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Term Structure, Amortization, and the Demand for Mortgages in Canada

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TERM STRUCTURE, AMORTIZATION, AND THE DEMAND FOR MORTGAGES IN CANADA

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September, 1992

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September 19, 1992

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Abstract

This project is directed at understanding the factors which caused mortgage demand to fluctuate to the degree witnessed in the 1980's. To this end we model the mortgage choice decision as involving options on both the term and the amortization period. Viewing the process in this manner adds a new dimension to the literature, which has effectively limited itself only to the choice of term.

A large and extensive database is used which contains details on the financial and demographic characteristics of households. It spans several years which are characterized by major swings in the housing market. In addition, all of the mortgage applicants have the common characteristic of being credit constrained in the sense of requiring mortgage default insurance. The econometric approach is to use a simultaneous bivariate ordered probit estimator.

The variables considered can influence mortgage choice either directly, or indirectly through the simultaneous nature of the model. In terms of a direct influence, we find that several sets of variables are important: these can be grouped as (a) demographic, (b) financial (c) capital constraints and (d) regional and seasonal. We model demographic influences through age, marital status and household type variables. These variables are significant for both term and amortization choice, in contrast to earlier studies. Financial variables are modelled by interest rate levels, the spread between the short and long rates, and expectations regarding future interest rates. This set of variables are found to significantly influence the term decision. Capital constraints enter through two variables; these are the ratio of debt service payments to income, and the percentage of the purchase price formed by the loan. In contrast to the interest rate variables, capital constraints significantly influence only the amortization choice decision. Finally, regional and seasonal factors are both found to be important. These reflect regionally different attitudes towards risk and differing circumstances surrounding mortgage applicants at different times of the year. The regional differences are important for both decisions while the seasonal factors affect only the term choice decision.

Using these estimates, a sensitivity analysis is undertaken to examine the responsiveness of mortgage choice behaviour to changes in policy variables such as the level of interest rates, and the spread between short and long term rates.

KEY WORDS:

Mortgage; Term structure; Amortization; Bivariate Ordered Probit; Canada

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Executive Summary

Prior to the 1980's the suppliers of mortgage funds (i.e. banks, savings and loan associations) relied mainly on a standard fixed payment mortgage with terms of five years in Canada and as long as thirty years in the U.S. The rising and the more volatile interest rates in the seventies created significant duration risk exposure as the portfolios of financial intermediaries were rendered unbalanced. In an effort to hedge this duration risk, these institutions shifted to mortgage terms ranging from six months to five years. This development has continued unabated. In the early 1980s, interest rates reached unprecedentedly high levels and exhibited high volatility. Concurrently, there were enormous fluctuations in the demand for mortgages of different terms. This presented major challenges for financial institutions, households and government agencies charged with the housing of Canada's population.

This project is directed at understanding the factors which caused mortgage demand to fluctuate to the degree that has been observed. To this end, we model the fundamental mortgage choice problem as a bivariate decision involving options on the term and the amortization period. Viewing the decision process in this manner adds a new dimension over existing studies which effectively considered only the choice of term.

From a data standpoint, this study has at least three distinct advantages over the majority of existing studies. First, we have a very large database comprising over 750,000 observations with extensive details on both financial and demographic characteristics. Second, because the data spans several years involving major swings in the housing markets, we can pool large cross-section sample periods during which there was considerable variability in the economic environment. Third, the choices available in the Canadian mortgage market are more clearly defined than in the U.S. Specifically, the choice between an ARM and a FRM in the U.S. market is considerably more complex than just being a binary decision. In fact, there have existed as many as four hundred types of ARM in the U.S. In contrast, the Canadian Rollover mortgage essentially offers a two-dimensional choice — the length of the amortization period (typically five to thirty years) and the term of the mortgage (typically six months to five years).

From a methodological standpoint, this is the only study of which we are aware that formally models the choice of term and the amortization period simultaneously. The econometric approach involves a simultaneous bivariate ordered probit methodology. In fact, we find that a univariate model of term choice which neglects the joint amortization decision suffers from misspecification.

Finally, the database, which was obtained from the Canada Mortgage and Housing Corporation (CMHC), comprises only mortgage applicants who are capital-constrained and, by statutory requirement, must purchase mortgage insurance. This homogeneity property of our sample is unique in mortgage studies and, given this capital constraint, it is likely that demo-

graphic variables may well influence mortgage choice.

Using the above methodology on a pooled cross-section time series data base, the structural form of the model shows that mortgage choice is determined by both financial and demographic variables. The results are of interest not simply because they reflect the two-dimensional choice faced by borrowers, but also because the existing literature finds no role for non-financial variables. Furthermore, the coefficient estimates are efficient in that we take into account cross-equation correlation, and their magnitude and significance are robust to the estimation methodology.

The empirical findings may be summarized as follows. Demographic influences enter through age, marital status and family type variables – in contrast to Brueckner and Follain(1988) who find no support for age or family variables. Older applicants take shorter terms and longer amortization periods than younger applicants suggesting that income constraints in this class of applicants increase with age. It also appears that either being married and/or having children reflects a certain degree of commitment to the immediate family. This group of borrowers, as would be expected, are more risk averse and take longer term mortgages. In addition, married borrowers apparently wish to see their mortgage paid off more quickly than those who are not married, perhaps reflecting the likelihood of higher potential income.

The financial variables influence the choice of mortgage term in a manner similar to that found in the literature. In particular, higher levels of interest rates reduce the term of the mortgage because borrowers believe that they will return to a lower level in some future time period. A variable depicting the spread between one and five year rates indicates a similar behaviour; the larger the spread the shorter the term. Since the term structure typically has a positive slope, a large spread would imply that long rates are relatively expensive compared to short rates, and thus a negative sign is consistent with expectations that an applicant would move to a short rate.

We also considered the monthly percentage change in the five-year rate designed to capture the role of expectations on choice. We find that if the 5-year rate is expected to rise, borrowers will prefer a longer rate, *ceteris paribus*, in the belief that rates will continue to move in the same direction. We believe this is new finding.

The extent to which the applicant is financially constrained can be determined from the role of the liquidity ratios: gross debt service payments to income and the percentage of the purchase price formed by the loan. These variables are not significant in the term equation when the amortization decision is simultaneously considered. In contrast, each has a strongly significant coefficient in the amortization equation corresponding with theoretical priors: the higher the loan percentage and/or the greater the debt service ratio, the longer the amortization period. Finally, the effect on the income variable is negative indicating that higher incomes enable the borrower to amortize the mortgage over a shorter period. We find no evidence that incomes play a direct significant role in the determination of the term choice.

Other explanatory variables considered are regional and seasonal dummies. We find that

there is significant difference between the regions in Canada with respect to the mortgage choice decision, possibly reflecting cultural differences and attitudes towards risk. The coefficients indicate that fourth quarter mortgage applications are associated with shorter terms than applications at other times of the year. The fact that a much smaller percentage of borrowings are made in the last quarter of the year indicates that the circumstances surrounding such decisions are likely quite different from those in the rest of the year. We find, however, that seasonal variables have no direct effect on amortization.

Using these estimates, we undertake a sensitivity analysis to evaluate the responsiveness of mortgage choice behaviour to changes in policy variables. We find that both the short and long term options, as well as the short amortization period option are highly elastic with respect to both interest rate levels and spread. A policy implication is that changes in such instruments will lead to large fluctuations in both term and amortization choices; indeed, it was the high volatility of mortgage term choice during the 1980s that prompted this study.

In summary, we model the mortgage choice problem faced by Canadian home-buyers who are capital-constrained to the extent that they are required to purchase mortgage insurance at the outset. Our model of mortgage choice involves a simultaneous decision of term and amortization period. Using a simultaneous bivariate ordered estimator on a pooled cross-section time series database, we find the following main results. First, we confirm the existing literature that financial variables are important in this joint decision. However, in contrast to previous studies, we find that demographic, regional and seasonal variables are significant. Even more important is the finding that these variables have differential impacts on the term and amortization decision. Second, inflationary expectations, which to our knowledge has not been examined previously, play a significant role in the choice of term. Finally, a mortgage choice model which neglects the amortization decision suffers from misspecification.

DURÉE DES PRÊTS, PÉRIODE D'AMORTISSEMENT ET DEMANDE DE CRÉDIT HYPOTHÉCAIRE AU CANADA

Résumé

Avant les années 1980, les fournisseurs de crédit hypothécaire (banques, caisses d'épargne et de crédit) se fiaient principalement au prêt hypothécaire ordinaire à paiements égaux assorti de termes de cinq ans (au Canada) ou même de trente ans (aux États-Unis). Au cours des années 1970, la hausse des taux d'intérêt et leur instabilité accrue posèrent un risque considérable relativement à la durée des prêts et entraînèrent un déséquilibre des portefeuilles des intermédiaires financiers. Ces derniers s'efforcèrent alors d'atténuer ce risque et adoptèrent des termes de six mois à cinq ans, lesquels ont encore cours aujourd'hui. Au début des années 1980, les taux d'intérêt ont atteint des niveaux sans précédent et ont fait preuve d'une très grande instabilité. Simultanément, la demande de crédit hypothécaire assorti de différents termes a fluctué considérablement, ce qui a posé des défis de taille aux institutions financières, aux ménages et aux organismes gouvernementaux chargés de procurer un logement aux Canadiens.

L'objet de la présente étude est la compréhension des facteurs qui ont entraîné une telle fluctuation de la demande. À cette fin, nous modélisons le problème essentiel du choix du prêt hypothécaire comme une décision bidimensionnelle portant sur le terme et sur la période d'amortissement. Le fait d'envisager la décision de cette façon ajoute une nouvelle dimension par rapport aux études antérieures, qui considéraient uniquement le choix du terme.

Du point de vue des données, la présente étude comporte au moins trois avantages par rapport à la majorité des études antérieures. Premièrement, nous disposons d'une base de données très importante comprenant plus de 750 000 observations et des détails abondants sur les caractéristiques financières et démographiques. Deuxièmement, puisque les données couvrent plusieurs années durant lesquelles les marchés de l'habitation ont connu des fluctuations importantes, nous sommes en mesure de regrouper des données pour de longues périodes au cours desquelles la situation économique a varié considérablement. Troisièmement, les choix offerts sur le marché hypothécaire canadien sont définis plus clairement qu'aux États-Unis. Dans ce pays, le choix entre le prêt hypothécaire à taux variable et le prêt hypothécaire à taux fixe est beaucoup plus complexe qu'une simple décision binaire. En fait, il y a eu jusqu'à quatre cent catégories de prêts hypothécaires à taux variable aux États-Unis. Au Canada, au contraire, le prêt hypothécaire à taux révisable permet essentiellement un choix bidimensionnel : la durée de la période d'amortissement (habituellement de cinq à trente ans) et le terme du prêt (généralement de six mois à cinq ans).

Du point de vue de la méthodologie, la présente étude est la seule, à notre connaissance, à modéliser formellement le choix du terme et de la période d'amortissement simultanément. L'approche économétrique fait appel à la méthode des probits à équations simultanées avec deux variables. En fait,

nous constatons qu'un modèle à une variable relative (choix du terme) qui ne tient pas compte de la décision conjointe relative à la période d'amortissement comporte une erreur de spécification.

Enfin, la base de données que nous avons obtenue de la Société canadienne d'hypothèques et de logement (SCHL) comprend uniquement les données relatives aux demandeurs de prêts hypothécaires qui ont un capital insuffisant et qui doivent obligatoirement acheter une assurance hypothécaire. L'homogénéité de notre échantillon est donc unique et, compte tenu de cette insuffisance de capital, les variables démographiques peuvent vraisemblablement avoir une incidence sur le choix du prêt hypothécaire.

Si l'on applique la méthode ci-dessus à une base de données transversales et chronologiques, la structure du modèle démontre que le choix du prêt hypothécaire est déterminé à la fois par des variables financières et démographiques. Les résultats sont intéressants non seulement parce qu'ils font ressortir le choix bidimensionnel des emprunteurs, mais également parce que la documentation existante nie l'influence des variables non financières. De plus, les estimations des coefficients sont efficaces dans la mesure où nous tenons compte de la corrélation entre les deux équations et elles ont une importance et une signification considérables pour la méthode de l'estimation.

