores the possibility that a lender may internalize any externalities created by the failure of other firms to make mortgages in an area by making those mortgages itself. The property rights arguments of the housing market failure model, in which landlords cannot capture spillover benefits of their investments, do not apply to mortgage markets.

Lastly, "statistical discrimination" has been mentioned as a cause of redlining. In this case, lenders have unbiased estimates of the expected return and risk on mortgages across neighborhoods but it is too costly to collect information on the characteristics of individual mortgage applicants. These unbiased estimates may not be minimum variance estimates because the screening devices used by lenders to identify default probability are not elaborate.[11] As a result, many applicants will be offered mortgage terms which differ from those which would be offered if lenders used a minimum variance screening process. However, this type of "statistical discrimination" would not necessarily cause redlining because mortgage terms would not necessarily differ across neighborhoods.

Many possible causes of redlining have been advanced in the literature. The appropriateness of these causes depends on the definition of redlining adopted. Given our economic definition, potential causes of redlining include lender prejudice and biased information on expected profits due, for example, to biased estimates of appraisals and/or default losses. However, problems caused by market failure in housing markets or by statistical discrimination must be distinguished from redlining.

Part IV: Empirical Studies of Spatial Mortgage Markets

Both the economic and legal definitions of redlining discussed earlier pertain to differential treatment of mortgage applicants based on property location.

[11] The degree of precision in screening devices is determined by an extremely complex market for information. Lenders produce both mortgages and information on creditworthiness. The amount of information produced by lenders will depend on their ability to capture gains from this information and/or on the willingness of applicants to pay for production of this information. Full specification of this market for information on the probability of default is beyond the scope of this paper.

This differential treatment may manifest itself at any stage of the borrower's interaction with the lender. Specifically, it may appear at the prescreening stage when the initial inquiries are made, at the application stage when there is a formal written contract with the lender, or at the endorsement stage when the final terms of a note are formulated. Previous empirical studies of redlining have either been direct attempts to observe differences in treatment of individuals at one or more of these stages, or indirect attempts to separate out those actions of lenders which unambiguously indicate redlining behavior from those actions which do not. Clearly, the validity of these studies depends on the definition of redlining which is adopted and the model of lender behavior used to generate testable consequences. In many cases these empirical studies permit one to determine whether redlining has occurred in the legal, but not in the economic sense of the term.

Some basic problems are common to the general empirical literature on redlining and spatial mortgage markets. First, it is difficult to define neighborhood. Given existing data limitations, the census tract is the finest level of geographic differentiation that may be used in empirical work. Many studies analyze spatial variation at the level of the county or similar geopolitical unit, which corresponds to the concept of community rather than neighborhood. The area suspected of being redlined is then a set of census tracts with distinctive mean or median values of family income, racial composition, percentage of units lacking plumbing, and percentage of foreign born population. The implicit assumption is that if lenders redline, they use variables available in the fourth-count census of population and housing summary tables (or other variables highly correlated with the census variables) to distinguish target areas for redlining. The alternative approach is to identify neighborhoods or areas which, based on expert opinion, might be targets of redlining. Although such definitions of neighborhood are arbitrary, data availability requires their use by the researcher.

Problems are also posed by the prevalence of single equation models in empirical research on mortgage markets. Mortgage flows are generated by the interaction of lenders and borrowers. Hence, single equation estimates must, at best, be viewed as reduced-form estimates. Since formal definitions of redlining pertain to lender behavior, single equation estimates may not provide the information needed to determine whether redlining has occurred.

Empirical studies of spatial urban mortgage markets may be grouped by the type of data used. The five basic categories of data used in these studies are: (1) data on the spatial distribution of annual mortgage activity or of the mortgage portfolio of lenders, (2) data on the terms of loans made in different neighborhoods by lenders, (3) data on the terms of loans offered to applicants by specific lenders, (4) survey data on the mortgage problems of recent house buyers and sellers, and (5) data on default or default loss on loans made in different neighborhoods by specific lenders.

A. Data on the Spatial Distribution of Mortgage Activity

Studies of the spatial distribution of mortgages contributed significantly to testimony in support of current regulations on redlining.[12] Indeed, the Home Mortgage Disclosure Act requires that financial institutions make available data on the location, by census tract, of mortgages made and held in their portfolios. State provisions in Massachusetts, New York, and California requiring regulated lenders to disclose the geographic location of their mortgage loans have also provided data for these studies. Many of these studies only examine the geographical distribution of mortgages made by selected lenders, excluding much of the mortgage market.[13]

Perhaps the most comprehensive mortgage flow study was undertaken for Baltimore. This study relied on a complete record of all housing purchases for 1971, and found a systematic spatial pattern of lender behavior with FHA financing and mortgage bankers more prevalent in lower income inner city areas.[14] This basic empirical relationship has also been found in subsequent studies using more elaborate theoretical and econometric approaches. Hutchinson, Ostas, and Reed (1978) use Home Mortgage Disclosure Act data to estimate a lending flow equation for Toledo, Ohio, with the ratio of government-insured to conventional mortgages as the dependent variable. They find that the proportion of conventional mortgages is smallest for census tracts with about 45 percent black population but that it is higher for larger or smaller percentages of black population. Fullerton and MacRae (1979), for Philadelphia; and Austin, MacRae and Yezer (1979), for Philadelphia, Pittsburgh, Chicago, Houston, and San Diego, model the flow of FHA-insured mortgage activity by census tract. These studies find strong statistical support for the hypothesis that FHA programs serve moderate to middle-income households in border or racially mixed neighborhoods. FHA mortgage insurance activity declines, as expected, in low income areas due to the lack of units which meet the economic soundness criterion. FHA activity also declines in higher income areas. This occurs because FHA mortgage insurance must be purchased at a single premium regardless of expected default loss. As a result, profit-maximizing lenders have an incentive to offer more attractive mortgage insurance terms to "low risk" borrowers by offering them conventional mortgages.[15] In the debate concerning both the

[12] In particular see: U.S. Senate, Committee on Banking, Housing, and Urban Affairs, *Hearings on the Home Mortgage Disclosure Act of 1975*, S1281, May 5-8, 1975.

[13] Studies based on the Home Mortgage Disclosure Act have the hidden problem that only recent mortgages held in the portfolio of the lender at the date when disclosure is required are contained in the data. Any mortgages sold off are exempt from the disclosure requirement.

[14] The data were recorded in Lust, "Maryland Real Estate Guides." See Home Ownership Development Program, "Home Ownership and the Baltimore Mortgage Market," in the U.S. Senate, Committee on Banking, Housing, and Urban Affairs, *Hearings on the Home Mortgage Disclosure Act of 1975*.

[15] In view of this effect, it is not surprising that studies of the impact of neighborhood effects on the volume of lending by particular financial institutions, such as Muth's work on state chartered savings and loan associations, show a significant fall in the volume of lending in inner city or minority residential areas.

Home Mortgage Disclosure Act and the Community Reinvestment Act, the concentration of FHA activity in moderate income neighborhoods was cited as evidence that FHA mortgage activity follows the spatial patterns noted in these debates. However, this is not evidence of redlining in the economic sense of the term.

These results have been augmented by numerous descriptive studies using data on mortgage lending by census tract.[16] There is, however, a general problem with existing analyses of mortgage flows. As noted by King (1979), both supply and demand determine the quantity of mortgage credit extended in a neighborhood. Single equation models of mortgage flows therefore describe a reduced-form relationship between mortgage activity and neighborhood characteristics, rather than the supply behavior of lenders. If redlining is associated with differential supply behavior across neighborhoods, then mortgage flow studies have little ability to isolate markets in which redlining has occurred.[17]

An additional weakness of mortgage flow studies is that they fail to take into account the geographic distribution of lender portfolios. If lenders are risk-averse, it is rational for lenders to evaluate additional loans on the basis of those loans' contribution to portfolio risk. This contribution is partly based on loans already in the lender's portfolio.

B. Data on Loan Terms Observed in Different Neighborhoods

Disclosure requirements imposed on lenders in California, Massachusetts, and New York have produced data on individual loan terms along with borrower, property, and neighborhood characteristics. These data have also been used to analyze allegations of redlining.

