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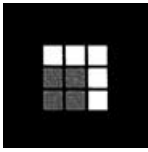

Regressive Interest Rate Expectations and Mortgage Instrument Choice in the United Kingdom Housing Market

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The paper considers the choice of mortgage instrument when the rate of interest is fixed for a short duration, with reversion to a variable (bullet) rate mortgage contract. The research is the first direct test for regressive interest rate expectations using United Kingdom data while testing for wealth and portfolio effects. The econometric modeling uses a variety of nonparametric and parametric techniques to control for classification error in the dependent variable. There is evidence that households adopt regressive interest rate expectations. The lack of statistical significance of wealth and portfolio effects confirms the short run cash flow perspective of United Kingdom mortgage choices.

There is now a wide theoretical and empirical literature on the choice between a fixed rate mortgage (FRM) and an adjustable rate mortgage (ARM) in the United States (Alm and Follain 1987; Sa-Aadu 1987; Bruekner and Follain 1988, 1989; Sa-Aadu and Sirmans 1995) and Canada (Breslaw and Irvine 1996). Econometric work concerned with U.K. mortgage choices is sparse (Leece 1995a, 2000a, 2000b). The research that is reported in this paper significantly extends previous U.K. work on mortgage choices, both methodologically and empirically.

The U.K. mortgage market differs from that in the United States in several important respects. The fixed rate contracts in the United Kingdom (FRMs) are typically fixed for short duration, 1 to 5 years compared with 15 to 30 years. For the sample period 1991 to 1994, there was seldom an option to convert to a further fixed rate contract, and the mortgage reverted back to the variable mortgage interest rate. There was active discouragement of prepayment and remortgaging with other lenders. Currently borrowers can pay from three to six

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months interest or up to 5% of the debt in redemption costs.[1] In marked contrast to the United States, where prepayment risk is mutualized in the secondary mortgage market, U.K. lenders impose high transaction costs to minimize this risk. These characteristics of U.K. mortgage contracts are important because they give a short run focus to the household's property finance decisions. For example, high redemption penalties reduce the value of the option to prepay and thus narrow the leeway for the adjustment of debt.

The short run nature of U.K. mortgage contracts also arises from the forms of finance used by lenders to fund mortgages. Mortgage lending has typically been financed from short-term retail deposits of banks and building societies. For example, the law restricts building societies to financing mortgage loans by at least 50% using retail deposits, and this percentage is often as high as 75%. Though there has been an increase in "off balance sheet finance," there is no well-developed use of securitized mortgages (see European Mortgage Federation 1998). This contrasts with the United States where a much larger proportion of mortgages is financed via the securitized mortgage market. The link with retail deposits means that U.K. mortgage pricing relates to competition for retail deposits. This adds to uncertainty in that changes in the variable mortgage rate do not immediately reflect changes in the base rate of interest, with the mortgage rate experiencing stickiness. This stickiness is similar and possibly greater than that for the prime lending rate in the United States. Of course in the United States, adjustable rate debt is indexed, with regular adjustment periods. This distinction is important because anticipating the timing and direction of changes in the variable interest rate will inform U.K. household debt financing decisions and also lead to a focus on the short run.

The above considerations give a study of the U.K. context particular interest. The focus of household choice is likely to be the short period when the tilting of real mortgage payments and other capital market imperfections has most force. The household's choice of mortgage instrument will be centered on the short-term behavior of the variable mortgage rate: the spot rate of interest (albeit a sticky one). This contrasts with research for the United States, which has considered the choice between a long-term fixed rate instrument and adjustable rate mortgages where the option to prepay has value. So, what implications does any short-run focus to decision making in the United Kingdom have for mortgage choices and economic policy making in general?

[1] Detailed historic data on redemption costs are not available. However, they are known to have been prevalent and high during the period covered by this study (see *What Mortgage* 1995).

High levels of owner occupation and high leverage at variable rates mean that the U.K. economy is very sensitive to interest rate changes. These aspects of the U.K. housing market are major impediments to the integration of the United Kingdom into the European Monetary System. An increase in the take up of fixed rate mortgages comparable to other European countries would reduce this interest rate sensitivity. However, this is less so for debt fixed for a short duration (Earley 2000). Even when contracts are available for a longer period of fix (typically 10 years) there is a reluctance to fix the rate for this length of time.[2]

To understand the reluctance to switch to fixed rate contracts of a longer duration, we need to understand the basis upon which households choose their mortgage instrument. This choice may simply be informed by comparative costs; however, it is more likely that households will behave on the basis of some interest rate expectations mechanism, albeit short term. For example, the current level of the variable rate of interest may suggest the likelihood and direction of the next impending change. This is a form of regressive expectations. It is this hypothesis that is tested by the research in this paper.

There are episodes when the level of the variable mortgage interest rate would have given a contradictory signal to households compared to the interest rate expectations implied by the premium charged on fixed rate mortgages. From the first quarter of 1993 through to the first quarter of 1995, the variable mortgage interest rate stabilized at around the 8% level. This was below the historical mean gross rate of 9%. The premium on fixed rate over variable rate debt fell from 2% down to close to zero, only to rise to approximately 3%. Even if the premium and the level of the variable rate agree on the expected direction of change, they may imply significant differences in its extent. Regressive expectations may apply a brake to the take up of long-term fixed rate contracts. For example, a high variable rate may induce a low take up of such debt, even if the risk premium suggests an increasing spot rate of interest.[3]

There is anecdotal evidence that households have regressive expectations and are reluctant to lock into fixed rate contracts when the variable rate is "high" (Coles 1993). Some term structure studies have also found such an effect (Kessel

[2] It is estimated that during 1994 there were only 10 ten-year contracts available compared to 55 five-year mortgages (Leece 2000a).

[3] This behavior is less likely when the yield curve is inverted and the premium on fixed rate mortgages is negative (as in 1997/1998). Though here the expectation might be that the variable rate was not likely to fall any lower.