Les constatations empiriques peuvent se résumer comme suit. L'âge, l'état civil et le type de famille constituent des variables démographiques tandis que Brueckner et Follain (1988) considèrent que l'âge ou la famille n'ont aucune incidence. Les demandeurs de prêts plus âgés choisissent des termes plus courts et des périodes d'amortissement plus longues que les jeunes demandeurs, ce qui laisse supposer que les restrictions sur le plan du revenu s'intensifient avec l'âge. Il semble également que le fait d'être marié ou d'avoir des enfants se traduise par un certain degré d'engagement vis-à-vis de la famille immédiate. Comme on pourrait s'y attendre, ce groupe d'emprunteurs redoute davantage les risques et choisit des prêts hypothécaires assortis de termes plus longs. En outre, les emprunteurs mariés désirent apparemment rembourser leur prêt hypothécaire plus rapidement que les célibataires, ce qui dénote peut-être la probabilité d'un revenu éventuel supérieur.

Les variables financières ont une incidence sur le choix du terme du prêt comme l'indiquent les ouvrages consultés. En particulier, la hausse des taux d'intérêt pousse les emprunteurs à choisir un terme plus court parce qu'ils pensent que les taux vont baisser à un moment donné. Une variable représentant le ratio entre les taux des prêts de un an et de cinq ans révèle un comportement semblable : plus le ratio est grand, plus on choisit un terme court. Comme la relation entre les taux à court terme et les taux à long terme est habituellement représentée par une pente positive, un ratio élevé signifie que les taux à long terme sont relativement dispendieux comparativement aux taux à court terme et, par conséquent, la relation inverse entre les deux variables est consistante avec l'a priori selon lequel un demandeur choisirait un prêt à court terme.

Nous avons également examiné le pourcentage de variation mensuel du taux des prêts de cinq ans pour découvrir le rôle des prévisions sur le choix du terme. Nous constatons que, si les emprunteurs s'attendent à une hausse du

taux des prêts de cinq ans, ils vont opter pour un terme plus long, toutes choses étant égales par ailleurs, parce qu'ils croient que les taux vont continuer à évoluer dans la même direction. Nous pensons qu'il s'agit là d'une nouvelle constatation.

L'importance des contraintes financières auxquelles le demandeur doit faire face peut être déterminée par les coefficients de liquidités, c'est-à-dire le rapport entre les mensualités servant à l'amortissement brut de la dette et le revenu ainsi que le pourcentage du prix d'achat servant à fixer le montant du prêt. Il ne s'agit pas de variables significatives en ce qui concerne l'équation relative au terme lorsque l'on examine simultanément la décision touchant la période d'amortissement. Par contre, chacune de ces variables a un coefficient fortement significatif dans l'équation relative à l'amortissement qui correspond à des a priori théoriques : plus le pourcentage du prêt est élevé ou plus le coefficient d'amortissement de la dette est important, plus la période d'amortissement est longue. Enfin, l'incidence sur la variable revenu est négative, ce qui signifie qu'un revenu supérieur permet à l'emprunteur d'amortir le prêt sur une période plus courte. Nous n'avons aucune preuve que le revenu joue un rôle direct et significatif sur le choix du terme.

Les autres variables explicatives examinées sont les variables binaires régionales et saisonnières. Nous constatons une différence considérable entre les régions du Canada en ce qui a trait au choix du prêt hypothécaire, ce qui dénote probablement une différence de culture et d'attitude en ce qui concerne le risque. Les coefficients révèlent que les demandes de prêt hypothécaire présentées au cours du quatrième trimestre de l'année sont assorties de termes plus courts que celles qui sont faites à d'autres moments de l'année. Le fait que le pourcentage des emprunts contractés durant le quatrième trimestre de l'année soit beaucoup plus faible révèle que le contexte dans lequel les emprunteurs prennent leurs décisions est probablement très différent de celui qui a cours pendant le reste de l'année. Toutefois, nous constatons que les variables saisonnières n'ont aucun effet direct sur le choix de la période d'amortissement.

À l'aide de ces estimations, nous effectuons une analyse de sensibilité afin d'examiner le comportement des emprunteurs en ce qui a trait au choix du prêt hypothécaire en fonction des variations des variables de politique. Nous constatons que le choix de prêts à court et à long terme ainsi que le choix de périodes d'amortissement courtes sont très élastiques en ce qui concerne à la fois le taux d'intérêt et le ratio entre les taux. Une conséquence sur le plan de la politique est que les modifications apportées à de tels instruments entraîneront de fortes variations quant au choix du terme et de la période d'amortissement. Bien entendu, c'est la très grande inconstance dans le choix du terme des prêts hypothécaires au cours des années 1980 qui est à l'origine de la présente étude.

En résumé, nous modélisons le choix du prêt hypothécaire auquel doivent faire face les acheteurs canadiens qui ne disposent pas d'un capital suffisant et qui doivent acheter une assurance hypothécaire. Notre modèle est établi en fonction d'une décision simultanée quant au terme et à la période d'amortissement. En appliquant un estimateur pour équations simultanées à deux

variables à une base de données transversales et chronologiques, nous obtenons les principales constatations suivantes. Premièrement, notre étude confirme les conclusions de la documentation existante, soit l'importance des variables financières dans la décision conjointe. Cependant, contrairement aux études antérieures, nous constatons que les variables démographiques, régionales et saisonnières sont significatives et, ce qui est encore plus important, c'est que ces variables ont une incidence différente sur la décision concernant le terme et la période d'amortissement. Deuxièmement, les prévisions inflationnistes qui, à notre connaissance, n'ont pas fait l'objet d'études antérieures, jouent un rôle considérable dans le choix du terme. Troisièmement, un modèle de choix hypothécaire qui ne tient pas compte de la décision concernant la période d'amortissement comporte une erreur de spécification.

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Term Structure, Amortization, and the Demand for Mortgages in Canada

1 Introduction

The mortgage choice problem is usually viewed as involving two, not necessarily independent decisions. The first relates to the type of mortgage to assume – this includes choices on term, amortization, and fixed or adjustable rates. The second, the termination decision, involves the option to prepay or default or maintain the status-quo. This paper examines only the first decision – the mortgage assumption decision on the part of Canadian home-buyers who are required to purchase insurance at the outset. The following general question is addressed.

> *How do demographic and economic factors influence mortgage behaviour? In particular, how do these factors determine the choice of both term and amortization period?*

Thus the objective of this research is to examine mortgage demand behaviour in Canada in the recent past. The enormous volatility in the demand for mortgages of different terms witnessed in the last decade poses major challenges to all participants in the mortgage market: financial institutions, households, and government agencies charged with the housing of Canada's population. This project is directed at understanding the factors which cause mortgage demand to fluctuate to the degree that we have witnessed. This is achieved by estimating a multivariate model of term structure and amortization choice, using a large data-base supplied to us by the Canada Mortgage and Housing Corporation. As a result of improving our understanding of this market, the costs and risks which are borne by the funding agencies may be reduced substantially.

Prior to the 1980s the suppliers of mortgage funds (Banks, Saving and Loan Associations etc.) relied heavily on a standard fixed-payment mortgage with terms of 5 years in Canada or as long as 30 years in the U.S. The rising and more volatile interest rates of the sixties and seventies posed problems for institutions with portfolios which were highly unbalanced from the standpoint of the terms of their assets and liabilities. This was particularly true in the U.S. Had these institutions issued more variable-rate (or even shorter term) loans during this period, loan and deposit rates would have moved in tandem to a greater extent and fewer problems would have emerged.

The eighties thus saw financial intermediaries attempt to extricate themselves from the heavy interest rate risk which they had incurred in the seventies by shifting to shorter term mortgages. In Canada these took the form of fixed-rate six month to five years terms while in the U.S. they took the form of adjustable rate mortgages (ARMs). The most important benefit of this development for the intermediary is the shift in interest rate risk to the borrower. Of course this shift can only be achieved at the cost of taking on more default risk. Because, if

rates rise, borrowers who are faced with sharp mortgage payment increases are more likely to default than those on fixed-rate mortgages

Some of the characteristics of short term mortgages which make them attractive to lenders make them unattractive to borrowers. Thus, for short term mortgages (or ARMs), lenders must provide compensating advantages to induce borrowers to take them on. The first such characteristic is that they typically bear lower average interest payments over the life of the mortgage. Second, they may be attractive to borrowers whose incomes are related to interest rate levels (though this is probably a rather small proportion of borrowers); this point is discussed in Peek (1990). Third, the fact that short term mortgages typically have lower rates means that households may be able to purchase a house earlier in their life-cycle, or purchase a larger house which would be more in line with their longer term needs, than if they were forced to pay the higher rate on long term mortgages, (or FRMs).

From a data standpoint, this study approaches this question with three distinct advantages over the majority of existing studies. First, we have a very large data base comprising over 750,000 observations with extensive details on both financial and demographic characteristics. Second, because the data spans several years involving major swings in the housing markets, we can pool large cross-section samples periods during which there was considerable variability in the economic environment. And third, the choices available in the Canadian mortgage market are more clearly defined than in the U.S. Specifically, the choice between an ARM and a FRM in the U.S. marketplace is considerably more complex than this binary decision would seem to indicate. For example, Peek (1990) has pointed out that there have existed as many as four hundred different types of ARM in the U.S. market This proliferation occurs because there are different frequencies with which interest rates are adjusted, different caps on interest rates, different limits on the extension of amortization periods when the cap has been reached etc. In contrast, the Canadian Rollover mortgage essentially offers a two dimensional choice — the length of the amortization period (typically five to thirty years) and the term of the mortgage (typically six months to five years). This occurs because the mortgage market in Canada is much less segmented than in the U.S., in the sense that nationwide institutions control a high percentage of mortgage loans and, as a result, variations in the design of the mortgage instrument are minimal.

From a methodological standpoint, this is the only study of which we are aware that formally models the choice of term and the amortization period simultaneously. The econometric technique involves a bivariate ordered probit estimator while accounting for the simultaneity. We find that a univariate model of term choice which neglects the joint amortization decision suffers from misspecification. We also find that, in contrast to earlier studies, demographic, seasonal and regional variables are statistically significant. In addition, an apparently new result is that inflationary expectations play a significant role in the joint choice.

The remaining of the paper is organized as follows. In Section 2, we present a literature review followed by an exposition of an econometric model of mortgage choice in Section 3. In Section 4, we describe, in detail, the data base used as well as summary statistics. We also present, in brief, the main responsibilities of the Canada Mortgage and Housing Corporation

(CMHC), and we conclude this section by defining the variables used in the estimation. The empirical findings are presented and discussed in Section 5. Concluding remarks are given in Section 6.

2 Review of the Literature

The literature on mortgage choice has focused on two main aspects of the decision process.[1] The first, and more well-developed, deals with the mortgage termination experience. In this case, the household faces a decision which involves the concurrent choice of default or prepayment. The second part of the mortgage choice literature is concerned with the mortgage origination experience. Essentially, the borrower must choose, at the outset, between a fixed rate mortgage (FRM) or an adjustable rate mortgage (ARM). We now examine the main aspects of the mortgage origination choice problem while observing that the review of the relevant literature has described mostly the U.S. experience.[2]

The mortgage choice problem is primarily concerned with the goal of identifying the household attributes and market variables that are important determinants of the probability that a borrower will choose an ARM over a FRM. The theoretical studies on mortgage choice include Alm and Follain (1987), Baesel and Biger (1980), Brueckner (1986), Edelstein and Guttentag (1982) and Statman (1982).

Baesel and Biger (1980) view an ARM as a loan plus a hedge against inflation. As such they hypothesize that mortgage choice is mostly affected by the correlation between the borrower's expected future income stream and inflation. If this correlation is positive and high, then an ARM should be chosen since increased housing costs would be offset by increase earnings.

Using a probit model, Dhillon *et. al.* (1987) examined the mortgage application records provided by a Lousiana bank so as to delineate the relationship between borrower characteristics and mortgage preferences. They found, contrary to Baesel and Biger, that the relationship was not significant. Similarly, Breuckner and Follain (1988), considered a sample of 475 real estate transactions in 1985 yielding 316 FRMs and 159 ARMs. The data was drawn from the Residential Mortgage Finance Database compiled by the National Association of Realtors from three national surveys. They also found that borrower attributes were not significant in the mortgage decision although there is a tendency for mobile borrowers to choose ARMs. This is quite interesting since Dunn and McConnell (1983) and Quigley (1987) have found that mobility may account for a minimum level of prepayment. This is because most conventional mortgages

[1] Follain(1990) defined mortgage choice as involving a set of problems faced by a home-owner that includes the choice of LTV ratio, the refinancing and default decision and the choice of mortgage instrument. These choices are obviously not independent.