Benston, Horsky, and Weingartner (1978) use such data to determine whether loan terms differ significantly between neighborhoods alleged to be redlined and "nonredlined" neighborhoods. Their study, using data from Rochester, New York, finds little support for the hypothesis that loan terms differ systematically by the neighborhood classification used in their analysis. A recent study by Muth (1979) contains similar findings. That is, mortgage terms at state-chartered Savings and Loan Associations in Oakland, California did not vary significantly among neighborhoods, though racial composition and lack of plumbing had small significant effects on interest rates. Recent work by Schafer (1978) is perhaps the most comprehensive study of how con-

[16] Among the most ambitious is Schafer's study of mortgage lending in New York State. Schafer estimates separate mortgage flow equations for areas deemed a priori to be redlined in other areas. Using the coefficients of the estimated nonredlined equation, he is able to predict mortgage flows for redlined areas and then compare actual with predicted flows. Similarly, it is possible to compute predicted flows for nonredlined areas using the coefficients of the redlined areas equation. In many cases, the mortgage flows predicted are greater than the actual flows.

[17] Models based on mortgage flow data may have some potential for use in analysis of lender price discrimination. Once again, there is a problem of separating supply behavior of individual lenders from effects based on the demand curves which they face. But it might be possible to model the determinants of demand facing individual lenders based on characteristics of the borrower and hence separate supply and demand effects.

ventional mortgage terms on 1-4 family homes are influenced by neighborhood characteristics. He estimates a simultaneous equation system in which maturity, loan-to-value ratio, and interest rate are related to one another and to neighborhood characteristics. The results are mixed in that some neighborhood characteristics have effects on loan terms counter to theory, though most neighborhood attributes have the expected impact. Though Schafer finds evidence of discrimination in housing markets, there is no strong evidence of redlining in mortgage markets.

Like mortgage flow studies, most analyses of mortgage terms are based on reduced-form equations that do not permit one to determine whether mortgage terms differ because of neighborhood differences in loan supply or loan demand. Moreover, studies of mortgage terms are limited to transactions actually made, and consequently, cannot determine whether redlining occurs at the prescreening or application stages in mortgage markets. Finally, unless information on default losses is available, it is difficult to determine whether any observed differences in loan terms reflect redlining, or instead compensate for neighborhood differences in default losses.

Another potential issue is raised by balance sheet constraints facing lenders. Because of such constraints, mortgage decisions made by banks and savings and loan associations are not independent of decisions pertaining to nonmortgage lending and deposits. Consequently, mortgage terms depend upon nonmortgage lending rates and rates paid on deposits. For example, mortgage interest rates will change in response to changes in binding Regulation Q deposit rate ceilings. This interdependence of interest rates should be reflected in properly specified models of determinants of mortgage terms.

C. Data on the Terms of Loans Offered to Loan Applicants

A third type of redlining model focuses on differences in loan terms offered to individual applicants. Applicant data, unlike data on loan terms, include information on treatment of borrowers during the application stage. However, they provide no information about the prescreening stage of borrower/lender interaction. Problems persist in using applicant data to identify demand and supply effects and in determining whether different treatment of applicants reflects variation in default losses. However, these studies are still in a preliminary stage and some of these problems may be resolved in future work.

Using applicant data from regulated financial institutions in Columbia, South Carolina, Warner and Ingram (1979) estimated two discriminant functions. The first used only risk and return variables to distinguish between accepted and rejected mortgage loan applications. The second discriminant function contained risk and return variables as well as "prohibited variables," including race, sex, and neighborhood median income. The second function did not discriminate between accepted and rejected applications better than the first discriminant function. The implication is that "prohibited variables" were not used to supplement risk and return variables in making lending decisions.

However, the authors note, with apparent surprise, that only 6 percent of all applicants, including all races, ages, sexes, and neighborhoods, were rejected.

This is consistent with Benston and Horsky's (1978) estimates of the percentage of home buyers with mortgage problems. Overall, this small incidence of rejection suggests that applicant data are not likely to reveal sharp differentials in treatment of borrowers based on neighborhood location.

D. Survey Data on the Mortgage Problems of Recent House Buyers and Sellers

A fourth approach to the analysis of redlining relies on surveys of recent buyers and sellers of houses. Testimony in support of the Home Mortgage Disclosure Act was, in part, based on informal surveys of this sort. Benston and Horsky (1978) recently conducted an elaborate, systematic survey of buyers and sellers in both an inner city area with high redlining potential and a suburban control area. Survey questions dealt with a range of mortgage finance problems, including reasons for rejection of applicants.

Such surveys provide interesting information on the functioning of local housing markets. However, there is little survey evidence that mortgage problems are systematically related to neighborhood location. A higher proportion of potential buyers in inner city areas experienced difficulty in securing mortgage financing that prevented a housing purchase (8.1 percent vs. 2.4 percent for suburban areas). However, this was apparently due to borrower income and creditworthiness rather than property location.

It is possible that fear of violating the Community Reinvestment Act may prevent lenders from citing neighborhood location as a reason for loan rejection. Nevertheless, survey approaches reveal whether redlining is perceived as a problem by borrowers and sellers. Hence, Benston's and Horsky's suggestion that more surveys of this type be conducted prior to implementing regulations is of some merit.

E. Data on Default or Default Loss on Loans Made in Different Neighborhoods

A fifth type of data set used to analyze spatial urban mortgage markets consists of observations on default and/or default loss experience. Single equation models of default experience on FHA-insured mortgages estimated by Von Furstenberg (1969), and Jackson, Kasserman and Thompson (1979) have shown that default probability increases with the loan-to-value ratio and term of the mortgage, and is also affected by borrower characteristics, particularly income, and by property attributes.

Studies done by Von Furstenberg and Green (1974) of mortgage delinquencies (payments 40+ days in arrears) in the portfolio of a Pittsburgh savings and loan association indicate that loan terms and borrower income affect delinquency much as they do default. Neighborhood racial composition is significant only when age of the unit is omitted from the regression. Von Furstenberg and Green conclude that borrower and property characteristics dominate neighborhood location as determinants of delinquency on home mortgages.

The most ambitious study of the spatial variation in probability of delinquency and foreclosure was conducted by Schafer (1978) using data from regulated lenders in Buffalo, Rochester, New York and Nassau-Suffolk. Descriptive tabulations of the data indicate substantial variation in foreclosure and delinquency rates across neighborhood and lenders. However, differences in these rates were not systematically related to neighborhood income. Equations relating the probability of delinquency, of severe delinquency, and of foreclosure to economic burden (ratio of monthly payment to income, etc.), equity, building characteristics, borrower attributes, and neighborhood characteristics were estimated by ordinary least squares. These estimated equations produced mixed results. Economic burden and equity variables often affected delinquency and default in ways anticipated by economic theory. However, reasonable and reliable parameter estimates appeared difficult to obtain from delinquency and foreclosure models estimated with micro data. Most notably, neighborhood characteristics failed to exhibit a consistent and significant relationship to the probability of delinquency and serious delinquency.

F. Summary

Empirical analyses of redlining have relied on various types of data to determine whether neighborhood location has a discernible impact on: (1) mortgage flows, (2) mortgage terms, and (3) mortgage default. For several reasons, mortgage flow studies provide limited evidence about either the presence or absence of redlining. First, most of these studies fail to distinguish differences in mortgage flows caused by demand factors from those caused by supply. Since both legal and economic definitions of redlining emphasize lender behavior, only differences due to supply are relevant for detecting redlining. Second, even if differences in mortgage flows could be attributed solely to lender behavior, this would, at best, be indirect evidence of redlining in the economic sense. This is so because price discrimination neither implies nor is implied by specific mortgage flow patterns. For example, two neighborhoods could receive identical mortgage flows, and yet redlining could still occur if mortgages were offered on different terms to each neighborhood. Conversely, portfolio diversification by lenders could produce mortgage flow patterns that appeared to be redlining when in fact redlining was not taking place.

Empirical analyses of the relation between mortgage terms and neighborhood attributes are directly related to both legal and economic definitions of redlining. However, so long as redlining is viewed as a supply phenomenon, single equation models of loan terms cannot provide definitive confirmation that redlining does or does not occur. A further limitation of many models is their failure to include neighborhood variations in default experience as a determinant of loan terms.

Analyzing the impact of neighborhood characteristics on default experience of lenders is not a direct test of whether redlining occurs. However, determining which neighborhood characteristics, if any, affect default, is essential for both detection and regulation of redlining. A common defense by lenders against allegations of redlining is that lending in certain neighborhoods is riskier than lending in other areas. Government regulations prohibit lenders from using certain neighborhood characteristics. Empirical studies of the spatial determinants of default should therefore provide evidence both of the validity of lenders' claims, and the impact of various government regulations.

With the exception of Schafer's study, there has been little systematic analysis of the relation between neighborhood characteristics and default. Our empirical analysis presented below provides further evidence on the spatial determinants of default.