1965; Van Horne 1965; Wood 1983). Theoretical work on the behavior of the spot rate of interest in money markets has predicted random variation with reversion to the mean rate (Vasicek 1977; Cox, Ingersoll and Ross 1981), a phenomenon which could inform regressive expectations. There has also been some evidence of reluctance to take up fixed rate debt at historically high interest rates, implying a form of regressive expectations, found in U.S. data (see James, Miller and Riddiough 1995), suggesting that this form of behavior merits further investigation.

The data set is enhanced, compared to previous research (Leece 2000a), by using the panel nature of the data to calculate the covariance between mortgage rates and incomes and to supply information on wealth and investment. This additional data assists in further determining whether U.K. households choose their debt instrument on the basis of short run considerations or the long term factors that might effect the demand for housing over their life cycle (*e.g.*, the impact of wealth).

The period of study (1991–1994) was also characterized by intense competition in the mortgage market, generating extensive product heterogeneity. Heterogeneity might impose information demands upon consumers that increase the likelihood of misreporting of the chosen mortgage type. Misclassification can be a serious econometric problem that may affect the efficiency and consistency of estimation of discrete choice models (Hausman and Scott Morton 1994; Leece 2000a). The empirical estimation reported in this paper corrects for classification error.

The methodological innovation of the paper is the use of the non/semiparametric general additive model (GAM). This procedure assists in visualizing the likely extent and impact of classification error. Controlling or correcting for classification error also requires selection from a menu of parametric and nonparametric specifications; the general additive model assists in establishing the most appropriate choice. The methodology is further extended by the use of bootstrapping techniques to identify problem observations. An accurate understanding of the quantitative basis of mortgage choices requires that parameter estimates are efficient and consistent. The techniques applied in this research assist in ensuring such consistency and efficiency. The nonparametric and semiparametric approach has the added benefit of minimizing the number of prior expectations in an area where the theory (household formation of regressive expectations) is comparatively underdeveloped.[4]

[4] The demands on consumers are particularly complex given the uncertainty over the likely persistence or change of a current variable mortgage interest rate.

Literature Review and Background

The purpose of this section of the paper is to review the salient features of the empirical specification of the econometric model, as suggested by previous research into mortgage choices. Particular attention is paid to the expected sign on the variable mortgage interest rate. It is also necessary to consider any modifications dictated by the particular circumstances of the U.K. mortgage market.

A common empirical finding of research into the determinants of the choice of mortgage instrument in the United States is that a significant influence is the difference between the rate of interest on the FRM and that on the ARM. This can be considered as a risk premium or simply a variable indicating the relative cost of the two mortgage instruments (Phillips and Vanderhoff 1994; Bruekner and Follain 1988, 1989). The premium can be viewed as a pure interest rate risk adjustment and be assumed to be given exogenously. The likelihood of choosing adjustable rate mortgage debt is generally found to be a positive function of the absolute size of the premium. A term structure variable is also usually found to be statistically significant and negative in sign.

Theoretical work and numerical simulation offers insights into likely interest rate effects on the choice of mortgage instrument. Alm and Follain (1987) deduce that the choice of an ARM is less likely at high ARM rates. This result reflects the increased exposure of consumers when interest rates are high. The latter prediction is contrary to "regressive" expectations where the demand for fixed rate debt falls at high interest rates. A further theoretically important variable is the covariance between the mortgage interest rate and income. Negative covariance would induce the choice of a fixed rate instrument. High levels of wealth also allow portfolio diversification, which might reduce the need to hedge by taking up an FRM. This argues for the inclusion of variables reflecting covariation, wealth, and portfolio characteristics in any econometric specification.

Interest rate effects will be conditional upon the influence of other explanatory variables such as personal characteristics and industry/occupational variables. Few studies have found personal characteristics to be important, excepting Sa-Aadu and Shilling (1994) and Sa-Aadu and Sirmans (1995). The latter models differ by incorporating the heterogeneity of mortgage contracts into the empirical modeling.

An important issue is how far the research framework established in the context of the U.S. mortgage market can be applied in the United Kingdom. In principle, the same choice of instrument models will apply (see Leece 2000a). It is only

necessary to ascribe the variable rate mortgage (VRM) to the ARM choice, with the short-run fixed rate contract as the FRM choice. However, as previously noted, there are a number of particular complications pertaining to the U.K. mortgage market.

United Kingdom lenders primarily finance the issue of variable rate mortgage debt with short-term retail deposits. Mortgage pricing mainly reflects short-run interest rates. During the 1960s and the 1970s, mortgage market rationing and an interest rate cartel were able to "smooth out" interest rate variations arising from short-run movements in rates (Buckle and Thompson 1995). Since the early 1980s, mortgage market rationing has been attenuated and the pricing cartel is no longer in existence (Meen 1990; Leece 1995b). Subsequently, mortgage rates have more closely tracked short-run interest rate movements. This depiction is stylized to the extent that there are significant lags in the adjustment of the variable mortgage interest rate that impart a level of fixity to ostensibly variable rate contracts (Miles 1994; Leece 2000a). It is necessary to reflect these features in the econometric specification.

Consumers choosing short-term fixed rate contracts with high redemption penalties and reversion to the variable rate at the contract end will have a short-run focus on their choice of mortgage instrument. At times of high variable interest rates, liquidity constraints at the margin of borrowing and the well-known tilting of real payments will force an emphasis upon the expected direction of change in the next interest rate movement and its likely extent. Rate changes will have immediate consequences for cash flow and liquidity (Kearl 1978). It is possible that exposure at high variable rates might induce the take up of fixed rate debt, but consumers may be less inclined to lock into high real payments and severe tilting in the repayment schedule. Thus an interesting empirical test is the determination of the sign on the variable interest rate term in the reduced form short-run fixed rate debt demand equation.

Financial commentary is typically couched in terms of the reluctance of consumers to lock into high mortgage rates and expectations gleaned from current spot rate behavior.[5] Thus regressive expectations is an assumption adopted by many market participants and commentators, yet is a largely untested hypothesis.

