Testing a Basic Theoretical Model of Mortgage demand on United Kingdom Data

David Leece

Testing a Basic Theoretical Model of Mortgage demand on United Kingdom Data

Journal:	*Applied Economics*
Manuscript ID:	APE-04-0093.R1
Journal Selection:	Applied Economics
Date Submitted by the Author:	12-Apr-2005
JEL Code:	C31 - Cross-Sectional Models|Spatial Models < C3 - Econometric Methods: Multiple/Simultaneous Equation Models < C - Mathematical and Quantitative Methods, D14 - Personal Finance < D1 - Household Behavior and Family Economics < D - Microeconomics, R21 - Housing Demand < R2 - Household Analysis < R - Urban, Rural, and Regional Economics
Keywords:	mortgage, demand, housing, estimation

Testing A Theoretical Model of Mortgage Demand on United Kingdom Data

Professor David Leece

Department of Business and Management Studies, MMU Cheshire, Manchester Metropolitan University

Testing A Theoretical Model of Mortgage Demand on United Kingdom Data

Abstract

Mortgage demand is a little understood and under researched aspect of the financial behaviour of households. This paper empirically tests the basic results of Brueckner's model of mortgage demand (Brueckner, 1994) on United Kingdom mortgage market data. The choice of mortgage instrument is used to identify impatient debt maximisers and patient borrowers who borrow at intermediate levels. Thus the research confirms the conditions under which households will use the largest possible mortgage and the circumstances under which savings are invested in the property. A unique contribution of the work is the estimation of mortgage demand equations corrected for endogenous housing demand, for a single housing finance system, where borrows face different opportunity costs of equity in their owner occupied property, allowing a purer test of the theoretical model.

Introduction

Mortgage demand is an important financial choice of households that is not yet fully understood. Brueckner (1994) has deduced some basic theoretical results for mortgage demand, under certainty and uncertainty, and drawn out their implications for econometric estimation. His work demonstrated the critical nature of the interest rate regime, that is the relative magnitudes of the net of tax mortgage interest rate and the net of tax savings rate (also see Alm and Follain, 1987). The research also emphasised the need to correct for the endogeneity of housing demand in mortgage demand equations. An argument of this paper is that the choice of mortgage instrument provides the basis for estimating mortgage demand equations for groups of borrowers who face a different relationship between the opportunity cost of equity in their property and the net of tax mortgage interest rate. This produces the conditions for testing the qualitative predictions of Brueckner's model with uncertainty, for example the circumstances under which households maximise debt. The theoretical predictions differ according to the interest rate regime, in this case as it varies between households.

Understanding the determinants of mortgage demand is important for both the evaluation of monetary and fiscal policy and rigorous housing and mortgage market analysis. Mortgage debt has significant implications for the economic welfare of individuals and their life opportunities (see Leece 2004). The paper builds on previous work that compares the mortgage demand of endowment and repayment mortgage holders (Leece, 1995, 2000, 2001). It significantly extends that research in two ways. Firstly, the comparison of mortgage demand equations is used to test Brueckners 1994 mortgage demand model. Previous research, published in this journal (Leece, 1995, 2000) and elsewhere (Leece, 2001), has not been guided by an explicit theoretical model of mortgage demand. A true test of the basic results of such a mortgage demand model requires observed variations in the relationship between net borrowing costs and the net foregone return on financial savings. This paper argues that a comparative study of the mortgage demand of endowment and annuity mortgage holders provides this variation and is thus a true empirical test of this specific mortgage demand model.

Secondly, the research reports the results of testing for the simultaneity of mortgage and housing demand in primarily cross section data. This simultaneity has been tested for and detected in US work (see Ling and McGill, 1998), but it has been neglected in previous UK mortgage demand estimation (for example, Devereaux and Lanot, 2004). In the papers previously published in *Applied Economics* Leece has tested for the simultaneity of mortgage demand and the choice of mortgage instrument but not for the endogeneity of housing demand. More recent work, has partially addressed this issue (see Leece 2004) but for endowment mortgage holders only, thus foregoing a comparative estimate of the mortgage demand model and accompanying specification tests when opportunity cost of equity in property might vary by household and be reflected in the choice of mortgage instrument.

Estimating mortgage demand for households that face different comparative costs within a single housing finance system overcomes a number of difficulties. The theoretical model can be tested with respect to a shared menu of mortgage contract choices, and a given fiscal and regulatory framework. The exercise also reflects upon the validity of aggregating mortgage demand in time series studies of national markets. Different opportunity cost of equity within a single housing finance system are likely to correspond with some form of market segmentation or selectivity, or be associated with other features of borrowing such as liquidity constraints. If appropriate segmentation is signalled by the choice of mortgage contract (e.g. borrower impatience), joint borrowing and savings outcomes predicted by Brueckner's model can be empirically evaluated. The research reported in this paper considers households, which maximise debt, and borrowers who have intermediate levels of borrowing.

The estimation of mortgage demand equations by mortgage type, using UK data, has been reported elsewhere (Leece, 2000 b; Leece, 2004; Devereaux and Lanot, 2004). The work reported here extends previous research by controlling for endogenously determined housing demand, and analysing the debt maximising behaviour of annuity (repayment) mortgage holders. The research also covers a more recent period, 1990-1994, compared to previous work – e.g. 1985 to 1989 in the case of Devereaux and Lanot, 2004). [1]An additional interest is the joint borrowing and saving decision evident in the choice of an endowment mortgage. Leece (2000 b) has indicated the information content in the choice between the endowment and the annuity mortgage and those ideas are extended here. The research reports estimates of mortgage demand equations for two types of mortgage holder, endowment and repayment. The expectation is that the savings and borrowing decisions of households within these two groups will correspond with important subsets of behaviour predicted in Brueckner's model.

The repayment mortgage is a conventional annuity mortgage with a level payment combining interest and repayment of principal. The repayment mortgage can have a variable term, and thus affords some flexibility in the rate of amortisation (Leece, 1997). The endowment mortgage is an interest only (or balloon) mortgage with accompanying contractual payments into an investment fund. For popular 'with profits endowment policies' it was expected that on maturity the sum accrued would exceed the

[1] United States research concerns credit rationed or liquidity constrained groups (Linnemann and Wachter, 1989, Follain and Dunsky, 1997).

nominal value of the mortgage debt. Thus endowment mortgages are a joint housing finance/financial savings decision[2]. Most previous research on UK endowment mortgages has been concerned with the valuation of the option to default (Chinloy, 1995; Pereira et al, 2003). Research relevant here concerns the choice between an endowment and a repayment mortgage (Leece, 1995 b). Endowment mortgage holders are argued to have a high foregone rate of return on savings. High opportunity costs of equity in property, *ceterus paribus*, leads to lower rates of amortisation of debt (see Plaut, 1985), with the limit being zero amortisation and the balloon mortgage. This and other characteristics of the two types of debt are used to predict the expected behaviour of mortgage holders.

The data comes from the British Household Panel Survey (BHPS), a rich source that has observations dating from 1991. The demand equations were estimated for the period 1991 to 1994. There are later panels of data available, but these were not used. Post 1994 the UK mortgage market became increasingly complex in the choices available, with heavy discounting (teaser rates), and a greater variety of cash back (front loaded payments), fixed rate or capped deals. This complexity is of great interest but creates difficulties for aggregating mortgage types and determining mortgage type within the BHPS. The relationship between net of tax mortgage rates and opportunity cost of equity becomes more ambiguous and difficult to establish. Noise is also evident in the growing dissatisfaction with the performance of endowment mortgages[3]. Thus the period 1990 to 1994 provides a window for the comparison of estimates of mortgage demand classified by mortgage choice, suggested here. One difficulty is that the panel does not cover a full interest rate cycle, though there is significant and non-trending variation in the premium charged on fixed rate debt (see Leece, 2000 a, 2001 a).