Part V: Empirical Models of Default Risk

A. Specification of a Single Equation Default Model

In this section, we present an empirical analysis of the relationship between the probability of default on a mortgage and the characteristics of the neighborhood in which the property is located. We first estimate a single equation specification and then estimate a multiple equation model in which loan terms and the *ex ante* probability, P, that the borrower will default on his mortgage are determined simultaneously. P is determined jointly with the terms of the loan, including the loan amount, L, and the interest rate, i:

(4) $P = P\,[L, i, y_1, r_1, a, f(r_2)]$,

where y_1 is the borrower's income, r_1 is the flow of consumption services provided by the property, a is the rate of return on nonhousing assets, and $f(r_2)$ is the lender's subjective distribution of the uncertain rate of return on the property in the second period. The second period rate of return is based on the house's selling price in that period which is unknown at the time of the initial mortgage loan. Substitution of the endogenous loan terms in equation (4) also yields a reduced-form relationship between *ex ante* default and the exogenous variables of the model:

(5) $P = P\,[y_1, r_1, a, \lambda, f(r_2)]$,

where λ is the lender's cost of capital (See Appendix for a derivation of these relationships).

Data on *ex ante* default probabilities are not available. However, *ex ante* default equations, structural or reduced form, may be estimated if it is assumed that *ex ante* perceptions are based on past observations of actual defaults. The structural expression for *ex ante* default, equation (4), can thus be used to specify an estimating equation with *ex post* default probability as the dependent variable:

(6) $D = P[y_1, r_1, a, L, i, f(r_2)] + u$,

where: D equals 0 in the absence of default and 1 if default actually occurs, and
u is a disturbance term including factors which cause *ex post* default to diverge from *ex ante* default.

Because actual default is known with certainty, the *ex post* probability equals either 0 or 1. Default equations similar to (6) appear frequently in the existing literature. These studies typically include mortgage terms such as the loan amount, maturity, downpayment amount, and/or interest rate as determinants of default. However, in relying on single-equation estimation methods, these studies implicitly assume that the error term in equation (6) is uncorrelated with the regressors. To deal with this issue, we also estimate a multiple-equation default model that does not require this statistical assumption.

B. Data and Empirical Specification of a Single Equation Default Model

The basic mortgage data used in the empirical work are obtained from the 1975 Annual FHA-Master Statistical File (FHA-MSF).[18] This data set contains information on FHA mortgage insurance written under various sections of the National Housing Act. Our analysis was confined to transactions involving existing units under Section 203(b) because this unsubsidized program most resembles conventional mortgage insurance activity in cities.

The FHA-MSF is a sample of all FHA mortgage insurance activity. Insuring offices are sampled at a rate that varies inversely with the level of insurance activity at each insuring office. Within each office, the sample of insured loans, representing new endorsements, is chosen randomly. In creating the Annual FHA-MSF (F31), detailed data on loan terms, borrower characteristics and property characteristics are taken from FHA forms 2800, 2900 and 9100. This file is updated annually so that it is possible to observe which mortgages are terminated.[19] Because our goal is to distinguish determinants of default, a 10 percent random sample of endorsements not in default and 100 percent of default terminations were used. As a result the ratio of default terminations to total endorsements in the final sample rose to 12.78 percent from 1.44 percent.[20]

Most of the variables required to estimate equation (6) were taken directly from the FHA-MSF. The income term, y_1, was measured by net effective income (Y), an FHA estimate of the borrower's expected after-tax income during the early years of the mortgage. Information was also available on terms of the loan, including the term to maturity, a variable included in the empirical analysis but not in the theoretical model.[21]

[18] The authors are indebted to William Shaw and Barbara Mariner-Volpe for their aid in obtaining the sample drawn from the FHA-MSF used in this study. Thorough documentation for the FHA-MSF is provided in Royster (1975). Most of the discussion in the text is based upon this source. Our sample actually consists of endorsements in 1974 and 1975 and those mortgages which were in default (foreclosed) by the end of 1977.

[19] FHA mortgage insurance may terminate due to default and foreclosure, in which either the mortgage or the property is typically conveyed to HUD and the mortgagee claims the insurance benefits. This is the notion of default termination adopted in this paper so that the observation of a default termination is an indication that the market value of the property was insufficient to cover the principal outstanding. However, nondefault terminations may also arise due to prepayment, voluntary agreement between mortgagor and mortgagee, etc. Only cases of actual default terminations were regarded as indicating mortgage default in our analysis.

[20] In interpreting our empirical results presented below it is therefore important to adjust for the over-sampling of default terminations. This is done by multiplying percentage defaults by a conversion factor of 0.113. In other words, one should multiply our estimated coefficients by 0.113 to get effects in terms of percentage points of the true default rate.

[21] Term to maturity is not discussed in the theoretical appendix because of the two-period time horizon used in the utility maximization model.

Because the FHA data were taken from a cross section, some arguments of the default equation, namely, a and λ, may be treated as constant. Obtaining suitable measures of $f(r_2)$ is more complex. If r_2 is assumed to be normally distributed, the expected value and variance of r_2 completely describe $f(r_2)$. In this case, variables which determine the expected value and variance of r_2 are appropriate proxies for $f(r_2)$.

In our two-period model, the change in the asset price of housing, r_2, is given by equation (7)

$$(7)\quad r_2^{ijk} = [(V_2^{ijk} - V_1^{ijk})/V_1^{ijk}] = [(p_2^{ij}\, Q_2^{k} - p_1^{ij}\, Q_1^{k})/(p_1^{ij}\, Q_1^{k})]\ ,$$

where: subscripts 1 and 2 refer to time periods of the theoretical model,
superscript k refers to a particular housing unit,
superscript i refers to the city in which the unit is located,
superscript j refers to the neighborhood in which the unit is located,
V is the asset price of the housing unit,
p is the price of housing services,
Q is the quantity of housing services provided by the unit.

The variables V_2, p_2 and Q_2 are all random variables. Consequently, the expected value and variance of r_2 are ultimately determined by the expected values and variances of V_2, p_2 and Q_2.

The future price of housing services, p_2, is clearly determined by market supply and demand based on location effects at both the city and neighborhood level. Evidence presented by de Leeuw and Struyk (1975) suggests that the price of housing services is positively affected by growth in urban population and income. Such growth should also be reflected at the neighborhood level but it is difficult to obtain direct indicators of the economic vitality of individual areas in a large city. Indirect measures are sometimes available. For example, future expectations of housing prices may be reflected in the current condition of structures in a neighborhood. That is, current owners have an economic incentive to reduce property maintenance if they expect future housing prices to fall or rise less rapidly than in the past.

The future quantity of housing services, Q_2, is determined by structural attributes of the property itself, as well as by the behavior of the mortgagor/occupant. Structural attributes such as type of construction, age, and overall condition are likely to affect the flow of housing services from a given unit. Changes in income, cost of producing housing services, and prices of other goods, may also cause desired housing services to diverge from actual ones. In the absence of transactions costs, households could obtain the "desired" level of housing simply by moving from one unit to another. However, because moving entails considerable transactions costs, households may choose instead to adjust the level of services obtained from the unit in which they live. For example, a household might respond to a decline in desired housing services by remaining in the same unit while lowering maintenance levels. Hence, household characteristics related to the desired quantity of housing services may affect Q_2. Particularly relevant would be any characteristics reflecting the stability of household income.

Thus, several variables have been identified that affect p_2 and Q_2, and therefore, r_2. The future price of housing services, p_2, should vary with housing market conditions in both cities and neighborhoods. The future quantity of housing services, Q_2, should vary with property attributes and borrower characteristics. Consequently, vectors of city, neighborhood, property, and borrower characteristics are included as proxies for $f(r_2)$ in our default equation. Determinants of the variation in r_1, the last argument of the structural default equation, are essentially identical to those for r_2.

Empirical specification of the single equation default model is completed by choosing a particular function form for the relationship. The general form of the specification is:

$$(8)\quad D_i = a_o + a_1 (L/V)_i + a_2 (TERM)_i + a_3 (MP/Y)_i + a_N N_i + a_C C_i + a_B B_i + a_S S_i + u_i,$$

where: i is an index of individual mortgage transactions, i = 1 .....number of cases,
D_i is a dummy variable equal to 1 if default occurs and 0 otherwise,
(L/V) is the loan-to-value ratio,
(TERM) is the term to maturity,
(MP/Y) is the monthly payment-to-income ratio,
N is a vector of neighborhood location characteristics including dummy variables for central city and rural location and a dummy variable indicating location in a code enforcement or blighted neighborhood.
C is a vector of city location characteristics including the rate of new single-family housing starts, fraction of housing built before 1940, SMSA size, city population growth, SMSA income growth, SMSA income per capita, and SMSA percentage black population.
B is a vector of borrower demographic characteristics including dummy variables for minority status, marital status, sex of family head, and multi-worker family status, as well as a continuous variable reflecting years of marriage.
S is a vector of structure condition variables including dummy variables for FHA appraisal as fair or poor structural condition, type of construction, and continuous variables reflecting structure age, and the number of housing units in the structure.
a_N, a_C, a_B, and a_S are appropriate vectors of coefficients, and
u_i is an error term.
(Note: A glossary of variables is at the end of the paper)

If the disturbance term, u, satisfies the conventional assumptions, equation (8) may be estimated by ordinary least squares and the coefficients interpreted as marginal effects of the regressors on the expected probability of default. Probit and logit estimation techniques are often used for models with binary dependent variables.[22] However, the size of our sample is large, OLS estimates of the parameters are consistent, and a number of applied econometric studies have found that these techniques yield essentially the same results as OLS.

