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**ABSTRACT**

Mortgage interest tax deductibility is needed to treat debt and equity financing of homes equally. Countries that limit deductibility create a debt tax penalty that presumably leads households to shift from debt toward equity financing. The greater the shift, the less is the tax revenue raised by the limitation and smaller is its negative impact on housing demand. Measuring the financing response to a legislative change is complicated by the fact that lenders restrict mortgage debt to the value of the house (or slightly less) being financed. Taking this restriction into account reduces the estimated financing response by 20 percent (a 32 percent decline in debt vs a 40 percent decline). The estimation is based on 86,000 newly originated UK loans from the late 1990s.

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# The Sensitivity of Household Leverage to the Deductibility of Home Mortgage Interest

In many economies debt financing of housing is penalized relative to equity financing, i.e., interest payments are not fully tax deductible. In the Commonwealth countries – Australia, Canada, New Zealand, and the UK (since 1999) – interest is not deductible; in most European countries (the UK in the quarter century prior to 1999) interest is only partially deductible, being limited by a ceiling on the deductible amount, application of a lower tax rate to the deduction, or both. As a result, the Modigliani-Miller (1958) debt neutrality theorem does not hold; the user cost of capital for owner-occupied housing (through the weighted average cost of capital) is not independent of LTV choice.[1] Knowing how LTVs respond to deductibility limits is thus crucial to understanding how housing choices will be affected by changes in such limits.

There are two fundamental problems in explaining LTV behavior. First, the tax penalty on debt usage depends on intricate tax law provisions and the level of debt usage itself. For example, in the UK during the decade 1983-92, there was a penalty only for loan amounts above £30,000, and between 1993 and 1999 for some households there was also a penalty for loans below £30,000. In the U.S., a penalty exists for some low-income households, households with low mortgage debt living in states with low house prices and low taxation, and quite high-income households. Thus estimating the penalty for individual households is complicated. Second, it is almost a universal law that LTVs on newly-originated loans are bounded between (are truncated/censored at) zero and one (debt is bounded between zero and house value). Moreover, initial LTVs of first-time home buyers are highly skewed toward the highest lender-permitted LTV (Hendershott, Pryce and White, 2003), while as many as half of older homeowners have zero LTVs (Ling and McGill, 1998). The upper bound of unity or the lender-permitted maximum constitutes credit rationing. Because the economic response to a debt penalty is to reduce debt, the more a borrower is rationed, the less his response to a given penalty will be. The combined effect of LTVs suffering from both truncation and a highly skewed distribution creates substantial modeling problems.

[1] See Hendershott and Slemrod (1983) and Woodward and Weicher (1989).

This paper addresses these complications and modeling problems. We incorporate the simultaneity of the decision to borrow more or less than the £30,000 threshold by using a “two stage least squares” type approach, running a probit regression to estimate the probability of being above the ceiling and then using the predicted probabilities of paying penalties above and below the ceiling in an instrumental variables approach to estimate the effect of the tax penalty on LTV. The fundamental truncation/censoring of observed LTVs is addressed by employing truncated regression (Maddala, 1992, 342-44) and censored regression (Amemiya 1973) to model the unrationed response to a tax penalty. These results are then contrasted with responses estimated in credit rationing regime where the LTV is bounded by zero and one. We arrive at the constrained rersponses by utilizing Papke and Wooldridge’s (1996) “Fractional Response” estimation.

We employ the UK data set of Hendershott, Pryce and White (2003). These data are especially useful because they are a random sample of all house purchasers who made a deliberate leverage decision. Thus we do not need to be concerned with lagged responses of existing mortgagees to changes in the debt penalty and other variables. We illustrate how different estimation methodologies affect estimates of the sensitivity of LTV choice to a debt tax penalty. We then simulate mortgage demand with full deductibility and with zero deductibility and compute the impact of shifting from full to zero deductibility.

The paper is divided into seven sections. We begin with a discussion of the debt tax penalty and some earlier LTV research. Section 2 contains our econometric model. Section 3 discusses estimation alternatives to ordinary least squares. Section 4 presents the data, and section 5 reports the results. Section 6 uses simulation analysis to compute the percentage decrease in debt usage in response to removal of mortgage interest deductibility, and section 7 concludes.

## 1. The Debt Tax Penalty and Earlier Research on Mortgage Debt Usage

Home mortgage interest deductibility is a means of extending the fundamental tax advantage of owner-occupied housing, the nontaxation of the implicit rents owners pay to themselves and the low (often zero) taxation of capital gains, to households who use debt finance. Deductibility does not make debt cheaper than equity; rather it maintains tax equality between the two costs. Thus to the extent that the interest deduction is limited, there is a tax cost or penalty to using debt and one would expect debt usage to be less.

Mortgage interest has never been *fully* deductible in the US. Low income households or households with low mortgage debt living in states with low house prices and low taxation (state taxes and mortgage interest are the two largest deductible expenses) would select not to itemize expenses because taking the standard deduction instead would lower their taxes (Ling and McGill, 1998). For these households there is effectively no deductibility. Further, even if a household did itemize, not all mortgage interest was effectively deductible (the amount of interest that raised total deductible expenses to the standard deduction was "wasted"). The amount of wasted interest (and the number of households that chose not to itemize) grew following the 1986 tax act for two reasons (Hendershott, Follain and Ling, 1987). First, a number of expenses that were previously deductible could no longer be itemized, probably the most important being the interest on consumer credit debt. Second, the standard deduction was sharply increased. Finally, the 1986 act also phased out itemized deductions when household income rose above threshold levels, limiting deductibility for very high income households to as little as 20 percent of their interest paid.

Follain, Ling, and various associates have used the change in the effective deductibility of mortgage interest induced by the 1986 tax act to test the hypothesis that household leverage is sensitive to the tax penalty on debt (Follain and Ling, 1991, Ling and McGill, 1998, Follain and Dunsky, 1997, and Dunsky and Follain, 2000). In each case, the leverage of individual households was found to be related significantly to the effective deductibility of mortgage interest. Using the Dunsky and Follain estimates, Follain and Melamed (1998) built a simulation model and predicted that removal of the mortgage interest deduction (MID) would lower mortgage debt by 41 percent. We note that this estimate is based on removal relative to 1988 US tax law, not removal relative to full interest deductibility. The latter would be an even larger percentage decline in mortgage debt. This work on US data requires forecasting various unavailable household expenses and determining whether households would itemize or take the standard deduction. Moreover, the empirical analysis is not of households at their decision point (when the loan is originated), but wherever they happen to be in the debt cycle, including whether they have a below-market, fixed-rate mortgage (which would obviously dampen borrower incentives to reduce debt).

The tax penalty argument can be formalized in the following way. In general, the weighted average cost of capital for owner-occupied housing is just an average of the debt (CD) and equity (CE) costs where the weights are the loan to value ratio, LTV, and 1-LTV:

$$WACC = (LTV)CD + (1-LTV)CE. \tag{1}$$

If both costs equal the after-tax interest rate, (1-T)r, then WACC = (1-T)r (we abstract from risk premia). However, if a tax penalty at rate p is imposed on debt usage, its cost is (1-T+p)r and

$$WACC = (1-T)r + LTVrp. \tag{2}$$

If the penalty is the nondeductibility of interest, p = T and the WACC is increased by the product LTVTr.

How much removal of the MID would raise the WACC (and tax revenue) depends on how much households change their LTV in response to the loss of deductibility. The more households reduce their LTVs, the less the WACC is increased and thus the less will be the reduction in homeownership and housing demand. Also, the less revenue the government would gain by removing the MID.

UK borrowers have also been subject to substantially greater variation in limitations on interest deductibility than US borrowers. During the last quarter century, the mortgage interest deduction in the UK has been limited in two ways. First, in 1974 the deduction was restricted to that on a £25,000 mortgage (and the deductibility of interest on other household debt was eliminated). In 1983, the limit was raised to £30,000 (the median UK house price level had nearly tripled to £29,400). Subsequently the limit was never again raised in spite of rising house prices (the median tripled again to £87,300 in 1999). Second, the maximum tax rate at which interest could be deducted was cut from the 40 percent maximum income tax rate to 25 percent in 1992, to 20 percent in 1994, and to 10 percent in 1995 (finally to zero in 1999). Given that there were effectively only two household income tax brackets during this period, 25 and 40 percent, after 1993 no household paying taxes could deduct mortgage interest at their full marginal income tax rate.

Of the ceiling and tax rate maximums, the former has been far more important for new borrowers who have reasonably high initial loan-to-value ratios (the average of our sample is 0.78). With a median house price in 1995-98 of £53,000 outside the London/Southeast region and £76,000 within this region, over four-fifths of new mortgage originations were above the £30,000 mortgage limit and thus interest was not deductible at all on the margin.

