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House price rises and borrowing to invest

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Abstract

Household borrowing and spending rise with house prices, particularly for leveraged households, but household spending is not consumption. We propose a borrow-to-invest motive by which house price gains affect household spending on residential investment: rational, leveraged households have an incentive to make additional residential investments when house prices rise. Credit constraints then matter through reducing access to leveraged returns and so reducing lifetime resources, rather than through consumption smoothing. We test this motive by comparing responses in different categories of spending across more and less leveraged households. We find strong evidence of the borrow-to-invest motive in UK data.

Keywords: House prices, leverage, consumption, home investment
JEL Codes: E21, D14, D15, G51

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1 Introduction

Over the past 30 years, households have taken on massive amounts of debt, often on the back of house price increases. This has generated wide concern in the popular press about over-consumption and sustainability. This concern rests on the belief that households are borrowing to consume, which is also the standard explanation in the economics literature: rising house prices relax credit constraints for the highly leveraged and allow these households to increase current consumption (Andersen and Leth-Petersen (2021); Cooper (2013); Mian and Sufi (2011)). This explanation implies leveraged households have had a strong desire for faster consumption growth, and over a sustained period.

Our paper proposes an alternative. Recent work (Kuhn, Schularick, & Steins, 2020) has highlighted the dominance of housing in the portfolios of middle class households, and the centrality of housing returns to their wealth accumulation. However, for many of these households, mortgages are a counterpart to homeownership and form a key part of portfolio decisions. This mortgage debt leverages the portfolio and increases the expected return. Our point is that new debt need not finance consumption: household spending is not only consumption, there is also investment spending that can either enhance the value of existing properties or be used to acquire new properties. Our proposition is that household borrowing after house price increases funds, at least in part, investment spending. We call this the *borrow to invest motive*.

This borrow to invest motive operates through two channels. First, if the household is leveraged and the portfolio share of housing exceeds one, a house price increase will *decrease* (not increase) the household's portfolio share of housing, and portfolio rebalancing requires additional housing investment (not divestitures). Alternatively, if a household's holding of gross housing wealth is constrained by Loan-to-value (LTV) limits, a house price increase will relax that constraint and allow them to move towards their desired portfolio. This scenario shares with the standard consumption story the idea that borrowing constraints are relaxed by the house price rise, but differs in that it is investment, rather than consumption, that is constrained. The share of housing in the portfolio may be less than one if household holds other financial wealth or treats human wealth as a portfolio asset. Even in this scenario, the borrow-to-invest motive can drive borrowing through the relaxing of LTV constraints. Both channels are relevant for highly-leveraged households.

According to the borrow to invest motive, the spending response to a price increase and the relaxation of borrowing constraints among leveraged households follows from a wealth-building motive, rather than a purely consumption smoothing motive. This offers a different and perhaps more positive perspective on household borrowing.

Before presenting our empirical test, we illustrate the borrow-to-invest motive with a life-cycle model of housing as a portfolio choice. We use a highly simplified version of the model to draw out the first channel. We then extend the model numerically in multiple directions. We add loan-to-value and loan-to-income constraints on borrowing to study the second channel. We also add stochastic labour income to introduce a human capital asset to the portfolio and transactions costs to capture the partial illiquidity of housing assets. In each of the versions we study, reasonable parameter values imply that increases in house prices lead to increases in borrowing among the highly leveraged that is used to invest further in housing, rather than for extra consumption.

We test for the borrow-to-invest motive by comparing how different categories of household spending - consumption spending and residential investment spending - respond to house price changes and how those responses vary with household leverage. Our measure of residential investment spending includes home improvements, extensions and fixed durables, which can enhance property values in addition to providing households with a consumption flow. Both more traditional models of credit-constrained consumption and the borrow-to-invest motive predict that highly-leveraged households should have larger responses to house price increases. However, the borrow-to-investment motive implies that the extra spending response of leveraged households should be in investment categories of spending, while a constrained consumption model would suggest spending responses in pure consumption categories. We use detailed household-level data on borrowing, consumption and residential investment decisions from the UK. We link data on households' balance sheets from a panel survey with spending data in a household budget survey using two-sample IV methods (Angrist and Krueger (1992)). We use instruments based on credit and housing market conditions at the time of house purchase, which have a persistent effect on leverage. This IV strategy accounts for the fact that leverage is endogenous in our framework. An additional often cited concern is the endogeneity of house prices. We avoid this concern by using variation in leverage within local housing markets and birth cohorts. In other words, we compare the spending responses across spending categories and degrees of leverage of otherwise similar households who experienced the same house price change.