The first section of the paper presents the theoretical background to the research. This includes the basic results of mortgage demand presented by Brueckner (1994), and a discussion of the basis of choice between a repayment and an endowment mortgage. The sample and estimation issues are discussed in the subsequent section, followed by a discussion of results. Brueckner addresses some key questions. Under what circumstances will households have the largest possible mortgage? When will households use existing assets to reduce the size of any mortgage? When will households rely exclusively on savings to finance the purchase of a property? The first two of these questions are addressed empirically in this paper. The results confirm that impatient borrowers facing a low opportunity cost of equity will exhibit maximum borrowing. The results also suggest that households with lower levels of impatience and high opportunity cost of equity will have intermediate levels of borrowing combined with saving in an alternative investment to housing. Given that under uncertainty the signs on variables in the latter case are ambiguous then the parameter estimates are of further interest.

[2] It might be argued that only payments over and above the amount expected to secure debt repayment is saving. While this does not materially effect the analysis the endowment holder is still making a savings decision in regard to the repayment of the debt.

[3] There are a number of serious issues concerning information asymmetry and agency problems in the endowment market, with accusations of mis-selling and accompanying financial scandals. These issues are not discussed in this paper. The critical point is that households holding an endowment expected a rate of return in excess of the net of tax mortgage interest rate.

Brueckner's Basic Results

The econometric specification reported in this paper is derived from the basic results of mortgage demand established by Brueckner (1994). That model demonstrates the effects on the comparative static's of a mortgage demand equation of differences in interest rate regimes. The modelling covers conditions of certainty and uncertainty. The uncertainty model allows variance in the rate of return on financial savings. Certainty models can usefully inform econometric specification, but it is likely that households making joint mortgage and investment choices will operate under uncertainty. In this case the comparative static's are ambiguous. However, the model has some important qualitative results relating to circumstances under which mortgage debt will be maximised, and when it will be combined with financial saving and investment. These qualitative results provide the focus for this paper.

This section of the paper presents the basic framework of Brueckner's model. This is a two period model. Households simultaneously determine housing h, mortgage demand m and levels of saving s. Decisions on saving and the allocation of expenditure between housing and a numeraire commodity x effect future (second period) wealth, from which utility is also derived. The household's objective function, equation 1, is the combined utility function and budget constraint. In this equation household utility U is a function of non housing consumption x (eliminated by substitution of the budget constraint for x in U), housing, and wealth which originates from interest on savings r_s, income y, the value of property ph less the final balloon payment and interest due on the mortgage $(1+r_m)m$. Future utility of wealth V is discounted by the borrowers rate of time preference δ.

$$U[w-s-(ph-m),h]+\delta V[y+(1+r_s)s+ph-(1+r_m)m] \qquad (1)$$

Households face several borrowing constraints. Borrowing for purposes other than the purchase of a property is precluded, and therefore savings must be positive or zero $(s \geq 0)$ indicating a liquidity constraint. Mortgage borrowing must be less than the exogenously given maximum loan to value ratio $(\alpha ph \geq m)$ indicating some potential mortgage credit rationing. Also, the mortgage must be greater than zero $(m > 0)$ so that households cannot issue their own mortgage debt. Given these reasonable restrictions then optimising (1) yields Kuhn-Tucker optimality conditions for s, m and h.

Of course in a perfectly competitive market, with equal interest rates on borrowing and saving, then the household would be indifferent between the use of saving or mortgage borrowing in shifting wealth between periods. The model precludes this possibility by restricting mortgage borrowing to the first period, and limiting this to the finance of housing[4]. There is also a critical assumption of differences in borrowing and lending rates driven primarily by the possibility of the different tax treatment of the mortgage interest rate and the rate of return on the appropriate savings vehicle. In the United Kingdom for example returns on endowment mortgage investment funds were tax-free. Arguments presented

[4] See Brueckner (1994) p. 252 for a discussion of these assumptions.

later in this paper suggest that differential opportunity costs of borrowing can emerge because borrowers have different alternative financial investments to housing, and that this difference in the relevant savings vehicle is reflected in the choice of mortgage instrument.

Note that the three sets of optimal results represent the simultaneous determination of the level of housing services, savings and mortgage size, and this is critical to the econometric estimation reported later[5]. However, we follow Brueckner (1994) in combining the optimality conditions for just s and m and holding h constant[6]. This then focuses upon the choice between the mortgage and savings and facilitates an analysis of the impact of different interest rate regimes.

The key equation is equation (2), which is derived from a combination of the first order conditions for s and m, with h assumed exogenously given. The arguments $(\lambda, \mu, \vartheta)$ in equation (2) are the respective multipliers. The equality represents optimum combinations of saving and mortgage debt. For a given relationship between r_s and r_m the required comparative sizes of the multipliers and thus borrowing behaviour can be derived. For example, given that the multipliers cannot be negative then in the case of $r_s > r_m$, and with certainty, debt must be maximised[7].

$$(1+r_s)\delta V' + \lambda = (1+r_m)\delta V' + \mu - \vartheta \qquad (2)$$

The key feature of equation (2) is the importance of the interest rate regime. There are several subsets of possible behaviour when the values of r_s and r_m are known with certainty. The rate of time preference or degree of impatience δ plays a key role in delineating these behaviours. When the mortgage rate is less than the savings rate borrowers will maximise their debt. When the mortgage rate is higher than the rate of return on savings then the outcome depends upon the degree of impatience. Highly impatient borrowers will still maximise debt but they will have zero financial savings, though in practice such households may demand some liquidity. Borrowers with intermediate levels of impatience will borrow less than the maximum value and have zero financial savings. Very patient households will have positive financial savings but zero mortgage debt. The certainty model yields comparative static results which can inform the specification of a mortgage demand equation. In the cases where the loan to value ratio binds then comparative static effects are zero on all variables except h which can be increased to overcome this constraint. Other than this case mortgage demand is a positive function of housing and income and a negative function of initial wealth and the borrowers discount rate.

The complications in mapping the theory onto empirical specification arise in the case when r_s and

[5] The optimality equation for housing is given by $-pU_x + U_h = p\delta V' + \alpha p\mu = 0$ where p is the price per unit of housing services. So housing is a choice variable which will require the use of instrumental variables in the estimation of the mortgage demand equations.
[6] See Brueckner (1994, p. 254).
[7] See Brueckner (1994, pp. 254-255).

r_m have uncertain values. The modified version of equation (2) is presented below as equation (3) and now includes the appropriate integrals and probability density functions (ϕ), when r_s is uncertain[8]. With uncertainty and when $r_s > r_m$ borrowers may no longer maximise debt but rather both borrow and save in a financial asset. It is this additional possibility that leads to the ambiguity of expected signs on variables. In the case where $r_s < r_m$ then the subsets of behaviour correspond to those under certainty. That is impatient borrowers will maximise debt and have zero financial savings, less impatient borrowers will have intermediate levels of debt with no financial savings, and patient borrowers will have no debt with positive savings in an alternative asset to property.

$$\int (1+r_s)\delta V'\phi dr_s + \lambda = (1+r_m)\int \delta V'\phi dr_m + \mu - \theta \qquad (3)$$

Given the possible importance of house price uncertainty for mortgage demand then equation (3) can be extended to include a third integral, and probability density function, to represent house price uncertainty. Brueckner (1994) conducts this exercise and concludes that this makes no difference to the theoretical predictions of the model of mortgage demand under uncertainty, that is the conditions under which debt maximisation, minimisation or intermediate borrowing take place remain the same[9].