It may also be the case that wealth and portfolio considerations might be less critical to mortgage choice. Long-run hedging considerations may not be relevant

[5] See "Fixed Rate Lending and Remortgaging Continue to Decline," Council of Mortgage Lenders, Press Release, May 21, 1999.

and income adjustments may significantly lag short-run interest rate changes, be the covariance negative or positive. The relevant objective function will be the expected net cash flow rather than portfolio variance. There is some parallel here with the impact of liquidity constraints on income sensitivity in consumption. Testing for the significance or otherwise of wealth effects and so forth, provides a further test of the short-run focus upon the choice of instrument. A key question is how consumers form their interest rate expectations under these circumstances.

Leece (2000a) applied a direct test of the risk premium hypothesis to the choice of mortgage instrument in the United Kingdom. The study found no statistically significant effect; this was the case even after the adjustment of the risk premium for lags in the adjustment of the variable rate to the short-run money market rates. A significant time trend, possibly indicating supply-side selling pressures, was also detected. There has been no explicit test of the regressive expectations hypothesis on U.K. data and no control for wealth and portfolio effects. Neither has the appropriateness of a parametric functional form and parametric correction for classification error been subject to testing. The research that is reported in this paper remedies these omissions.

The Data and Sample Issues

The base sample is 760 owner-occupiers who have entered owner occupation or moved properties some time between 1991 and 1994. This sample is drawn from the British Household Panel Survey (BHPS; Waves 1 to 4), a panel of approximately 5,000 households and approximately 15,000 individuals. The characteristics of this sample and the details of an algorithm used to identify the holders of fixed rate mortgage debt is discussed in Leece (2000a). Two criteria were used to identify fixed rate contracts: (i) the recorded constancy of mortgage payments over time and (ii) discrepancies between payments forecast from the current variable interest rate and observed payments. Of these two criteria the constancy of payments is likely to be the most reliable.

A subsample of 307 households was drawn from the 760 owner-occupiers. This consisted of households that had been continuously in owner occupation since 1990. This group provided continuous data on their mortgage payments for the period 1990 to 1996 facilitating the identification of fixed mortgage choices through constancy of payments between periods. Moreover, the continuous existence of income data over the period facilitated a measure of the covariation between the variable mortgage interest rate and household income, a theoretically important variable.

The restriction of the sample period to 1991 to 1994 is conducive to analysis, in that it misses out the period of very heavy discounting of mortgage debt that occurred primarily from 1995 onwards. This sample also excludes later periods when even five-year fixed rates were cheaper than the variable rate. Later waves of the BHPS (Waves 5 and 6) are useful in providing data to measure comparative wealth and liquidity, again theoretically important variables.

Previous research in the United States has addressed the issue of selection bias when the only interest rate observed is that paid on the chosen mortgage contract (Brueckner and Follain 1988, 1989). That is, the rate of interest on the rejected mortgage instrument is not observed. For example, to calculate the unobserved ARM rate for consumers choosing an FRM, Brueckner and Follain (1989) regress monthly rates in the sample on a national average rate and include regional dummy variables. The research that is reported in this paper uses an estimate of national average rates.[6] Regional variations in the interest rate structures facing consumers are unlikely for the United Kingdom.

The Research Methodology

The appropriate empirical specification of the econometric model for the U.K. mortgage market is given by Equation (1):

$$F_i = \phi(Age, VariableRate, Gap, Income, Trend, Corriv, Wealth). \quad (1)$$

In this case F_i is the probability of household i choosing a fixed rate mortgage instrument. This is taken to be a function of the age of the head of household (*Age*), the level of the variable mortgage interest rate (*VariableRate*), the gap between the mortgage rate and short-term money market rates (*Gap*), household income (*Income*), a time trend (*Trend*), the correlation between income and mortgage interest rates (*Corriv*) and wealth (*Wealth*). The focus of the specification in (1) is the expected negative signs on *VariableRate* and *Gap*. A high negative correlation between the variable mortgage interest rate and income is predicted to encourage the take up of a fixed rate mortgage. High levels of wealth allow hedging possibilities that make fixed rate debt less attractive. *Gap* represents the degree of stickiness of the variable mortgage rate.

Equation (1) contrasts with the usual U.S. mortgage choice specification (Dhillon, Shilling and Sirmans 1987; Brueckner and Follain 1988, 1989).

[6] Individual interest rate payments were not reported directly in the BHPS survey except for consumers opting for interest-only mortgages (endowment mortgages).

Estimates using the more conventional approach, for example, including a measure of the premium on fixed rate debt and the level of the variable rate of interest, were made. Further experimentation included a measure of interest rate expectations based upon the term structure. Either the parameter estimates lacked statistical significance, or they were incorrectly signed. Given the discussion of U.K. mortgage market characteristics, which suggests a focus on the short-run behavior of the variable rate of interest and the lack of empirical success of the more typical specification, then the econometric model reflects regressive expectations. More specifically the hypothesis is that the demand for fixed rate mortgage debt is a negative function of the level of the variable mortgage rate. That is high (low) rates are expected to fall (rise). The expectations mechanism is the anticipated short-run behavior of the variable mortgage rate and not any interest rate path implied by the risk premium or term structure variables.

The research uses several semi- and nonparametric techniques to determine the appropriate econometric specification for a choice of mortgage instrument equation and to analyze the impact of classification error in the dependent variable. These two issues are related in that an appropriate specification is required to identify classification problems (Hausmann and Scott Morton 1994). Though classification problems result from the particular measure used in this research, it is a potentially important issue in the use of survey or even lender-based data (Leece 2000a). Given the heterogeneity of mortgage contracts, it would be surprising if significant classification error did not exist in surveys concerned with this choice.

The discussion of the research methodology takes the form of three related sections. Firstly, a nonparametric general additive model is introduced (GAM), which tests for the appropriateness of a parametric specification and facilitates the preliminary analysis of classification error and other sources of bias. This is followed by the discussion of a binomial probit incorporating the endogenous estimation of the extent of classification error. Finally, a sensitivity test for coefficient bias is conducted using a "jackknife after bootstrap" simulation. The GAM provides the appropriate specification for the parametric analysis while the jackknife after bootstrap provides triangulation of the often unstable parametric estimation and also a bias-modified sample amenable to further analysis. In particular, simultaneity and other tests can be more readily applied to the bias-modified sample.