[22] For a discussion of estimation issues, see Pindyck and Rubinfeld (1976).

In equation (8) the loan terms are entered in a functional form common in the literature. The loan amount and equity, taken together, determine the loan-to-value ratio. Although term of the loan was not considered in the two-period default model, it influences the rate at which the principal is retired and, hence, the rate of equity accumulation in the unit. The monthly payment is approximately equal to one-twelfth the product of interest and loan amount. Thus the interest rate enters the default equation through the monthly payment-to-income ratio.

As noted in data discussion, location characteristics (both neighborhood and city attributes) enter the default equation because they influence both r_1 and the mean and variance of r_2. Structure characteristics enter the equation for similar reasons. The borrower characteristics in equation (8) were included for a variety of reasons. First, they represent "prohibited" borrower attributes which may not be used by lenders under equal credit opportunity regulations. Second, they separate groups which may differ systematically in variables omitted from the equation, such as wealth, and human capital. Third, they differentiate households that may be subject to discrimination in labor and housing markets.

C. Single Equation Estimation Results

Ordinary least squares estimates of equation (8) are presented in Table 2. Nine different specifications of the default relationship are presented to illustrate the sensitivity of results to inclusion of various categories of regressors. These equations show the impact on default of four categories of explanatory variables: (1) loan terms, (2) borrower characteristics, (3) structure condition, and (4) location characteristics, including both neighborhood and city characteristics.

Terms of the loan are almost always significant determinants of default. Both the loan-to-value ratio and the monthly payment-to-income ratio have the expected positive signs. This finding is consistent with those of most existing default studies. The term to maturity is negative and significant in eight of the nine equations, and positive but insignificant in the remaining equation. Some other studies have produced opposite results. For example, Jackson, Kasserman, and Thompson (1979) and Herzog and Early (1970) find that term to maturity has a positive and significant impact on default.

Borrower characteristics have mixed impacts on default probability. The probability of default is not significantly different for Hispanic mortgagors than for the reference group of white, male-headed, newly married households. The default probability of female-headed households differs from that of the reference group by an amount equal to the sum of the coefficients of the not married and the female-headed family variables. Borrowers who have been married for some time are significantly less likely to default than newly married households. Black borrowers appear to have significantly higher default probability. As noted above, the estimated impacts of these demographic variables, particularly race, reflect a variety of omitted factors, including wealth and human capital, and discrimination in labor and housing markets.

Some, but not all, property condition variables have an impact on default probability. Condition of the structure and construction type both significantly

TABLE 2

Single Equation Estimation of Probability of Default
Dependent Variable – Default Probability
(One if Foreclosed; Zero Otherwise)

Dependent Variable	Eq. R1	Eq. R2	Eq. R3	Eq. R4	Eq. R5	Eq. R6	Eq. R7	Eq. R8	Eq. R9
Intercept	–0.3957**	–0.4204**	0.0559	–0.4464**	0.0527	–0.4122	0.0676	–0.4652	0.1062
Loan Terms									
Loan-to-Value Ratio	0.6279**	0.6394**	0.6193**	0.6222**	0.5894**	0.6370**	0.5776**	0.5613**	0.5127**
Term-to-Maturity (months)	–0.0002*	–0.0002*	–0.0006*	–0.0002	–0.0005**	–0.0002*	–0.0005**	0.00002	–0.0004**
Monthly Payment-to-Income Ratio		0.1012*	0.1947**	0.1359**	0.2315**	0.1055*	0.2442**	0.1524**	0.2593**
Borrower Characteristics									
Hispanic								–0.0136	–0.0136
Black								0.1136**	0.1087**
Years Married								–0.0009*	–0.0010*
Not Married								0.0132	0.0071
Female Head of Household								–0.0271*	–0.0308**
Property Characteristics									
Structure: Fair to Poor Condition						0.0381**	0.0325**		0.0316**
Age of Structure						–0.0002	–0.0002		–0.0004
Wood Construction						0.0006	0.0213**		0.0233**
Neighborhood Characteristics									
Central City				0.0177**	0.0269**		0.0265**		0.0125*
Rural				–0.0016	0.0132		0.0096		0.0120
Blighted				0.0411**	0.0496**		0.0518**		0.0338**

TABLE 2, *continued*

	Eq. R1	Eq. R2	Eq. R3	Eq. R4	Eq. R5	Eq. R6	Eq. R7	Eq. R8	Eq. R9
City Characteristics									
Fraction of New Single Family Starts			−0.8136**		−0.8261**		−0.8398**		−0.7597**
Fraction of Pre-1940 Housing			−0.4582**		−0.4996**		0.5053**		−0.4688**
SMSA Size			0.0042*		0.0049**		0.0067**		0.0043*
City Population Growth (1970-1975)			−0.5115**		−0.5573**		−0.5579**		−0.4883**
City Income Growth (1970-1975)			−0.0113		0.0112		−0.0089		0.0004
SMSA Per Capita Income (1975)			−0.00000004**		−0.00000004**		−0.00000004**		−0.00000005**
Percentage Black Population (1970)			0.0016**		0.0013**		0.0014**		0.0002
R-Square	0.0100	0.0103	0.0315	0.0121	0.0346	0.0113	0.0361	0.0323	0.0525
F-Statistic	50.56	34.73	31.66	20.56	26.83	19.2	22.7	41.85	25.6
Sample Size	10050	10050	9731	10050	9731	10050	9731	10050	9731
Mean Value of the Dependent Variable	0.1279	0.1279	0.1279	0.1279	0.1279	0.1279	0.1279	0.1279	0.1279

* denotes significance at the 90% level

** denotes significance at the 95% level

A complete description of the variables is contained in a Glossary of Variables at the end of the paper.

affect default. Structures in only fair-to-poor condition, and those constructed out of wood, both have significantly higher default probabilities. However, age of the structure does not have a significant impact on default. These results are consistent with some of Schafer's findings (1978). However, they differ from those of Jackson, Kasserman, and Thompson (1979), who find no significant impact for their measure of structural and locational quality.

Property location influences default probability through both the neighborhood and city characteristics variables. Neighborhood characteristics generally affect the probability of default. More specifically, the default probability is significantly higher if a mortgage loan is made in a central city or slum area. This finding is invariant with respect to the specification of the default equation in Table 2. Thus, the risk of default on a mortgage does vary significantly and systematically by neighborhood. As a result, one would expect lenders to adjust loan terms to reflect neighborhood differences in risk. Such differences in loan terms by geographical area, however, would not imply redlining. Indeed, if the loan terms were uniform across neighborhoods, price discrimination would be present.

City characteristics generally have the expected impact on default. Of the seven variables representing these characteristics, only one is consistently insignificant. This variable is SMSA income growth. Four of these variables have a negative and significant effect on the probability of default. These variables are the rate of new single-family housing growth, the fraction of housing built before 1940, city population growth and SMSA per capita income. Therefore, higher levels or growth of city economic activity reduce defaults. The SMSA size variable has a significant and positive impact on default. The coefficient of the racial composition variable, percentage black population, is positive and highly significant in three of the four regression equations in which it appears. However, if borrower characteristics are controlled for, this variable ceases to be significant. Since there are sound economic reasons for including borrower characteristics, this finding indicates some of the consequences of excluding relevant variables from the default equation.

D. Specification and Estimation of a Multiple Equation Default Model

The default probability model estimated above included terms of the loan as regressors. Single-equation estimation techniques seem justified because the dependent variable is *ex post* default which occurs some time after endorsement of the loan. Such sequencing in time appears to impart a single direction to the causal relationship among variables so that loan terms may be regarded as uncorrelated with the error term in the estimating equation.