[2] Several recent studies have dealt with the default-prepayment choice problem. These include Sa-Aadu(1988), Vandell and Thibodeau (1985), Lea and Zorn (1986), and Cunningham and Capone Jr. (1990). In general, the empirical literature on mortgage termination experience has found the following main result: current equity dominates the default decision while mortgage and property variables dominate the prepayment decision. As well ARMs have greater default risk than FRMs, while ARMs have lower prepayment probabilities.

are not assumable, forcing home-owners to prepay loans if they move. This could occur in the presence of constant interest rates.

Alm and Follain (1987), and Brueckner (1986) proposed that the borrower's degree of risk aversion, his/her discount rate of future consumption and the intensity of demand are important determinants of the mortgage choice. For example, a borrower with low risk aversion and a high discount rate will likely choose an ARM. On the other hand a high demander of housing will probably be sensitive to interest rate risk and probably choose a FRM.

Brueckner and Follain (1988) tested this proposition by using a proxy FAMILY for the combined effects of the three borrower characteristics stated above. FAMILY is a dummy variable indicating the presence of children in the household. Based on the above considerations, it is expected that FAMILY will have a negative on ARM choice probability. The empirical results show that the effect was statistically insignificant.

The studies by Alm and Follain (1987), as well as by Brueckner (1986), also proposed a role for the level and variability of income streams on the mortgage choice. The Brueckner model concludes that borrowers with rapidly rising income streams would probably choose ARMs, while an increase in the level of the income stream reduces the probability of selecting an ARM.

Brueckner and Follain (1988) used AGE of the borrower as a proxy for the rate of increase of income. The assumption made here is that young borrowers are more likely to experience rapid increases in their incomes than borrowers with more job tenure. The variable to capture income levels is generated from interval data in the original sample. The results are that FAMILY is insignificant, and the income variable, while marginally significant, is of the wrong sign.

It is clear to this point that borrower attributes appear not to affect the household mortgage decision. However, in a recent paper, Tucker (1991) proposed that mortgage choice is sensitive to the borrower discount rate and holding period. Using a simulation model, he demonstrated that, based on the maximization of the present value of cost advantages, borrowers with a holding period of less than or equal to 6 years should choose ARMs irrespective of their discount rates. After 6 years and for low discount rates, FRMs dominate. For holding periods less than 11 years, lower discount rates produced the most favourable ARM comparison and for holding periods greater than 11 years, higher discount rates produced higher ARM benefits. Clearly, Tucker has found in favour of borrower preferences and the interaction of the individual discount rate and holding period affects the choice between ARMs and FRMs.

Another hypothesis stated by Alm and Follain (1987) relates to the role of market variables in the mortgage decision. The greater the FRM-ARM interest rate spread, the higher the probability of choosing ARMs. But if investors expect that ARM rates will rise, then ARM demand may be reduced. The general finding in all related empirical studies is that this hypothesis is confirmed. Brueckner and Follain found that high FRM-ARM spreads have a significant positive impact on ARM demand. As well, for a given spread, the higher the FRM rate, the higher the ARM demand. Tucker found similar results:

"A narrowing of the spread between fully indexed ARMs and FRMs as well as the initial rates offered under ARMs and FRMs make a FRM preferable for all but the shortest holding periods."

Thus the general conclusion from the literature regarding mortgage choice is that market variables dominate. The FRM-ARM spread and the level of the FRM rate are the main determinants of the mortgage choice between ARM or FRM.

The review of the literature on the borrower decision regarding mortgage termination and mortgage origination is, with the exception of Lea and Zorn (1986), a record of the U.S. experience. Given that the Lea and Zorn study dealt with mortgage termination, the literature on mortgage choice between ARMs and FRMs has been conspicuous by the absence of any Canadian study.

One of the main reasons for this deficiency in the literature is probably the fact that in Canada, there is no counterpart of the American fixed rate mortgage. Rather, mortgages are rolled over fixed adjustment periods. Essentially the rollover mortgage is an instrument whose interest rate adjusts every six months to five years. At the time of adjustment (rollover), the mortgage contract rate is set to the current market rate, at which time it is fixed for another period. In this sense, all conventional mortgages are ARMs, with adjustment rates normally ranging from 6 months to 5 years.

There are three main differences between the Canadian and U.S. mortgage markets that are relevant for a study of mortgage choice. First, Canadian home-owners cannot deduct mortgage interest when computing their taxable income. Clearly this would encourage lower loan-to-value ratios and more partial prepayments than in the U.S. Second, Canadian lenders discourage prepayments, within the adjustment period, of more than 10% of outstanding balances by imposing a penalty equal to three times the monthly mortgage payment. The final difference is that U.S. borrowers can choose between FRMs and ARMs, while in Canada FRMs are virtually unavailable.

This poses a different choice problem from that usually considered in the literature. In the U.S. the choice is normally between an ARM and its fixed rate counterpart. For Canada, the decision involves the concurrent selection of the adjustment period(and therefore the frequency of rate adjustment) and the borrower's amortization period.

3 An Econometric Model of Mortgage Choice

The basic model presupposes that the term structure decision and the amortization length decision are made simultaneously by the applicant at the signing of the mortgage. This decision process can be viewed as the outcome of utility maximization by the individual, subject to income, interest rates and risk preference, all of which are considered exogenous. Thus these decisions will be determined by the exogenous variables of the system, which include both economic and risk preference variables.

Neither of the two endogenous variables – the term structure and the amortization length – is continuous. For the term decision, the applicant chooses the number of years from the set of integers between one and five, with 90% choosing 1, 3 or 5. An approach to modeling this is to assume a latent, unobserved variable – desired term, and a categorical observed indicator – the term selected. In the present context, since relatively few applicants chose 2 or 4 year terms, an effective approach is to consider three categories – short (one year), medium (2 to 4 years), and long (5 years). Similarly, although the amortization period chosen at the time of mortgage can be continuous between 1 year and the maximum permitted by the lending institution (typically 40 years), we again observe that applicants limit their choices: 96% choose either a 15, 20, or 25 year amortization period. It would seem that many institutions suggest only a very limited number of amortization categories to mortgage applicants. Thus we again assume a latent, unobserved variable – desired amortization period, along with a categorical observed indicator – the amortization period selected. Two categories are considered – short (less than 25 years), and long (25 years or longer).

If the task involved the only a single latent variable, then the problem to be considered would be the efficient estimation of the (kx1) vector of β coefficients in the k variable stochastic single equation regression model:

$$y^* = X\beta + \epsilon \tag{1}$$

where y^* is an (nx1) vector of a latent dependent variable, X is an (nxk) matrix of independent variables, and ϵ is an (nx1) vector of disturbance terms. y^* is not observed; rather we observe a categorical indicator y. For the amortization problem, only two alternatives exist, and the estimation procedure would be standard probit. For the term period case, which is a trichotemous situation, the corresponding y_j^* has an ordered categorical representation, y_j, if there is a set of thresholds or delineation points, α_j such that:

$$y = \begin{array}{lll} 1 & \text{if} & y^* < \alpha_1 \\ 2 & \text{if} & \alpha_1 \leq y^* < \alpha_2 \\ 3 & \text{if} & \alpha_2 \leq y^* \end{array} \tag{2}$$

The ordered probit (and logit) models have been widely used for analyzing ordered categorical response data. If ϵ is assumed normally distributed across observations; $\epsilon_i \rightarrow N(0, \sigma_\epsilon^2)$

and letting Φ be the cumulative normal density function, we have:

$$\begin{aligned} \Pr(y=1) &= \Phi(\alpha_1 - \beta'\mathbf{x}) \\ \Pr(y=2) &= \Phi(\alpha_2 - \beta'\mathbf{x}) - \Phi(\alpha_1 - \beta'\mathbf{x}) \\ \Pr(y=3) &= 1 - \Phi(\alpha_2 - \beta'\mathbf{x}) \end{aligned} \tag{3}$$

The likelihood follows directly, and the β can be estimated using standard maximum likelihood techniques.

Since we have two, jointly selected latent variables, a system wide approach is appropriate. The simultaneous equation system for two latent endogenous variables can be expressed as:

$$y_1^* = X_1\beta_1 + \gamma_1 y_2^* + \epsilon_1 \tag{4}$$

$$y_2^* = X_2\beta_2 + \gamma_2 y_1^* + \epsilon_2 \tag{5}$$

where X_1 and X_2 are matrices of exogenous variables, y_1^* and y_2^* are unobserved latent variables, and ϵ_1 and ϵ_2 are disturbance terms that are multivariate normally distributed, $\{\epsilon_1, \epsilon_2\} \rightarrow N(0, \Omega)$. $\{y_1^*, y_2^*\}$ are not observed; rather we observe categorical indicators $\{y_1, y_2\}$. X_1 and X_2 are not necessarily distinct. As in the standard probit model, the coefficients in this model can only be estimated proportional to the variance of the disturbance, and we follow the practice of specifying unit variances. Thus

$$\Omega = \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}$$

If $\{\epsilon_1, \epsilon_2\}$ are independent, $\rho = 0$. Conversely, if the disturbance terms involve excluded variables that are important in the choice decision, and the such variables are significant for both choice decisions, then it is likely that the correlation may be substantial.

This type of model is discussed at length in Maddala (1983) for the censored, truncated and binary cases. Mallar (1977) considered this model for the case when $\{y_1, y_2\}$ were both dichotomous. Using a two stage approach, Mallar estimated each of the reduced forms using a probit methodology. The second stage involves the substitution of the predicted values of $\{y_1^*, y_2^*\}$ back into the structural equations, and estimating each structural equation, again using the probit methodology. Given the correct structural form, the parameters estimated by this two stage method are consistent. They will not in general be maximum likelihood, and in any case the parameter covariance matrix derived from the second stage will be biased, since the predicted values are used on the RHS, and not the true value of the latent variable. Amemiya(1978) has derived the correct covariance matrix for the dichotomous case, but this still does not account for the correlation between ϵ_1 and ϵ_2, and in the present context, this correlation may be significant. Consequently, although we will demonstrate the two stage process, it is clear that a maximum likelihood (ML) estimation procedure would be desirable.

The reduced form of equations (4) and (5) is:

$$y_1^* = \frac{1}{1-\gamma_1\gamma_2}[X_1\beta_1 + \gamma_1(X_2\beta_2)] + \frac{\epsilon_1 + \gamma_1\epsilon_2}{1-\gamma_1\gamma_2}$$

$$
\begin{aligned}
&= X_1\pi_{11} + X_2\pi_{12} + \mu_1 \\
&= X\pi_1 + \mu_1 \qquad (6)
\end{aligned}
$$

$$
\begin{aligned}
y_2^* &= \frac{1}{1-\gamma_1\gamma_2}[\gamma_2(X_1\beta_1) + (X_2\beta_2)] + \frac{\gamma_2\epsilon_1 + \epsilon_2}{1-\gamma_1\gamma_2} \\
&= X_1\pi_{21} + X_2\pi_{22} + \mu_2 \\
&= X\pi_2 + \mu_2 \qquad (7)
\end{aligned}
$$

and $\{\mu_1, \mu_2\} \rightarrow N(0, \Omega^*)$ where:

$$
\begin{aligned}
\Omega^* &= \frac{1}{(1-\gamma_1\gamma_2)^2}\begin{bmatrix} 1+2\rho\gamma_1+\gamma_1^2 & \gamma_1+\gamma_2+\rho(1+\gamma_1\gamma_2) \\ \gamma_1+\gamma_2+\rho(1+\gamma_1\gamma_2) & 1+2\rho\gamma_2+\gamma_2^2 \end{bmatrix} \\
&= \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}
\end{aligned}
$$

Thus maximum likelihood estimates of the structural parameters can be derived by estimating equations (6) and (7) using a bivariate ordered probit methodology. Let $\{\alpha_1, \alpha_2\}$ be a set of delineation points for each latent variable. Then:

$$
\begin{aligned}
\Pr\{y_1^* = i,\ y_2^* = j\} &= \Pr\{\alpha_{1\,i-1} < y_1^* \le \alpha_{1i},\ \alpha_{2\,j-1} < y_2^* \le \alpha_{2j}\} \\
&= \Pr\{\alpha_{1\,i-1} - \pi_1'x < v_1 \le \alpha_{1i} - \pi_1'x,\ \alpha_{2\,j-1} - \pi_2'x < v_2 \le \alpha_{2j} - \pi_2'x\} \\
&= \int_{\alpha_{1\,i-1}-\pi_1'x}^{\alpha_{1i}-\pi_1'x}\int_{\alpha_{2\,j-1}-\pi_2'x}^{\alpha_{2j}-\pi_2'x} \phi(s_1, s_2, \Omega^*)ds_1\, ds_2
\end{aligned}
$$

where ϕ is the bivariate normal density function.