Our test finds strong evidence of the borrow-to-invest motive. Relative to similar less-leveraged households experiencing the same house price increase, more leveraged households have significantly larger increases in residential investment spending, but do not disproportionately increase their consumption spending. To be precise, we find that a household with a leverage ratio one unit higher than average increases residential investment by 8.8% more in response to a 10% increase in house prices than a household with average leverage. We obtain similar results using narrower measures of residential investment spending that only cover structural changes to the property such as extensions. We also show that more leveraged households are more likely to make second home purchases in response to rising local prices over longer time horizons. Importantly, we do not find evidence of differential increases in spending on luxuries among highly leveraged households, indicating that this behaviour is unlikely to be driven by pure consumption motives.

In the years since the financial crisis, policymakers have been increasingly interested in macro-prudential measures that use credit constraints to limit borrowing among households during asset booms. The borrow-to-invest motive highlights three key points about credit constraints. First, loan-to-value constraints are relaxed by house price increases and so loan-to-value restrictions impose less restraint on borrowing during house price booms. By contrast, loan-to-income constraints are not affected by the current state of house prices and so continue to act to constrain borrowing. Second, in the borrow-to-invest framework, investment rather than consumption is constrained. This means that rather than hindering consumption smoothing, credit constraints limit portfolio returns. These lower returns imply an important effect of credit constraints is to lower life-time wealth. Finally, there may be unintended distributional consequences of restricting borrowing, depending on who is constrained by the policies.

Related Literature: The borrow-to-invest motive provides a reinterpretation of the finding in a large and convincing literature that borrowing responses to house price changes are larger for leveraged households (see Cloyne, Huber, Ilzetzki, and Kleven (2019), Aladangady (2017), Cooper (2013), Mian and Sufi (2011), Disney, Gathergood, and Henley (2010) and DeFusco (2018)). These papers focus on the response of total spending or debt, and often interpret those changes as a consumption response without delving into the composition of the response. The most common interpretation in these papers is that consumption spending is constrained, and this constraint is relaxed by house price increases. Mian, Rao, and Sufi (2013) do consider the composition of spending in response to house price changes (at county-level), but they do not separate out household investment spending from other categories and only examine heterogeneity in spending by leverage for auto purchases (which they observe at zip-code level). Berger, Guerrieri, Lorenzoni, and Vavra (2017) provide an alternative interpretation of increased spending, whereby households at greater risk of facing a binding credit constraint would be expected to accumulate precautionary savings, which they would then decumulate faster in response to a rise in house prices. Kaplan, Mitman, and Violante (2020) show how a combination of relaxing credit constraints and more optimistic beliefs about future housing demand can generate a housing boom, boosting consumption spending through a wealth channel. In contrast to our empirical work, these papers focus on an overall spending response without disaggregating into consumption and investment.

The two papers closest to our work are DeFusco (2018) and Benmelech, Guren, and Melzer (2023). DeFusco (2018) finds that relaxing collateral constraints on homeowners leads to an increase in borrowing and also applications for home improvement permits.

The latter is a level effect and consistent with the borrow-to-invest motive, but also with consumption motives. Relative to DeFusco (2018), we explicitly test the implications of the borrow-to-invest motive - namely that residential investment spending responses to house price increases should be higher for more leveraged households. Benmelech et al. (2023) examine spending on housing goods increases immediately after home purchase and therefore show how consumer spending is related to moving house. Our focus is on residential investment responses to house price changes that occur regardless of whether households move.[1]

Our discussion has concentrated on house price increases leading to extra investment by leveraged households. Conversely, when house prices fall, the housing portfolio share for leveraged households will rise, and they will want to pay-down debt or reduce housing investment to rebalance their portfolios. This behaviour provides a mechanism for the 'debt-overhang' effects reported by Dynan (2012), who shows that households cut spending when over-leveraged. Related to this behaviour, Melzer (2017) shows that households invest less in their homes when over-leveraged and at risk of repossession.

The remainder of this paper is structured as follows. Section 2 illustrates the borrow to invest motive with a life-cycle model of housing as a portfolio choice. Section 3 describes our data and provides descriptive evidence that households re-leverage by increasing borrowing when house prices rise. Section 4 tests the borrow-to-invest channel by comparing consumption and investment responses to house price changes at different degrees of leverage. Section 5 concludes.