The econometric estimation reported in this paper attempts to detect two major subsets of predicted borrowing behaviour under uncertainty. These are the impatient debt maximisers for whom $r_s < r_m$ (*subset 1*) and the fairly patient borrowers who have joint financial savings and borrowing and face $r_s > r_m$ (*subset 2*). This paper argues that self selection in the UK mortgage contract market results in a sorting of borrowers into these two groups by patience and thus allows a test of the qualitative predictions of the model, that is conditions under which debt maximisation takes place and conditions where borrowers make a contribution to the equity in their property and save in an alternative financial asset. Of the remaining predicted types of behaviour when $r_s < r_m$ zero borrowing is excluded from the empirical analysis while intermediate borrowers with no saving in an alternative financial asset might be detected within repayment mortgage holders (the endowment requiring compulsory saving in a financial investment). Intermediate mortgage borrowers with no saving are empirically identified among repayment mortgage holders by having short durations of debt, which are indicative of a lack of debt maximisation with respect to time.

The Behavioural Basis of the Selection of an Endowment Mortgage

This section of the paper offers a brief review of the literature on the choice between an endowment and a repayment mortgage (Leece, 1995, 2000 a, 2000 b, 2004; Devereaux and Lanot, 2004). Previous

[8] Brueckner tests for an uncertain r_m which is more applicable to Canada than the USA and is also relevant to the UK mortgage market with its dominance of variable rate debt. This made no difference to the conclusions of the analysis.

[9] See Brueckner (1994) page 259.

research suggests the determinants of contract choice and the likelihood of any related selectivity bias in the estimation of mortgage demand equations. Devereaux and Lanot demonstrate that in a world of certainty, and with no preferential tax treatment, borrowers will be indifferent between the two types of mortgage. When the return on the investment fund is uncertain the choice reflects a separating equilibrium, with more risk averse borrowers adopting the repayment mortgage. A subsidy on mortgage interest payments induces the marginal borrower to switch so that some risk averse borrowers adopt the endowment. A decline in the subsidy would lead to a reduction in demand for the endowment mortgage but a separating equilibrium might remain.

Leece (1995, 2000 a) offers a different perspective based upon the non-price features of UK mortgage contracts. For example, the repayment mortgage can vary in term and facilitates flexible amortisation scheduling. In addition, the repayment mortgage is prepaid on moving to a new property, while the endowment mortgage is transferable. Prepayment means that repayment mortgage holders can take out a new loan using the same term (typically 25 years) reducing the rate of amortisation of their debt and effectively maximising their holding of housing debt with respect to time. This feature, along with repayment flexibility, may be attractive to liquidity constrained and/or impatient borrowers, or households facing capital market imperfections and incomplete portfolios (Leece, 2004). Thus there is an alternative basis for a separating equilibrium to that suggested by Devereaux and Lanot. Impatient borrowers may be concentrated among repayment mortgage holders.

There is empirical evidence for the importance of liquidity constraints and capital market imperfections for mortgage choice. Devereaux and Lanot estimate a discrete choice model of choice of mortgage instrument to be used as a correction for selectivity in disaggregated mortgage demand equations. The results suggested that either risk aversion or liquidity constraints provides the basis of choice, together with the relative cost of the two mortgage instruments. Leece (1995, 2000a) also finds evidence of liquidity and affordability concerns driving the choice of mortgage type. Moreover, the estimated mortgage demand equations demonstrate that repayment mortgage holders behave like a liquidity-constrained group of borrowers. A common finding in all the research is that there is no selectivity bias in mortgage demand estimation arising from the choice of mortgage instrument.

A choice equation was estimated for the purposes of testing for selectivity bias in the mortgage demand equations. The results of this estimation can be found in Table A1 in Appendix A. The overall equation is not statistically significant though the mortgage interest rate argument is significant and positive in sign. Endowment performance is positively related to the level of interest rates and so this result may reflect this effect. At the margin some borrowers are attracted by higher endowment performance as suggested by Devereaux and Lanot. There is no observable price effect (that is negative interest rate effect) to indicate the degree of substitutability between the two contracts. Also, there was no evidence of selectivity bias in the estimation of the disaggregated mortgage demand equations. Taken together with low explanatory value there is little evidence that the choices are close substitutes. The markets may be segmented and reflect unobservable preferences of borrowers that correlate with *constant* non-

price contractual features[10]. For example a desire to maximise debt with respect to time by impatient or liquidity-constrained borrowers that would render the repayment mortgage more suitable.

An important consideration is the effect of the subsidy on mortgage interest payments. According to Devereaux and Lanot (2004) this subsidy has the effect of inducing risk averse borrowers to take up the endowment mortgage. Several empirical features suggest that this subsidy may no longer have been large during the 1990s, and that the benefits of the subsidy arising out of the endowment choice were largely captured by lenders (Devereaux and Lanot, 2004). The standard rate of tax was reduced, as was the amount of interest rate subsidy allowed. Moreover, maintaining the upper threshold of borrowing eligible for relief in nominal terms led to a decline in the real value of this subsidy[11]. The cost differences between endowment and repayment mortgages have not been large suggesting that lenders captured some of the tax relief. More formal econometric analysis by Devereaux and Lanot suggests that this capture was indeed the case. Thus the major factor influencing the choice of the endowment mortgage was likely to be the expected rate of return on the endowment fund. This is consistent with the estimates of the selection equation for this paper, which nether the less shows this effect not to be large. Endowment and repayment mortgages may not have been viewed as close substitutes.

This paper argues that the mortgage demand of repayment mortgage holders reflects that of impatient borrowers who value the facility to defer the repayment of capital. Conversely, the mortgage demand of endowment mortgage holders will reflect the behaviour of more patient borrowers who combine ownership of property with investment in an alternative financial asset and do not follow a debt maximising rule. However, to map mortgage demand onto the qualitative results of Brueckner's model we also need to establish the likelihood that borrowers face different opportunity costs of equity in their property. For example, in the case of $r_s > r_m$ patient borrowers will forego debt maximisation and save in an alternative financial asset but if $r_s < r_m$ then no such saving should be evident

Endowment holders expect that the rate of return on their financial investment will exceed the mortgage interest rate, that is $r_s > r_m$. There is an expectation of a capital sum on maturity that exceeds the outstanding balance and so the endowment is also perceived as a savings vehicle. Flexible amortisation would suggest that the repayment mortgage has value for liquidity-constrained households and/or those with incomplete portfolios (Leece, 1995, 2000 a; Plaut, 1986; Goodman and Wassmer, 1992; Brueckner, 1984). Such households are likely to value liquidity and have a lower opportunity cost of equity in their property (Leece, 1995). Thus there are now two regimes, one with a comparatively low opportunity cost of equity combined with the possibility to defer capital repayments of interest to impatient borrowers. The other a high opportunity cost of equity regime with inflexible

[10] For example, if impatience does not vary with borrower characteristics that influence choice and the characteristics of contracts do not change, and contract features correlate with the unobservable borrower impatience then this will reduce the elasticity of substitution with respect to price between the contracts. The given contractual features are discrete (for example term can be adjusted or it cannot) and are not used as non-price features which can vary to achieve market equilibrium. Thus market segmentation is expected in this case.