Figure 1 illustrates how the debt tax penalty varied with loan size. The products of a given interest rate and the tax rate are on the vertical axis and loan amount is on the horizontal. The solid line is a household's marginal tax rate times the given interest rate. Holding house value constant, the larger is the mortgage loan, the more interest is deductible (unless the loan is above the ceiling, Lc), but the larger are the household's taxable investments and thus the higher is its taxable interest income. As long as the ceiling isn't binding, taxable income is at least roughly independent of loan size.[2] The dashed rT* line in the figure is the product of the given interest rate and the lower maximum tax rate, introduced in 1993, at which mortgage interest on the loan amount below the ceiling could be deducted. The tax penalty for loans above Lc is the product of the household's tax rate and the interest rate (Tr). The penalty below the ceiling is the product of the interest rate and the maximum of T-T* or zero (the latter for households with T < T*). The difference T-T* is independent of loan size.[3]

[2] When the loan exceeds the ceiling, the larger is the loan (and thus taxable investments), the higher is the household's taxable income. Thus at some point the household could be pushed into a higher tax bracket.

[3] These tax penalties, Tr and (T-T*)r, also apply to some U.S. borrowers, but the application is much different. Whereas the Tr penalty applies to large loans in the UK, in the US it applies only if the loan is sufficiently small that households minimize their tax liability by taking the standard deduction instead of itemizing. And whereas the (T-

**[Figure 1. The Debt Tax Penalty]**

Let $\psi$ be the probability that a borrower's loan will exceed the tax deductibility ceiling of £30,000, we have

$$WACC = (1\text{-}T)r + (LTV)Tr\psi + LTV(T\text{-}T^*)r(1\text{-}\psi). \quad (2')$$

Hendershott, Pryce and White (2003) estimated $\psi$ for individual households and then made the log of LTV a function of two tax penalty variables, $p^A$ and $p^B$, where the A and B refer to penalties applying to loans above and below the loan ceiling, which are defined as the second and third terms in equation (2') divided by LTV. The log of LTV was significantly negatively related to both penalty variables.

There are two problems with that estimation. First is the obvious negative correlation of the two variables owing to the complementary of the $\psi$ and 1-$\psi$ terms. Second is the use of predicted loan size (above or below £30,000) in explaining LTV. Smaller loans are likely to carry lower LTVs and thus the estimated negative impact of the penalty on small loans will be biased upward relative to that on large loans. In this paper, we first estimate $\psi$ and thus the two penalty variables. We then obtain a single tax penalty variable, $p^C$, as the prediction of a regression of the actual household tax penalty on the estimated $p^A$ and $p^B$.

## 2. Econometric Model

A household's demand for mortgage debt is driven by its consumption demand for housing relative to its wealth and the tax penalty. At one extreme are households with sufficient wealth relative to housing consumption demand that they demand zero mortgage debt. At the other extreme are households with a sufficiently high consumption demand relative to wealth that they select the maximum debt allowed by lenders (Hendershott, Lafayette and Haurin, 1997). In the more general case, households are trading off the

T*)r penalty applies to small loans in the UK, in the US it exists only for households with income sufficiently high that interest expense is not fully deductible.

debt penalty against portfolio diversification considerations (Brueckner, 1994). More debt is relatively expensive, but it allows the holding of additional nonhousing assets.

Given the constraints of zero and unity (or slightly less) on the LTV and its importance to the WACC, the LTV is a natural focal point for investigation. However, because the demand for debt is not necessarily homogenous of degree one in housing demand, determinants of this demand, such as real income and real house prices, are relevant to LTV choice.[4] Other determinants are variables that place households on the need to diversify spectrum. In the absence of a wealth measure, these include borrower age and whether or not they previously owned their home.

The diversification benefits of a higher LTV decrease with the level of the LTV; the lower the LTV, the more diversified the household would be. Thus the response of households to the debt penalty, the cost of greater diversification, should be greater the lower the LTV would be in the absence of the penalty. For example, the response should be greater for previous owners and for those in areas with lower real house prices. As a result, we partition our sample along these lines to see how the response to the penalty varies.

Following the above discussion LTV depends on basic or wage income ($Y^B_i$), other income ($Y^O_i$), the borrower's age ($AGE_i$), whether the borrower was a previous owner ($PO_i$), the debt tax penalty ($p_i^C$) and a vector of location and year dummy variables ($\mathbf{DUM}_i$). Thus the structural equations of the econometric model are:

$$\mathrm{LTV}_i = \mathrm{LTV}(PO_i, Y^B_i, Y^O_i, AGE_i, p_i^C, \mathbf{DUM}_{i,}) \qquad (3)$$

$$p_i^C = p_i^C\,[LTV_i T_i r\psi_i, LTV_i\,(T_i - T^*) r(1-\psi_i)] \qquad (4)$$

where

$$\psi_i = \psi_i(PO_i, Y^B_i, Y^O_i, AGE_i, LTV_i, \mathbf{DUM}_i) \qquad (5)$$

$$T_{i,} = T_{i,}(Y^B_i, Y^O_i)$$

[4] Most of the recent literature explains the quantity of mortgage debt and housing demand in a simultaneous equation framework (Follain and Dunsky, 1997, and Ling and McGill, 1998). Our formulation avoids the necessity of estimating the housing demand relationship.

$T^*$ = the maximum marginal tax rate at which interest can be deducted (equal to 0.1 during the period under consideration).

Re-writing (4) in terms of its underlying variables yields:

$$p_i^C = f(PO_i,\, Y^B{}_i,\, Y^O{}_i,\, AGE_i,\, r,\, LTV_i\,,\, T^*\,,\, \mathbf{DUM}_i). \qquad (4')$$

As is shown in Appendix A, the parameters in the LTV equation are exactly identified. While those in the tax penalty equation are not, we are not interested in those coefficients.

Our estimation of LTV follows a two-stage least squares instrumental variables rationale in that we control for simultaneity of LTV and $p^C$ by using the predicted values from a regression of the right hand side endogenous variable on all exogenous variables in the system (see Greene, 2003, p. 398). This process is complicated by the fact that neither LTV nor $p^C$ is necessarily estimated using OLS (we also use truncated/censored regression and FLR estimation techniques for explaining LTV, and $p^C$ is derived indirectly from a probit estimate of $\psi$).[5]

**3. Estimation Alternatives**

Our econometric estimation is complicated by the possible credit rationing that arises from lenders placing an upper bound on LTV at (or near) one. In perfectly informed credit markets we would not expect either equilibrium credit rationing or collateral constraints of the kind described respectively by Stiglitz and Weiss (1981) and Bester (1987), and OLS regression would provide unbiased estimates. But this is not the world we live in. Even beyond the bias issue, the high LTVs of many borrowers in our sample implies that removing the tax penalty will likely predict LTVs over 100 percent for many

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[5] In a world where mortgage interest is not tax deductible, the marginal tax rate paid by a household can depend on the LTV choosen. To illustrate, for a given house purchase, the larger the loan choosen, the more wealth the household has to invest in other assets and thus the higher is the taxable income of the household. To eliminate this source of endogeneity, we add an estimate of the interest a household could earn on their equity investment in the house to the income of the household before computing their marginal tax rate. The estimate is computed as the product of the mortgage rate and the difference between house purchase price and mortgage loan amount.

borrowers. Thus more sophisticated estimation techniques are needed if we want to estimate the constrained response.

In this section we consider a number of alternatives to OLS. First, we discuss Truncated and Censored Regression. The latter is an extension of the well-known Tobit estimation. While these address the issue of estimation bias, they do not deal with the issue of predictions above the maximum lender allowed LTV. Second, we describe Fractional Logit Regression and how we will use it to address both estimation bias and prediction constraints.

*Truncated and Censored Regression*

Some households that would be homeowners in the absence of a lender constraint on LTV will not be owners owing to the constraints. Figure 2 (adapted from Maddala 1992, p. 343), illustrates the bias that can result from excluding these potential borrowers – the OLS line in this case is shallower (i.e., the LTV variable is less responsive to changes in the tax penalty) than what it would be if we had information on the excluded applicants. The Truncated Regression (TR) model attempts to correct for the bias that results from applying OLS to samples drawn from a truncated distribution.

**[Figure 2 Impact of Excluded Borrowers: Correcting for Truncation Bias]**

Let the simple OLS regression model be denoted as

$$y^* = \beta x_i + u_i \qquad u_i \sim \mathrm{IN}(0,\sigma^2),$$

If observations are only included in the sample if $y^* \leq a$, where $a$ is the value of $y$ at which truncation occurs, then the total area under the normal curve up to $y^* < a$ is $F[(a - \beta x)/\sigma]$, where F(.) is the cumulative standard normal distribution (Maddala, 1992, p. 343). The probability density function of the observed $y_i$ (i.e. those included in our sample) is assumed by the TR model to be the standard normal density for this total area: “Since the total area under a probability density function should be equal to 1, we have to normalize by this factor” (*ibid*). This entails dividing the probability density function for $y_i$ by the area up to the truncation point. The log-likelihood function that results is identical to the maximum likelihood estimation of the linear regression model except for subtraction of $\Sigma \log F((a\text{-}\beta x)/\sigma)$.

Note also the implications of using TR to predict what LTVs will be when the tax penalty is zero. Because dLTV/d $p^C < 0$, removal of the tax penalty will result in a rise in LTV, causing the upper bound on LTV to bind in a greater number of cases. So, in principle at least, the predicted values from the TR regression for $p^C = 0$ will be estimates of what the LTVs would be if there were no upper bound on LTV. That is, neither TR nor OLS, constrains predicted, in the absence of a tax penalty, LTVs to be less than the maximum. We need an estimation method that will allow us to predict within the bounded range of values of LTV.