2 Life-Cycle Portfolio Choice

We set up a life-cycle model of housing as a portfolio choice. The purpose of the model is to draw out the two channels through which an investment motive for releveraging can arise particularly among households that are highly leveraged. This is either through an unconstrained portfolio adjustment motive or through movements towards a desired portfolio as constraints relax. We use a highly simplified version of the model to draw out the first channel. We then extend the model numerically in multiple directions. We add loan-to-value and loan-to-income constraints on borrowing to study the second channel. We also add stochastic labour income to introduce a human capital asset to the portfolio and transactions costs to capture the partial illiquidity of housing assets. We parameterise the numerical model to study highly leveraged households, whose behaviour is the subject of our empirical test.

[1] Our work also relates to the wider literature on housing investments and portfolio choices over the life-cycle. Cocco (2005) and Chetty, Sandor, and Szeidl (2017) consider how portfolio decisions and stock purchases are affected by the presence of housing and shocks to house prices.

2.1 Model Set-Up

Consider a unitary household, i, with two assets available to hold in its portfolio, that each period chooses consumption, $c_{i,t}$, the amount of housing, $h_{i,t}$, and liquid wealth $b_{i,t}$.

Households receive income, $y_{i,t}$ each period:

$$\ln y_{i,t} = \ln y^P_{i,t} + \ u_{i,t}, \qquad u_{i,t} \sim N(0, \sigma^2_u) \tag{1}$$

where $y^P_{i,t}$ is permanent income:

$$\ln y^P_{i,t} = \ln y^P_{i,t-1} + f_i(t) + \eta_{i,t} \qquad \eta_{i,t} \sim N(0, \sigma^2_\eta)$$

where $f_i(t)$ captures the deterministic age-trend. We assume there is no labour supply choice and retirement is exogenous. Income in retirement is deterministic and based on a replacement rate of one based on the permanent wage at the time of retirement.

Households can hold a risk-free asset (a bond) denoted $b_{i,t}$ with price 1 and interest rate r. Housing is a risky asset with price p_t, which generates a market return on housing as:

$$r^*_t = \frac{p_t}{p_{t-1}} - 1. \tag{2}$$

The excess market return of housing over the risk-free rate is i.i.d.:

$$r^*_t - r = \mu + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2_\varepsilon) \tag{3}$$

Equivalently, we can write the house price process as:

$$\ln p_t \approx \ln p_{t-1} + r + \mu + \varepsilon_t \tag{4}$$

The return on housing is common across individuals within a group, and so is not indexed by i. By assuming returns are i.i.d., we show how house price increases may affect investment decisions even if shocks to housing returns have no persistence. We assume households have rational expectations over the house price process. If there is persistence in housing returns or if households believe there is persistence, this would provide an additional reason to expect house price increases to affect residential investment, but our point is that we can rationalise investment behaviour without recourse to persistence or over-optimism.

Households can short the bond (that is, take a mortgage loan), but cannot short housing. We define debt as $d_{i,t} = -b_{i,t}$. Further, there are two additional credit constraints. First, a loan-to-income constraint:

$$d_{i,t} \leq \lambda_y y_{i,t} \tag{5}$$

Second, a loan-to-value constraint:

$$d_{i,t} \leq \lambda_h p_t h_{i,t} \tag{6}$$

where $h_{i,t}$ is the quantity of housing chosen in period t.

We assume that it is costly to adjust housing: the household must pay:

$$\kappa * \left| h_{i,t} p_t - \bar{h}_{i,t} p_t \right| \tag{7}$$

where $\bar{h}_{i,t}$ is the quantity of housing owned at the start of the period. In other words, the adjustment cost is proportional to the size of the adjustment.

We define the leverage position of the household (the loan-to-value ratio) as:

$$L_{i,t} = \frac{\text{debt}}{\text{gross housing wealth}} = \frac{d_{i,t}}{p_t h_{i,t}} \tag{8}$$

and the portfolio share of housing as:

$$\omega_{i,t} = \frac{\text{gross housing wealth}}{\text{net wealth}} = \frac{p_t h_{i,t}}{p_t h_{i,t} - d_{i,t}} = \frac{1}{(1 - L_{i,t})} \tag{9}$$

Leverage $0 < L_{i,t} < 1$ implies $\omega_{i,t} > 1$. For example, a household with a 95% "mortgage" ($L_{i,t} = 0.95$) has a housing portfolio share of $\omega_{i,t} = 20$, while for outright owners $\omega_{i,t} = 1$ if they hold no bonds.