A General Additive Model

A main strand of the modeling is a generalized additive model. This is a nonparametric estimation technique that uses a backward fitting algorithm to estimate

a kernel smoother for the data (Hastie and Tibshirani 1990). The general form of the additive model is as follows:

$$F_i = \alpha + \sum_{i=1}^{n} f_i(x_i) + \epsilon \tag{2}$$

Equation (2) indicates that the response variable, the choice of mortgage instrument (F_i), is not a linear function of the independent variables (x_i), but rather it results from an arbitrary smooth function of these variables (f_i) plus a constant term α. A general linear model (GLM) such as a logit or probit would be a subclass of this model.[7]

Considering a fully parametric model to be the ultimate degree of smoothing, then a GAM has the advantage of testing for the appropriateness of a parametric form and can assist in determining the pertinent specification. Correctly identifying the degree of classification error requires the correct specification of the underlying model (Hausman and Scott Morton 1994). There may also be occasions where a nonparametric estimation gives a more powerful explanation of the data and offers a better prediction tool (Pace 1998).

The GAM can be used to detect any nonparametric effects, which might result from classification error in addition to other sources of bias. Local clustering of observations may result in spurious nonlinear effects (Hastie and Tibshirani 1990). Moreover, there is a menu of approaches to modeling classification error from which to select, and the GAM is used to choose between parametric and nonparametric techniques. In the absence of a well-developed theory of how consumers form regressive interest rate expectations, the GAM is also a useful exploratory tool.

A General Linear Model with Correction For Classification Error

The ultimate purpose of the research is to estimate and test the validity of a binomial probit which models the choice of mortgage instrument based upon the theoretical expectations delineated in the discussion of Equation (1). Assuming that the GAM indicates that a parametric form is appropriate, then the usual probit log likelihood is applied. This is given in Equation (3) where β are the parameters to be estimated and x is the vector of independent variables.

[7] A further semiparametric generalization of the additive model allows the inclusion of linear estimates of the form typical of general linear models. This is particularly useful when the empirical specification contains dummy variables. The subsequent additive partially linear model takes the form of the following equation with βx_i indicating the linear (parametric) estimators: $F_i = \alpha + \sum_{i=1}^{n} f_i(x_i) + \beta x_i + \epsilon$.

The usual standard normal probability distribution function Φ applies. This distribution function is also the link in the local fitting algorithm used in the general additive model.

For the purposes of this exercise, x includes *VariableRate*, *Gap*, *Income*, and *Corriv*. Experimentation with interactions and measures of liquidity and wealth will be separately applied. A full list of variable names and labels is given in Table 4 in the Appendix, while Table 5 gives the corresponding descriptive statistics.

$$\ln L = \sum_{y_i=0} \ln [1 - \Phi(\beta' x_i)] + \sum_{y_i=1} \ln \Phi(\beta' x_i). \tag{3}$$

The econometric modeling also has to deal with the issue of classification error in the mortgage choice equation. The estimation adopts two approaches to this problem. Firstly, subject to the appropriateness of a parametric specification, the probit given in Equation (3) is modified to allow for the endogenous determination of the extent of classification error (see Hausmann and Scott Morton 1994; Leece 2000a). This involves estimation of the amended log likelihood given in Equation (4), where α is the probability that an observation is misclassified.

$$\ln L = \sum_{y_i=0} \ln [(1 - \alpha) + (2\alpha - 1) * \Phi(\beta' x_i)] + \sum_{y_i=1} \ln [\alpha + (1 - 2\alpha) * \Phi(\beta' x_i)]. \tag{4}$$

The GLM with correction for classification error can also be specified with the probability of misclassification varying according to the choice of mortgage instrument and by personal characteristics. These two possibilities are explored through the use of the GAM methodology. Classification problems may not be the only contributions to coefficient bias, and for some observations the effect may be negligible (Hausmann and Scott Morton 1994). Thus a more general approach for correcting bias is used via a jackknife after bootstrap, a form of sensitivity analysis based upon resampling of the data.

The Identification of Outlying Observations With a Jackknife after Bootstrap

Greater flexibility in analysis and estimation can be gained if misclassified observations, inducing high levels of bias, can actually be identified, for example, testing for the simultaneous choice of mortgage size and the choice of mortgage instrument. This research uses the methodology of the jackknife after bootstrap to identify those observations which add significantly to coefficient bias in estimation.

Observations with large absolute relative influence on coefficient bias were treated as outliers and excluded from the sample. This exercise gives deeper insight into the effects of classification error on the consistency of estimation. A number of tests were applied to check the validity of this approach. Conditional upon adequate correction for the misclassification of the choice of mortgage instrument, this is the sample used for the final parameter estimates including testing for wealth and portfolio effects.

The jackknife after bootstrap gives a measure of the uncertainty of β estimates derived from a nonparametric bootstrap of the sample. Bias is generally defined as the difference between the expectation of an estimator $\hat{\beta}_{(.)}$ and the quantity being estimated $\hat{\beta}$. The jackknife after bootstrap computes $\hat{\beta}$ for those samples where observation i is absent (see Efron and Tibshirani 1993). It should be noted that the jackknife after bootstrap may not isolate misclassified mortgage choices alone. There will be significant other sources of bias and some misclassified variables that contribute little to this problem.

In summary, the methodology encompasses semi- and nonparametric estimation techniques, used to correctly specify the functional form of a mortgage instrument choice equation and to identify the appropriate form of correction for classification error. The result of the econometric testing will reveal whether a polynomial, linear, or nonparametric function are appropriate—the extent of misclassification of the dependent variable and the appropriate parametric or semiparametric form of analysis, in this case. A corrected sample will be used to test the regressive expectations hypothesis and the sensitivity of the results to the inclusion of variables representing wealth and portfolio effects. This corrected sample will also be more amenable to other specification tests, for example, the simultaneity of mortgage demand and mortgage instrument choice.