The following estimation strategy is used. First each of the reduced form equations is estimated using the probit or ordered probit methodology. Based on these reduced form specifications, the probability for each applicant of selecting each of the categories for term and amortization is evaluated. These predicted values are then substituted for the explanatory latent variables in the structural equation, and the structural equations are estimated, again using probit or ordered probit methodology. These are the two stage results. We examine the robustness of these two stage coefficients by alternatively estimating each of the structural forms using a semiparametric methodology.[3] Finally, the system of equations (6 & 7), expressed in terms of the structural coefficients, is estimated jointly as a bivariate ordered probit.

[3] A discussion of this methodology is given in Appendix 3.

4 Institutions, Data and Variables

4.1 Institutions and Characteristics of Insured Mortgages

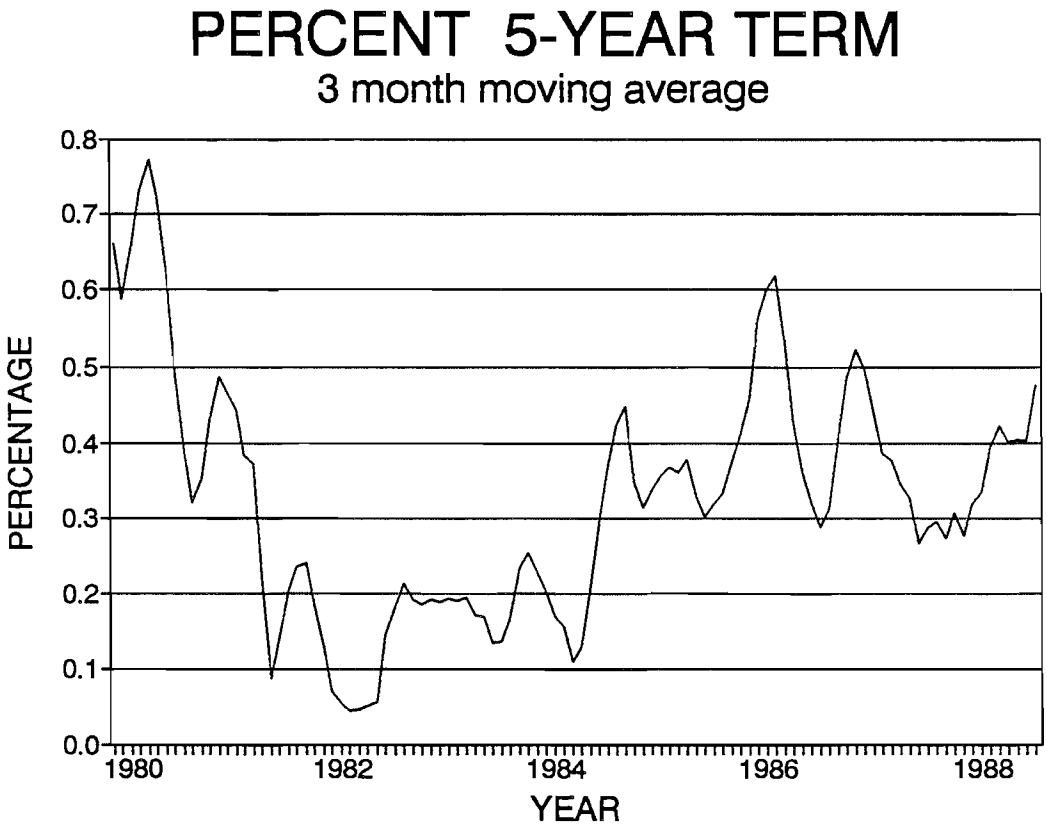
One of the major institutions in the Canadian housing market is the Canada Mortgage and Housing Corporation (CMHC). This Crown corporation was created in 1946 with responsibility for administering the National Housing Act (NHA). In 1944, the NHA embodied a number of programs, including joint federal-private mortgage lending, federal guarantees of home improvement loans, and low interest loans for low-cost limited-dividend housing. Subsequently, the NHA of 1954 essentially made the CMHC into a mortgage insurer. The availability of NHA insurance broadened the sources of funds to life insurance companies, trusts, mortgage loan companies, chartered banks and credit unions. Later still, in 1969, the NHA was changed to allow insurance of mortgages with a term of five years. Subsequently, terms were permitted from six months to five years.

Currently, almost all mortgages insured under the NHA originate from approved financial intermediaries. Under the NHA, the minimum equity required is, as a general rule, 10% of the value of the property. By law, any borrower requiring a mortgage on more than 75% of the total cost must be insured. CMHC currently insures about 20% of all residential mortgages, and this proportion has been relatively stable over the last five years. An average of about 80% of all NHA-insured mortgages originate in Quebec and Ontario, and a typical successful applicant is a family with two children and a total annual income of $52,000.

The characteristics of NHA loans has changed over time. In 1976, 96.4% of all families borrowing under NHA earned less than $35,000. However, this percentage declined steadily to only 12.6% in 1990. In fact, the family income distribution for NHA borrowers in 1990 is relatively uniform across all income classes. In 1980, no NHA loan exceeded $100,000, with 64% below $60,000. In 1990, the distribution was more disperse but relatively uniform with 37.1% of all loans over $100,000. The average loan amount in 1980 was $52,930 while by 1990 this figure had increased to $97,919. The ratio of Gross Debt Service to Income (GDS) is normally less than 35%. In 1980, 31.6% of all NHA-loans issued had GDS ratios over 27%, while by 1990, the proportion of all such loans was 43%.

The initial term of NHA loans has also been quite variable; indeed it is this variability that first motivated this study. In 1982, the proportion of loans with a term of one year was 30.5%. This fraction was relatively stable over the ensuing years until 1989 when it fell to 21% and rose to 36.5% in 1990. The three-year term was quite stable since 1986 at a value of about 23%. The longer five-year term, which is displayed in Figure 1, was quite volatile, ranging from a high of 71.7% in 1980 to a low of 12.4% in 1982. In contrast, the amortization lengths were evidently more stable. For example, for each of the years from 1987 to 1990, 20% of all loans had periods of less than 24 years.

Figure 1.


PERCENT 5-YEAR TERM
3 month moving average
PERCENTAGE
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1980
1982
1984
1986
1988
YEAR

4.2 Data description

The data base provided by the CMHC contains information on all mortgages for which the mortgage granting financial institution required NHA insurance. Thus considerable information is available on both financial and demographic characteristics of the applicant.[4] Once a mortgage loan has been approved, the loan remains insured for the life of the loan. Thus all transactions described in this data base represent new loans.

Although data is available from 1967 on, the CMHC did not start to insure mortgages with a term of less than five years until late 1979, and thus the analysis was restricted to post 1980 transactions. The data for 1980 to 1988 inclusive provides enough variability for model development and validation, since the period encompasses both the recession of the early eighties with the associated high interest rates, as well as the boom years of the middle eighties. A summary is shown in Table 1.

TABLE 1

Summary description of the CMHC data base.

Date	Frequency	Percent	Province	Frequency	Percent
$\leq$ 1979	6088	0.8	NFD	13469	1.7
1980	47223	6.0	PEI	2747	0.3
1981	33583	4.3	NS	18362	2.3
1982	44176	5.6	NB	17008	2.2
1983	111317	14.2	QUE	199417	25.4
1984	110568	14.1	ONT	269915	34.4
1985	114174	14.5	MAN	34105	4.3
1986	101770	13.0	SAS	37549	4.8
1987	106229	13.5	ALB	93992	12.0
1988	110312	14.0	BC	95185	12.1
			YUK	1626	0.2
			NWT	2044	0.3

The regional breakdown is roughly proportional to population size, and thus the data fairly represent the Canadian profile. However, it is clear that the distribution by application date is skewed. While only a subset of applications were encoded in the data base prior to 1980, thereafter the data base reflects 100% of all applications. Thus the low values for 1980–1983 reflect the impact of high interest rates that prevailed during this period on new mortgage applications. Since this analysis is concerned with mortgage behaviour conditional on a mortgage application having been made, it would be incorrect to permit this selectivity constraint to

[4] A copy of the CMHC questionnaire "Request – Undertaking to Insure" form is provided in Appendix 1.

influence sample design. Consequently, a random sample of 1000 observations per year was selected resulting in a sample set of 9000 observations. Thus this corresponds to an approximate 1% sample for a typical year, and proportionally more for the earlier years. The majority of these were for single dwellings (89%), and for existing dwellings (80%).

We imposed two restrictions on this sample. First, we restricted the analysis to the ten provinces, since economic conditions in the Yukon and North West Territories are not typical of Canada. And second, we restricted the sample to applicants who selected terms of one to five years inclusive – 99.75% of the sample fell in this group.[5] These restrictions, combined with list-wise deletion of observations containing missing values or obvious coding errors for variables of interest, resulted in a usable sample of 8156 observations. This is typically an order of magnitude greater than the database size used in the majority of previous studies that have analyzed mortgage choice behaviour.

The various choices open to the applicant, consisting of mortgages of differing term and amortization periods, can be viewed as classic examples of substitutes. Economic theory suggests that in such a case, the demand for any particular good will depend not only on its own "price", but also on the price of substitutes. The only price recorded in the CMHC data base is the interest rate actually charged on the mortgage chosen. The price of substitutes – mortgages of different term – requires additional information beyond that recorded. These additional economic variables were obtained from the CANSIM data base, and appended to the CMHC data base; details of these variables are described below.

4.3 Definition of Variables

The following variables were used in this analysis; a summary of mnemonics used are given in Appendix 2.

(a) Endogenous Variables

Term 99.75% of the sample have a term of five years or less, with a mean term of just over 3 years. The majority of observations are concentrated at one year (28.8%), three years (26.7%), and five years (33.8%). The distribution of the term of the mortgage is given in Figure 2. Since relatively few applicants chose two or four year terms, (7.3% and 2.5% respectively), three categories were established for term structure - 1 year, 2 to 4 years, and 5 years.

Amortization The mean amortization period is 22.8 years, with the majority of observations occurring for the 10, 15, 20 and 25 year periods. The distribution of the

[5]Six month mortgages were not generally available during this period. The vast majority of financial institutions only offered the integer choice of one to five years, and other term options outside of this set were exceptional.

amortization period for the sample is given in Figure 3. Since these are typically new mortgage applications, the amortization period is that set at the beginning of the loan. Two categories were established for amortization – less than 25 years (31.6%), and 25 years or more (68.4%).

(b) Explanatory Characteristic Variables

Age The mean age of borrowers is 33 years, ranging from 15 to 76 years. The distribution of age over the sample is given in Figure 4. In the present context, one would expect risk aversion to be positively related to age. Age is specified by six categorical dummies to capture the expected nonlinearities associated with it; the reference being less than 30 years.

Married 67% of the sample are married. Typically, one would expect risk aversion to be positively correlated with marriage.

Nuclear A nuclear family is defined as one in which the applicant is married and/or has children, but in which there is no other dependent. 73% of the sample falls in this category. 48% of the sample have children, and of these families, 96% have three or fewer children. Only 2.2% of applicants had other (non-spouse) dependents.

Debt Service The gross debt service to income ratio is calculated directly by the CMHC; it shows the total annual shelter payment, including heating costs, as a percentage of family income. The mean value is 23%. Generally, the CMHC restricts applicants to a maximum of 35% of family income for gross debt services. An applicant whose GDS ratio is too high can reduce it by choosing either a longer amortization, and/or a shorter term. The natural logarithm of gross debt service is used in this analysis.