The intertemporal budget constraint describing the evolution of net wealth, $x_{i,t}$ is:

$$x_{i,t} = (1 + r + \omega_{i,t-1} (r_t^* - r)) * (x_{i,t-1} - c_{i,t-1}) + y_{i,t} - \kappa * \left| h_{i,t} p_t - \bar{h}_{i,t} p_t \right| \tag{10}$$

This is distinct from cash-on-hand which requires paying the liquidation cost, κ.[2]

Households maximise expected lifetime utility subject to this intertemporal constraint, (10), and the borrowing constraints, (5) and (6).

$$U_{i,t} = \max_{c,h,d} E_{i,t} \left[\sum_{\tau=0}^{T-t} \beta^\tau \frac{(c_{i,t+\tau}, h_{i,t+\tau})^{1-\gamma}}{1-\gamma} \right] \tag{11}$$

[2]The model assumes that the price of additions to the housing stock moves in lock-step with the price of selling units of housing stock. This may not hold for additions to existing homes (such as renovations), potentially affecting the incentives of when to make these investments, but we believe it is more realistic that the costs of these additions moves with house prices than that they remain fixed.

2.2 The Merton Special Case

The first borrow-to-invest channel arises in the consumption and portfolio choice model of Merton (1969), which is a special case of the model above. To see this, assume that the household has no labour income ($y_{i,t} = 0$), there are no adjustment costs, κ, associated with housing, no borrowing constraints other than the inability to short housing and a no-bankruptcy condition, an infinite horizon and that the consumption value of housing does not enter the utility function.

In this model, wealth evolves as:

$$x_{i,t} = \left(1 + r + \frac{1}{1 - L_{i,t-1}} \left(r_t^* - r\right)\right) * \left(x_{i,t-1} - c_{i,t-1}\right) \tag{12}$$

This highlights the way that leverage magnifies risk and return.

For a particular house price realisation, we can show the impact on wealth:

$$x_{i,t} - E_{i,t-1}[x_{i,t}] = \omega_{i,t-1} \left(r_t^* - E_{i,t-1}\left[r^*\right]\right) * \left(x_{i,t-1} - c_{i,t-1}\right) \tag{13}$$

Equation (13) shows that the effect on net wealth of a given house price realisation will be greater when the portfolio share is greater: leveraged households have a greater increase in their wealth for a given house price realisation, and these effects are highly nonlinear in leverage. These larger wealth increases for leveraged households will impact both investment and consumption decisions. The borrow-to-invest channels that we highlight are in addition to this wealth effect. We can also express the change in wealth directly in terms of house prices:

$$x_{i,t} - E_{i,t-1}[x_{i,t}] = \left(p_t - E_{i,t-1}\left[p_t\right]\right) * h_{i,t-1}. \tag{14}$$

The policy rules in this simple model are well known. There is a linear consumption function:

$$c_{i,t} = \alpha x_{i,t} \tag{15}$$

and there is a constant target portfolio share for the risky asset:

$$\omega_{i,t} = \omega^* \tag{16}$$

In the Merton model, the portfolio share of the risky asset depends only on moments of the return distribution. As leverage is just a transformation of the housing portfolio share, this implies there is a constant target leverage that delivers the household's desired combination of risk and return.

The change in wealth due to a particular house price realisation (as shown in equation

(14)) is partly consumed:

$$c_{i,t} - E_{i,t-1}[c_{i,t}] = \alpha\left(x_{i,t} - E_{i,t-1}[x_{i,t}]\right) \tag{17}$$

and partly saved ($s_{i,t}$) according to the consumption function:

$$s_{i,t} - E_{i,t-1}[s_{i,t}] = (1-\alpha)\left(x_{i,t} - E_{i,t-1}[x_{i,t}]\right). \tag{18}$$

The point about these two equations is that ω only enters into these equations to the extent that ω affects the change in net wealth: there is no additional effect of leverage on consumption over and above the net wealth effect.

By contrast, when we consider the impact of house price changes on investment, the portfolio choice rule implies that the additional saving in equation (18) is leveraged by ω^* to generate an increase in housing wealth:

$$p_t * h_{i,t} - E_{i,t-1}[p_t * h_{i,t}] = \omega^*\left(1-\alpha\right)\left(x_{i,t} - E_{i,t-1}[x_{i,t}]\right). \tag{19}$$

This means that ω has an additional effect on the portfolio decision and enters into the portfolio decision over and above the direct effect that ω has on net wealth that is shown in equation (13). The greater effect of ω on investment spending forms the heart of our empirical test of the borrow-to-invest channel that we perform in Section 4.