The TR model is more general than the Tobit model. Maddala explains that, "In the censored regression model (tobit model) we have observations on the explanatory variable $x_i$ for all individuals. It is only the dependent variable $y_i^*$ that is missing for some individuals. In the TR model, we have no data on either $y_i^*$ or $x_i$ for some individuals because no samples are drawn if $y_i^*$ is below or above some level" (Maddala, 1992, p. 342). Truncated regression accounts for bias that might result from borrowers choosing not to be homeowners because they cannot obtain their desired LTV.

However, a more likely response for households where the benefits of owning with unrestricted lending over renting are large is to take $y'$, the maximum LTV on offer, even if this is below their optimum. If this were the case and rationing were common, we would expect to see many observations with LTVs exactly equal to the maximum. In terms of the above notation, the latent variable $y^*$ is observed if $y^* < y'$ and is not observed if $y^* \geq y'$ even though the values of the explanatory variables are observed. The observed dependent variable is therefore defined as follows:

$$y = \begin{cases} y_i^* = \beta x_i + u_i & \text{if } y_i^* < y' \\ 1 & \text{if } y_i^* \geq y' \end{cases}$$

where $u_i \sim \text{IN}(0,\sigma^2)$. This is the Tobit model, first suggested by Tobin (1958).

The basic Tobit model has limited usefulness when applied to our data because less than one percent of observations (850 cases out of 86,620 records) have LTVs exactly equal to one (when we applied Tobit to our data, coefficients and predicted values unsurprisingly were virtually identical to OLS estimates). Note that the low incidence of observations with LTVs exactly equal to one is not necessarily indicative of the absence of censoring. While some lenders may set the global maximum LTV at unity, others will set a maximum below this level, possibly based on their perception of the creditworthiness of the borrower concerned. Indeed, we find two lower cut-points, 0.95 and 0.90, with 15,254 and 3,848 cases having LTVs exactly equal to these thresholds, respectively. Together these cut-points represent 22 percent of our total sample. If a significant proportion of these observations are the result of credit rationing, rather than because borrowers choose to be at these points because of piecewise nature of mortgage pricing, then we still need to account for the censoring of the dependent variable.[6] We do this by applying Amemiya's (1973) Censored Regression model (CR) which is a generalized version of Tobit regression that allows for variable cutoffs (in our case, at LTVs of 1.00, 0.95, and 0.90). While Censored Regression will help us ascertain what the parameters of our model would be in the absence of rationing (and hence predict what the unconstrained LTV would be), like OLS and TR, the predicted CR values can exceed one.

*Fractional Logit Regression*

A popular way of modeling variables bounded between zero and one is to apply the log-odds transformation to the dependent variable ($\log[y/(1-y)]$) which allows OLS to be applied to the estimation of $\mathbf{x}\beta$. This approach has two major drawbacks for the estimation of LTVs which can take on the extreme values of zero and (in the UK at least) unity:

> "First, it cannot be used directly if $y$ takes on the boundary values, zero and one. While we can always use adjustments for the boundary values, such adjustments are necessarily arbitrary. Second, even if $y$ is strictly inside the unit interval, $\beta$ is difficult to interpret: without further assumptions, it is not possible to recover an estimate of $E(y|\mathbf{x})$, and with further assumptions, it is still nontrivial to estimate $E(y|\mathbf{x})$." (Wooldridge, 2002, p.662).

[6] We find little evidence of a straightforward positive relationship between the interest rates charged on mortgage contracts and LTVs. A simple regression of the mortgage interest rate on LTV reveals that there is no significant positive correlation between the two variables. Indeed, the average rate for 95 percent LTVs is a half basis point less than that for 90 percent LTVs.

The solution suggested by Papke and Wooldridge (1996) and Wooldridge (2002) is to model E(y|**x**) as a logistic function: $\mathrm{E}(y \mid \mathbf{x}) = \exp(\mathbf{x}\boldsymbol{\beta}) / [1 + \exp(\mathbf{x}\boldsymbol{\beta})]$

This method guarantees that "predicted values for *y* are in (0,1) and that the effect of any $x_i$ on E(y|**x**) diminishes as $\mathbf{x} \to \infty$." (Wooldridge, 2002, p.662). The effect is illustrated in Figure 3 where it can be seen that OLS tends to predict outside the [0,1] range at the extremes, whereas the recumbent "S" shape of the FLR fitted line ensures that the LTV constraints are binding for predicted values. Fully robust variance matrix estimates are derived by Papke and Wooldridge (1996) by applying the formulas from the dichotomous dependent variable case. It is this method, then, that is applied here, estimated using quasi-maximum likelihood and compared with the other estimation methods. Because the LTV regression is part of a simultaneous equation system and the right-hand-side endogenous variable (the debt tax penalty) enters non-linearly, the usual 2SLS standard errors are unlikely to apply to our OLS estimates. Thus we report the bootstrapped standard errors (based on 1,000 repetitions) for all regression results, rather than the 2SLS standard errors or those suggested by Papke and Wooldridge in the single equation context for FLR.[7]

**[Figure 3 Constrained Response: Predicting with the [0,1] Interval]**

## 4. Data

The empirical analysis is based on over eighty-six thousand observations extracted from the Council for Mortgage Lenders' annual survey of 5% of all mortgage originations over the period 1995 to 1998 (see Hendershott, Pryce and White 2003 for details). Because variable descriptives and regression coefficients tended to be noticeably different for London and the Southeast compared with the remaining Other regions, we present two sets of results in each table. Variable definitions and descriptives are presented in Table 1 (i) for London/SE and in Table 1 (ii) for Other. If a variable is continuous, we present the mean, median, and coefficient of variation (the standard deviation as a proportion of the mean); if a variable is dichotomous, we present the proportion. Notice that the mean house price is almost 50 percent higher in the London/SE region than elsewhere, and income is 30 percent higher. As a result of the former,

[7] See Mooney and Duval (1993) for an introduction to bootstrapping.

the proportion of loans above £30000 is much greater, 90 percent in London/SE versus 77 percent in Other. Half of all loans have LTVs of 89 percent or higher.

Table 2 divides the two area samples by age, buyer status (first time owners, FTOs, and previous owners, POs), and the tax rate paid, either 0.23 to 0.25 or 0.4. Of course, FTOs are younger than POs; nearly four-fifths of FTOs are under age 35, while only two-fifths of POs are. Conversely, less than a tenth of FTOs are over age 44, versus a quarter of POs. Holding age constant, POs have higher incomes than FTOs and are thus more likely to be paying the higher 40 percent tax rate. This is especially true because the POs, being older and having higher incomes, have greater imputed income on equity invested in the house. These statements are equally valid for those in the London/SE as those living elsewhere.

The mean LTVs for each age/tax-rate cell are also listed. As expected, LTVs decline with age and are lower for POs. The age impact is far less for FTOs than POs; LTVs decline by 0.17 (London/SE, low tax rate) and 0.20 (Other, low tax rate) between under age 25 to over 54 for FTOs versus declines of 0.35 (London/SE) and 0.39 (Other) for POs. Finally, as expected, LTVs are lower for borrowers in the higher (0.4) tax bracket, although this is not true for the oldest PO households.

## 5. Equation Estimates

The probit equations for loans above £30,000 are listed in Appendix B (Table B1) and are estimated separately for the London/SE and the Other regions. These regressions were used to predict the probability of exceeding the £30,000 ceiling, and this probability was used to compute the tax penalty variables above and below the ceiling ($p^A = Tr\psi$ and $p^B = \max(T - 0.1, 0)r(1- \psi)$, respectively). We then predict the household tax penalty from a regression of the actual tax penalty on $p^A$ and $p^B$, the results of which are reported in the second table of the Appendix (Table B2). The adjusted $R^2$ of this regression for the London/SE region is 0.91, while the predictive power is 0.82 for the Other regions. The higher relative power is due to the higher percentage of loans above £30,000.

Table 3 presents the LTV regressions for previous owners and first-time owners using the different regression techniques. We have not reported the TR results because they are so similar to the CR results, which implies that correcting for censoring has the same effect as correcting for truncation. The tax penalty variable is highly statistically significant (t-ratios, in parentheses, range from 10 to 35), irrespective of the regression technique (OLS, CR, and FLR) employed, as are basic income, other income, and age. As for the OLS and CR/TR tax-penalty coefficients, we anticipated that the OLS coefficient would be biased towards zero due to the omission of totally constrained borrowers from the CML data (i.e., households who were unable to obtain a mortgage at the minimum LTV needed to purchase a dwelling that would yield greater utility than their current dwelling). This is confirmed: the OLS coefficients are smaller in absolute terms than the CR/TR coefficients in both the previous owner and first time buyer regressions for both the London/SE and Other regions (and are significantly smaller in three of four cases). Note also that the tax-penalty responses under the OLS and CR estimations for first-time buyers are roughly half those for previous owners. This, too, was expected given the younger age, and thus lower accumulated wealth, of first-time buyers.