Percent Loan This variable is coded as the ratio of the NHA loan to the total cost of the property, including secondary financing and borrower's equity. The mean value is 84%. A high value for percent loan may imply significant financial constraints.

Real Income Mean real family income is evaluated by deflating nominal family income by CPI (1981 = 100). The mean value in 1981 dollars is $29,900. The natural logarithm of real family income is used in this analysis.

Region The distribution of applicants by region is given in Figure 5. Regional differences in mortgage behaviour are permitted by the use of regional dummies. Five regions were specified - Atlantic Provinces, Quebec, Ontario, Prairies, and British Colombia; the Atlantic Provinces were specified as the reference category.

Season The distribution of applications by season is given in Figure 6. The majority of mortgages are arranged in the first 9 months of the year - only 15% of all transactions occur in the last three months.

(c) Explanatory Generic Variables[6]

Expectations It would be expected that one of the determinants of the term structure decision is the expectation of future interest rates. If rates are rising (falling), and individuals form expectations by extrapolating immediate past experience, one would expect the individual to go long (short), so as to lock (not lock) himself in at the current rates. Expectations are modelled as the rate of growth of the average commercial bank five year mortgage rate, based on the current and previous month's value. The maximum positive month to month increase was 10%, and the largest decrease was 22.4%.

Interest Rates The five year average commercial bank mortgage rate is used as one price variable in the mortgage choice. When interest rates are historically high, as in the early eighties, individuals would be expected to take short term mortgages, because of the expectation that rates would be lower in the future. Conversely, when rates are historically low, applicants would be expected to lock themselves into long term mortgages, as an insurance against a rise in rates in the future. The second price variable is the spread between long and short term interest rates, defined as the ratio of the average 5 year rate to the average 1 year rate. Over the period, the mean value was 1.11, with a range of .98 to 1.27. A large spread implies that long term rates are relatively expensive compared to short term rates.[7]

Inflation Inflation is defined as the rate of change of CPI over the last twelve months. Over the period, the average rate of inflation was 6.5%, with a range of 3.4% to 12.9%. Inflation can affect mortgage behaviour in two distinct ways. First, it can act as a proxy for price expectations. And second, economic theory suggests that it is the real price that should play a role in the demand for goods, and thus the nominal interest rate should be discounted by the rate of inflation.[8] The extent to which this second effect does not occur provides a measure of money illusion.

[6]The average commercial bank one and five year mortgage rates, and the level of CPI were retrieved from the Statistics Canada CANSIM data base; they are B 14050, B 14051, and D 484000 respectively. Using this data, each observation was assigned the one year and five year average mortgage rate, based on the individual's application date. Similarly, the average one and five year rates for the preceding month were also assigned to each observation, as was the rate of inflation, evaluated as the rate of change of CPI over the preceding month.

[7]The interest rate actually charged is an endogenous variable, and cannot correctly be included as an explanatory variable without causing the estimated coefficient to be biased. Thus the price variables must be restricted to (exogenous) interest rates available for each type of term at the time of application.

[8]Hence the average real interest rate was 6.9%, with a range of 2.8% to 11%.

Figure 2.

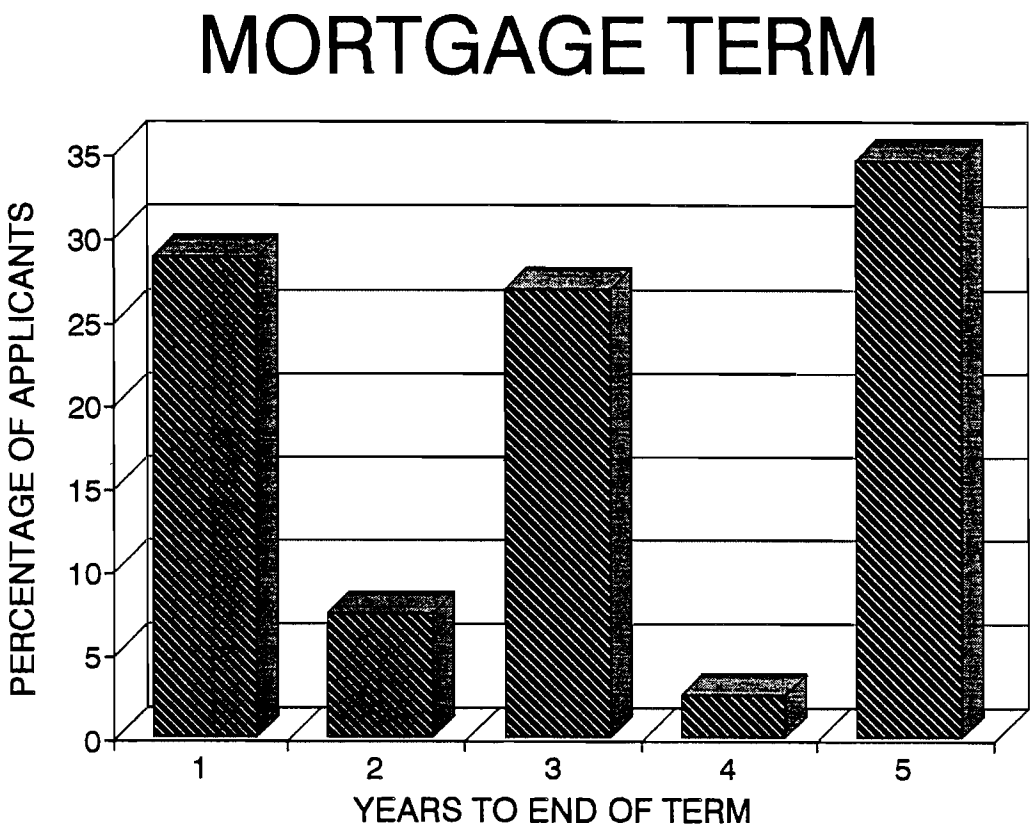

MORTGAGE TERM
PERCENTAGE OF APPLICANTS
35
30
25
20
15
10
5
0
1
2
3
4
5
YEARS TO END OF TERM

Figure 3.

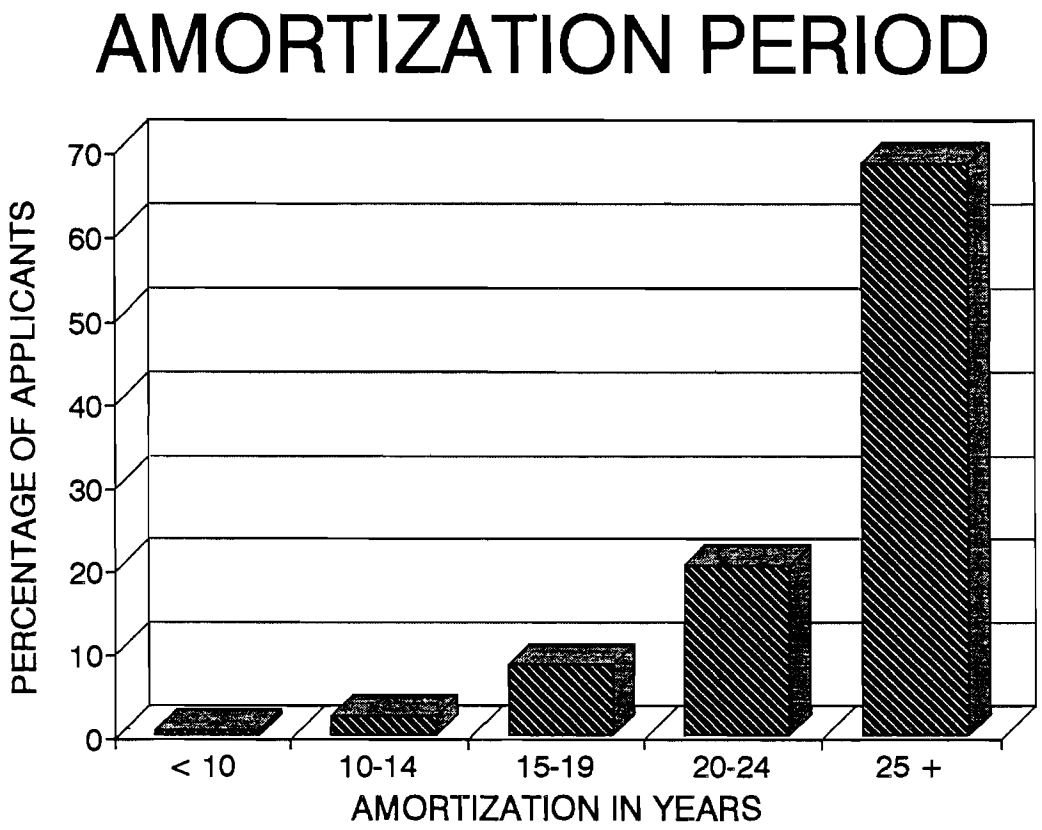

AMORTIZATION PERIOD
PERCENTAGE OF APPLICANTS
70
60
50
40
30
20
10
0
< 10
10-14
15-19
20-24
25 +
AMORTIZATION IN YEARS

Figure 4.

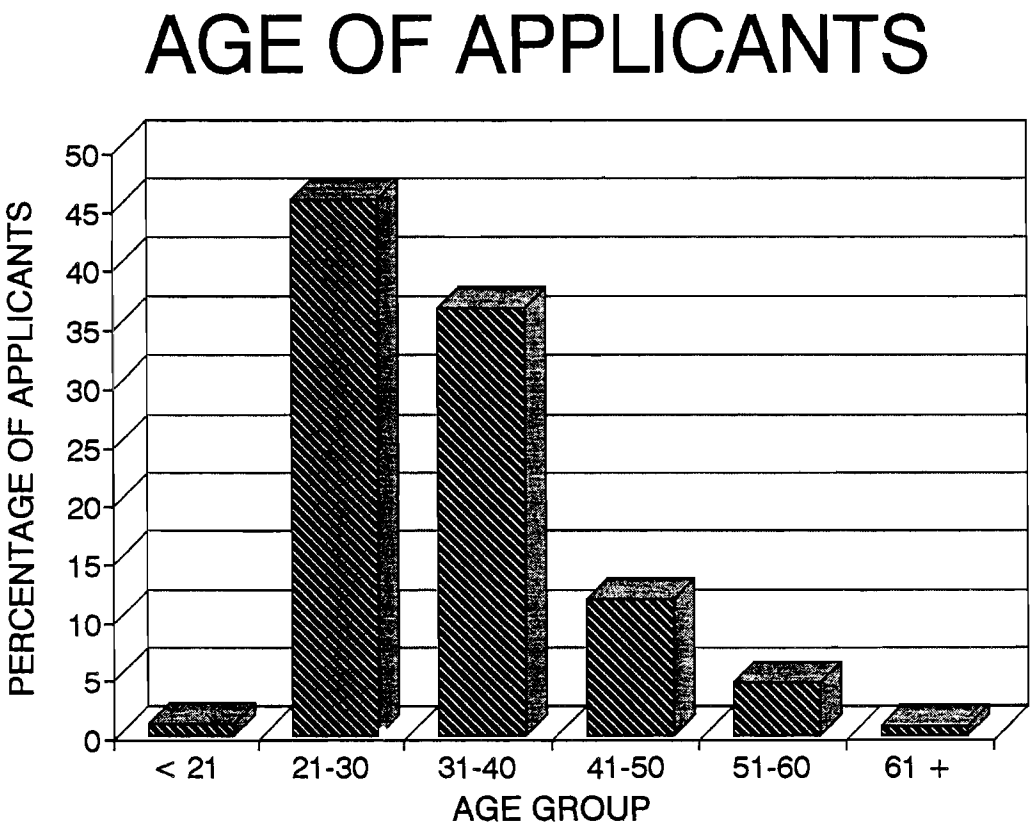

AGE OF APPLICANTS
PERCENTAGE OF APPLICANTS
50
45
40
35
30
25
20
15
10
5
0
< 21
21-30
31-40
41-50
51-60
61 +
AGE GROUP

Figure 5.