Using equation (14), equation (19) implies extra active investment in housing of:

$$\begin{aligned}(p_t * h_{i,t} - E_{i,t-1}[p_t * h_{i,t}]) - (p_t * h_{i,t-1} - E_{i,t-1}[p_t] * h_{i,t-1})\\ = (\omega^*(1-\alpha)-1)\left(p_t - E_{i,t-1}[p_t]\right)h_{i,t-1}\end{aligned} \tag{20}$$

The first term on the left-hand side of equation (20) is the change in desired gross housing wealth. The second term is the additional housing wealth that comes mechanically from the unexpected price increase. The difference between the two is the additional active investment in housing (funded by debt) to return the housing portfolio share to w^*. The key conclusion from this model is that, if there is an unexpected house price increase, a leveraged household will increase investment in housing and borrow to do so (even if the household believes that housing returns are i.i.d.), whereas consumption will change very little. Conversely, an unexpected house price fall will increase the leverage of the portfolio and the household will want to sell housing and retire debt to return to ω^*. In other words, the key margin of adjustment is investment in housing.

For example, suppose that the household owns a £600,000 house with $\alpha = 0.05$ and $\omega = 3$ (so that the household has 33% equity in the home.) If the house value unexpectedly goes up by 5% (£30,000), the consumption function implies that net wealth increases by £28,500 and the constant portfolio rule implies that the household then desires gross housing wealth of £685,500 . As the house value is now £630,000, the households makes new investment in housing of £55,500, financed by new debt. Note that the extra investment spending (£55,500) is much larger than the extra consumption spending (£1,500). The marginal propensity to invest $(\omega(1-\alpha)-1)$ is 1.85, and the marginal propensity to consume (α) is 0.05. Clearly in this example the balance sheet of the household has expanded quickly, and we show in the solution to the complete model how the presence of credit constraints and frictions moderate households' desire and ability to do this.

The framework of Merton (1969) shows the first channel through which house price increases generate an incentive to borrow-to-invest. The assumptions of this framework are very stark. We now add additional features to highlight the second channel in which constraints generate this incentive, and to explore how the first channel is moderated by the introduction of more realistic assumptions.

2.3 Borrowing Constraints, Transaction Costs and Stochastic Labour Income

We use numerical solutions to explore the full model outlined in Section 2.1. Relative to the Merton case above, we include loan-to-value and loan-to-income constraints, transactions costs on adjustments to housing, a finite horizon and stochastic labour income.[3] We show the effects of house price realisations on housing investment, analogously to Equation (20).

We solve this version of the model numerically using parameters specified in Table 1. We take parameter values from external sources and simulate the model with these values to illustrate the mechanisms at play. The numerical solution is a standard application of stochastic dynamic programming. The only complication is because of kinks in the policy functions induced by the transactions costs.

The expected return on housing and its standard deviation are estimated from aggregate UK house price data, imposing a unit root on house prices following Attanasio, Bottazzi, Low, Nesheim, and Wakefield (2012). The deterministic real rate of return on bonds is the average 3 month Treasury Bill rate in the UK, 1.5%. Deterministic growth in earnings is parameterised by a regression of log earnings on age and age squared. The coefficient of relative risk aversion is taken from Attanasio and Weber (1993) and the discount rate follows

[3]When non-insurable labour income risk is included, households effectively treat their remaining human wealth as another asset in their portfolio (Cocco, Gomes, and Maenhout (2005)), reducing the effective portfolio share of housing, possibly below 1, and inducing households to de-lever as they age. In this case, the Merton framework may generate a decrease in investment as house prices rise depending on discount rates etc, while the LTV story will still generate an increase in investment. However, it is clear that human capital is not tradable in the same way that financial wealth is. We do not include human capital in defining portfolio shares in Figures 1 and 2 below, but individuals make decisions that take account of human capital.

Attanasio et al. (2012). The loan-to-value and loan-to-income constraint parameters are typical for the UK. We consider various values of κ and report the decisions when $\kappa = 0.02$ on both buying and selling, compared to when $\kappa = 0$.