Because the FLR coefficients are not the first partial derivatives (due to the non-linear structure of the logit functional form), they cannot be directly compared with the OLS and CR coefficients. We note, though, that here, too, the responses of previous owners are significantly greater than those of first-time owners.

Figure 4 illustrates the general fit of the equations by comparing the kernel density function of the predicted values of our three estimation techniques with the kernel density plot of the actual values of LTV.[8] Note that none of the estimation techniques explains the extreme concentration of LTVs at or above 0.95 (almost a third of our sample), although the CR method seems to do a marginally better job. On the other hand, the CR method predicts a number of LTVs greater than unity. The OLS and FLR methods have quite similar distributions of predicted values.

**[Figure 4 LTV Kernel Density Plots]**

[8] "Kernel density estimation" is the term used to describe a series of algorithms for approximating the density function of an observed distribution. We use the standard Epanechnikov kernel with a halfwidth (the width of the density window around each point) set at 0.01 for Figures 4 and 5.

## 6. Simulated Impact of Removing the Mortgage Interest Deduction (MID)

During our estimation period all borrowers effectively had partial interest deductibility. To compute the impact on debt usage of shifting from full deductibility to no deductibility (or vice versa) then requires two simulations: one to determine what LTVs would be with full deductibility (no tax penalty) and another to determine LTVs with zero deductibility (tax penalty equal to Tr). The percentage reduction in LTV owing to the loss of interest deductibility is then computed as the difference between the latter simulated value and the former, times 100, divided by the former.

Table 4 reports mean percentage declines in LTV resulting from removal of the MID predicted by each of the three estimation methods for each of the cells in Table 2. The percentage decline is greatest (across all estimation methods) for older borrowers (particularly previous owners) because their LTV is lower at the outset (full deductibility) so the same absolute fall in LTV will have a larger percentage effect. The percentage declines for previous owners are roughly double those for first time owners (less than double for young households according to the FLR estimation and somewhat more for older households according to OLS estimation). This follows directly from the larger tax penalty coefficients in Table 3. Predicted percentage decreases are also greater for households in the 40 percent tax bracket than those in the 23-25 percent brackets (not that much greater for older households). This is again as expected because the former are having a larger tax penalty removed. Finally, predicted decreases are quite similar for the London/SE and Other regions.

Regarding the estimation method, the CR method consistently has estimates 20 percent higher than OLS for FTOs and 5 to 10 percent higher for POs, which is consistent with the argument that the OLS estimates are biased downward. FLR, on the other hand, gives smaller percentages than OLS or CR for those under age 44 and larger increases for older borrowers (larger than CR only for households over age 54). The reason for the smaller FLR predictions for younger borrowers is clear from Figure 5, which gives the predicted LTV distributions for the three estimation methods with full interest deductibility. The OLS and CR predictions have many borrowers with LTVs greater than unity, considerably greater in the case of FLR. The FLR predictions, which are capped at unity, are necessarily lower.

On the other hand, the FLR estimated response exceeds the OLS estimated response for borrowers with moderate initial LTVs, and for whom the upper limit on debt gearing is unlikely to bind. While the OLS slope is restricted to be the same for all values of the independent variable, the FLR slope is not. This is clear from Figure 3 where the central section of the FLR curve is steeper than the OLS line. And older borrowers in our sample are much more likely to lie on this section of the curve than are younger borrowers.

**[Figure 5 LTV Kernel Density Plots for Full Deductibility]**

The impact of removal of the MID is much greater for POs than for FTOs and is again estimated to be much larger by the FLR method. Younger households have less wealth and are thus less able to reduce debt in response to a debt tax penalty. Moreover, most of the OLS and CR predictions of LTVs above unity are for younger borrowers. And POs have likely accumulated more wealth than FTOs.

Next we calculate the aggregate mortgage debt of borrowers both with and without interest deductibility implied by the three estimation techniques. Here we multiply the predicted LTVs with (without) deductibility for each household by its house value to get the predicted loan size (capped at the house value in the FLR prediction) with (without) deductibility. Then we compute the averages for each of the cells in Table 2 and multiply them by the relevant weights for each cell. Adding these products gives the average loan size with and without interest deductibility, respectively. The percentage decline in average loan size is obtained by dividing the difference between the averages with and without deductibility (times 100) by the average with full deductibility. This is also the percentage decline in aggregate mortgage debt due to the removal of the MID.

Two sets of weights are given in Table 5. Each set distributes homeowners into three age classes (<35, 35-44, >44), allowing for FTOs and POs as well as low and high tax brackets. The first set is based on our origination data in Table 2 and is derived directly from the counts in that table. These weights are necessarily skewed toward young, mobile households who do most loan origination. To compute the aggregate debt reduction for the economy, we want weights based on the home-owning population, not just new borrowers. The second set of weights is based on the British Household Panel Survey (BHPS) which is based on a representative sample of British households.[9]

As can be seen, a full 96 percent weight is applied to previous owners in the 40 percent tax bracket. Because most owners have been in their houses for many years (the average age of previous owners is 42.3 years in the BHPS sample versus 34.6 years in the new originators sample), incomes are higher in the BHPS sample. Further, the average LTV for the BHPS sample is only 0.61 versus the 0.78 in the CML sample. Recall that the tax calculation is based on income including an estimate of the income that would have been earned if the household were not a homeowner, i.e., the product of the mortgage interest rate and the difference between the current house value and the loan balance is added to other income.[10] This imputation pushes many more BHPS than CML households into the 40 percent tax bracket). In the absence of this imputation, only 50.2 percent of POs in the BHPS sample would be in the top tax bracket.

The aggregate percentage debt declines from removing the MID based on OLS, CR, and FLR are listed in Table 6 for the two sets of weights. Using the loan origination weights, the aggregate debt decline is 17 to 23 percent. Using the homeowner population weights, the responses rise to 32 to 41 percent. The latter, our CR estimate, is identical to the 41 percent simulated aggregate decline based on analysis of US data obtained by Follain and Melamed (1998)[11] What we wish to emphasize, though, is the 20 percent lower FLR estimate of 32 percent. This lower response is attributable to capping the simulated LTVs with full MID at unity. As just shown, OLS and CR simulated values with the MID often exceeded unity. Thus the reductions from removal of the MID based upon these estimations are greater than those based on FLR.

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[9] We extracted a subsample of mortgage borrowers four years (1995-1998) of BHPS data which we treated as repeat cross sections, yielding a total of 11,313 observations. We used the BHPS rather than one of the cross sectional databases because it proved to be the only data set that could provide us with a sufficiently large number of observations on all of the variables needed to derive the cell weights: (1) whether the head of household was a previous owner; (2) date of purchase of dwelling; (3) price paid for dwelling; (4) value of outstanding mortgage debt; and (5) basic income of head of household.

[10] An estimate of the current house value in the BHPS is obtained by inflating the original purchase price by the house price deflator for the region is which the house is located. The deflator was based on the Nationwide UK regional price index available from **http://www.nationwide.co.uk/hpi/historical.htm.**

[11] Like Follain and Melamed, we have held house value constant. Removing the MID would, of course, reduce some combination of the price and quantity of housing demanded, leading to an even greater decline in mortgage debt. The larger is the leverage response to removal of the MID, the less will be the impact on housing demand.

Because the household LTV response acts to offset the impact of removing the MID, a smaller response means a larger impact on housing demand and government tax revenue.

**7. Conclusions**

Given the non-taxation of income from owner-occupied housing, interest deductibility creates neutrality between debt and equity financing and renders the user cost of capital (through the WACC) independent of LTV choice. Removing, fully or partially, deductibility creates a debt tax penalty and makes the user cost a positive function of leverage. Thus the impact of changes in deductibility on housing choices, both tenure and quantity demanded, would depend on borrower sensitivity to the debt tax penalty. Estimating this sensitivity is the purpose of this paper.

The UK gradually removed the home mortgage interest deduction during the 1974-99 period. During this period the penalty depended on whether the loan was above or below £30,000. Thus we estimate a two-equation model determining both the tax penalty based on the probability of a loan being above £30,000 and the LTV itself.

Explaining the LTV is complicated by the restraint that lenders place on the maximum value; 15 percent of our UK loans have an LTV of exactly 95 percent. Not only does this make the explanation tricky, but linear extrapolation of borrower responses to full interest deductibility is likely to lead to predictions of many borrowers having LTVs exceeding what we know to be the lender maximum. We address these complications by considering three estimation methodologies: Ordinary Least Squares, Censored Regression and Fractional Logit Regression (FLR). Only the latter restricts predicted LTVs to be less than a maximum.

We analyze LTVs of 86,000 home purchasers with a mean LTV of 78 percent (based on a random sample of all new purchase loans). The simulated responses vary widely based upon the age of the borrower and whether they are first-time or previous owners. To illustrate, the FLR percentage declines for first-time owners are 7 and 16 for ages 25-34 and 45-54. For previous owners, the comparable age responses are 12 and 35. The simulated weighted-average percentage decline in LTV for previous owners in response to a shift from full interest deductibility to no deductibility ranges from 23 percent for Censored Regression to 17 percent for FLR. The much lower FLR response is due to the constraint against simulated LTVs exceeding unity when full interest deductibility exists.