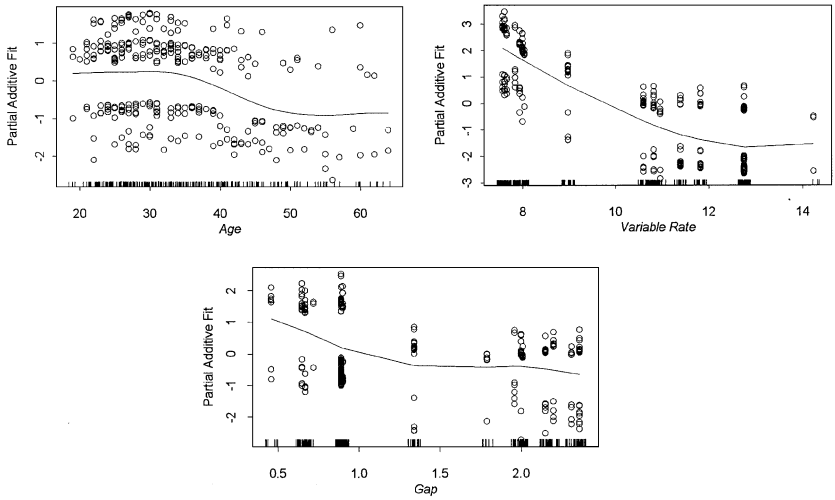
Estimation Results

This section of the paper reports the econometric results from estimating Equation (1). The results are reported in line with the methodology outlined above. The focus is on the parameter estimate for the variable rate of interest and possible wealth and portfolio effects on mortgage choice, the detection of classification error and misclassified observations, and an analysis of the consequences of misclassification for parameter estimates.

The General Additive Model

The first exercise was to test for nonlinear or nonparametric effects with a GAM model. The GAM estimates indicated that most variables could be specified in

Figure 1 ■ Partial additive fits for the GAM model (with residuals).



linear form. Only age (*Age*) suggested any nonlinearity, but this was due to a small number of outlying observations (people over the age of 65 years) that were subsequently removed from the sample ($n = 303$). A Chi-square test of nonparametric effects testing the reduced sample produced no statistically significant values at the 5% level. The analysis of residuals from this estimation supported a parametric methodology for the correction of classification error.

Figure 1 gives the partial additive fits for those variables found to be statistically significant at the 5% level in later estimations. Predicted values are given at the level of the response and the residuals are deviance residuals.[8] The visualization indicates relationships consistent with theoretical expectations. The probability of holding fixed rate debt falls with increases in the level of the gross variable mortgage interest rate (*VariableRate*). A negative relationship also holds for an increasing positive gap between the mortgage rate and short term money market rates (*Gap*).

The data visualization was also used as an initial assessment of any clustering of data that might suggest classification error in the dependent variable. Residual plots can highlight the salient aspects of a fit and signal potential problems (Hastie and Tibshirani 1990). Though there is some thinning of observations at

[8] Deviance residuals r_i^D are defined as $r_i^D = \text{sign}(y_i - \mu_i)\sqrt{d_i}$ where d_i is the contribution of the ith observation to the deviance. This form of deviance is particularly useful in isolating the impact of outlying observations.

given values of the interest rate terms, there is little evidence of a "pure region effect" (Hastie and Tibshirani 1990) producing spurious results. Preliminary evaluation suggests that any classification error may be randomly distributed. Classification error can lead to misleading apparent efficiency in estimation; no salient regions of tight dispersion are apparent.

The Binomial Probit With Correction For Classification Error

The second phase of the experimentation was to estimate a binomial probit with correction for classification error (see Hausman and Scott Morton 1994; Leece 2000a). Given the results of the general additive model, all variables were included in linear form. A parametric functional form also appeared appropriate. The estimates shown as Model 1 in Table 1 indicate that classification error accounts for 12.852% of the observations. Variables that were statistically significant in a probit without correction (Model 2) retain their significance and signs.

The log of gross household income (*Lincome*) and the correlation of income and the mortgage interest rate (*Corriv*) remain lacking in statistical significance. The variable *Had* represents the coincidence of mortgage demand with a housing move rather than remortgaging and also lacked statistical significance at the 5% level. The quarterly trend (*Trend*) was significant, though surprisingly negative in sign; this contradicts previous research (Leece 2000a) using a different sample. Possible reasons for this and the results of experimentation with year dummies are reported below.

The Jackknife After Bootstrap Adjusted Sample

The third stage in estimation was to use a jackknife after bootstrap to assess the bias of coefficient estimates. The results of this procedure were used to produce a sample excluding outliers ($n = 274$). Outlying and potentially misclassified observations were taken as cases that had an influence statistic of 2 or greater. This criterion is applied to variables that were statistically significant at the 5% level in the probit with correction for misclassification.

The validity of using the modified sample is shown by the value of the parameter estimates in the estimated probit (Model 3) which uses this data. The estimates are close to those of the estimated probit with correction for classification error (Model 1), and they have standard errors lying between the estimate with misclassification (Model 2) and that with the correction for misclassification (Model 1). Simulations by Hausmann and Scott Morton (1994) found that standard errors for the correctly classified population were located between the estimates with and without correction for classification error. Model 1

Table 1 ■ Comparison of treatments of the misclassification problem.