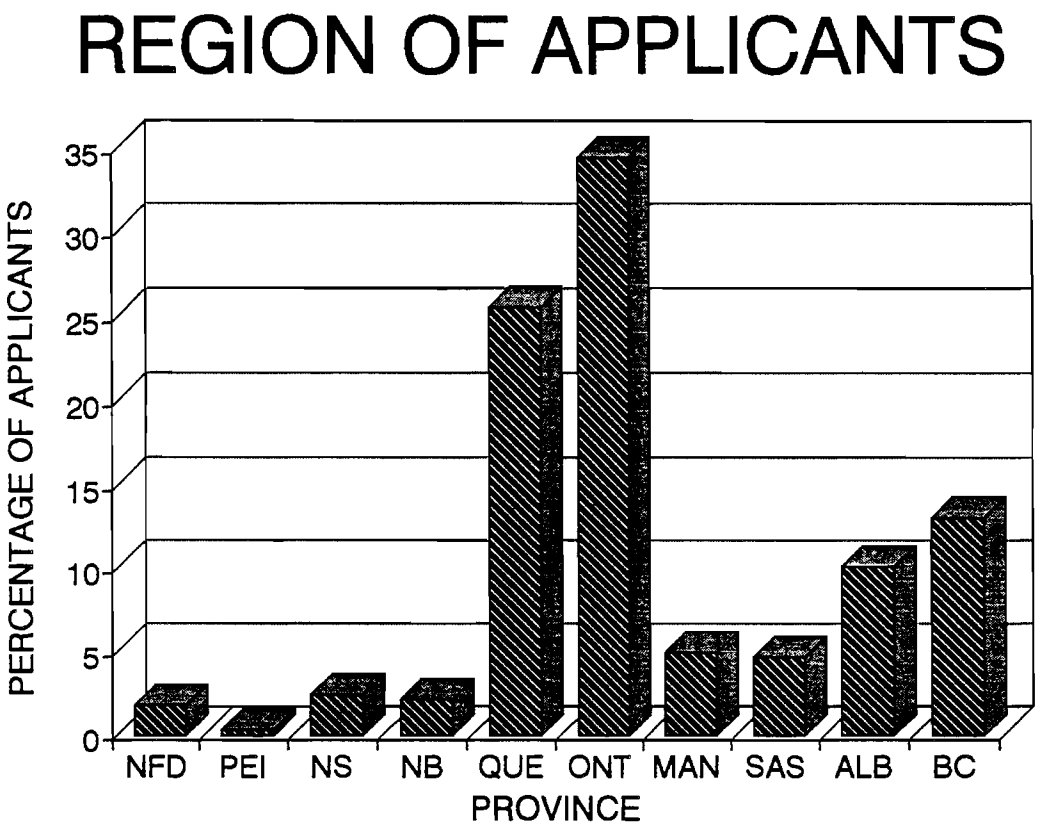
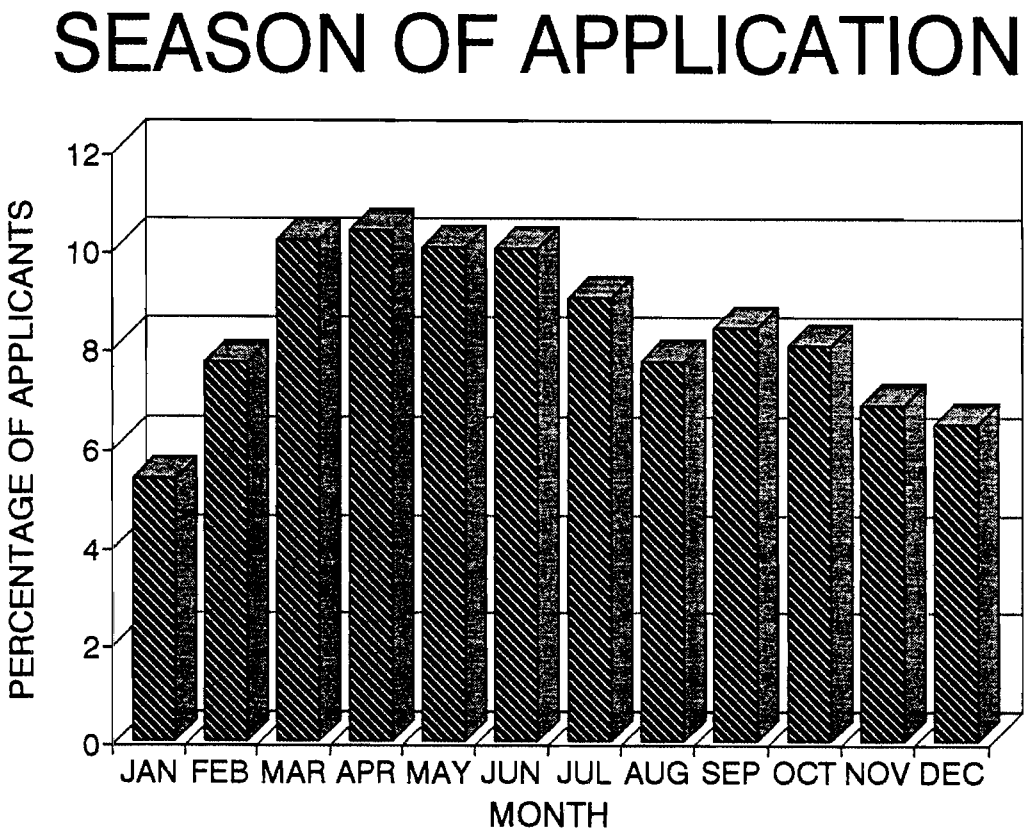

REGION OF APPLICANTS
PERCENTAGE OF APPLICANTS
35
30
25
20
15
10
5
0
NFD
PEI
NS
NB
QUE
ONT
MAN
SAS
ALB
BC
PROVINCE

Figure 6.


SEASON OF APPLICATION
PERCENTAGE OF APPLICANTS
0
2
4
6
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5 Econometric Results

The results of the econometric estimation are derived from the model presented in section 3. The first set, shown in Table 2, is for the reduced form equations (6) and (7), the second, shown in Table 3, is for the two stage structural estimates, and the final set, shown in Table 4, is for the full simultaneous structural model. This procedure facilitates a comparison with the existing literature in this area.

Table 2 contains the reduced form single equation results for term and amortization using the ordered probit and binary probit methodology respectively. The explanatory power of each equation (as measured by the percentage of observations correctly predicted) is quite reasonable, considering that this is cross-section data. We note, however, that the primary purpose of estimating these reduced form equations is not to examine the role of the explanatory variables, but to provide predicted values for each endogenous variable in the system which are then used in estimating the second stage structural equations.[9]

The structural form of the model was determined by examining the significance of the exogenous variables in the presence of the fitted endogenous variables: the resulting estimates are shown in Tables 3 and 4. The structural equations can be analyzed by grouping the variables into four broad categories: (a) demographic, (b) financial, (c) seasonal and regional dummy variables and (d) endogenous right hand side variables. The results are of interest not simply because they reflect the explicit two dimensional choice faced by borrowers, but also because variables which would theoretically be expected to play a role in a model of mortgage choice are indeed found to be significant, in contrast to several previous studies.

Before interpreting the role played by these variables, it should be noted that the econometric estimates in all the tables are consistent. However, the Table 4 estimates are also efficient since they take account of the cross-equation correlation in the error terms. Accordingly, our discussion is directed primarily to the Table 4 results, even though most of the estimated coefficient values in Tables 3 and 4 are of similar magnitude and significance. Furthermore, the sensitivity of the estimates in Table 3 to the assumption of normality has been tested by means of a semi–parametric estimation which is described in Appendix 3. While we omit reference to these estimates in the discussion which follows, it is clear that the model is robust to the normality assumption.

[9] Using the reduced form coefficients, the predicted probability for term and amortization is evaluated for each individual, for each category of choice. For amortization, there are two probabilities, summing to unity. The second probability, $\widehat{\texttt{AMORT}-2}$, is used in place of the latent variable, desired amortization, in the term equation. For term there are three probabilities, again summing to unity. We again exclude the first probability, and use the two variables $\widehat{\texttt{TERM}-2}$ and $\widehat{\texttt{TERM}-3}$, in place of the latent variable, desired term, in the amortization equation.

TABLE 2

Reduced Form Estimation.

	TERM		AMORTIZATION	
MARRIED	-0.0001	(0.00)	-0.1149	(1.84)
NUCLEAR	0.0557	(1.04)	0.0598	(0.90)
LGDS	0.1603	(3.26)	1.0569	(17.63)
PCNTLN	-0.1533	(1.05)	0.7100	(4.16)
AGE-2	-0.0800	(2.80)	0.0902	(2.61)
AGE-3	-0.1884	(4.65)	0.1278	(2.58)
AGE-4	-0.2180	(3.63)	0.1706	(2.27)
AGE-5	-0.6991	(4.11)	0.2431	(1.23)
AGE-6	-0.1727	(0.70)	-0.0292	(0.11)
Q1	0.1614	(4.24)	0.0101	(0.21)
Q2	0.1702	(4.67)	-0.0137	(0.31)
Q3	0.0976	(2.53)	0.0700	(1.48)
LRINC	0.1043	(2.71)	0.5196	(11.01)
DEL5	4.2803	(13.82)	2.7151	(7.12)
INFL	0.1148	(13.80)	0.0892	(8.59)
INT5	-0.2076	(20.73)	-0.1314	(11.05)
SPREAD	-0.0176	(7.70)	-0.0164	(6.05)
RGN-2	-0.6091	(11.18)	0.2773	(4.42)
RGN-3	0.0099	(0.19)	1.0396	(16.69)
RGN-4	-0.4723	(8.40)	0.6869	(10.53)
RGN-5	-0.5603	(9.29)	0.9107	(12.68)
α_1	-4.1430	(10.27)		
α_2	-3.0684	(7.62)		
β_1			2.7959	(5.93)
N	8156		8156	
LLF	-8305.93		-4462.01	
% Correct	46.49		73.05	

t-statistic in parenthesis
Mnemonics are given in Appendix 2

TABLE 3

Two Stage Structural Form Estimation.

	TERM				AMORTIZATION			
Parameter	Ordered Probit		Semi Parametric		Standard Probit		Semi Parametric	
MARRIED					-0.0933	(2.84)	-0.0990	(2.99)
NUCLEAR	0.0622	(2.16)	0.0324	(1.23)				
LGDS					0.9653	(16.17)	1.1032	(9.76)
PCNTLN					0.7618	(4.50)	0.9989	(5.87)
AGE-2	-0.0888	(3.09)	-0.0430	(1.60)	0.1295	(3.76)	0.1516	(4.23)
AGE-3	-0.1994	(4.93)	-0.1393	(3.62)	0.2313	(4.64)	0.2061	(4.02)
AGE-4	-0.2317	(3.86)	-0.1260	(2.21)	0.2980	(3.94)	0.3581	(4.46)
AGE-5	-0.7238	(4.23)	-1.0227	(7.28)	0.6329	(3.15)	0.6415	(3.14)
AGE-6	-0.1370	(0.56)	-0.4183	(2.29)	0.0783	(0.31)	0.2802	(1.14)
Q1	0.1592	(4.18)	0.1605	(4.37)				
Q2	0.1711	(4.70)	0.1930	(5.12)				
Q3	0.0892	(2.30)	0.1924	(5.18)				
LRINC					0.4728	(10.09)	0.5646	(9.23)
DEL5	3.8912	(11.83)	5.8659	(10.00)				
INFL	0.1037	(11.62)	0.1397	(9.40)				
INT5	-0.1900	(17.03)	-0.2577	(10.20)				
SPREAD	-0.0156	(6.43)	-0.0234	(7.69)				
RGN-2	-0.6446	(11.42)	-0.6446	(*)	0.6641	(9.72)	0.6641	(*)
RGN-3	-0.1316	(1.76)	-0.0205	(0.30)	1.0304	(16.58)	1.0172	(14.86)
RGN-4	-0.5704	(8.40)	-0.6155	(14.38)	0.9921	(14.30)	0.9446	(16.86)
RGN-5	-0.6768	(8.84)	-0.7736	(14.53)	1.2825	(16.94)	1.3008	(14.63)
$\widehat{\text{AMORT}} - 2$	0.4110	(3.04)	0.4147	(3.28)				
$\widehat{\text{TERM}} - 2$					-0.0390	(0.09)	0.1317	(0.31)
$\widehat{\text{TERM}} - 3$					1.8817	(13.77)	1.9945	(11.68)
α_1	-4.2877	(12.30)						
α_2	-3.2135	(9.24)						
β_1					6.2402	(16.86)		
N	8156		8156		8156		8156	
LLF	-8308.02		-8245.00		-4478.37		-4455.02	
% Correct	46.58		47.06		72.92		73.25	

t-statistic in parenthesis, * → normalization.
Mnemonics are given in Appendix 2

TABLE 4

Simultaneous Structural Form Estimation.
Bivariate Probit.