These aggregate mortgage responses reflect our home buyer sample, in which first-time homeowners and younger buyers are far over represented relative to their distribution in the total homeowner population. Computations based on the overall population, i.e., with far greater weight given to older, wealthier, previous owners, yields greater percentage declines in aggregate mortgage debt. The Censored Regression decline is virtually identical to the economy-wide response simulated by Follain and Mehammed (1998) for the US. However, the FLR 32.4 percent decline is 20 percent less.

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# Table 1: Descriptive Statistics

| | | (i) London/SE N = 33,541 | | | (ii) Other Regions N = 53,079 | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Description** | **Mean or Proportion** | **Median** | **CV** | **Mean or Proportion** | **Median** | **CV** |
| Age | Age of main borrower | 34.65 | 32.00 | 0.08 | 34.50 | 32.00 | 0.08 |
| LTV | Loan to value ratio | 0.77 | 0.87 | 0.08 | 0.79 | 0.90 | 0.07 |
| Income | Basic income at 1990 prices (£000s) | 15.94 | 13.01 | 0.49 | 12.03 | 10.13 | 0.42 |
| Other income. | Other income at 1990 prices (£000s) | 4.10 | 0.00 | 2.47 | 3.18 | 0.00 | 2.20 |
| Mortgage | Amount borrowed (£000s) | 67.47 | 59.00 | 0.34 | 47.37 | 42.00 | 0.29 |
| Price | Purchase price (£000s) | 94.28 | 76.00 | 0.45 | 63.87 | 53.75 | 0.37 |
| **Dummies:** | | | | | | | |
| ceil | = 1 if mortgage amount is > £30K | 0.90 | - | - | 0.77 | - | - |
| prev_oo | = 1 if a previous owner | 0.54 | - | - | 0.51 | - | - |
| age_lt25 | = 1 if age < 25 | 0.10 | - | - | 0.13 | - | - |
| age25_34 | = 1 if aged 25 to 34 | 0.48 | - | - | 0.46 | - | - |
| age35_44 | =1 if aged 35 to 44 | 0.26 | - | - | 0.25 | - | - |
| age45_54 | =1 if aged 45 to 54 | 0.12 | - | - | 0.12 | - | - |
| age_gt54 | =1 if age > 54 | 0.04 | - | - | 0.04 | - | - |
| incoth_d | = 1if the borrower has income other than basic | 0.46 | - | - | 0.48 | - | - |
| 1996 | = 1 if mortgage taken out in 1996 | 0.25 | - | - | 0.24 | - | - |
| 1997 | = 1 if mortgage taken out in 1997 | 0.31 | - | - | 0.29 | - | - |
| 1998 | = 1 if mortgage taken out in 1998 | 0.23 | - | - | 0.24 | - | - |
| LondSE | = 1 if house is located in either London or S. East | 1.00 | - | - | 0.00 | - | - |
| Y.Hum | = 1 if house is located in Yorshire or Humberside | 0.00 | - | - | 0.14 | - | - |
| E.Mids | = 1 if house is located in East Midlands | 0.00 | - | - | 0.13 | - | - |
| E.Ang. | = 1 if house is located in East Anglia | 0.00 | - | - | 0.07 | - | - |
| Lon. | = 1 if house is located in London | 0.34 | - | - | 0.00 | - | - |
| S.East | = 1 if house is located in South East | 0.66 | - | - | 0.00 | - | - |
| S.West | = 1 if house is located in South West | 0.00 | - | - | 0.17 | - | - |
| W.Mids | = 1 if house is located in West Midlands | 0.00 | - | - | 0.14 | - | - |
| N.West | = 1 if house is located in North West | 0.00 | - | - | 0.16 | - | - |
| Scot. | = 1 if house is located in Scotland | 0.00 | - | - | 0.11 | - | - |

# Table 2: Cell Counts and Average LTVs:

| | | (i) London/SE | | | | | | (ii) Other Regions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **First Time Owners:** | | | **Previous Owners:** | | | **First Time Owners:** | | | **Previous Owners:** | | |
| **Age:** | | **Tax Rate:** | | | **Tax Rate:** | | | **Tax Rate:** | | | **Tax Rate:** | | |
| | | **0.23-0.25** | **0.4** | **Total** | **0.23-0.25** | **0.4** | **Total** | **0.23-0.25** | **0.4** | **Total** | **0.23-0.25** | **0.4** | **Total** |
| <25 | $\overline{LTV}$ | **0.91** | **0.87** | | **0.76** | **0.64** | | **0.92** | **0.89** | | **0.82** | **0.77** | |
| | *n* | 2,802 | 152 | 2,954 | 434 | 66 | 500 | 6,156 | 70 | 6,226 | 654 | 43 | 697 |
| | *n* as % | 18.1% | 1.0% | | 2.4% | 0.4% | | 23.8% | 0.3% | | 2.4% | 0.2% | |
| 25-34 | $\overline{LTV}$ | **0.90** | **0.88** | | **0.79** | **0.73** | | **0.90** | **0.87** | | **0.81** | **0.76** | |
| | *n* | 7,114 | 1,870 | 8,984 | 4,119 | 3,081 | 7,200 | 13,043 | 881 | 13,924 | 8,178 | 2,086 | 10,264 |
| | *n* as % | 45.9% | 12.1% | | 22.8% | 17.1% | | 50.5% | 3.4% | | 30.0% | 7.7% | |
| 35-44 | $\overline{LTV}$ | **0.86** | **0.85** | | **0.69** | **0.66** | | **0.86** | **0.84** | | **0.71** | **0.68** | |
| | *n* | 1,695 | 838 | 2,533 | 2,610 | 3,442 | 6,052 | 3,233 | 649 | 3,882 | 6,062 | 3,218 | 9,280 |
| | *n* as % | 10.9% | 5.4% | | 14.5% | 19.1% | | 12.5% | 2.5% | | 22.2% | 11.8% | |
| 45-54 | $\overline{LTV}$ | **0.82** | **0.79** | | **0.56** | **0.55** | | **0.81** | **0.79** | | **0.58** | **0.57** | |
| | *n* | 586 | 253 | 839 | 1,552 | 1,571 | 3,123 | 1,172 | 258 | 1,430 | 3,321 | 1,787 | 5,108 |
| | *n* as % | 3.8% | 1.6% | | 8.6% | 8.7% | | 4.5% | 1.0% | | 12.2% | 6.6% | |
| >54 | $\overline{LTV}$ | **0.74** | **0.73** | | **0.41** | **0.47** | | **0.72** | **0.67** | | **0.44** | **0.50** | |
| | *n* | 140 | 36 | 176 | 801 | 379 | 1,180 | 322 | 37 | 359 | 1,491 | 418 | 1,909 |
| | *n* as % | 0.9% | 0.2% | | 4.4% | 2.1% | | 1.2% | 0.1% | | 5.5% | 1.5% | |
| **Totals:** | | 79.7% | 20.3% | 15,486 | 52.7% | 47.3% | 18,055 | 92.7 | 7.3% | 25,821 | 72.3% | 27.7% | 27,258 |
| | | | | | | | 33,541 | | | | | | 53,079 |

$\overline{LTV}$ represents the mean loan to value ratio in a cell.