	Model 1 Probit with Correction for Misclassification		Model 2 Probit Incorporating Misclassification		Model 3 Probit with Jackknife Correction (Excluding Points with High Relative Influence)	
	Coefficient	S.E.	Coefficient	S.E	Coefficient	S.E
Constant	21.5024	8.3082	11.0669	2.5117	20.3578	3.8913
Age	−6.4592	2.3851	−3.5329	0.8201	−6.4583	1.1984
VariableRate	−1.5857	0.5783	−0.7641	0.1599	−1.3875	0.2564
Gap	−1.3990	0.5797	−0.6319	0.2679	−0.9332	0.3065
Lincome	0.1015	0.2685	−0.0151	0.1394	−0.0441	0.1668
Trend	−0.3385	0.1849	−0.1522	0.0715	−0.3256	0.1118
Corriv	−0.1849	0.3032	−0.7373	0.1689	−0.0899	0.2145
Had	0.4736	0.5068	0.2355	0.2619	0.2828	0.3062
Alpha	0.1285	0.0490	—	—	—	—
Log likelihood	−165.2252		−167.1500		−96.7731	

The table shows the coefficient estimates and standard errors for three different ways of dealing with classification problems in a dependent variable, including estimates that make no attempt to correct for this problem. The results shown as Model 1 are derived from a maximum likelihood technique that estimates the degree of classification error and controls for this. Model 2 is estimated on a sample that is not corrected for classification error. Model 3 is estimated using a sample where possibly misclassified observations are excluded.

Table 2 ■ Comparison of jackknife adjusted and nonadjusted misclassification models.

	Jackknife Adjusted Sample		Nonadjusted Sample	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Constant	21.6197*	6.3606	20.1097*	7.3310
Age	−6.2052*	1.6804	−5.9986*	2.2054
VariableRate	−1.4945*	0.4569	−1.3864*	0.5159
Gap	−1.1685*	0.3503	−1.2577*	0.5245
Trend	−0.3284*	0.1815	−0.2788*	0.1641
Classification Error	0.0299	0.0282	0.1170*	0.0537
Log likelihood	−116.6307		−166.2140	

The table compares the estimates from a binomial probit of the choice of mortgage instrument, both sets of which are estimated using a maximum likelihood technique that corrects for classification error. The jackknife adjusted sample is estimated on a sample where potentially misclassified observations have been removed. The nonadjusted sample retains the potentially misclassified observations.

*Significant at the 5% level

assumes that each observation has an equal probability of being misclassified, while Model 3 provides further information by the attempted identification of misclassified observations. Note that the differences in parameter estimates between Model 1 and Model 3 are within one standard error of the coefficient estimates in Model 1; this does not hold for Model 2.

Interestingly, the proportion of influential observations excluded from the sample was 0.12859, a figure extremely close to the estimated degree of classification error. There is no assumption of direct identification of misclassified observations. It may be the case that the estimate of classification error in the GLM model results from some influential observations that are not misclassified.[9]

Table 2 gives the results of reestimating the binomial probit with correction for classification error on the full noncorrected sample and the jackknife adjusted sample. The specification includes statistically significant variables only. The

[9] A comparison of cumulative distribution functions (CDFs) for the sample with classification error and the sample with observations excluded on the basis of the jackknife after bootstrap revealed more marked asymptotic behavior for the jackknife adjusted sample. Classification error typically reveals itself in the tails of the CDF. In this case, we can see that the modified sample is more distinctly asymptotic at the values of 0 and 1. This is suggestive of the importance of classification error (see Hausmann and Scott Morton 1994).

estimate of the misclassification rate in the adjusted sample is 0.02992, but this estimate is not significantly different from zero at the 5% level. The estimate of α in the full sample is 0.1170 and is significantly different from zero. There is a high degree of correspondence between the coefficient estimates. Thus the jackknife adjustment appears to offer an alternative control for the bias represented by α.[10]

The price of a sample excluding outliers identified by the jackknife after bootstrap may be selectivity bias. This will be a particular problem if misclassification rates or other sources of bias are high. This is not unrelated to the assumed randomness of the error and observed bias. The GAM methodology and the comparison of models made in this paper suggest that selection bias is not a significant problem.

Estimation Using the Jackknife Adjusted Sample

The final stage in the estimation was to test the model of the choice of mortgage instrument using the sample that had been corrected by excluding possibly misclassifed observations. This sample was also used for a number of other experimental purposes.

The bias-corrected sample was used to predict the probability of holding a fixed rate mortgage, to be used as an instrument in a mortgage demand equation. The possible simultaneity of mortgage and instrument choice is explicit in theoretical work (Bruekner and Follain 1988). The binomial probit with correction for classification error assumes that each observation has an equal probability of being incorrectly classified, and the predicted probabilities are amended accordingly. The bias-corrected estimates give a specific prediction with classification error assumed to be zero and therefore makes for a more appropriate instrument. A simple modeling of mortgage demand with the predicted probability of holding fixed rate debt as an independent variable did not indicate any simultaneity.

The extended database incorporating Waves 5 and 6 of the British Household Panel Survey facilitated the testing of wealth effects. Sensitivity tests were

[10] Analysis of the nonparametric bootstrap on coefficient estimation provided further support for the use of the binomial probit with correction for classification error and the use of a parametric form to produce and analyze a bias-corrected sample. The bootstrap involved 1,000 simulations and produced normally distributed variations in coefficient estimates. The jackknife after bootstrap produced small mean estimates of coefficient bias, again indicating that particular observations are likely to contribute more to bias than others. This analysis offers further confirmation that observations contributing significantly to bias were distributed randomly throughout the sample.

Table 3 ■ GLM probit with wealth and liquidity using a jackknife adjusted sample.

Variable	Coefficient	*t*-value
Constant	11.86	4.9
Age	−0.04	−4.4
VariableRate	−0.81	−4.6
Gap	−0.83	−2.9
Trend	−0.15	−1.9
Corriv	−0.06	−0.3
Liquid 1	0.24	0.9
Liquid 2	0.07	0.2
Investment 1	−0.36	−1.0
Investment 2	0.36	0.7

This table shows the results of the final estimating equation using the jackknife adjusted sample and including the additional variables of correlation between income and mortgage rates and various measures of wealth and liquidity.

conducted on the bias-corrected sample to see if it was appropriate to include these measures. Wealth was measured in the form of two dummy variables indicating investments over £1000 (*Investment 1*) and over £5000 (*Investment 2*). Similarly liquidity was measured by the amounts in bank accounts using the same cut off points of £1000 (*Liquid 1*) and £5000 (*Liquid 2*). The results are reported in Table 3 for a model with previously nonsignificant variables excluded, except for *Corriv* which complements the inclusion of wealth.