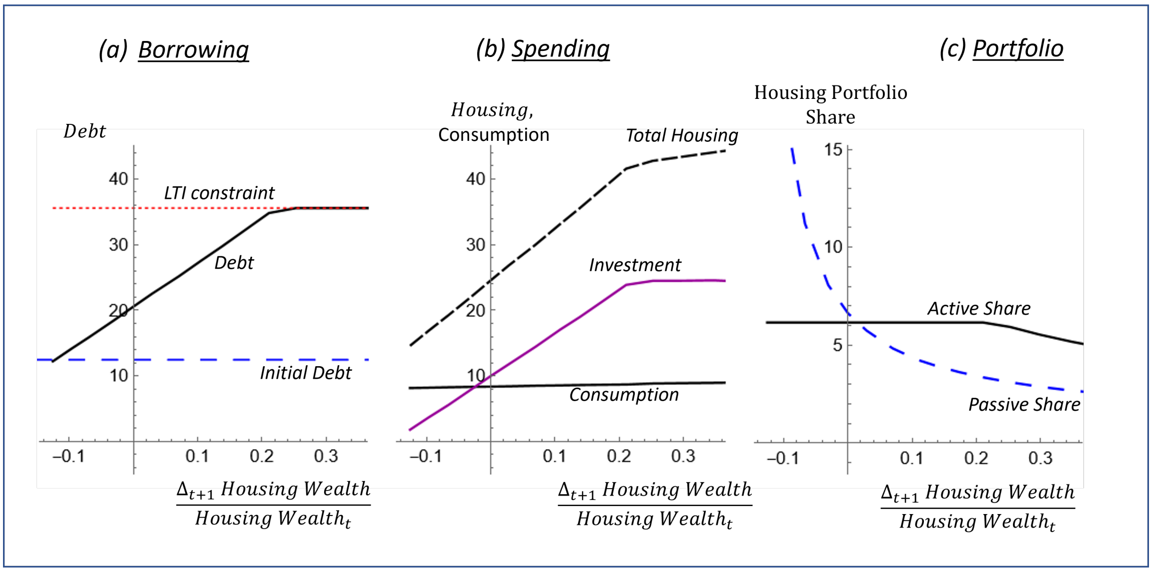
Table 1: Calibration Parameters

Parameter		**Value**
Expected Return on Housing	μ	0.025
Standard Deviation of Return on Housing	σ_ε	0.076
Deterministic Return on Bonds	r	0.015
Standard Deviation of Income	σ_u	0.1
Discount Factor	β	0.975
Coefficient of Relative Risk Aversion	γ	1.5
Length of Life (years)	T	50
Length of Retirement		10
Max loan-to-value	λ_h	0.85
Max loan-to-income	λ_y	3.5
Transactions cost	κ	{0,0.02}

Figures 1 and 2 show the behaviour for an individual following a house price increase. Figure 1 shows the choice rules when there are no transactions costs, and the household starts the period with their loan-to-value constraint binding, and so they are highly leveraged. Figure 2 shows the scenario when transactions costs are $\kappa = 0.02$, but households are still highly leveraged. We then consider how their behaviour responds to a change in the house price. The x-axis in all graphs is the proportional change in gross housing wealth resulting from the house price increase compared to its expected change. The impact of the house price shock on net wealth will depend on the leverage position, as in Equation (19). In Figures 1 and 2, we show the impact of a given house price change to highlight the borrow-to-invest channels. The graphs show the choice rules for debt, spending and portfolio shares. These choice rules are conditional on the initial quantity of housing $h_{i,t-1}$, the start-of-period debt and wage rate.