**Table 3. LTV Regressions**

## *(i) London/SE*

| | FTO | | | PO | | |
|---|---|---|---|---|---|---|
| | OLS | CR | FLR | OLS | CR | FLR |
| t_pen | -5.601 | -7.175 | -52.230 | -11.344 | -12.434 | -61.765 |
| | (-15.0) | (-14.8) | (-17.1) | (-11.3) | (-11.5) | (-12.4) |
| inc. | 0.012 | 0.015 | 0.113 | 0.018 | 0.019 | 0.108 |
| | (9.2) | (9.3) | (8.2) | (5.1) | (5.2) | (5.8) |
| $inc.^2$ | -2.0E-04 | -2.0E-04 | -2.0E-03 | -2.0E-04 | 2.0E-04 | -1.6E-03 |
| | (-4.5) | (-4.6) | (-4.2) | (-2.8) | (-2.9) | (-3.4) |
| $inc.^3$ | 8.8E-07 | 1.0E-06 | 9.8E-06 | 6.6E-07 | 7.1E-07 | 5.9E-06 |
| | (2.4) | (2.4) | (2.4) | (1.4) | (1.5) | (2.0) |
| O.inc. | 0.006 | 0.007 | 0.053 | 0.010 | 0.012 | 0.054 |
| | (10.8) | (8.5) | (9.2) | (7.4) | (7.6) | (7.4) |
| $O.inc.^2$ | -3.0E-04 | -4.0E-04 | -2.7E-03 | -4.0E-04 | 2.4E-06 | -1.8E-03 |
| | (-6.8) | (-4.9) | (-5.2) | (-3.4) | (-3.4) | (-3.3) |
| $O.inc.^3$ | 2.7E-06 | 3.4E-06 | 2.6E-05 | 2.2E-06 | 1.0E-05 | 1.0E-05 |
| | (5.1) | (3.0) | (3.0) | (1.6) | (1.6) | (1.5) |
| age | -0.001 | -0.002 | -0.036 | -0.010 | -0.012 | -0.066 |
| | (-0.6) | (-1.9) | (-4.7) | (-7.7) | (-9.5) | (-10.2) |
| $age^2$ | -5.0E-05 | -3.0E-05 | 3.0E-05 | -9.2E-06 | 1.0E-05 | 2.0E-04 |
| | (-3.1) | (-2.0) | (0.3) | (-0.6) | (0.9) | (2.9) |
| 1996 | -0.017 | -0.021 | -0.145 | -0.044 | -0.046 | -0.246 |
| | (-6.3) | (-5.6) | (-5.3) | (-6.9) | (-6.6) | (-7.9) |
| 1997 | -0.024 | -0.029 | -0.223 | -0.039 | -0.043 | -0.210 |
| | (-8.5) | (-7.5) | (-8.4) | (-7.6) | (-7.6) | (-8.1) |
| 1998 | -0.056 | -0.060 | -0.510 | -0.041 | -0.043 | -0.211 |
| | (-18.3) | (-15.1) | (-18.7) | (-8.1) | (-7.9) | (-8.4) |
| S.East | 0.009 | 0.013 | 0.090 | 0.029 | 0.033 | 0.141 |
| | (4.8) | (4.7) | (4.7) | (8.0) | (8.3) | (8.0) |
| Const. | 0.952 | 1.032 | 3.128 | 1.059 | 1.151 | 2.967 |
| | (53.1) | (48.6) | (22.5) | (44.2) | (43.2) | (19.2) |
| N | 15,486 | 15,486 | 15,486 | 18,055 | 18,055 | 18,055 |
| $Adj.R^2$ | 0.122 | - | - | 0.235 | - | - |
| LL | 11,623 | 1,367 | -4,108 | 2,523 | -1,195 | -7,954 |
| AIC | - 23,200 | -2,704 | 8,244 | -5,018 | 2420 | 15,936 |

All figures in parentheses are t-ratios derived from bootstrapped standard errors using 1,000 repetitions. "LL" stands for log-likelihood.

## *(ii) Other Regions*

| | FTO | | | PO | | |
|---|---|---|---|---|---|---|
| | OLS | CR | FLR | OLS | CR | FLR |
| t_pen | -5.892 | -7.506 | -53.458 | -13.497 | -14.983 | -69.492 |
| | (-12.7) | (-12.5) | (-13.9) | (-32.4) | (-34.3) | (-35.4) |
| inc. | 0.009 | 0.011 | 0.081 | 0.031 | 0.034 | 0.162 |
| | (5.2) | (4.8) | (4.2) | (23.3) | (22.3) | (34.2) |
| $inc.^2$ | -1.0E-04 | -1.0E-04 | -9.0E-04 | -6.0E-04 | -6.0E-04 | -3.0E-03 |
| | (-1.6) | (-1.4) | (-1.2) | (-13.5) | (-12.7) | (-22.4) |
| $inc.^3$ | 2.9E-07 | 3.5E-07 | 2.4E-06 | 2.7E-06 | 3.0E-06 | 2.0E-05 |
| | (0.5) | (0.4) | (0.4) | (8.5) | (8.0) | (15.1) |
| O.inc. | 0.009 | 0.010 | 0.093 | 0.012 | 0.013 | 0.070 |
| | (11.2) | (8.6) | (12.5) | (8.5) | (8.3) | (9.7) |
| $O.inc.^2$ | -6.0E-04 | -1.0E-03 | -6.4E-03 | -4.0E-04 | -1.0E-03 | -2.9E-03 |
| | (-5.9) | (-4.6) | (-6.6) | (-3.4) | (-3.3) | (-4.3) |
| $O.inc.^3$ | 6.9E-06 | 8.2E-06 | 1.0E-04 | 3.6E-06 | 3.8E-06 | 3.0E-05 |
| | (3.1) | (2.3) | (3.4) | (1.9) | (1.8) | (2.6) |
| age | -0.002 | -0.004 | -0.048 | -0.017 | -0.022 | -0.113 |
| | (-2.0) | (-3.8) | (-8.5) | (-19.1) | (-21.5) | (-23.9) |
| $age^2$ | -3.9E-05 | -2.1E-05 | 1.2E-04 | 6.6E-05 | 1.1E-04 | 6.6E-04 |
| | (-3.3) | (-1.8) | (1.7) | (6.2) | (8.9) | (12.4) |
| 1996 | -0.015 | -0.015 | -0.132 | -0.043 | -0.045 | -0.218 |
| | (-6.8) | (-4.6) | (-5.6) | (-11.2) | (-10.0) | (-11.3) |
| 1997 | -0.016 | -0.015 | -0.146 | -0.023 | -0.023 | -0.111 |
| | (-7.7) | (-5.0) | (-6.9) | (-6.2) | (-5.6) | (-6.0) |
| 1998 | -0.040 | -0.038 | -0.377 | -0.011 | -0.006 | -0.047 |
| | (-17.3) | (-11.9) | (-17.2) | (-2.8) | (-1.3) | (-2.5) |
| Y.Hum | 0.007 | 0.006 | 0.068 | 0.004 | 0.004 | 0.022 |
| | (2.1) | (1.3) | (2.0) | (0.8) | (0.6) | (0.8) |
| E.Mids | 0.001 | -0.004 | 0.012 | 0.002 | 0.001 | 0.011 |
| | (0.4) | (-0.8) | (0.4) | (0.3) | (0.2) | (0.4) |
| N.West | 0.011 | 0.006 | 0.114 | 0.003 | 0.002 | 0.018 |
| | (3.6) | (1.4) | (3.5) | (0.5) | (0.3) | (0.6) |
| Scot. | -0.002 | -0.007 | -0.022 | 0.008 | 0.005 | 0.046 |
| | (-0.5) | (-1.3) | (-0.6) | (1.4) | (0.8) | (1.5) |
| W.Mid | -0.001 | -0.010 | -0.013 | -0.010 | -0.011 | -0.043 |
| | (-0.3) | (-2.2) | (-0.4) | (-1.7) | (-1.7) | (-1.5) |
| S.West | -0.004 | -0.012 | -0.042 | -0.005 | -0.006 | -0.016 |
| | (-1.2) | (-2.5) | (-1.2) | (-0.8) | (-1.0) | (-0.6) |
| E.Ang. | -0.005 | -0.011 | -0.058 | 0.003 | 0.004 | 0.021 |
| | (-1.4) | (-2.1) | (-1.5) | (0.4) | (0.6) | (0.6) |
| Const. | 1.003 | 1.111 | 3.688 | 1.205 | 1.334 | 3.906 |
| | (64.2) | (54.3) | (27.9) | (62.7) | (60.8) | (37.6) |
| N | 25,821 | 25,821 | 25,821 | 27,258 | 27,258 | 27,258 |
| $Adj.R^2$ | 0.122 | - | - | 0.276 | - | - |
| LL | 19,689 | 1,323 | -6,643 | 4,653 | -1901 | -11,600 |
| AIC | -39,300 | -2,604 | 13,325 | -9,267 | 3,844 | 23,170 |

All figures in parentheses are t-ratios derived from bootstrapped standard errors using 1,000 repetitions. "LL" stands for log-likelihood.

## Table 4. Percentage Decline in LTV Due to a Shift from Full to Zero Interest Deductibility

| | | London/SE | | | | Other Regions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | FTO | | PO | | FTO | | PO | |
| **Age:** | | **0.23-0.25** | **0.4** | **0.23-0.25** | **0.4** | **0.23-0.25** | **0.4** | **0.23-0.25** | **0.4** |
| <25 | **OLS** | 10 | 17 | 20 | 32 | 11 | 17 | 22 | 33 |
| | **CR** | 12 | 20 | 21 | 33 | 13 | 20 | 23 | 35 |
| | **FLR** | 7 | 11 | 13 | 20 | 7 | 9 | 11 | 15 |
| 25-34 | **OLS** | 10 | 17 | 21 | 33 | 11 | 18 | 23 | 35 |
| | **CR** | 12 | 20 | 22 | 34 | 13 | 21 | 24 | 37 |
| | **FLR** | 8 | 13 | 15 | 23 | 8 | 13 | 14 | 20 |
| 35-44 | **OLS** | 11 | 18 | 24 | 36 | 11 | 18 | 26 | 39 |
| | **CR** | 13 | 21 | 25 | 38 | 13 | 22 | 28 | 41 |
| | **FLR** | 11 | 16 | 22 | 31 | 11 | 16 | 22 | 29 |
| 45-54 | **OLS** | 12 | 19 | 28 | 41 | 12 | 19 | 31 | 43 |
| | **CR** | 14 | 22 | 30 | 43 | 15 | 23 | 33 | 46 |
| | **FLR** | 15 | 21 | 32 | 42 | 16 | 21 | 33 | 41 |
| >54 | **OLS** | 13 | 20 | 37 | 48 | 13 | 20 | 39 | 49 |
| | **CR** | 15 | 24 | 39 | 51 | 16 | 24 | 42 | 52 |
| | **FLR** | 21 | 29 | 43 | 51 | 22 | 25 | 44 | 50 |

Figures have been rounded to the nearest integer.