[11] Devereaux and Lanot note a reduced aggregate cost to the Inland Revenue from £7.7 billion in 190/91 fell to £3.5 billion by 1994/1995.

amortisation scheduling but with the accumulation of financial capital to meet the debt and attracting more patient borrowers. It is possible that savers in financial assets could be indifferent between the two contracts, take out a repayment mortgage and invest elsewhere, and so for those households $r_s > r_m$. In this case we adopt the usual assumption of separating equilibrium where a borrower indifferent to two choices will adopt the choice compatible with the separating equilibrium. There might also be lower transactions costs from packaging the investment fund and the mortgage, which would reinforce this division of borrowers.

The Empirical Specification of the Mortgage Demand Models

The econometric estimation involves two dependent variables, the real mortgage balance M^* and the loan to value ratio lv, both measured at origination. There are good reasons in the case of the UK housing market to use measures of mortgage debt measured at origination (see Leece, 2004). Firstly, this eases comparison with other UK studies (Devereaux and Lanot, 2004) where the data set constrains the dependent variable to be new mortgages (BSA data). Secondly, given prepayment penalties in the UK then there can be large divergences between desired and actual mortgage balances and thus the actual and market value of debt; such discrepancies are minimised at the point of adoption. Each of these equations will be separately estimated for endowment and repayment mortgage holders.

The coefficients on all variables except housing and the constant term are restricted to be the same for estimates involving both dependent variables (that is the use of an instrument effectively controls for variations in housing expenditure evident in the denominator of the loan to value ratio). There are different expectations regarding the effects of housing expenditure on the loan to value ratio in the case of debt maxi misers, to be discussed below. The general specification of the mortgage demand equation is given by expression (4). The model is expressed in terms of natural logarithms.

The econometric specification follows Brueckner (1994) in that the focus is upon the endogeneity of housing demand and mortgage demand under different interest rate regimes, reflected here by the choice of mortgage instrument. The remaining arguments in the empirical estimation reflect those variables typically expected to impact on housing/mortgage demand and found in previous UK estimations (see Leece, 1995, 2000, 2001). Thus mortgage demand is taken to be a function of a constant term (a), age (A), the net of tax mortgage interest rate (r_m), the premium on fixed rate debt (r_p), the discrepancy between savings and mortgage loan rates ($r_s - r_m$), income (I), an instrument for housing expenditure (H_I), lagged values of house price inflation (p_h)and a vector of personal/household characteristics (V).

$$\ln(M^*) = \Omega \ln(a, A, r_m, r_p, r_s - r_m, I, H_I, p_h, V) \qquad (4)$$

The variable names for the empirical counterparts to these theoretical variables are mostly designed to

be self-explanatory and are presented as descriptions in Tables of results. Note that the interest rate is the average nominal mortgage interest rate net of standard rate tax adjusted for any changes in this tax during the period of study. Income relates to gross annual household income. House price inflation is measured by changes in the Department of Environment annual house price index. Though house price volatility may impact upon mortgage demand the main focus of econometric estimation in this paper is the cross section analysis. The span of time for time varying effects is just four years, and is a period of continuously declining house prices; therefore house price volatility is assumed constant in this model. In addition the first order conditions in the theoretical model do not suggest any unique role for house price volatility.

The previously discussed theory offers the following predictions regarding the behaviour of the two types of mortgage holder.

- Annuity mortgage holders are impatient debt maximisers who face $r_s < r_m$. This implies zero saving in an alternative asset to housing and zero coefficients in the mortgage balance equation, other than for endogenously determined housing demand ($\frac{\partial M^*}{\partial H_1} > 0$), as is the case under certainty.

- Endowment mortgage holders are savers and with a risky investment are less likely to be debt maximisers, despite $r_s > r_m$. The coefficients on explanatory variables remain ambiguous in sign and their determination is of interest. For example, $\frac{\partial M^*}{\partial H_1} \geq 0$ or $\frac{\partial M^*}{\partial H_1} > 0$ can hold.

- That in the case of debt maxi misers there is no systematic relationship between the demand for housing and the observed loan to value ratio ($\frac{\partial lv^*}{\partial H_1} = 0$). The loan to value ratio provides an absolute constraint. Increased housing demand merely raises absolute levels of borrowing to overcome this constraint.

- That for borrowers facing $r_s > r_m$ (endowment holders) and adopting an intermediate level of borrowing there is the possibility of a systematic relationship between the demand for housing and the loan to value ratio, though with uncertainty the expected sign on housing expenditure in such an equation is ambiguous ($\frac{\partial lv^*}{\partial H_1} \geq 0$ or $\frac{\partial lv^*}{\partial H_1} < 0$).

In summary, the UK mortgage market during the sample period had two mortgage instruments, which attracted different types of borrower facing exogenously given differences in the opportunity cost of equity in housing. The existence of low opportunity cost of equity induces maximising behaviour and zero saving when those borrowers are impatient. Contractual features mean that such impatient borrowers are likely to be found among annuity mortgage holders. Endowment mortgage holders will

be joint borrowers and investors most likely to borrow at intermediate levels. These predictions conform to the subsets of behaviour identified in the mortgage demand model of Brueckner (1994). The remainder of the paper discusses the estimation of mortgage demand equations for these two groups.

Sample and Estimation Issues

The sample is 760 mortgage holders drawn from the British Household Panel Survey (1990 to 1994). The period does suffer from generally high mortgage interest rates and thus the sample has less interest rate variability than might be desired. However, there is variation in the cost of fixed rate mortgage debt, which was an important innovation for the United Kingdom market at that time (see Leece, 1995; 2001). Also a fall in tax relief in mortgage interest rates in April 1993 adds a significant source of variation. There are several important reasons for limiting the empirical analysis to this time frame. The chosen window precedes the increasing complexity of mortgage offers during periods of heavy discounting post 1994. It is also a time period during which concerns with the agency problems in endowment mortgage selling had not yet reached its height; endowments were still 57% of all new mortgages between 1990 to 1994, with repayment mortgages 34%[12]. There was a radical move out of endowment mortgage debt post 1994, for example they were only 21% of new mortgage loans by 1999. Prepayment of mortgage debt was also discouraged by heavy penalties and so this aspect of mortgage demand would also be absent. These features mean that the choice of study period provides critical controls that facilitate the estimation of the basic mortgage demand model.

The typical estimation technique used in the US literature is the simultaneous Tobit modelling housing and mortgage demand (Ling and McGill, 1998; Follain and Dunsky, 1997). This controls for zero observations in the dependent variable, when zero mortgage holders are observed among owner-occupiers. The model estimated here differs in that a standard two stage least squares regression is used. The sample considers mortgage debt at the point of house purchase. Movers are more likely to incur some mortgage debt so zero debt is less likely. An exception would be those in retirement who trade down properties but these are likely to be a small proportion of this sample. Interestingly endowment mortgages are transferable and follow the household between housing moves. Also, the endowment mortgage choice implies a desire to maintain debt to maturity so that observing zero debt is not likely until much later stages of the lifecycle. The tendency for repayment mortgage holders to extend maturity has also been noted. Finally, there is a problem in identifying which households that have paid off their mortgage debt would have held an endowment mortgage.