	TERM		AMORTIZATION	
MARRIED			-0.0770	(2.66)
NUCLEAR	0.0626	(2.34)		
LGDS			0.8109	(14.57)
PCNTLN			0.4761	(3.83)
AGE-2	-0.0835	(2.91)	0.1065	(3.27)
AGE-3	-0.1922	(4.75)	0.1931	(4.16)
AGE-4	-0.2283	(3.80)	0.2500	(3.61)
AGE-5	-0.7255	(4.20)	0.5965	(2.98)
AGE-6	-0.1197	(0.43)	0.0253	(0.08)
Q1	0.1152	(3.68)		
Q2	0.1142	(3.85)		
Q3	0.0899	(2.88)		
LRINC			0.4119	(10.78)
DEL5	3.8003	(12.61)		
INFL	0.1071	(13.17)		
INT5	-0.1849	(16.16)		
SPREAD	-0.0178	(8.81)		
RGN-2	-0.6312	(11.55)	0.5538	(9.23)
RGN-3	-0.1216	(1.68)	0.8526	(13.77)
RGN-4	-0.5504	(8.60)	0.8180	(13.18)
RGN-5	-0.6672	(9.20)	1.0598	(16.02)
γ_1	0.1585	(3.01)		
γ_2			0.5471	(17.46)
α_1	-4.2758	(11.65)		
α_2	-3.2020	(8.74)		
β_1			3.1759	(8.72)
ρ	-0.6590	(15.05)		
N	8156			
LLF	12784.23			

t-statistic in parenthesis
Mnemonics are given in Appendix 2

In the first place we find demographic influences entering through the age variable – in contrast to, for example, Brueckner and Follain, who find no support for the role played by age or family variables. The AGE variable is specified as a series of dummies to permit non linearities. Relative to the youngest age group we observe a pattern which indicates that shorter terms are associated with older borrowers, with no effect for the very oldest group. Since older applicants (who are income constrained in any case, since they require CMHC insurance) take shorter terms and longer amortization periods than younger applicants, it would appear that income constraints for this class of applicants increases with age. Second, the marital status/family structure is important. At the outset, the exact specification of such variables was not at all clear. Essentially however, what appears to matter is whether or not there is a degree of commitment on the part of borrowers to others in the immediate family. That is, either being married and/or having children implies a certain type of responsibility – regardless of whether the family is a single parent family or not. This group of borrowers we term "nuclear" family. In contrast, being either not married (with no dependents) or having a dependent other than spouse or children implies a different kind of behaviour: Single borrowers or those with a "live-in" grandparent have different responsibilities and/or perhaps additional sources of funds. In the term equation, NUCLEAR has the theoretically correct sign: borrowers with responsibilities are more risk averse and take longer term mortgages. Furthermore, married borrowers apparently wish to see their mortgage paid off more quickly than those who are not married, perhaps reflecting the likelihood of higher potential income.

The financial variables influence the choice of term in a manner similar to that already noted in the literature. However, their influence on the amortization choice is mainly an indirect one; that is, through their effect on the choice of term. The nominal rate on five year mortgages, INT5, has a strongly significant negative effect on term, as expected. This indicates that higher levels of interest rates reduce the term of the mortgage, because borrowers believe that levels will return to a lower value in some future time period. Accordingly, they are reluctant to lock themselves into a long term, and conversely. The SPREAD variable indicates similar behaviour; that is, the larger the spread the shorter the term. Since the term structure typically has a positive slope, a large spread implies that long rates are relatively expensive compared to short rates, and thus a negative sign is consistent with expectations that an applicant would move towards the (cheaper) short rate.

The DEL5 variable is designed to capture the effect of expectations on choice. It is defined as the percentage change in the 5-year rate over the preceding month. The positive sign associated with it indicates that recent changes are expected to continue. For example, if the 5-year rate is moving upward, borrowers will prefer a longer rate, *ceteris paribus*, in the belief that rates will continue to move in the same upward direction. To our knowledge, this is a new finding. We also experimented with longer formation periods for expectations with no change in the conclusion regarding the role of expectations.

The effects of inflation and the roles played by the real and nominal interest rates can be

introduced in different ways. The regressions in Tables 3 and 4 can be interpreted to reflect the influence of both real and nominal interest rate variables. INT5 is the nominal interest rate on 5-year mortgages. Since the real rate is defined as the nominal rate minus the inflation rate, the coefficients can obviously be rewritten to quantify the effects of inflation and the real interest rate. Such a transformation yields a coefficient of −0.1849 on the real interest rate and −0.0778 on the pure inflation rate. Thus inflation appears to have a negative effect on the term choice. While there is a well–developed theory to explain why inflation positively affects the amortization decision (e.g. Schwab, 1981), we are unaware of any findings or theory which correspond to our result here. However, a negative sign for both the inflation and the real interest rate coefficients make sense: higher rates for either variable may indicate a belief that, relative to the norm, rates are high and will likely return to lower values in the future. Consequently, borrowers prefer not to cut themselves off from the prospect of an early return to lower "normal" rates by locking themselves into longer terms.

The extent to which the applicant is financially "squeezed" can be ascertained from the logarithm of gross debt service payments to income ratio, LGDS, and the percentage of the purchase price formed by the loan, PCNTLN. These two variable were not significant in the term equation when the amortization decision is correctly modelled. In contrast, each has a strongly significant coefficient in the amortization equation corresponding with theoretical priors: the higher the loan percentage, the longer the amortization period and the greater the debt service ratio the longer the amortization period.

Real income enters through two channels: as an independent variable in logarithmic form LRINC, and in conjunction with monthly service payments LGDS. While neither is significant in the term equation, both are significant in the amortization equation. It is straightforward to see that the coefficient on the log of income is −0.3990, implying that higher incomes reduce the amortization period correspondingly. This is exactly what the theory would predict: other things equal, higher incomes enable a borrower to amortize the mortgage over a shorter period. The common belief is that households with higher incomes can "afford" to take the shorter, and usually cheaper, terms because they can afford to meet whatever hiccups occur in the short rates in future time periods. In contrast, low income families are in a less favourable position to meet such (temporary) high short rates and effectively insure themselves by taking a longer term. However, we found no evidence of this behaviour.

The third set of variables is made up of the regional and seasonal dummies, RGN and Q respectively. In both the term and the amortization equation, a significant difference between regions is apparent. Relative to region 1, the Atlantic Provinces, most regions indicate shorter terms and longer amortization periods. We interpret these results to indicate that there are significantly different patterns at work across the country which are attributable to cultural differences and differences in risk aversion. We attribute the significance of the seasonal variable to differences among families in the nature of dwelling changes at different times of the year. For example, families with school age children tend to make housing decisions at a time which

will enable school moves to be made between academic years. More generally, the fact that a much smaller percentage of borrowings are made in the final quarter of the year indicates that the circumstances surrounding such decisions are likely quite different from those during the other three quarters. The coefficients indicate that fourth quarter mortgage applications are associated with shorter terms than applicants at other times of the year; however the seasonal variables had no direct effect on amortization. Seasonality in this market is consistent with well known results regarding seasonality of house prices (Hosios & Pesando, 1991).

The endogenous right hand side variables comprise the fourth set. We have permitted each to be an explanatory variable in the simultaneous decision of term and amortization. This simultaneity is modelled through either the two stage procedure, or the bivariate ordered probit procedure. The respective coefficients in Table 3 are defined by the variables TERM2, TERM3 and AMORT2. Since the amortization variable takes on two possible values and the term variable three, one category is omitted in each instance to avoid singularity. The corresponding coefficients in Table 4 are γ_1, the coefficient on amortization in the term equation, and γ_2, the coefficient on term in the amortization equation. Both are positive, with the latter being large and strongly significant,[10] and are consistent with the existence of payment constraints. That is, when an applicant selects a long term, which is relatively expensive, the trade-off involves the choice of a long amortization period, which will mitigate this expense. This effect is highly significant. The corresponding effect in the term equation is of lower significance – the high monthly payments associated with a short amortization period is offset by a short (but cheaper) term.

The remaining coefficients are functional form parameters. The coefficients α_1, α_2 and β_1 are the estimated delineation points in the probit or ordered probit distribution. The coefficient ρ, which shows the correlation between the disturbances of the two structural equations, takes a value of –0.66, and is significant. This implies that a negative disturbance in the term equation (due perhaps to excluded variables) would be associated with a positive disturbance in the amortization equation. This is intuitively reasonable, since if such excluded variables represent unmeasured financial constraints, then this is consistent with the type of behaviour that would be expected – a short term and a long amortization.

While the results presented above present a coherent picture of mortgage choice, it is of interest, from a policy standpoint, to examine some of the effects in a more intuitive manner. Specifically, since the dependent variables are in terms of probabilities, it is of value to examine the effect of a percentage change in policy variables on the probability of switching from one term to another or from one amortization to another. This analysis is undertaken for two policy variables: interest rate (INT5), and interest spread (SPREAD). In each case, the elasticities are evaluated at the mean of the sample.

The elasticities are presented in Table 5. The entries in the top half of the table define the

[10]The coefficient values for the two stage procedure exhibit a similar pattern.

percentage change in the probability of choosing each length of term due to a unit percentage change for each policy variable. For example, the first entry shows that there is a 3.39% increase in the probability of choosing a short term mortgage in response to a 1% increase in the five year rate, evaluated at the mean of the sample over all mortgage amortization periods. Correspondingly, there is a 3.09% fall in the probability of choosing a long term in response to a 1% increase in the five year rate. The elasticities associated with a change in the interest rate spread are given in the second row of the top panel. The signs of these elasticities are consistent with our earlier discussion.

In the lower panel we present the elasticities defining the percentage change in the probability of choosing a short or long amortization period in response to a 1% change in the value of the same two policy variables, again evaluated at the sample mean for all term durations. For example, the first entry shows that there is a 2.10% change in the probability of choosing a short amortization period in response to a 1% change in the five year interest rate. Similar results follow for a change in spread. These elasticities are consistent with the reported coefficients: an inverse relationship between term and interest rates (or spread), and a direct relationship between amortization and term. Thus a rise in interest rates results in shorter terms, and hence shorter amortization periods.

TABLE 5

Elasticities of Term Choice with respect to Policy Variables.

	Term		
	Short	Medium	Long
INT5	3.39	0.18	-3.09
SPREAD	2.68	0.15	-2.45

Elasticities of Amortization Choice with respect to Policy Variables.

	Amortization	
	Short	Long
INT5	2.10	-0.89
SPREAD	1.68	-0.70

6 Conclusion

In this paper, we model the mortgage choice problem faced by Canadian home-buyers who are required to purchase insurance at the outset. Our econometric model of mortgage choice involves a simultaneous decision of term and amortization period, and is estimated using a simultaneous bivariate ordered probit procedure on a sample of 9000 applicants to the CMHC. We also estimate a two-stage discrete choice model, using both an ordered probit and a semi-parametric methodology, and determine that the results are robust to the estimation procedure. We find the following results:

First, we confirm the existing literature that financial variables are important in this joint decision. However, in addition to the customary array of interest rate variables, we find that expectations of the future path of interest rates are important. To our knowledge, this is a new finding.

Second, we find that significant demographic influences enter through the age and family structure variables. In general, older applicants take shorter terms and longer amortization periods, while applicants who are either married, and/or have children are more risk–averse and typically take longer term mortgages. A reason for finding significant explanatory power in the demographic variables may lie in the fact that previous studies either have used samples which are too heterogeneous or have not been able to control for borrower type along the lines indicated in our study. Our data base is fairly homogeneous, since it consists only of a particular class of borrowers - those who are highly levered and hence require insurance.

Third, there are significant differences between the regions in Canada with respect to mortgage choice, possibly reflecting cultural differences and attitudes towards risk. In addition, there is evidence of seasonality in the term decision: in particular, fourth quarter applications are associated with shorter terms. Seasonal variables have no direct effect on the amortization decision.