The theoretical model developed in Section V implies that loan terms are determined simultaneously with the *ex ante* default probability, P. Equation (8) may be viewed as an *ex ante* default probability equation, with *ex post* default used as the dependent variable because *ex ante* default probabilities are not observable. It is this *ex ante* default equation that is relevant for assessing the determinants of loan supply and demand in the theoretical model. Clearly, loan terms are not exogenous in the true *ex ante* default equation. Consider a simple model in which mortgage amount and term are fixed so that the interest rate is the only variable term of the mortgage. The structural equations of this model would be:

(9) $i = b_o + b_1 P + b_2 X + u$, and

(10) $P = c_o + c_1 i + c_2 X + e$,

where the Xs are appropriately chosen vectors of exogenous variables. In this case, i and P are jointly dependent variables so that P and i are not independent of u and e, respectively.

It is plausible to assume that *ex ante* default differs from *ex post* default by a random variable, so that:

(11) $D = P + f$,

where f is a random disturbance term. Equations (10) and (11) may be combined to form an expression for *ex post* default in terms of the determinants of *ex ante* default:

(12) $D = c_o + c_1 i + c_2 X + e + f = c_o + c_1 i + c_2 X + (e+f)$.

Since i is not independent of the error term, (e+f), in equation (12), use of ordinary least squares will result in coefficient estimates that are both biased and inconsistent.

An additional statistical problem of selection bias should be given attention when estimating models of mortgage supply, mortgage demand, and default. Rejection of applicants on the basis of formal credit scoring procedures means that *observed* defaults are drawn from a population with an *ex ante* default which is less than or equal to a certain "critical" value. That is, the dependent variable is censored from above. Heckman (1979) has shown that sample selection bias of this sort leads to specification error that is analogous to the problem of omitted variables. Both FHA and conventional mortgage applications are evaluated with reference to certain formal criteria. However, FHA insurance criteria exclude both neighborhood economic and demographic variables. This reduces the likelihood that estimates obtained from data on FHA-insured mortgages will suffer from the bias discussed by Heckman. By contrast, estimates based on conventional mortgage data are more likely to suffer from such bias because more latitude may be exercised in using formal credit scoring procedures.

A multiple equation model was formulated with loan terms from the default equation expressed as endogenous variables. On most mortgages, these loan terms, including the loan-to-value ratio, term to maturity, and monthly payment-to-income ratio, are the result of simultaneous interaction of supply and demand forces. The estimated coefficients of such equations would normally be difficult to interpret because supply and demand effects often work in opposite directions. However, because section 203(b) insurance is provided to all qualified borrowers at a fixed premium, the final combination of loan terms should reflect demand side effects only. That is, FHA insurance eliminates the normal lender incentives to raise interest rates to maintain expected profit when an increase in the loan-to-value ratio raises the expected default loss.

The multiple equation system consists of five equations, including equations for housing expenditure, monthly payment-to-income ratio, term-to-maturity, loan-to-value ratio, and the probability of default. These are discussed in turn below.

Total housing expenditure is based on housing demand, which is determined by family income, demographic characteristics, and the price of housing services. Unfortunately, there is no direct measure of the price of housing services on individual units. However, indirect measures are available including the ratio of house value to number of rooms or number of bathrooms, and city characteristics which are related to differences in housing prices. In addition, total expenditure on the housing unit should rise if the unit includes appliances such as a stove, refrigerator, washer, etc. In effect, the consumer purchases more than structural services when such consumer durables are part of the transaction. Therefore, the housing expenditure equation has the form:

$$(13)\quad V_i = b_o + b_1 Y_1 + b_B B_i + b_C C_i + b_O O_i + b_A A_i + u_i \, ,$$

where: i is an index of the observation number,
V is the FHA assessed value of the property,
Y is family net effective income,
B is a vector of demographic characteristics of the family,
C is a vector of city characteristics for the area in which the unit is located,
O is a vector of other variables, specifically the appraised value-to-rooms ratio and the appraised value-to-bathrooms ratios,
A is a vector of dummy variables reflecting the presence of various appliances in the housing unit,
u is a disturbance term, and
the b's are appropriately scaled vectors of parameters.

The estimates are presented in Table 3, and are generally consistent with expectations. Family income and the presence of appliances have significant positive effects on expenditure. Price effects, as reflected both in the value-to-rooms and value-to-bathrooms ratios and in the city characteristics, were generally positive and significant. Such an expenditure effect is consistent with the inelastic own-price elasticity of demand for housing generally reported in the literature.

The monthly payment-to-income ratio, like other loan terms, is determined by borrower preferences. From the borrower's perspective, a higher monthly payment-to-income ratio implies a greater commitment of current household income or cash flow to housing. The willingness of households to commit a large fraction of cash flow should vary inversely with the importance of the alternative uses of cash. Possibly the best measure of the value of this cash flow is the family's net effective income per person which should vary inversely with

TABLE 3

Multiple Equation Estimation of Probability of Default
(One if Foreclosed; Zero Otherwise)

Independent Variables	Dependent Variables				
	Probability of Default	Loan-to-Value Ratio	Term-to-Maturity (Months)	Monthly Payment-to-Income-Ratio	FHA Appraisal Value Including Closing Costs
Intercept	−1.0362*	0.9968**	326.3289**	1.3641**	−5926.0075
Probability of Default		0.0683**	115.7114**		
FHA Appraised Value		−0.000002**	0.0008**	−0.000001**	
Loan Terms					
Loan-to-Value Ratio	1.7851**			−1.5287**	
Term to Maturity	−0.0009			0.0011**	
Monthly Payment-to-Income Ratio	0.6160**				
Borrower Characteristics					
Hispanic	−0.0224*	0.0039*	2.7513	0.0067*	−468.3823**
Black	0.0964**	−0.0036**	−15.0040**	0.0009	−181.9307*
Years Married	0.0001	−0.0005**	0.0586	−0.0015**	
Not Married	0.0120	−0.0061**	−2.9212*	0.0011	
Female Head of Household	−0.0348**	−0.0049**	8.7174**	0.0005	185.9844
Both Work		0.0031**	3.2146**	−0.0280**	
Number of Dependents					400.9344**
Net Effective Income per Person		−0.0000007	0.0060**	−0.00004**	−0.1937
Net Effective Income					5.4562**
Property Characteristics					
Structure: Fair or Poor Condition	0.0263*	−0.0029*	−5.6981**	−0.0047	
Age of Structure	−0.0007	−0.0002**	−0.4752**		
Wood Construction	0.0177*				
Number of Living Units				−0.0103	2139.8583**
Oven Only		−0.0029	−1.5367	0.0086*	903.0171**
Oven with Other Kitchen Appliances		−0.0106**	−3.4593**	−0.0109**	3467.2107**
Washer or Dryer		−0.0100*	−3.3867	−0.0077	940.2452**
Washer and Dryer		−0.0075**	2.5590	−0.0097*	1023.6095**
Carpeting		0.0077**	3.7222**	0.0108**	234.6987**
Central Air Conditioning		−0.0033**	−2.4299**	−0.0105**	902.5475**

TABLE 3, *continued*

Independent Variables	Probability of Default	Loan-to-Value Ratio	Term-to-Maturity (Months)	Monthly Payment-to-Income-Ratio	FHA Appraisal Value including Closing Costs
	Dependent Variables				
Neighborhood Characteristics					
Central City	0.0070	−0.0011	0.2768		
Rural	0.0156	−0.0081	−0.6133		
Blighted	0.0368**	−0.0059**	5.6121**		
City Characteristics					
Fraction of New Single-Family Starts	−0.8560**				3244.7213*
Fraction of Pre-1940 Housing	−0.4256**				894.0734*
SMSA Size	0.0023				94.4469**
City Population Growth (1970-75)	−0.4645**				2350.2833**
City Income Growth (1970-75)	0.0177				−348.0559
SMSA Per Capita Income (1975)	−0.00005**				0.2288**
Percentage Black Population (1970)	0.0007				25.0791**
Other Variables					
Mortgagee Not a Mortgage Banker				0.0079**	
Value/Bath Ratio					0.0588**
Value/Room Ratio					4.0525**
Sample Size	9727	9727	9727	9727	9727
Mean Value of the Dependent Variable	0.1270	0.9465	350.9932	0.2182	23614.7710

* denotes significance at the 90% level

** denotes significance at the 95% level

A complete description of the variables is contained in a Glossary of Variables at the end of the paper.

the value of cash flow. Similarly, families purchasing more expensive houses and accepting higher loan-to-value ratios might have smaller cash flow problems. Also, households purchasing a variety of appliances with the housing unit might accept higher monthly payment-to-income ratios because they are financing consumer durables as well as the housing structure. The overall monthly payment-to-income ratio equation then becomes:

$$(14)\quad (MP/Y)_i = c_o + c_1 V_i + c_2 (L/V)_i + c_3 TERM_i + c_4 (Y/N)_i + c_B B_i + c_A A_i + c_O O_i + u_i ,$$

where: i is an index of the observation number , i = 1. . . . .N,
MP/Y is the monthly payment-to-income ratio,
V is FHA appraised property value,
L/V is the loan-to-value ratio,
TERM is the term to maturity
Y/N is the net effective income per person,
B is a vector of borrower demographic characteristics,
A is a vector of dummy variables reflecting the presence of various appliances in the housing unit,
O is a dummy variable equal to unity if the loan was not made by a mortgage broker and zero otherwise,
u is a disturbance term, and
the c's are appropriately scaled vectors of parameters.