# Table 5. Cell Weights

### (a) CML Cell Weights

| | FTO | | PO | |
|---|---|---|---|---|
| Age: | **0.23-0.25** | **0.4** | **0.23-0.25** | **0.4** |
| <35 | 0.336 | 0.034 | 0.155 | 0.061 |
| 35-44 | 0.057 | 0.017 | 0.100 | 0.077 |
| >44 | 0.026 | 0.007 | 0.083 | 0.048 |

### (b) BHPS Cell Weights

| | FTO | | PO | |
|---|---|---|---|---|
| Age: | **0.23-0.25** | **0.4** | **0.23-0.25** | **0.4** |
| <35 | 0.003 | 0.009 | 0.012 | 0.217 |
| 35-44 | 0.001 | 0.003 | 0.005 | 0.309 |
| >44 | 0.001 | 0.005 | 0.004 | 0.430 |

# Table 6: Percent Decline in Aggregate Mortgage Debt

| | **CML Weights** | **BHPS Weights** |
|---|---|---|
| OLS | 21 | 39 |
| CR | 23 | 41 |
| FLR | 17 | 32 |

Figures have been rounded to the nearest integer.

## Appendix A

Consider first the order conditions of our system of simultaneous equations comprised of equations (3) and (4') in the text. Following Maddala (1992, p.360), let $g$ be the number of endogenous variables in the system, and let $k$ be the total number of variables (endogenous and exogenous) missing from the equation in question. For equation (3) we can see that $k = 1$, and for equation (4') $k = 0$. If $k = g - 1$, the equation is said to be exactly identified, whereas if $k$ is greater (less) than $g - 1$, then the equation in question is said to be over (under) identified. Because we have two endogenous variables in the system (LTV and $p^C$) $g = 2$, and equation (3) is exactly identified according to the order condition, but equation (4') is under identified.

Now consider the rank rule for identification. This rule says that if we represent our system of equations as a matrix (with the columns designating variables and the rows representing equations), and if we place zeros in the columns where variables are not included in a particular equation and ones where variables are included, then if we delete the row of the equation in question and make a new matrix from the rows and columns that correspond to the zeros in the equation in question, we would need at least $g - 1$ rows and columns in this new matrix that are not all zeros for the equation in question to be identified (i.e. either over or exactly identified). If we cannot find $g - 1$ rows and columns that are not all zeros, then the equation is not identified (i.e. under identified). Because we only have two equations in our system, the rank rule is trivial. The matrix of variables is as follows:

| Equation | LTV | $p^C$ | R | $PO_i$ | $Y^B{}_i$ | $Y^O{}_i$, | $AGE_i$ | **DUM**$_i$ |
|---|---|---|---|---|---|---|---|---|
| (3) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| (4') | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Applying the rank rule to equation (3), because there is only one zero, we are left a second matrix of one element that is non zero, with row and column dimensions = 1, which equals $g - 1$. So according to both the rank and order conditions, the equation of interest – equation (3) – is exactly identified.

# Appendix: Table B1: Probit Results

## *(Dependent variable = ceil)*

| | London/SE | Other Regions |
|---|---|---|
| PO | -0.424 | -0.193 |
| | (-11.8) | (-8.3) |
| Income | 0.048 | 0.082 |
| | (12.8) | (18.3) |
| other.income | 0.027 | 0.073 |
| | (7.5) | (22.8) |
| other income dummy | 0.395 | 0.293 |
| | (11.6) | (13.1) |
| age < 25 | -0.361 | -0.287 |
| | (-2.8) | (-3.4) |
| age 25 to 34 | 0.946 | 0.484 |
| | (11.6) | (7.2) |
| age 35 to 44 | 1.112 | 0.899 |
| | (14.9) | (13.7) |
| age 45 to 54 | 0.373 | 0.664 |
| | (4.8) | (10.1) |
| inc. * (age < 25) | 0.168 | 0.173 |
| | (12.1) | (18.9) |
| inc. * (age 25 to 34) | 0.034 | 0.085 |
| | (6.3) | (15.0) |
| inc. * (age 35 to 44) | 0.004 | 0.018 |
| | (0.7) | (3.5) |
| inc. * (age 45 to 54) | 0.015 | -0.012 |
| | (2.9) | (-2.4) |
| PO * (age < 25) | -0.052 | 0.206 |
| | (-0.6) | (3.1) |
| PO * (age 25 to 34) | 0.084 | 0.148 |
| | (1.6) | (4.5) |
| 1996 | 0.001 | 0.034 |
| | (0.0) | (1.8) |
| 1997 | 0.053 | 0.130 |
| | (1.8) | (6.9) |
| 1998 | 0.059 | 0.118 |
| | (1.8) | (5.9) |
| S.East | -0.115 | - |
| | (-4.8) | - |
| Y.Hum | - | 0.244 |
| | - | (8.5) |
| E.Mids | - | 0.263 |
| | - | (8.9) |

| | | |
|---|---|---|
| N.West | - | 0.305 |
| | - | (10.8) |
| Scot. | - | 0.253 |
| | - | (8.3) |
| W.Mid | - | 0.430 |
| | - | (14.5) |
| S.West | - | 0.555 |
| | - | (19.2) |
| E.Ang. | - | 0.411 |
| | - | (12.0) |
| Const. | -0.405 | -1.802 |
| | (-5.7) | (-27.9) |
| N | 33,541 | 53,079 |
| LL | -8,568 | -21,700 |
| $Chi^2$ | 5,270 | 14,000 |
| AIC | 17,176 | 43,418 |

Figures in parentheses are t-ratios.

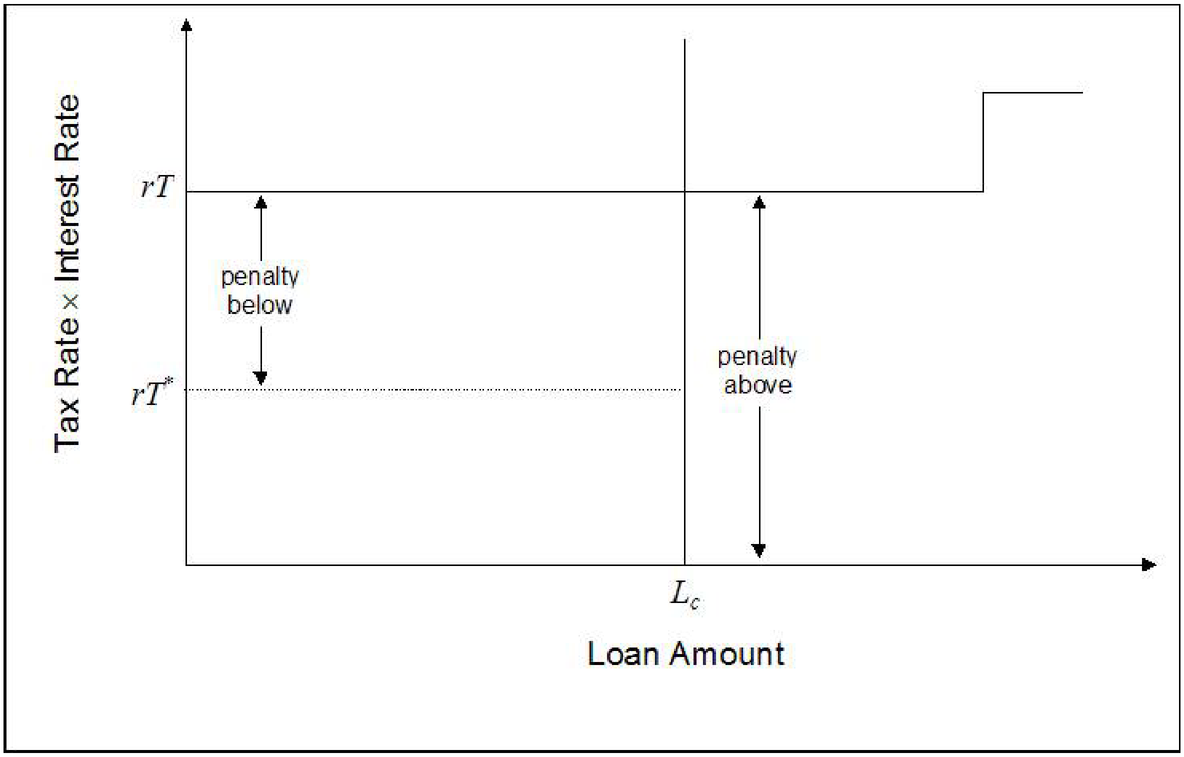
## Appendix: Table B2: Tax Penalty (Above and Below) Regressions

### *(Dependent Variable: tax_pen = the actual tax penalty)*

| | London/SE | Other Regions |
|---|---|---|
| tax_above | 0.999 | 0.986 |
| | (576.4) | (446.5) |
| tax_below | 0.939 | 0.881 |
| | (130.4) | (135.2) |
| Const. | 0.000 | 0.000 |
| | (2.3) | (0.0) |
| N | 33,541 | 53,079 |
| Adj $R^2$ | 0.911 | 0.817 |