Finally, in a sensitivity analysis, we examine the effect of a change in policy variables on the probability of switching from one term to another or from one amortization period to another. We find that both the short and long term options, as well as the short amortization period option are highly elastic with respect to both interest rate levels and spread. A policy implication is that changes in nominal interest rates lead to large swings in both term and amortization choices. To the extent that such policy changes are frequent, there will be a concomitant high volatility in mortgage choice variables.

In summary, the findings outlined above significantly enhance the existing literature from a methodological as well as from a data standpoint. In addition, this study is unique in that it addresses the mortgage choice problem for the Canadian market.

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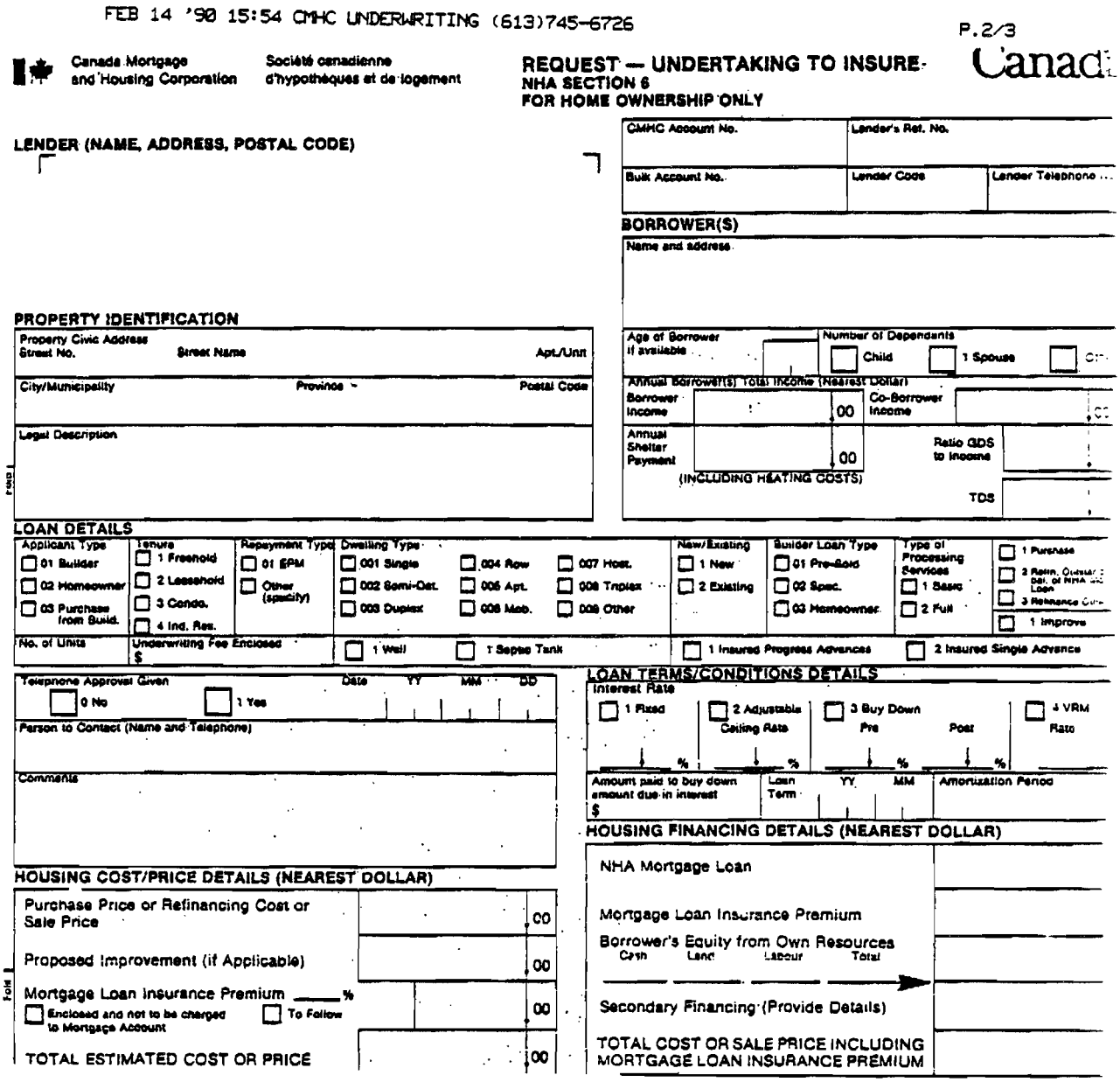
Appendix 1: Data Source

Each mortgage request results in the completion of a CMHC: "Request undertaking to Insure" form. This information provided the basis for the data used in this report. A copy of this form is shown below.



FEB 14 '90 15:54 CMHC UNDERWRITING (613)745-6726 P.2/3

Canada Mortgage and Housing Corporation / Société canadienne d'hypothèques et de logement

REQUEST — UNDERTAKING TO INSURE
NHA SECTION 6
FOR HOME OWNERSHIP ONLY

Canada

LENDER (NAME, ADDRESS, POSTAL CODE)

CMHC Account No. | Lender's Ref. No.
Bulk Account No. | Lender Code | Lender Telephone

BORROWER(S)
Name and address

PROPERTY IDENTIFICATION
Property Civic Address — Street No. / Street Name / Apt./Unit
City/Municipality / Province / Postal Code
Legal Description

Age of Borrower if available
Number of Dependants: Child / Spouse / Other
Annual Borrower(s) Total Income (Nearest Dollar): Borrower Income .00 / Co-Borrower Income .00
Annual Shelter Payment .00 (INCLUDING HEATING COSTS) / Ratio GDS to Income / TDS

LOAN DETAILS

Applicant Type	Tenure	Repayment Type	Dwelling Type			New/Existing	Builder Loan Type	Type of Processing Services	
01 Builder	1 Freehold	01 EPM	001 Single	004 Row	007 Host.	1 New	01 Pre-Sold	1 Basic	1 Purchase
02 Homeowner	2 Leasehold	Other (specify)	002 Semi-Det.	005 Apt.	008 Triplex	2 Existing	02 Spec.	2 Full	2 Refin. Other Det. of NHA MI Loan
03 Purchase from Build.	3 Condo.		003 Duplex	006 Mob.	009 Other		03 Homeowner		3 Refinance Conv.
	4 Ind. Res.								1 Improve

No. of Units | Underwriting Fee Enclosed $ | 1 Well | 1 Septic Tank | 1 Insured Progress Advances | 2 Insured Single Advance

Telephone Approval Given: 0 No / 1 Yes — Date YY MM DD
Person to Contact (Name and Telephone)
Comments

LOAN TERMS/CONDITIONS DETAILS
Interest Rate: 1 Fixed % / 2 Adjustable Ceiling Rate % / 3 Buy Down Pre % Post % / 4 VRM Rate %
Amount paid to buy down amount due in interest $ | Loan Term YY MM | Amortization Period

HOUSING COST/PRICE DETAILS (NEAREST DOLLAR)

Purchase Price or Refinancing Cost or Sale Price	.00
Proposed Improvement (if Applicable)	.00
Mortgage Loan Insurance Premium ____ % (Enclosed and not to be charged to Mortgage Account / To Follow)	.00
TOTAL ESTIMATED COST OR PRICE	.00

HOUSING FINANCING DETAILS (NEAREST DOLLAR)

NHA Mortgage Loan	
Mortgage Loan Insurance Premium	
Borrower's Equity from Own Resources (Cash / Land / Labour / Total)	
Secondary Financing (Provide Details)	
TOTAL COST OR SALE PRICE INCLUDING MORTGAGE LOAN INSURANCE PREMIUM	

Appendix 2: Mnemonics Used

Age	AGE-1	Age < 30 (reference category).
	AGE-2	Age 30 - 39.
	AGE-3	Age 40 - 49.
	AGE-4	Age 50 - 59.
	AGE-5	Age 60 - 65.
	AGE-6	Age > 65.
Amortization	AMORT-1	Amortization < 25 years.
	AMORT-2	Amortization ≥ 25 years.
Economic	DEL5	Monthly growth rate of 5 year commercial bank mortgage rate.
	INFL	Rate of inflation (12 month rate).
	INT5	Five year average commercial bank mortgage rate.
	SPREAD	Ratio of 5 year to 1 year commercial bank mortgage rate.
Individual	LGDS	Natural logarithm of Gross debt shelter to income ratio.
	LRINC	Natural logarithm of real family income.
	MARRIED	Unity if married.
	NUCLEAR	Unity if married and/or children, and no dependent.
	PCNTLN	Loan as percent of total cost.
Region	RGN-1	Atlantic Provinces (reference category).
	RGN-2	Quebec.
	RGN-3	Ontario.
	RGN-4	Prairie Provinces.
	RGN-5	British Colombia.
Season	Q1	1st quarter.
	Q2	2nd quarter.
	Q3	3rd quarter.
	Q4	4th quarter (reference category).
Term	TERM-1	Term $= 1$ year.
	TERM-2	Term > 1 year and < 5 years.
	TERM-3	Term $= 5$ years.

Data Source:

Applicant specific data:	CMHC data base.
Commercial bank mortgage rate:	CANSIM vectors B 14050-1.
Consumer price index:	CANSIM vector D 484000.

Appendix 3: Semiparametric Estimation

The development of nonparametric and semiparametric techniques is one of the most active areas of econometrics. While the nonparametric method makes no assumptions whatsoever about the functional form, the semiparametric estimation permits the estimation of parametric models, but with less restrictive distributional assumptions. A number of methods exist for implementing these techniques, one of the most common being the kernel smoother.

Let I_{ij} be an indicator function, taking the value unity if observation i and j fall in the same category, else zero. Let $z_i = \mathbf{x}_i'\beta$ be the index associated with the ith observation. The semiparametric estimator of $F(z_i)$, the predicted probability of observation i occurring in the observed category, is a kernel estimator, derived as the weighted average of the indicator variable with weights given by the kernel $K_h(z)$, a function which tends to zero as the magnitude of its argument increases. The metric that is used to weight the observations in the kernel is the Euclidean distance. The univariate Gaussian kernel is given by:

$$K_h(z_i - z^*) = \frac{1}{(2\pi)^{.5}} e^{-.5\left(\frac{z^* - z_i}{h}\right)^2}$$

where z^* is the reference index, and the degree of smoothness is determined by h, the window width.

The window width, h, is important in kernel estimations, since it determines the amount of smoothing undertaken. In this context, we used the default window width specified in Silverman (1986) as an adequate measure of the degree of smoothing. In a probability context, the parameters of the index β can be estimated using standard maximum likelihood techniques. The log-likelihood is given by:

$$\text{LLF} = n^{-1} \sum_{i=1}^{n} \log \hat{f}(z_i)$$

where the density estimate $\hat{f}(z_i)$ is constructed as:

$$\hat{f}(z_i) = (nh)^{-1} \sum_{j} I_{ij} K_h(z_i - z_j)$$

Klein and Spady (1987) prove that this estimator is consistent (up to a normalization on β), and under specific conditions is distributed asymptotically normal.[11]

Since the argument of the kernel involves the difference between two indices, it follows that a constant cannot be estimated, and that the β vector can only be estimated up to a

[11] A review of nonparametric estimation as used in economics is provided by Ullah (1988). A review of nonparametric and semiparametric estimation of discrete choice models is given in Pagan and Ullah (1992). See also Newey *et. al.* (1990) for and an application using the Klein and Spady estimator in a labour supply context.

normalization.[12] It is highly inefficient to use (6) directly for calculating $f(z)$ at a grid of points, since for n points the kernel must be estimated n^2 times. Since the kernel estimate is a convolution of the data with the kernel, it is much faster to use a FFT to perform the convolution. Thus, using a Gaussian kernel for a 1000 observation sample, the direct evaluation of (6) takes between 100 and 200 times as long as using a FFT technique. (Silverman (1982)). For a data set of 4000 observations, the FFT technique is essential. Using these techniques, the β vector and window width h can be estimated from (5) using standard maximum likelihood techniques. Note that in the semiparametric case, the ordering is not used - thus the parametric equivalent is the multinomial choice model.

[12]We have taken the parameter value for region2 derived in the corresponding probit estimation as a constant as the normalization, such that the parameter values in the two estimations can be directly compared.