Results obtained by estimating equation (14) using instrumental variables for the included endogenous variables (V, L/V, and TERM) are shown in Table 3. Family income per person, appraised value, and the loan-to-value ratio all have negative signs and are highly significant. The positive and significant effect of term to maturity seems puzzling. However, households desiring longer term mortgages would be expected to have greater cash flow problems. The effect of appliances was generally random. The other variable, a dummy variable reflecting a mortgagee which was not a mortgage banker, was inserted on the theory that screening processes might direct borrowers with cash flow problems toward mortgage bankers rather than financial institutions. The positive and significant coefficient suggests just the opposite effect.

Demand for longer term-to-maturity of the loan should be based, in part, on borrower perceptions of default risk. Longer term means slower retirement of principal and hence smaller losses for the borrower if the value of the property falls. Therefore, *ex ante* default probability should have a positive effect on the term-to-maturity demanded. Property characteristics and neighborhood characteristics should not have an influence on the term to maturity independent of their impact on borrowers' uncertainty over future market price. However, these variables were included in the analysis to capture any effects not included in the endogenous default variable. In part this reflects an attempt to demonstrate the ability of *ex post* default to capture *ex ante* default perceptions. The general term-to-maturity equation is written as:

$$(15)\quad TERM_i = d_o + d_1 D_i + d_2 V_i + d_3 (Y/N)_i + d_B B_i + d_S S_i + d_A A_i + d_N N_i + u_i ,$$

where: i is an index of the observation number, i = 1. . . . . . .N,
TERM is the term-to-maturity in months,
D is the default probability,
V is the FHA appraised value,
(Y/N) is net income per person,
B is a vector of borrower demographic characteristics,
S is a vector of structure characteristics,
N is a vector of neighborhood characteristics,
u_i is a disturbance term, and
the d's are appropriately scaled vectors of parameters.

Estimates of equation (15) using instrumental variables for default, D, and appraised value, V, are presented in Table 3. Both included endogenous variables, have positive signs and are highly significant. Also, with the exception of the blighted neighborhood dummy, the structure and neighborhood variables included in the equation do not have the positive effect on term to maturity that would be expected. This indicates that the included default variable is effective in capturing the influence of anticipated default on the borrower's demand for a longer term mortgage.

Demand for higher loan-to-value ratios, like the demand for longer term to maturity, should increase with the borrower's perception that future property value may fall. Higher loan-to-value ratios mean lower downpayments and hence less equity at risk in the event of default. As with the term-to-maturity equation, both property characteristics and neighborhood characteristics were added to the equation to determine if they had an impact on the demand for a higher loan-to-value ratio independent of the influence which they exert through an increase in *ex ante* probability of default when structure condition and/or neighborhood are poor. The general form of the loan-to-value equation is:

$$(16) \quad (L/V)_i = e_o + e_1 D_i + e_2 V_i + e_3 (Y/N) + e_B B_i + e_S S_i + e_A A_i + e_N N_i + u_i,$$

where: i is an index of the observation number, i = 1. . . . .N,
(L/V) is the loan-to-appraised value ratio,
D is the default probability,
V is the FHA appraised value,
(Y/N) is net family income per person,
B is a vector of borrower characteristics
S is a vector of structure characteristics,
A is a vector of dummy variables reflecting the presence of various appliances in the housing unit,
u is a disturbance term, and
the e's are appropriately dimensioned vectors of parameters.

Table 3 contains estimates of equation (16) using instrumental variables for the included endogenous variable, D and V. Note that default probability has the expected positive sign and is highly significant. The structure and neighborhood variables also have negative signs and small magnitudes (half are statistically significant). This indicates a negative effect of poor structure and neighborhood quality on the loan-to-value ratio demanded.

The four equations discussed thus far are not intended to represent a formal model of the demand determinants of loan terms and housing expenditure. Rather, these four equations have been presented to indicate that reasonable estimates of the multiple equation system could be obtained. They also indicate that use of *ex post* default probability as a substitute for the unobservable *ex ante* default probability produced reasonable results.

The default equation of the multiple equation model is based on equation (8). Consequently the results reported in Table 3 may be compared directly with those in column R9 of Table 2. Instrumental variables are used for the loan terms, (L/V), TERM, and (MP/Y). Both the loan-to-value ratio and the monthly payment-to-income ratio have the anticipated positive and significant effect on default probability. The marginal effects of these variables on default are considerably greater than in the single equation model. However, term to maturity no longer has a significant effect on default. This result may be contrasted to the negative and significant effect of term to maturity in the single equation model.

The exogenous variables of the default equation have similar effects in both the single and multiple equation model. Location of the property has the anticipated effect, with significantly higher default probability in blighted neighborhoods and in cities with lower per capita income and slower growth in the population and single-family housing stock. Note that two location variables, SMSA size and central city location, which were positive and significant in the single equation estimates have smaller and statistically insignificant coefficients in the multiple equation estimates. This is an important difference. The multiple equation result suggests that geographic location of the property in a larger city or nearer the city center has no independent effect on default probability when neighborhood condition and city economic vitality variables are present in the estimating equation. Borrower characteristics, with the exception of years married, have similar effects in both models. Structure condition also influences default in the expected direction, with inferior condition and wood siding increasing default. The location effects are most critical to the analysis of redlining. The results are discussed in the final section of the paper.

Part VI: Conclusions and Policy Implications

Regulators of financial institutions have recently become concerned about redlining. This concern is reflected in some parts of the Fair Housing Act of 1968, in the Home Mortgage Disclosure Act of 1975, and the Community Reinvestment Act of 1977. In particular, the Community Reinvestment Act (CRA) provides a statutory framework for vigorous enforcement of anti-redlining provisions, as illustrated by a recent case in Brooklyn, New York. In April 1979, a savings bank was denied permission by the Federal Deposit Insurance Corporation (FDIC) to open a branch in Manhattan because the bank "failed to meet the residential mortgage needs of the community." This denial was the first significant test of the CRA. In commenting upon this decision, Alan Miller, deputy to

FDIC Board Chairman Irving H. Sprague, noted that ". . . . . it means we fully intend to uphold the Community Reinvestment Act."[23]

Regulators are, therefore, likely to include CRA criteria in deciding upon all future branching, merger, and acquisition decisions. Consequently, financial institutions should have a much stronger economic incentive to take into account the Fair Housing, Home Mortgage Disclosure, and Community Reinvestment Acts when making mortgage lending decisions. The potential impact of these regulations on mortgage markets requires that one be able to determine whether redlining has taken place. An important related issue is whether criteria that lenders are and are not allowed to use by regulators are economically justified.

Definition is the first step toward identification of redlining. There are both legal and economic definitions. The legal approach to defining redlining is to list those features of property location that lenders may and may not take into account in the loan negotiation process. The economic approach evaluates lender behavior against the standard of profit maximization under risk. Redlining in the economic sense occurs when actual lender behavior departs from profit maximizing behavior. There are several major differences between these two definitions. Economic conceptions of redlining tend to focus on inefficiency in mortgage markets rather than income distributional inequality. Legal conceptions often blur the distinction between equity and efficiency. Perhaps more significantly, the benchmark used for identifying redlining differs under the two definitions. The statutory approach presumes that certain actions by lenders will produce undesired outcomes in mortgage markets. Consequently, redlining is defined in terms of those actions. The economic approach distinguishes between profit and nonprofit maximizing actions. Redlining is presumed to occur when actions are not consistent with profit-maximizing behavior of mortgage lenders.

Vigorous enforcement of anti-redlining regulations may impose substantial costs on financial institutions and the public. The Home Mortgate Disclosure Act has imposed additional record-keeping requirements, while other record-keeping is required to demonstrate compliance with the CRA. This is in addition to the monitoring and enforcement costs incurred by regulators. Furthermore, if regulations compel or induce institutions to grant more credit than warranted to "truly" risky applicants, default losses experienced by some lenders may increase. Some portion of such cost increases would be passed on to borrowers.

Given the potential costs of anti-redlining statutes, it is appropriate to ascertain the magnitude of the problem addressed by such regulations. An economic (as opposed to legal) test of whether redlining has occurred involves determining whether terms of mortgage loans vary systematically by location after all factors affecting profits in a risky environment have been taken into account. If, after controlling for such factors, loan terms vary systematically by location, it is plausible that redlining exists.