There is significant regional variation in house price inflation in the UK and this is expected to influence housing demand more than mortgage demand and gearing[13]. Experimentation proved this to be the case and regional location was used to identify the equation estimating the instrument for housing demand. The housing demand equation also contains proxies for the user cost of owner

[12] Housing Statistics Summary, 2003, Number 17, Table 1.1, p. 2. (Office of the Deputy Prime Minister).
[13] Brueckner re-appraises his model for variations in the rate of house price inflation and finds no significantly different effects.

occupation, which is nominal interest rates and lagged values of house price inflation. Changes in the subsidy of mortgage interest rates is recognised by the adjustment of the relevant monthly mortgage interest rate. Interestingly, the lagged value of house price inflation or alternative measures of this component of user costs has no statistically significant effect on housing demand, a fact that might reflect the generally negative rates of house price inflation prevailing over the period of study which may have generated a renewed concern with liquidity among house purchasers. House price inflation was subsequently included in the mortgage demand equation and those results are reported here. The results of estimating the housing demand equations can be found in Tables B1 to B3 in Appendix B which shows results for the whole sample and classified by choice of type of contract.

Table 1

There are a number of measurement issues involved in the research. BHPS respondents were asked for the value of their property on purchase, not for the current value. Both of these measures can be subject to measurement error though recollection of price paid should be less so. The purchase price of the property was corrected and expressed in real terms. The data contained no direct measure of the choice between fixed and variable rate debt. The choice was imputed from an algorithm, devised by the author, that inferred choice from observed periodic payment patterns. This imputed discrete choice was then corrected with a model used to detect classification error in the dependent variable. This procedure produces reliable and consistent estimates and is reported elsewhere (Leece, 2000 a, 2001 a). Econometric issues involved here are potential selection bias in the endowment/repayment mortgage choice and the possibility that the choice between fixed and variable rate mortgage debt is endogenous to mortgage demand. The results of tests to detect the presence and extent of these potential problems are reported in this paper.

The choice between a fixed (FRM) and a variable rate mortgage (VRM) proved to be exogenously determined. This involved tests for selectivity and simultaneity. Having established this exogeneity the estimated probability from a discrete choice model was used to measure the likely premium paid by an household taking up fixed rate debt (that is FRM rate – VRM rate). This was measured as the estimated probability of take up multiplied by the premium on five year fixed rate contracts. Thus those households with an higher probability of take up were hypothesised to be willing to pay a larger fixed rate premium, with the highest probability representing payment of the full five year cost. This measure was possible because the premium had no statistically significant effect on the choice between these two mortgage instruments a result established elsewhere (Leece, 2000 a; 2001 a). The expected sign on this variable is negative indicating lower cost instruments increase mortgage demand.

The qualitative predictions tested in this paper relate to two major subsets of behaviour, under different interest rate regimes, established by Brueckner (1994). Brueckner's work can also be considered as a test of joint hypothesis of saving and mortgage borrowing. The BHPS for 1995 has data on savings and some measures of wealth, though it is not always complete. In fact a sub sample of only 264 observations for which there was complete wealth and savings data was available. Of these 51 were annuity mortgage holders and 174 endowment mortgage holders (39 had a mix or other types of

mortgage). This sample is too small and unrepresentative to directly infer any patterns in savings behaviour for the two groups of borrowers. In any case zero saving should not be interpreted literally as precautionary and other motives for saving will be present in addition to life cycle and portfolio effects. Thus the estimates in this paper relate to mortgage borrowing alone.

One obvious response to attempts to detect debt maximisation behaviour is to suggest that econometric estimation is unnecessary. Mortgage debt of 100% of the value of the property, or very high loan to value ratios would indicate debt maximisation. Indeed reference to the descriptive statistics given in Table 1 indicates that endowment holders have significantly higher loan to value ratios. However, there are several problems with such a simplistic approach. Prudential lending rules vary by time, institution, individual and dominant lending rule (for example, loan to value ratio or multiples of income). The key issue is whether factors other than the instrument for housing expenditure determine mortgage demand. The sample of mortgage holders contains households at different stages of their life cycle. Thus some households will have equity arising from increases in property prices. Debt maximising borrowers would adjust their level of borrowing to withdraw this equity and finance current consumption. This may be limited by transactions costs and by lenders constraints on equity withdrawal at times of uncertain property prices, thus there will be some variations in gearing even for debt maximisers.

The endowment involves the indirect payment of debt via a reverse annuity (based upon a bonus system) so that for any given loan to value ratio the actual net balance of capital owing is unobservable. So high loan to value ratios for endowment holders are deceptive and the equation using this variable should be interpreted with caution. However, variations in initial gearing can still reflect attitudes to risk and/or the substitution of mortgage debt for financial wealth. In addition the real mortgage balance at the point of house purchase acts as a proxy for the outstanding capital owed. If the rate of return on the endowment equals the rate of inflation then falls in real value will correspond with growth in the investment fund. In practice the return is expected to be higher than this but if all households are subject to the same degree of bias in estimation the coefficient estimates will be consistent.

Econometric Estimates

The econometric estimates relate to the two groups of borrowers. The results reported in Table 2 are demand estimates for repayment mortgage holders. It is expected that borrowers having an annuity /repayment mortgage will conform to the predictions for an impatient debt maximising household (subset 1 above). The results reported in Table 3 relate to the mortgage demand of joint borrowers/investors who are expected to hold intermediate levels of mortgage debt (subset 2 above), that is endowment mortgage holders. Table 2 and Table 3 report results using the log of the real mortgage balance at origination as the dependent variable. Where relevant, parameter estimates using the log of the loan to value ratio at origination as the dependent variable will be reported. Both of these dependent variables have been used in the literature to date (Cho et al, 1995; Follain and Dunsky, 1997) and can provide complimentary interpretations of the phenomenon under investigation.

There is a methodological problem with predicting zero coefficients. The reported statistical tests may

not be of sufficient power to confirm the null hypothesis. This is worrying because the sample size for repayment mortgage holders is significantly smaller than that for endowment mortgage holders. To declare for the null hypothesis means that a Type II error might be committed. The best we can say is that the estimation suggests that the null hypothesis is correct, or that it has not been rejected. There are also arguments against applying power tests *post hoc* after the sample has been generated (Goodman and Berlin, 1994; Gerard et al, 1998; Hoenig and Heisey, 2001) so that this is not done in this case. It is legitimate to comment on the size of the estimates. Also, a stronger test concerns the collective significance of variables other than housing expenditure, which is a test of the restriction that the sum of these effects is zero. F tests for the restricted and unrestricted models are reported in Table 4 below.

Table 2

Table 3

The estimates for annuity mortgage holders, in Table 2, are consistent with theoretical expectations for debt maxi misers. Most coefficients are not significantly different from zero, with low values. Moreover, the F tests of the restriction of zero coefficients on variables other than housing expenditure, reported in Table 4, indicate that the restriction holds in the annuity mortgage case, that is restricted and unrestricted models are not significantly different at the 5% level. This applies to both dependent variables. The lack of statistical significance at the 5% level of the log of housing expenditure, with the loan to value ratio as the dependent variable, can be tentatively interpreted as reflecting a binding borrowing constraint for these households. This constraint can vary by household, and desired borrowing levels are achieved through higher levels of housing expenditure. There is no evidence via household income of a binding loan to income ratio.

There might be a prior expectation of heteroskedacticity in the estimation of absolute levels of mortgage demand for debt maxi misers, for example larger standard errors may emerge from higher levels of housing expenditure. This problem was slight and was largely removed by using the log form of the dependent variables, and controlling, by the use of a dummy variable, for those who borrowed small amounts for short durations.[14] The dummy variable representing durations of less than 24 years was statistically significant and negative indicating low loan to value ratios of around 0.5. This result is consistent with a group of more patient non-savers for whom $r_s < r_m$, who wish to pay off expensive debt more quickly; and constitutes yet another subset of behaviour identified in Brueckner's theoretical model. Otherwise the generally positive association between debt size and maturity is suggestive of debt maximisation. The sample of shorter durations was too small to estimate the full model using this sub sample and results were sensitive to the cut off point used to create the dummy variable.