None of the measures of wealth or liquidity or any interactions with other variables proved statistically significant. These results confirm the short-run gamble afforded by U.K. mortgage contracts subject to high redemption penalties. *Corriv* was not a statistically significant variable at the 5% level. However, the data from which *Corriv* was constructed was a short panel which might result in measurement error for this variable. Further work on longer dated panels would be useful, though the lack of significance of wealth and liquidity suggest that considerations of hedging were not dominant.

The initial GAM estimation suggested thinness of observations at some interest rate levels. It was considered useful to reestimate Model 3 using a weight representing the exogenously given proportions of fixed rate debt for each year. The results are reported in Table 6 in the Appendix. With the exception of a slight reduction in the coefficient on *Age*, the salient findings of the research are robust to this exercise.

A comparison of the results of this exercise with research findings for the United States is of interest. The few studies that have used measures of wealth including

assets and debts tend to find a small impact upon choice probabilities and/or statistically insignificant parameter estimates (Dhillon, Shilling and Sirmans 1987; Philipps and Vanderhoff 1994). This result is now confirmed on U.K. data.

The impact of own price on ARM choice is typically found to be negative in U.S. studies (Dhillon, Shilling and Sirmans 1987; Brueckner and Follain 1988, 1989), where the dependent variable is the choice of an ARM ($ARM = 1$). The sign on a premium on fixed rate debt would be predicted as positive. In the U.K. case, fixed rate mortgages are the innovation and the choice of a fixed rate mortgage is the dependent variable ($Fixed = 1$). If we adapt representative U.S. empirical specifications for a mortgage choice equation (Dhillon, Shilling and Sirmans 1987; Brueckner and Follain 1988, 1989), then the cost of variable rate debt (*VariableRate*) is included in the estimating equation together with the premium on fixed rate debt (*Fixed* minus *VariableRate*). The premium represents the comparative cost of the two mortgage instruments, and it has a predicted negative sign. The level of the variable rate has a predicted positive sign.

Testing the amended model on the corrected sample produces incorrect signs or insignificant coefficients depending on the particular specification adopted. A positive sign on the premium for fixed rate debt might be a proxy for interest rate expectations. Controlling for this by including a variable representing interest rate expectations beyond a year and also the term structure of interest rates altered neither the significance nor the sign on this variable. The expectations variable was also incorrectly signed, with or without the premium. The negative sign and the coefficient on the variable rate of interest were robust to these specifications.

The results of the estimation reported in Table 3, together with the lack of statistical significance of the premium (markup) on the FRM and alternative specifications more typical of North American work,[11] suggest that a different choice mechanism might be in operation, namely regressive interest rate expectations. This possibility is reinforced by the statistical significance of the

[11] The probit using the sample adjusted for coefficient bias was estimated in several ways to capture interest rate expectations and the effect of the premium on fixed rate contracts. For example, including the variable rate plus the premium on fixed rate debt did not significantly alter the results and the margin was not statistically significant ($t = 0.29$) and incorrectly signed. Variables indicating expectations over five years (that is the difference between one- and five-year fixed rates) were not statistically significant ($t = -1.62$) either. Removing *Gap* pushed the premium and the expectations variable into statistical significance, but they still retained unexpected signs on the coefficients.

gap between the current variable mortgage rate and the base rate of interest, reflecting lags in mortgage rate adjustments.

United States research has found some evidence of regressive interest rate expectations. That is, when interest rates are high, then borrowers are reluctant to lock in to fixed rate contracts. James, Miller and Riddiough (1995) specify an ARM market share model that includes the difference between the FRM and ARM rates and the absolute size of the FRM rate. There is a significant positive impact of FRM rate, which they interpret as affordability, or possible regressive interest rate expectations. The statistically significant and negatively signed coefficient on the variable interest rate is the equivalent finding for the United Kingdom. The significance of deviations between the variable rate and the base rate of interest, together with the lack of significance of wealth and liquidity variables, reinforces the regressive interest rate expectations interpretation of this result. The dominance of this interpretation appears to be unique to the U.K. mortgage market.

Another variable that is unique to this research is the linear time trend. This was chosen in preference to binary variables for several reasons. There was increasing promotion of fixed rate debt by lenders during the early to mid-1990s and fixed rate mortgages were a major innovation. Thus the expectation was that there might be a positive trend in the adoption of this mortgage instrument. Such a trend might result from increasing awareness and propensity to adopt, and also supply-side selling pressures (Leece 1995a, 2000a).

Given the unexpected negative sign on the time trend, the results of the final estimating equation reported in Table 3 were tested for their sensitivity to the inclusion of binary variables. Just the one-year dummy for 1994 was statistically significant and positive in sign. Reestimating using the 1994-year dummy did not produce significantly different results from using a time trend. Neither is there any clear reason why the uptake of fixed rate debt should be greater during 1994.[12] Given no strong empirical reason for using this specification and given that maximum likelihood algorithms can be less than sympathetic to binary variables, making convergence difficult to achieve, the original specification was retained. The period 1991 to 1994 in the United Kingdom was one of increasing competition and transition; discounts (teaser rates) previously only available to first-time purchasers were gradually extended to existing

[12] In fact, the onset of more aggressive discounting of variable rate debt late in 1994 might lead to the opposite expectation (see Leece 2000a).

owner-occupiers.[13] Given the likely dominance of former owner-occupiers in this sample, the negative time trend may be a control for this effect.

The summary statistics for the jackknife adjusted sample using the more parsimonious model reported in Table 3 indicated a good overall fit. The pseudo-R^2 was 0.344 and the number of correctly predicted ones was 0.873 with correct zero predictions of 0.66. Interestingly, the overall fit improved significantly when compared to the model estimated with misclassified or highly biased observations included. The latter model had a pseudo-R^2 of 0.189 and correct predictions for the dependent variable coded 1 of 0.80 with the proportion of zeros correctly predicted at 0.55. It is also apparent that estimating a simple probit with the presence of misclassification can lead to smaller (and possibly misleading) standard errors than any of the alternative corrected specifications (see Table 1). Moreover, there are significant differences in parameter estimates between corrected and uncorrected estimates.