OLS regressions

**Figure 1. The Tax Penalty**



# Figure 2 Impact of Excluded Borrowers: Correcting for Truncation Bias

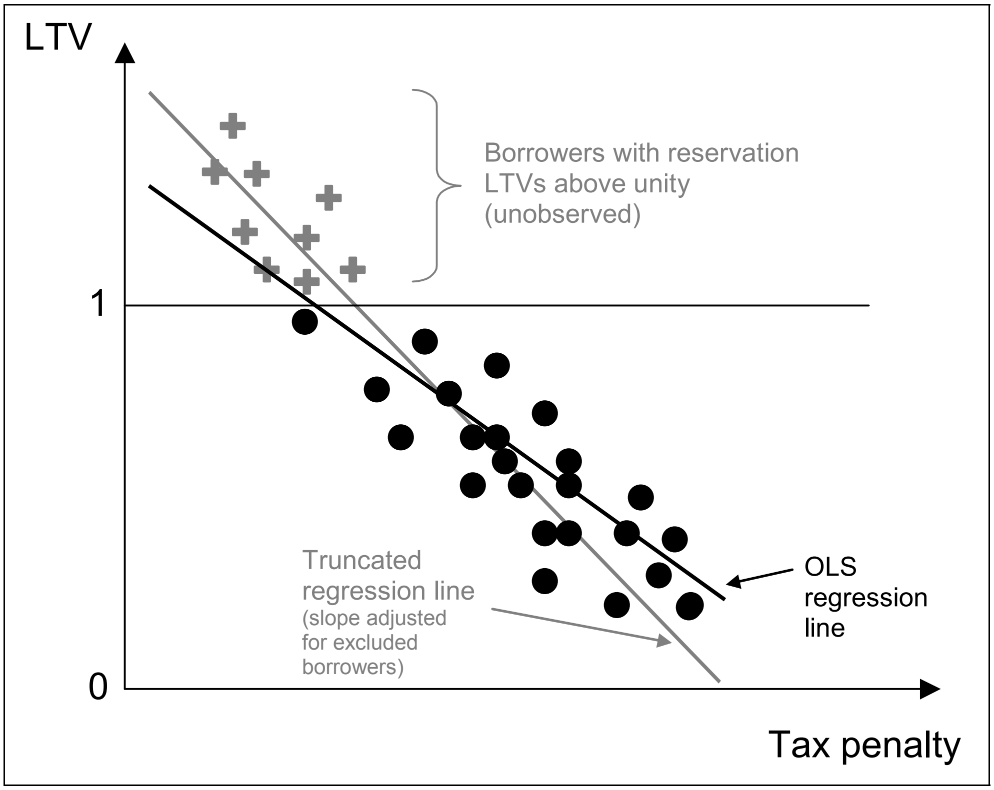
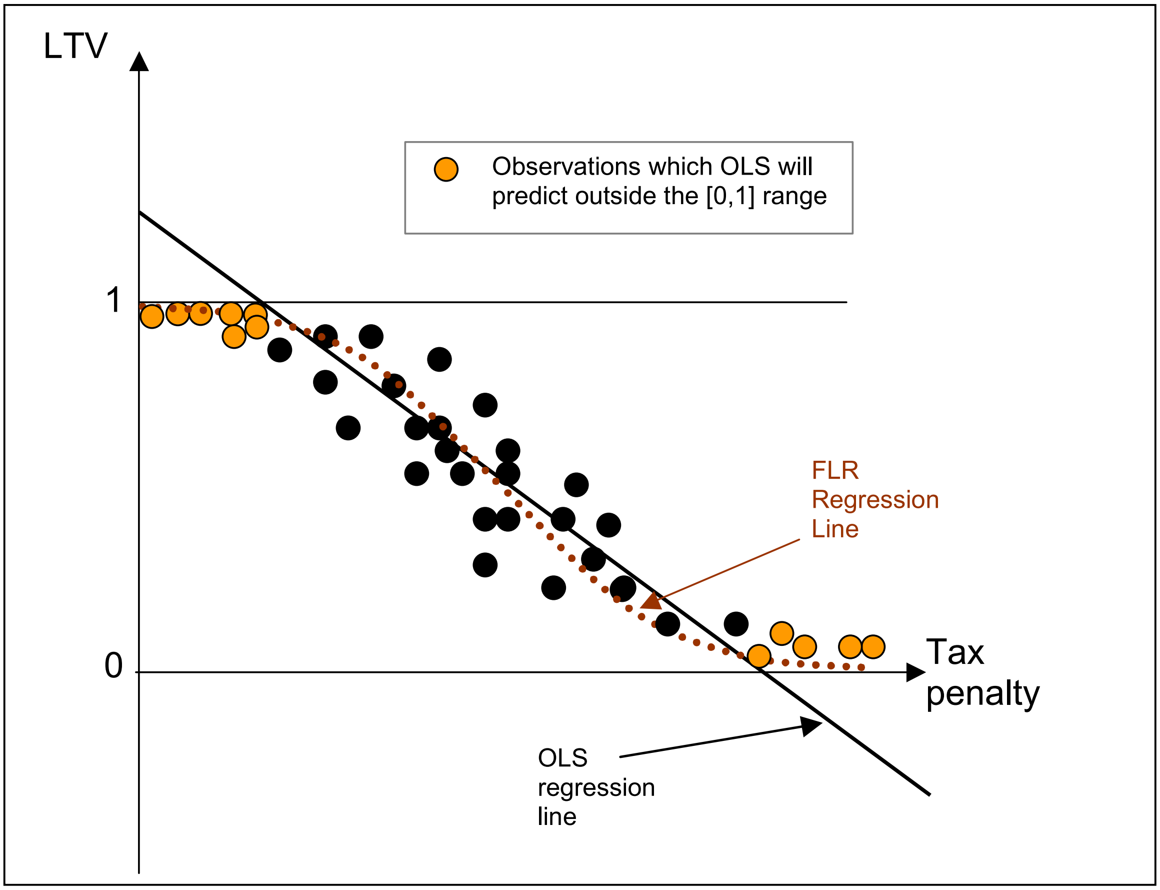


**Figure 3 Constrained Response: Predicting with the [0,1] Interval**



# Figure 4 LTV Kernel Density Plots

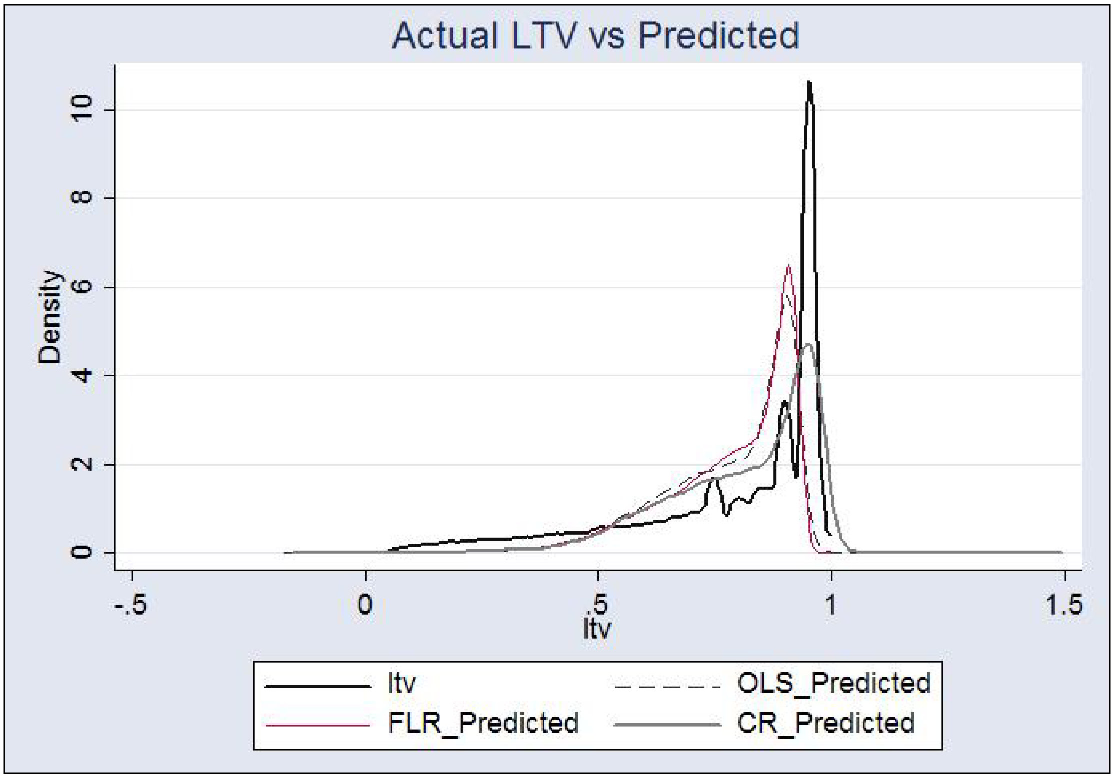


**Figure 5 LTV Kernel Density Plots for Full Deductibility**