The estimated mortgage demand for joint borrowers/investors reported in Table 3 provides an interesting contrast to the annuity mortgage results. The log of housing expenditure is statistically

[14] A robust White covariance matrix was estimated and standard errors where corrected but there was little difference in the estimates. Data visualisation of the distribution of errors against predicted values suggested a small but not serious degree of heteroskedasticity.

significant at the 5% level. This also applies when using the loan to value ratio as the dependent variable. Thus there is some systematic influence of housing decisions on gearing for endowment mortgage holders. The elasticity of the real mortgage balance on log of housing expenditure is high at 0.842. The estimated elasticity of the loan to value ratio is small at –0.158. However, the results offer some evidence for the absence of a binding constraint on gearing. The F test of the restricted and unrestricted models reported in Table 4 indicate that variables other than housing expenditure are collectively significant at the 5% level a result not consistent with the pure debt maximisation model.

Table 4

The sign on log of housing expenditure using the loan to value ratio for endowment mortgage holders as the dependent variable was negative. This is consistent with some previous US research (Chow et al 1995). Housing expenditure can raise the risk profile of household portfolios (see Brueckner, 1997) and lower gearing compensates by facilitating hedging. Alternatively, if high levels of expenditure on housing are a proxy for wealth then there might be some substitution of non-housing wealth for mortgage debt (see Hendershott and Lemon, 1975; Jaffee and Rosen, 1979; Ioannides, 1989). However, some research finds a positive relationship between non-housing wealth and mortgage debt (Jones, 1994; Jones, 1995; Cho et al, 1995). The research reported in this paper has insufficient data to test the various joint hypotheses of investment and housing demand behaviour. Also, the research reported here treats the main mortgage for the purchase of property, further borrowing could reflect portfolio motives (see Jones, 1993, a; 1993 b; 1995) and should also be the subject of further work.

The endowment mortgage estimates reveal two more variables statistically significant at the 5% level. These are the nominal mortgage interest rate and marital status. The mortgage interest rate has a negative sign, though the elasticity of demand is low at 0.2. Brueckner's model is ambiguous with respect to the expected sign on the interest rate for this type of borrower. The negative sign is consistent with previous UK research. (see Leece, 2000 b)[15]. The estimated premium on fixed rate debt is negatively signed, but is only statistically significant at the 10% level. Marital status has a negative impact upon gearing a result consistent with treating this variable as a proxy for risk aversion and the likely higher propensity to save of married households.

The results of this research contrast with previous UK work. Leece (2000 b) estimated mortgage demand by mortgage choice, for 1980 to 1986, with the aim of detecting the impact of financial deregulation. The results of that research, published in this journal, revealed endowment mortgage holders to be motivated by real mortgage interest rates. Income was also a significant explanatory variable in the demand for mortgage debt by annuity mortgage holders. The early 1990s provide an interesting contrast to this period. Negative equity for many households added to borrowers uncertainty and they may have adopted a more cautious view of gearing. However, for both periods there are clear and significant differences in the mortgage demand equation of holders of these two types of mortgage

[15] The paremeter estimates for the mortgage demand of endowment mortgage holders presented by Leece (2004) differ slightly from those presented here. This arises from some differences in the specification. For example, the inclusion of house price inflation in the actual mortgage demand equation discussed here.

instrument. Thus there is some evidence of continuing separating equilibrium in the United Kingdom mortgage market based on non varying contractual features.

A number of specification tests were conducted to test the robustness, consistency and efficiency of the econometric estimates. The repayment/endowment choice was modelled using a probit equation, and a selectivity equation estimated. The inverse mills ratio was not significant in either mortgage demand equation (probability 0.70 annuity, 0.78 endowment). A mover (endowment) /stayer (annuity) model controlling for possible endogenous selectivity (e.g. on the mortgage interest rate) was also estimated. This exercise was not successful in that satisfactory convergence of the algorithm was not achieved. This could reflect either or both the extensive use of dummy variables, or the low explanatory value (pseudo R2=0.01) and poor predictive ability of the auxiliary selection equation (only 1 repayment mortgage choice was predicted correctly). Other research utilising the UK endowment/repayment mortgage choice has found no evidence of such selectivity bias in a mortgage demand equation (see Devereaux and Lanot. 2004)[16]. These results support the treatment of the holders of the two mortgage instruments as segmented groups of borrowers.

A Hausmann test of endogeneity, using the residual from the housing expenditure equation as a regressor in the mortgage demand equation suggested the simultaneous determination of housing and mortgage demand (see Smith and Blundell, 1986). This was the case for all the models tested.

Selectivity test for the endogeneity of the fixed/variable rate mortgage choice indicated that this was an exogenous influence for both categories of borrower. This result is also consistent with previous UK research (see Leece, 2001 b). The estimates were also robust to a number of different specifications of the user cost of owner occupation variable (e.g. different lags on the rate of house price inflation), and different means of specifying the estimated fixed rate premium paid[17]. For endowment estimates the statistical significance of the mortgage interest rate variable is not robust to excluding the discrepancy between savings and mortgage rates. Though the latter was not statistically significant at the 5% level the impact of changes in mortgage costs might be expected to be greater when the discrepancy is less, thus the need to control for this factor. The nominal interest rate effect also looses significance when house price inflation is excluded from the estimating equation. This suggests the importance of the real rate of interest for this group, but the coefficients on house price inflation and mortgage cost are not sufficiently close, in this case, to support a user cost based argument of mortgage demand.

[16] Models incorporating switching regressions were not generally successful with convergence proving difficult. These models involve a two stage least squares estimation of the two mortgage demand equations with the switching based on predicted probabilities generated by the probit on endowment choice (this can also be exogenously or endogenously modelled). Given the different nature of the mortgage balances in each equation (that is endowments carrying mortgage debt to maturity) then in any case it might not be legitimate to conduct a two stage least squares regression on these two choices.

[17] The final measure used was the probability of selecting fixed rate debt multiplied by the premium where the probability of selection was greater than 0.5.

Summary and Conclusions

This paper has reported the results from estimating the mortgage demand of households who are argued to face different opportunity costs of equity in their property. This difference facilitated a test of the qualitative results of Brueckner's theoretical model of mortgage demand. In particular it was possible to test for those circumstances were mortgage debt might be maximised and the conditions under which the household used their own savings to finance the purchase of a property. The research identified a group of mortgage holders likely to be mortgage maxi misers with zero saving in an alternative investment to housing (repayment mortgage holders), and borrowers who were likely to demand an intermediate size of mortgage debt (endowment mortgage holders). A comparison of the parameter estimates of mortgage demand equations, for the two types of borrower, confirmed this predicted difference in behaviour. This allowed a true test of the theoretical model whose predicted results critically depended upon the relationship between borrowing and savings rates. This was also the first cross section tests of the simultaneity of housing and mortgage demand using United Kingdom data and was an important update and improvement of previous mortgage demand estimates reported in this journal.

Various specification tests were conducted on the estimates to test for robustness, selectivity and simultaneity. Housing and mortgage demand were simultaneously determined though this may reflect constrained debt maximisation in the case of repayment mortgage holders and wider portfolio considerations in the case of endowment mortgage holders. There was no evidence of selectivity bias in estimating mortgage demand by mortgage type and the choice between a fixed rate and a variable rate mortgage appeared also to be an exogenous and not very significant influence.