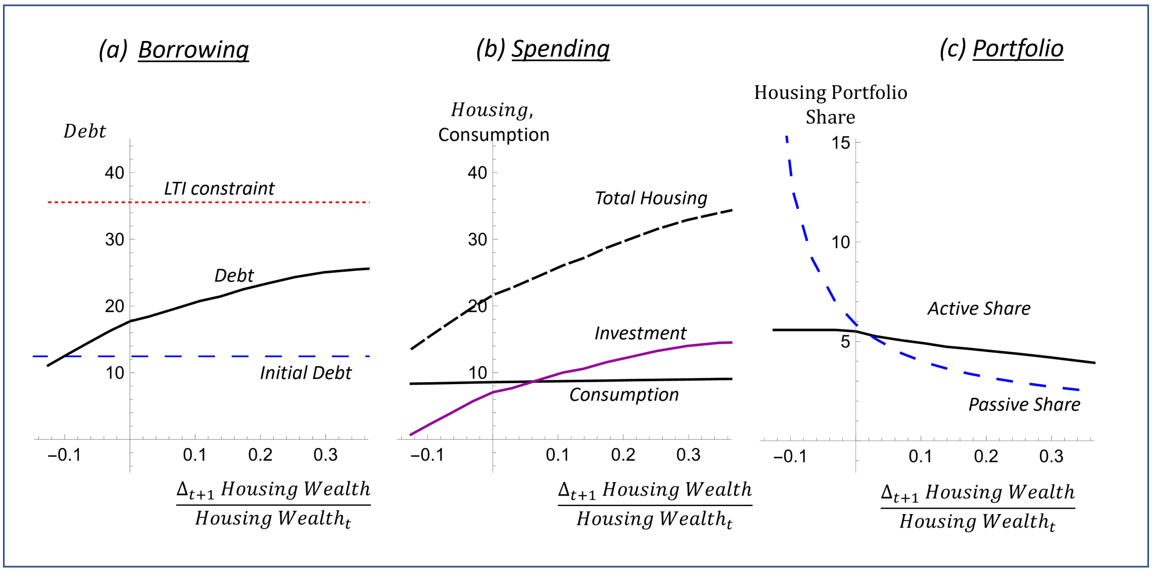
Panel (a) of Figure 1 shows that increases in house prices lead households to increase their holding of debt until their LTI constraint binds. This expansion in borrowing is well studied (Berger et al., 2017). The important question that we address in this paper is how do households use this additional borrowing. Panel (b) shows how consumption and active housing purchases change, as well as showing total housing values after these purchases. The solid black line shows that consumption changes only fractionally in response to the net wealth increase. The Marginal Propensity to Consume averages 0.13 out of the increase in the house price. This is at a level similar to a life-cycle MPC, despite the fact that households are constrained by their loan-to-value. The MPC is calculated as the difference in consump-

Figure 1: Debt, Consumption and Investment after a House Price Shock ($\kappa = 0.0$)



Notes: Δ Housing Wealth is the change in home values compared to its expected change. LTI constraint is the loan to income constraint set at 3.5 times incomes. The solid, sloping purple line in panel (b) shows active investment in housing. The dashed black line shows the total value of housing after this investment. The dashed blue line in panel (c) shows the mechanical change in housing portfolios as prices rise, while the solid line shows the change accounting for active housing investments. The household head is age 30.

Figure 2: Debt, Consumption and House Purchases Following a House Price Shock ($\kappa = 0.02$)



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tion between a proportional housing wealth increase of 0.2 and 0.1, analogously to panel (b) in Figure 1. By contrast, active housing investments increase sharply as house prices increase: the Marginal Propensity to Invest (ie active purchases) averages 3.53, again calculated using the difference caused by a proportional housing wealth increase of 0.2 and 0.1. The net wealth increase is leveraged to increase the value of housing, and the extra borrowing is used primarily for investment, rather than consumption. This value for the MPI is very similar to what is predicted by the simple Merton model. In other words, the MPI is not much attenuated by the finite horizon or the labour income risk. However, part of the reason for the high MPI in this simulation is that households are highly leveraged and close to their LTV constraints, rather than just being driven by a simple portfolio allocation decision. Once the LTI constraint binds, active investment stops as the household cannot borrow any more. Further increases in the house price beyond this point will lead to increases in the value of housing through the direct increase, but the flatter line shows this is not leveraged.

Panel (c) shows the implications for the housing portfolio share. The dashed blue line shows how the portfolio share would change mechanically as the house price increases if there were no behavioural response: an increase in house prices would lead to a decline in the portfolio share of housing if debt does not respond. The solid black line shows how the portfolio share actually changes accounting for the new investment in housing, shown in panel (b), which are funded by the increase in debt shown in panel (a). As long as the LTI constraint does not bind, households keep the portfolio share constant, and hence at the same risk-return trade-off. A binding LTI constraint means that households are unable to increase their borrowing in response to the house price increase, and so their housing portfolio share must decline.

Figure 2 shows what happens to these choices when we increase transactions costs. Panel (a) shows that debt still rises when house prices increase, but the increase in debt is more muted in the presence of transactions costs. Panel (b) shows that consumption remains flat in response to the wealth increase, with an MPC averaging 0.095. New investment in housing increases with net wealth increases, but both the level and rate of increase of housing investment are lower than in the absence of transactions costs. The average Marginal Propensity to Invest is 1.53, calculated using the difference caused by a proportional housing wealth increase of 0.2 and 0.1. Compared to our baseline simulation, the MPI is substantially attenuated by the introduction of a transaction cost. Panel (c) shows the implication for the housing portfolio share. The increase in net wealth drives the portfolio share down mechanically as before (shown in the blue line). The active share reflecting household investment choices falls as house prices increase because debt does not increase as sharply when there are transaction costs. However, it is still the case that the new housing investment shown in panel (b) implies that the resulting housing portfolio share declines less than if there had been no debt increase and no additional housing investment.