A major difficulty in performing such tests is to determine what constitutes profit-maximizing behavior by lenders. Another difficulty arises in distinguishing

[23] Mr. Miller's statement was quoted in the *Washington Star*, April 27, 1979.

differences in outcome due to lender behavior from those reflecting borrower preferences. Much existing research on mortgage flows fails to distinguish between supply and demand effects. Data on applicant rejection rates may allow one to detect redlining at the application stage. However, the usefulness of such data may be limited by the apparent low incidence of rejections. Moreover, determining whether redlining occurs at the application level does not provide information about whether discrimination occurs through prescreening or after the loan application has been accepted.

An alternative approach to detecting redlining is to: (a) estimate the degree to which default risk varies by location, (b) estimate the adjustments in loan terms justified by such differences, and (c) compare the estimated adjustments to those actually made by lenders. Using FHA data to estimate an empirical default model provides information on the spatial determinants of default. Our results indicate that default risk is significantly affected by location based on both neighborhood and city characteristics. This implies that appropriate adjustment of mortgage terms based on location is consistent with profit maximization. This type of adjustment would not be redlining in the economic sense.

The estimated coefficients of the default model may also be used to estimate the size of appropriate adjustments in mortgage terms. As an illustration we used the estimated default equations to determine the default probability of a hypothetical property located in a blighted neighborhood of a central city with income per capita, income growth, population growth, and rate of single-family housing growth all one standard deviation below their sample means. The estimated default probability was then compared to the average default probability of the sample. For this rather extreme case, the default probability was estimated to be roughly 2.4 times greater than average using the single-equation estimates, and roughly 2 times greater than average using the multiple equation estimates. In order to reduce the estimated default rate to the average default rate the downpayment ratio would have to rise roughly sevenfold in the single equation case and by 2.4 times in the multiple equation case.

Estimates such as these indicate the "appropriate" difference in loan terms between an "extremely risky" and an "average" property location. One could, in principle, use such estimates to adjust the loan terms of conventional lenders to determine whether any differentials remained on loans made in "risky" and "average" locations. Any such differentials, particularly if they discriminated against the "risky" area, would indicate the potential presence of redlining. Ideally, such calculations would be done for each SMSA, using estimates of spatial default variation within each SMSA.

In general, our results indicate that many, but not all, property and locational characteristics affect default. From the standpoint of regulatory policy, these characteristics can be grouped into three categories; those prohibited by regulations, those permitted by regulation, and those potentially prohibited. Currently, lenders are proscribed from limiting credit due to the age of the property and racial composition of the neighborhood. Our results indicate that neither prohibited attribute has a significant impact on default once other factors are taken into account. By contrast, the Fair Housing Act allows lenders to take into account both the structural condition of the property itself and the structural condition of nearby properties. Our results indicate these characteristics do significantly affect default rates. Finally, future enforcement of the CRA may make it more difficult for lenders to use neighborhood income as a criterion. Our results indicate that SMSA income per capita is a significant geographical determinant of default. This suggests that neighborhood income may also significantly affect default rates. If so, compelling lenders to grant more credit to "low and moderate income" neighborhoods may increase their exposure to default losses. Such increased exposure would raise the costs of mortgage credit in some areas.

In sum, anti-redlining regulations may require considerable changes in lender behavior. However, defining and detecting redlining is extremely complex. These complexities should not be ignored in regulatory efforts to deal with redlining.

Glossary of Variables

FHA Appraised Value: FHA appraised value in dollars [V].

Loan Terms

Loan-to-Value Ratio: Ratio of endorsed loan amount to FHA appraised value. [L/V].

Term to Maturity: Loan duration in months. [TERM]

Monthly Payment-to-Income Ratio: Ratio of mortgage payment including taxes and insurance to mortgagor's monthly effective income. [MP/Y]

Borrower Characteristics

Hispanic: Variable coded 1 if mortgagor is Hispanic; coded 0 otherwise.

Black: Variable coded 1 if mortgagor is Black; coded 0 otherwise.

Years Married: Variable coded number of years mortgagor has been married; coded 0 otherwise.

Not Married: Variable coded 1 if mortgagor is not married; coded 0 otherwise.

Female Head of Household: Variable coded 1 if female is head of household; coded 0 otherwise.

Both Work: Variable coded 1 for husband-wife family with both working; coded 0 otherwise.

Net Effective Income per Person: Ratio of monthly net effective income in dollars to persons in family. [Y/N]

Property Characteristics

Structure: Fair or Poor Condition: Variable equals 1 if FHA appraisal of condition of house is fair or poor; variable coded 0 otherwise.

Wood Construction: Variable coded 1 if exterior finish of house is wood; coded 0 otherwise.

Number of Living Units: Number of housing units in structure (range 1-4)

Oven Only: Variable coded 1 if oven is only kitchen appliance in unit; coded 0 otherwise.

Oven with Other Kitchen Appliance: Variable coded 1 if oven plus 1 or more kitchen appliances are in unit; coded 0 otherwise.

Washer or Dryer: Variable coded 1 if only washer or dryer laundry equipment in unit; coded 0 otherwise.

Washer and Dryer: Variable coded 1 if both washer and dryer laundry equipment are in unit; coded 0 otherwise.

Carpeting: Variable coded 1 if unit is carpeted; coded 0 otherwise.

Central Air Conditioning: Variable is coded 1 if unit is centrally air conditioned; coded 0 otherwise.

Neighborhood Characteristics

Central City: Variable is coded 1 if property is in central city of SMSA; coded 0 otherwise.

Rural: Variable is coded 1 if property is in rural location; coded 0 otherwise.

Blighted: Variable is coded 1 if property is in blighted or code enforcement neighborhood; coded 0 otherwise.

City Characteristics

Fraction of New Single-Family Starts in 1975-1976: Variable equals total number of new private housing unit building permits x percent of single unit structures of the total number of private housing unit building permits divided by number of owner-occupied housing units x 100.

Fraction of Pre-1940 Housing: Number of units in SMSA built before 1940 divided by number of all occupied housing units in 1970.

SMSA Size: SMSA population in 1974 divided by 1000.

City Population Growth (1970-1975): (1975 population – 1970 population) divided by 1970 population.

SMSA Per Capita Income (1975): Total personal nonfarm income by SMSA in 1975 divided by SMSA population in 1974.

Other Variables

Mortgagee Not a Mortgage Banker: Variable coded 1 if mortgage was made by an institution other than a mortgage banker; variable coded 0 otherwise.

Value/Bath Ratio: Ratio of FHA appraised value to number of half and full bathrooms in house.

Value/Room Ratio: Ratio of FHA appraised value to number of rooms in house.

APPENDIX

A SIMPLE MODEL OF THE DEMAND FOR AND SUPPLY OF A SINGLE MORTGAGE LOAN

In this Appendix, we present a simple two-period model of a single mortgage transaction. This entire section draws heavily upon an analysis of the borrower-lender relationship presented in a series of articles by Smith (1971a,b, 1972a,b). These articles demonstrate that the existence of equity generates an externality, so that the competitive equilibrium solution is not Pareto optimal. Smith shows, however, that credit rationing can generate a solution which is Pareto efficient. Smith's approach is used here to analyze the interrelationships among the key variables in a mortgage transaction, including the risk of default.[24] The model is based on expected utility-maximizing behavior by both the individual borrower and the lender.

A. Borrower Behavior

The individual is assumed to maximize the following two-period utility function

$$(1)\quad EU(c_1, c_2) = V(c_1) + EW(c_2),$$

where c_1 and c_2 are consumption in each of the two periods. It is further assumed that both V and W are twice continuously differentiable with positive and diminishing marginal utilities, thus assuring that the individual is subject to risk aversion. Uncertainty is present in this model because an individual purchases a home in the first period with known return but with unknown return in the second period. The known return in the first period $0<r_1<1$ is due to the flow of consumption services produced by the house. In the second period the house yields a return of $-1\leqslant r_2\leqslant\infty$ based upon its second-period price which is unknown at the time of the purchase. This return r_2 depends upon factors such as age of house, condition, size, location, and services in the area. Since most, if not all, home purchases involve a mortgage loan and a downpayment, it is also assumed that the individual borrows an amount L at a rate of interest i and makes a downpayment of E, the equity in the house, at the time of the purchase.[25]

The individual's optimal consumption pattern is also assumed to depend on default. We assume that default occurs when

$$(2)\quad (1+r_2)(E+L) \leqslant (1+i)L.$$

This expression states that an individual will default on a mortgage loan when the total dollar value of a house is less than the total cost of the loan. This equation may be rewritten as

$$(3)\quad \frac{L(1+i)}{(E+L)(1+r_2)} \leqslant 1,$$

[24] It should be pointed out that in an interesting paper, Jackson, Kasserman and Thompson (1979) also rely upon a version of the model developed by Smith. Unlike our paper, however, they concentrate exclusively on the risk of default and default losses.