Summary and Conclusions

The now extensive literature on the choice of mortgage instrument in the context of the U.S. mortgage market has established a number of key influences on this choice such as the importance of own price, the premium on fixed rate debt, and interest rate expectations. The U.K. mortgage market and contract designs differ in a number of important ways that tend to induce households to take a short-term perspective on instrument choice. This has led to some results that differ from research findings for the United States (Dhillon, Shilling and Sirmans 1987; Alm and Follain 1987; Phillips and Vanderhoff 1994). Differences include the lack of statistical significance or incorrectly signed premium on fixed rate mortgages and the negative sign on the variable interest rate when they are used to explain fixed rate choice ($Fixed = 1$). The results were consistent with those studies that have found a regressive interest rate effect (James, Miller and Riddiough 1995), though the U.K. research reported here gives stronger credence to regressive interest rate expectations informing consumers' mortgage choices.

The basis on which U.K. households made their choices of mortgage instrument has important policy implications. The research established the presence of regressive interest rate expectations where households were reluctant

[13] The source for the mortgage interest rate data indicated a gradually increasing number of contracts with discounts available for new borrowers, not just for first-time buyers. The comparative numbers are 29 discount deals for first-time buyers in June 1990 compared to 7 for new borrowers, while for January 1995, the figures are 14 for first-time buyers and 41 for existing borrowers. The trend in the percentage difference in the number of contracts is distinctly linear from January 1991 onwards, with a crossover point around January 1992 (42 discounted contracts for first-time buyers and 43 for new business). Source: *What Mortgage*, January 1990–January 1995.

to lock in to fixed rate contracts at historically high levels of the variable interest rate. The short-run focus to housing finance decisions helped to explain the reluctance to switch into long-term fixed rate debt. This reluctance and the persistence of contracts fixed for just a few years has the important implication that the U.K. housing market will not readily move to the type of fixed rate mortgage which will insulate the economy from short-run interest rate shocks. This also implies the likely persistence of an important obstacle to monetary and mortgage market integration with Europe (Britton and Whitley 1997).

The results do offer some hopeful signs for policy makers. If households can be persuaded that low interest rates are sustainable, then they may be more willing to lock into fixed rate debt. It may be that households then perceive a lesser need for fixed rate terms. However, it is more likely that the continuing development of the secondary mortgage market and the diminution of prepayment penalties will facilitate the adjustment of borrowing to needs and desired interest rate exposure, thus facilitating a longer-term perspective. Indexing of variable mortgage rates to the base rate of interest will remove the uncertainty surrounding interest rate stickiness and encourage the switching into fixed rate mortgage debt of longer duration. Finally, the spread of mortgage contracts with more flexible amortization schedules will also assist in overcoming liquidity problems and capital market imperfections (Leece 1997), further attenuating the short-term perspective.

Given the importance of the choice of mortgage instrument for macroeconomic stability and policy making, it is also important to obtain efficient and consistent parameter estimates. In this respect the paper differs methodologically, in important ways, from previous work on the choice of mortgage instrument. The research has demonstrated the need to control for classification error and other sources of coefficient bias. A general additive model facilitated the choice between parametric and nonparametric approaches to these problems and aided the visualization of potential specification and estimation issues. A jackknife after bootstrap allowed the identification of problem observations and proved an effective means of dealing with sources of coefficient bias. The use of nonparametric and semiparametric techniques allowed estimation with few priors regarding the statistical distribution and restrictions on functional form. These approaches are new to the mortgage choice literature and are particularly suitable to testing a nonstandard model of mortgage instrument choice particularly adapted to the circumstances of the U.K. mortgage market.

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Appendix

Table A1 lists the variables used in this paper and their descriptions and Table A2 lists the corresponding descriptive statistics. Table A3 shows the results of a reestimation of Model 3 using a jackknife corrected sample.

Table A1 ■ Variable names and labels.

Variable	Description
Fixed	The dependent variable. Holding a fixed rate mortgage equals 1.
Age	Age of household reference person in years as at 12/12 in the Interview Year.
VariableRate	The gross variable rate of mortgage interest.
Gap	The difference between the gross variable mortgage interest rate and the base rate of interest.
Lincome	The log of gross household income.
Trend	An index from 1 to 16 indicating the quarter and year in which the mortgage debt was assumed.
Corriv	The correlation between gross household income and the gross mortgage interest rate.
Had	A dummy variable with 1 indicating a coincidence of quarter and year of housing move and the assumption of a mortgage and a zero implying a discrepancy in dates and a possible remortgage.
Liquid 1	A dummy variable with 1 indicating bank balances over £1000.
Liquid 2	A dummy variable with 1 indicating bank balances over £5000.
Investment 1	A dummy variable with 1 indicating investments over £1000.
Investment 2	A dummy variable with 1 indicating investments over £5000.

Table A2 ■ Descriptive statistics ($n = 303$).

Variable	Mean	Standard Deviation
Fixed	0.5709	0.4957
Age	0.3387	0.0986
VariableRate	10.1805	2.0926
Gap	1.3469	0.6456
Lincome	9.6324	0.6007
Trend	7.2640	4.6688
Corriv	−0.2328	0.4845
Had	0.8944	0.3078
Wealth and Liquidity ($n = 277$)		
Liquid 1	0.2780	0.4488
Liquid 2	0.1227	0.3287
Wealth 1	0.0975	0.2971
Wealth 2	0.0505	0.2195

Table A3 ■ Weighted probit using a jackknife corrected sample.

Variable	Coefficient	t-value
Constant	19.19	4.6
Age	−4.68	−3.5
VariableRate	−1.30	−4.6
Gap	−0.86	0.4
Lincome	−0.12	−0.7
Trend	−0.31	−2.4
Corriv	−0.08	−0.4
Had	0.59	1.9

This table shows the results from using the jackknife adjusted sample excluding potentially misclassified observations while weighting the estimation by the known proportions of fixed and variable rate mortgage debt in the national economy over the period of study.

Log likelihood −105.0888.