There are some interesting comparisons with US research. Given the argument that the opportunity cost of equity in property is higher than the net of tax mortgage interest rate in the United States (Ling and McGill, 1998), then the relevant comparison is with the mortgage demand of endowment holders. Both US and UK studies confirm the simultaneity of mortgage and housing demand. The estimates of the interest rate elasticity of mortgage demand differ. Follain and Dunsky (1997) find an interest rate elasticity of -1.00 to –1.5 compared to the estimate here of 0.2. This may be less in the UK because of the lack of simultaneous determination of mortgage demand and mortgage instrument choice, or may reflect the size of discrepancies between opportunity cost and the net of tax mortgage interest rate. Income is not statistically significant in the UK equations as it generally is in the US (see Ling and McGill, 1998). Also, though a comparison of estimates based upon instruments must be tentative the housing expenditure variable in US studies can be significantly larger (see Follain and Dunsky, 1997).

Regardless of the housing finance system concerned the paper does establish the need to identify the key subsets of mortgage borrowers classified by expected behaviour. This is important both for the evaluation of the impact of fiscal and monetary policy, and rigorous housing and mortgage market analysis. Future research within national housing finance systems, and with richer sources of financial data, may have more success identifying market segmentation by estimating switching regressions, with either exogenous or endogenous determinants of selectivity.

References

Alm, J and J.R. Follain, (1987), Consumer Demand for Adjustable Rate Mortgages, *Housing Finance Review* 6: 11-17.

Breslaw, P.J. I. Irvine and A. Rahman. 1996. Instrument Choice: The Demand for Mortgages In Canada, *Journal of Urban Economics* 39: 282-302.

Brueckner, J.K. 1984. The Flexible Mortgage: Optimal Financing of a Consumer Durable, *Journal of the American Real Estate and Urban Economics Association* 12: 136-152.

Brueckner, J.K and J.R. Follain. 1988. The Rise and Fall of the ARM: An Econometric Analysis of Mortgage Choice', *Review of Economics and Statistics*10: 93-102.

Brueckner, J.K. and J.R. Follain. 1989. ARMs and the Demand for Housing, *Regional Science and Urban Economics* 19: 163-187.

Brueckner, J.K. 1994. a. The Demand for Mortgage Debt: Some Basic Results, *Journal of Housing Economics* 3:251-62.

Brueckner, J.K. 1997. Consumption and Investment Motives and the Portfolio Choices of Home-Owners, *Journal of Real Estate Finance and Economics* 15: 159-180.

Brueckner, J.K. 2000, Mortgage Default and Asymmetric Information, *Journal of Real Estate Finance and Economics* 20(3): 251-274.

Cho, M., I. M. Kim, and I. F. Megbolugbe. 1995. *Simultaneous Estimation of Housing Demand and Mortgage demand: An Extended Two-Stage Approach With Two Sequential Choices*, Unpublished Working Paper, Fannie Mae Office of Housing Research.

Chinloy, P. 1995. Privatized Default Risk and Real Estate Recessions: The UK Mortgage Market, *Real Estate Economics* 23: 401-20.

Devereaux, M.P. and G. Lanot. 2004. Measuring Tax Incidence: An Application to Mortgage Provision in the UK, *Journal of Public Economics* (forthcoming).

Dunsky, R.M. and J.R. Follain. 2000. Tax-Induced Portfolio Reshuffling: The Case of Mortgage Insurance Deduction, *Real Estate Economics*, 28(Winter): 549-580.

Follain, J.R. and R.M. Dunsky. 1997 . The Demand for Mortgage Debt and the Income Tax, *Journal of Housing Research* 8(2):155-200.

Gerard, P.D., D.R. Smith, and G. Weerakkody. 1998. *Limits of Retrospective Power Analysis, Journal of Wildlife Management 62*: 801-807.

Goodman, S.N, and J.A. Berlin. 1994. The Use of Predicted Confidence Intervals When Planning Experiments and the Misuse of Power When Interpreting Results, *Annals of Internal Medicine* 121: 200-206.

Goodman, A.C. and R.W. Wasmer. 1992. Optimal Mortgage Design When Transactions Costs Constrain Mobility, *Journal of Housing Economics* 2(1): 17-37.

Hendershott, P.H. and Lemmon, R.C. 1975. The Financial Behavior of Households: Some Empirical Estimates, *Journal of Finance* 30: 733-759.

Hoenig, L.V., and D.M. Heisey. 2001. The abuse of power: the pervasive fallacy of power calculation for data analysis. *The American Statistician 55*: 19-24.

Ioannides, Y.M. 1989. Housing, Other Real Estate and Wealth Portfolios, *Regional Science and Urban Economics* 19: 259-280.

Institute of Actuaries (I of A). 1999, *Report of the Endowment Mortgage Working Party, I of A*, London.

Jaffee, D.M. and K.T. Rosen. 1979. Mortgage Credit Availability and Residential Construction, *Brookings Papers Economics Activity* 2: 333-386.

Jones, L.D. 1993 a. The Demand for Home Mortgage Debt, *Journal of Urban Economics* 33: 10-28.

Jones, L.D. 1993 b. Home Mortgage Debt Financing of Non Housing Investments, *Journal of Real Estate Finance and Economics* 9: 91-112.

Jones, L.D. 1995. Net Wealth, Marginal Tax Rates, and the Demand for Home Mortgage Debt, *Regional Science and Urban Economics* 25: 297-322.

Jones, S.T., N.G. Miller and T.J. Riddiough. 1995. Residential Mortgage Choice: Does Supply Side Matter?, *Journal of Housing Economics* 4(1): 71-90.

Leece, D. 1995.a. Rationing, Mortgage Demand and the Impact of Financial Deregulation, *Oxford Bulletin of Economics and Statistics* 57(1): 43-67.

Leece, D. 1995. b. An Econometric Analysis of the Choice of Mortgage Design in the United Kingdom, *Applied Economics* 27: 1173-1186.

Leece, D. 1997. Mortgage Innovation in the 1990s: Theoretical and Empirical Issues', *Journal of Property Finance*, 8(3): 226-245.

Leece, D. 2000.a. Household Choice Between Fixed and Floating Rate Debt: A Binomial Probit Model with Correction for Classification Error, *Oxford Bulletin of Economics and Statistics* 62(1): 61-82.

Leece, D. 2000.b. Choice of Mortgage Instrument, Liquidity Constraints and the Demand for Housing Debt in the United Kingdom', *Applied Economics* 32: 1121-1132.

Leece, D. 2000.c. Inappropriate Sales in the Financial Services Industry: The Limits of the Rational Calculus?, *Managerial and Decision Economics* 21: 133-144.

Leece, D. 2001 a. Regressive Interest Rate Expectations and Mortgage Instrument Choice in the United Kingdom Housing Market, *Real Estate Economics* 29(4): 589-614.

Leece, D. 2001. b. The Impact of Mortgage Market Innovation On Housing Demand and Household Gearing In the United Kingdom: A Simultaneous Equation Model, *RICS Cutting Edge Conference*.

Leece, D. 2004. *Mortgage Market Economics: Perspectives on Household Decision Making*, Blackwell Scientific, London.

Linnemann, P and S. Wachter, 1989, The Impact of Borrowing Constraints on Home ownership, AREUEA Journal 17(4): 389-402.