[25] It is assumed here that the contract rate of interest is a datum. Baltensperger (1976) argues persuasively, however, that one should make the borrower's payment to the lender depend upon both the size and quality of a loan. Since such a change would not affect our basic results, the simpler assumption is retained.

which states that an individual will default when the loan $[L(1+i)]$ to value $[(E+L)(1+r_2)]$ ratio is greater than one.[26]

At the time the mortgage is negotiated, borrowers and lenders know only the expected value of the loan-to-value ratio because the return r_2 is uncertain.[27] However, if the lender and the borrowers know the subjective distribution of r_2, they can estimate the expected value of r_2 and, therefore, the expected loan-to-value ratio. The lender and borrower, however, may have different beliefs about the subjective distribution of r_2. If so, the expected loan-to-value ratios for the lender and borrower will differ. This may explain why borrowers receive a mortgage loan which is less than requested.

Equation (3) may also be rearranged to determine the rate of return which triggers a default. This expression is:

$$(4) \quad r_2^* \leqslant \frac{iL-E}{E+L}$$

The two-period consumption pattern depends upon whether an individual defaults. In the event of default the consumption pattern is

$$(5) \quad c_1 = y_1 - M - E + r_1(E+L)$$

$$(6) \quad c_2 = (1+a)M ,$$

where y_1 is the initial endowment, M is the amount of nonhousing assets, and a is the certain return on those assets. M represents the amount of secure or safe assets held for purposes of diversification.

In the event the individual does not default the consumption pattern is

$$(7) \quad c_1 = y_1 - M - E + r_1(E+L)$$

$$(8) \quad c_2 = (1+a)M + (1+r_2)(E+L) - (1+i)L ,$$

since it is assumed that M is not held as collateral for the mortgage loan.

The individual maximizes expected utility by choosing values of c_1 and c_2 or, after substitution, values for M, E and L that maximize equation (1). The specific maximand is

$$(9) \quad E(U) = V[y_1 - M - E + r_1(E+L)] + \int_{-1}^{r_2^*} W[(1+a)M]\, f(r_2)\, dr_2 + \int_{r_2^*}^{\infty} W[(1+a)M + (1+r_2)(E+L) - (1+i)L]\, f(r_2) dr_2 \ .$$

[26] If an individual attaches some positive costs to a lower credit rating in the event of a default or there is additional collateral on the loan, this equation would have to be accordingly modified. Note also that an individual may acquire more than one asset by borrowing funds. In such a situation, the probability of default on a mortgage loan may not be independent of the risk of default on, say, an automobile loan, especially if the house serves as collateral for the auto loan. Such complications are ignored here.

[27] Of course, information may be acquired and used to reduce the variance of the return. The optimal amount of information will be such that the marginal return from an additional unit of information will equal the marginal cost. This optimization process, however, may be constrained by precluding lenders from collecting and using information relating to race, sex, and age, among other factors. Such government regulations may therefore hinder lenders from using certain types of information, even if it is economically profitable to do so. The correct assessment of risk is thereby made more difficult.

The first-order conditions for a maximum are:

$$(10)\ \frac{\partial E(U)}{\partial M} = -V_{c1} + \int_{-1}^{r_2^*} (1+a)W_{c2}\, f(r_2)dr_2 + \int_{r_2^*}^{\infty} (1+a)W_{c2}\, f(r_2)dr_2 = 0$$

$$(11)\ \frac{\partial E(U)}{\partial E} = -(1-r_1)V_{c1} + \int_{r_2^*}^{\infty} (1+a)W_{c2}\, f(r_2)dr_2 = 0$$

$$(12)\ \frac{\partial E(U)}{\partial L} = r_1 V_{c1} + \int_{r_2^*}^{\infty} [(1+r_2)-(1+i)]W_{c2}\, f(r_2)dr_2 = 0.$$

These are both necessary and sufficient conditions for a maximum since strict concavity was assumed for $V(c_1)$ and $W(c_2)$. The first of these equations states that the marginal rate of time-preference $([V_{c1}/E(W_{c2})]-1)$ equals the return to the safe asset. The second equation is interpreted in a similar manner. The third equation states that the expected marginal utility from a unit of L weighted by its return $[E(r_1 V_{c1}+r_2 W_{c2}]$ should equal the expected marginal utility weighted by its cost $[E(iW_{c2})]$.

Equations (10), (11) and (12) imply the following structural demand equations for M, E and L as well as the following probability of default equation:

$$(13)\ M^D = M^D[y_1, E, L, r_1, i, a, P]$$

$$(14)\ E^D = E^D[y_1, M, L, r_1, i, a, P]$$

$$(15)\ L^D = L^D[y_1, M, E, r_1, i, a, P]$$

$$(16)\ P = P[E, L, i, f(r_2)].$$

These equations indicate the interdependence among M, E, L and P. Clearly, the probability of default depends upon the terms of the loan (E, L and i) and $f(r_2)$, though not directly y_1.[28] As we discuss below, ordinary least squares estimation of equation (16) may suffer from simultaneous equation bias.[29]

B. *Lender Behavior*

The lender's utility is assumed to be linear in profits over the two-period time horizon. As a result, expected utility is maximized whenever expected profits are maximized.[30] When the borrower does not default, profits are:

$$(17)\ \pi_1 = (1+i)L-(1+\lambda)L,$$

where π_1 is profits and λ is the cost of capital. When default occurs, profits are:

$$(18)\ \pi_2 = (1+r_2)(E+L)-(1+\lambda)L.$$

[28] In the empirical work, account must also be taken of the term to maturity on the mortgage loan. This factor is not considered in the simple two-period model presented here.

[29] The probability of default considered here is the ex ante probability. Once a default has occurred, the probability of default becomes an ex post probability. The difference between these two probabilities should be a random error with a mean of zero. The reason is that lenders will presumably form expectations about default risk which are, on average, correct. This means that lenders should not systematically under- or over-estimate default risk.

[30] It is therefore assumed here that the lender is risk neutral.

Total expected profits are therefore:[31]

$$(19)\ E(\pi) = \int_{r_2^*}^{\infty} [(1+i)L-(1+\lambda)L]f(r_2)dr_2 + \int_{-1}^{r_2^*} [(1+r_2)(E+L)-(1+\lambda)L]f(r_2)dr_2 .$$

The firm maximizes this expression with respect to L, obtaining the first-order condition:

$$(20)\ \frac{\partial E(\pi)}{\partial L} = \int_{r_2^*}^{\infty} [(1+i)-(1+\lambda)]f(r)dr + \int_{-1}^{r_2^*} [(1+r_2)-(1+\lambda)]f(r_2)dr_2 = 0.$$

This expression may be rewritten as

$$(21)\ Pr(r>r^*)(1+i) + Pr(r\leqslant r^*)(1+r) = 1+\lambda ,$$

which states that expected profits are maximized by equating expected marginal revenue with expected marginal cost.

It is important to note that expected profits increase as E rises. Therefore, *ceteris paribus*, the greater the downpayment, the greater the firm's expected profits. The firm's supply of L may thus be written as

$$(22)\ L^S = L^S[E, i, \lambda, f(r_2)] .$$

Combining equations (15) and (16) with equation (22), after eliminating M and E through the appropriate substitutions, yields the three-equation system:

$$(23)\ L^S = L^S[y_1, r_1, a, i, \lambda, P]$$

$$(24)\ L^D = L^D[y_1, r_1, i, a, P]$$

$$(25)\ P = P[y_1, r_1, a, L, i, f(r_2)] .$$

Several remarks about these equations are in order. First, since L, i, and P are simultaneously determined, these equations should be estimated by simultaneous equation methods. Second, when the loan is guaranteed, as in the case of FHA insured mortgages, the lender faces no default risk. Profit maximization in this case requires that $i=\lambda$, which implies that the L^S curve is horizontal. In this particular case, it is only equations (24) and (25) that need to be estimated simultaneously. Lastly, if r_2 depends upon neighborhood characteristics, P will also depend on those characteristics, even when L^S is horizontal. That is, P will still vary by neighborhood, even though the lender need not take such variations into account because of mortgage insurance.

[31] It is assumed that defaults result in foreclosures. No distinction is made between these two types of events nor are compliance and penalty costs associated with various government regulations. As regards this latter point, a firm may weigh any returns associated with not complying with a regulation against the expected costs or penalties associated with noncompliance. These particular factors are omitted from the model presented here.

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