Ling, D.C and G.A. McGill. 1998. Evidence on the Demand for Mortgage Debt by Owner-Occupiers, *Journal of Urban Economics* 44: 391-414.

Pereira J.A.A, D.P. Newton and D.A. Paxson, 2003, Fixed-Rate Endowment Mortgage and Mortgage Indemnity Valuation, *Journal of Real Estate Finance and Economics* 26 (2?3): 197-221.

Plaut, S.E. 1986. Mortgage Design in Imperfect Capital Markets, *Journal of Urban Economics* 20: 107-19.

Smith, R.J. and Blundell, R.W. 1986. An Exogeneity Test for a Simultaneous Equation Tobit with an Application to Labour Supply, Econometrica 54 (3): 679-87.

Appendix A

Table A1
The Behavioural Basis of Endowment Choice

N=689 Log Likelihood= -381.5970 Restricted Log Likelihood= -383.8374!

Dependent Variable Endowment=1

Variable	Coefficient	t-value
Log(Income)	-0.0121	-0.187
Log(Age)	-0.0608	-0.390
Log(Mortgage Rate)**	0.4513	2.020
Log(Housing)	-0.0004	-0.896
Chi Squared= 4.480693 Significance Level= 0.2140189		

Appendix B

Table B1

Estimation of the Instrument for Housing Demand

(Aggregate Estimates)

N= 744 R2=0.3298

Variable	Coefficient	t-value
Constant*	7.4322	14.001
Log(Age)	0.0486	0 .747
Log(Income) *	0.3105	9.683
Child under 5 years of age	0.0819	1.389
Male	0.0171	0 .435
Married *	0.2388	6.258
South East*	0.4901	8.758
South West *	0.4457	5.589
Midlands*	0.2662	3.984
Northwest*	0.3129	4.072
Yorkshire**	0.1778	2.339
North	0.0054	0.065
East Anglia*	0.2389	2.343
Log(Mortgage rate)	-0.1757	-1.417
House price inflation	0.0023	0.181
Log(savings rate-mortgage rate)	0.4138	2.041

* Sig at 1% level ** Sig at 5% level

Table B2

Estimation of the Instrument for Housing Demand

(Repayment Estimates)

N=167 R2=0.3239

Variable	Coefficient	t-value
Constant*	9.8964	5.499
Log(Age)	-0.3082	-1.553
Log(Income)*	0.3152	4.116
Child under 5 years of age	-0.0869	-0.729
Male	-0.0129	-1.373
Married*	0.3850	3.904
Southeast*	0.3714	2.653
Southwest**	0.4772	2.458
Midlands	0.2849	1.624
Northwest	0.1610	0.699
Yorkshire	0.2895	1.567
North	-0.3107	-1.063
Eastanglia	0.2067	0.824
Log(Mortage Rate)	-0.5342	-1.248
Log(savingsrate-mortgage rate)	-0.0258	-0.050
Fixed rate premium	-0.1245	-1.082

* Sig at 1% level ** Sig at 5% level

Table B3

Estimation of the Instrument for Housing Demand

(Endowment Estimates)

N=508 R2=0.3757

Variable	Coefficient	t-value
Constant*	7.4164	9.073
Log(Age)	0.1260	1.313
Log(Income)*	0.2669	7.789
Child under 5 years of age **	0.1479	2.148
Male	0.0645	1.531
Married *	0.2255	5.652
Southeast *	0.5442	9.131
Southwest *	0.3613	4.260
Midlands*	0.2788	4.061
Northwest*	0.3295	4.199
Yorkshire	0.1269	1.603
North	0.0798	0.984
East Anglia	0.1818	1.753
Log(Mortgage rate)	-0.0947	-0.490
Log(savings rate-mortgage rate)	0.3064	1.404
LOGDPPRE	0.0520	.935
* Sig at 1% level ** Sig at 5% level		

Table 1 Descriptive Statistics

Annuity Mortgage			Endowment Mortgage			All of Sample		
	Mean	SD		Mean	SD		Mean	SD
Real Mortgage Balance	46277.55	31956.04	Real Mortgage Balance	46403.92	22244.74	Real Mortgage Balance	46372.65	24974.69
Loan to Value ratio	0.70	0.28	Loan to Value ratio	0.81	0.20	Loan to Value ratio	0.78	0.22
Age of reference person	34.24	11.35	Age of reference person	33.84	10.16	Age of reference person	33.94	10.46
Mortgage rate	9.42	1.91	Mortgage rate	9.77	1.98	Mortgage rate	9.68	1.97
Fixed rate premium	0.76	0.29	Fixed rate premium	0.74	0.29	Fixed rate premium	0.74	0.29
Savings rate-mortgage rate	2.26	0.26	Savings rate-mortgage rate	2.22	0.26	Savings rate-mortgage rate	2.23	0.26
Gross household income	9.63	0.63	Gross household income	9.62	0.59	Gross household income	9.62	0.60
Housing Expenditure	75655.60	52869.30	Housing Expenditure	62289.55	44249.68	Housing Expenditure	65596.40	46846.76
Child less than 5 years of age	0.17	0.38	Child less than 5 years of age	0.09	0.28	Child less than 5 years of age	0.11	0.31
Male	0.59	0.49	Male	0.68	.47	Male	0.66	0.48
Married	0.40	0.49	Married	0.54	0.50	Married	0.50	0.50
House price inflation	-0.17	1.73	House price inflation	-0.31	1.56	House price inflation	-0.28	1.60

Table 2

Mortgage Demand Estimation: Debt Maximisation (Repayment Mortgage Holders)

N= 167

Dependent Variable = Log (Real Mortgage Balance)

R2=0.320

Variable	Coefficient	t-value
Constant	0.373	0.128
Log (Age)	0.052	0.275
LOG(Mortgage rate)	0.279	0.710
LOG(Fixed rate premium)	0.144	1.403
LOG(Savings rate-mortgage rate)	0.304	0.707
LOG(Income)	0.072	0.755
LOG(Housing)	0.799	3.531
Child under 5 years of age	0.092	-0.908
Male	-0.119	-1.399
Married	-0.191	-1.489
House price inflation	0.015	0.635
Duration<24 years.	-0.518	-6.348

Table 3

Mortgage Demand Estimation (Intermediate Borrowers and Savers: Endowment Mortgage Holders)

N=508

Dependent Variable = Log (Real Mortgage Balance)

R2=0.6136

Variable	Coefficient	t-value
Constant	1.849	2.752
Log (Age)	-0.079	-1.179
LOG(Mortgage rate)	-0.293	-2.059
LOG(Fixed rate premium)	-0.063	-1.609
LOG(Savings rate-mortgage rate)	-0.205	-1.312
LOG(Household income)	0.045	1.358
LOG(Housing)	0.842	12.146
Children under 5 years of age	0.047	0.964
Male	0.016	0.533
Married	-0.107	-3.394
House price inflation	-0.012	-1.305

Table4

A Comparison of the Restricted and Unrestricted Models: Regression Diagnostics

(Real Mortgage Balance Estimates)

Diagnostics	**Subset 1 Annuity Mortgage Holders**	**Subset 2 Endowment Mortgage Holders**
F Statistic	0.2768	2.4574
Probability	0.5996	0.0096
Restricted Model Log Likelihood	-171.2195	-358.4519
Unrestricted Model Log Likelihood	-113.4292	-111.3849

This table reports the results of testing the restriction that a subset of variables have zero collective impact upon the absolute real size of mortgage debt. In the case of the annuity mortgage both the instrument for housing expenditure and the dummy variable for duration< 24 years are assumed to have non zero parameter estimates.