The point of these numerical examples is to show in a wider setting that households are releveraging and rebalancing their portfolios through new housing investment following the house price rise. The response of consumption, with MPCs around 0.1, is muted and in line with much of the literature. We show the borrow-to-invest behaviour arises even in the presence of borrowing constraints, transactions costs and uncertain labour income flowing from human wealth.

When the borrow-to-invest motive operates, one impact of the LTV constraint is to limit opportunities for investment. This implies that households can be constrained and yet have low values of the MPC out of an increase in net wealth. Further, a significant impact of credit constraints is on wealth building rather than on consumption smoothing. Whether or not the borrow-to-invest motive operates is, in the end, an empirical question that we address directly in the rest of this paper.

The model predicts a much larger response of investment spending than consumption. This is particularly true for more leveraged households for whom a given house price increase maps into a larger wealth effect, and this wealth effect will be leveraged at a greater rate. By contrast, consumption responses will depend only on the wealth effect, without any further impact of leverage. It is this difference in investment behavior by leveraged versus less leveraged households that we exploit in testing for the borrow-to-invest motive. In other words, we use a double comparison of spending responses between categories of spending (consumption versus residential investment) and between more and less leveraged households.

There are other features that could be added to the model which might mitigate or exacerbate the borrow-to-invest channel. If shocks to house returns are persistent or if households believe this to be the case, this would further strengthen the borrow-to-invest motive. Our simulations have shut down the consumption value of housing in the utility function. This is clearly a simplification. We think of this as the limit of the case where households hold more housing than they expect to consume in the future. As Buiter (2008) points out, this is necessary for house price increases to have a positive wealth effect: if future housing consumption needs equal current housing wealth, there is no wealth effect of a house price increase. If housing provides a flow of utility rather than simply being a portfolio asset, this would temper the borrow-to-invest motive by reducing the wealth effect associated with any price rise. Further, the house price rise would induce substitution away from housing consumption, dampening demand for housing spending.[4]

[4]Moreover, there is a gap between the housing assets held and housing consumed. In the UK, tax statistics indicate there were 2.8 million unincorporated landlords in 2021, which would equate to around 16% of owner-occupying households (if we assume households do not contain multiple separate landlords and that no landlords rent their own properties) (HMRC, 2023). This figure does not include individuals whose property income falls below the threshold for taxation. At the same time, according to the English Housing Survey,

Various papers have introduced housing into the utility function directly, but in specific ways that economise on computation. One approach is to have deteministic house prices, which is not suited to analysing responses to house price shocks. An alternative is to have stochastic house prices but make utility depend on the value, rather than the quantity of housing. This is problematic because the utility of housing would then increase as houses become more expensive. An implication of such an approach, for example if housing enters utility with a Cobb-Douglas specification, is that the quantity of housing will decline over time as prices rise. A third approach makes prices a function of permanent income, which is in turn stochastic (see, for example, Cocco (2005)). This is attractive as a long-run relationship, but it is less suited for our analysis of responses to shocks. Because none of these approaches seems suitable to the question we study, we economise on computation by leaving housing out of the utility function.

Households could also hold other assets beyond housing, debt and human wealth. In practice, for the vast majority of middle-class households, housing wealth is by far the most important asset that households hold (Kuhn et al., 2020). It is also unique in having historically offered a mix of both high returns with a relatively low variance (Jordá, Knoll, Kuvshinov, Schularick, and Taylor (2019)).

3 Data and Descriptive Evidence on Borrowing

In this section, we describe the three datasets that we use for our empirical work. We then provide descriptive evidence, plotting average profiles of leverage, borrowing and the incidence of spending on residential investment by age and time. In Section 4, we use this data to test the borrow-to-invest channel.

3.1 Data

The first dataset we use is the Living Costs and Food Survey and its previous incarnations the Expenditure and Food Survey and Family Expenditure Survey (which we shall refer to collectively as the LCFS) (Department for Environment, Food and Rural Affairs, Office for National Statistics, 2016). The LCFS is a comprehensive, long-running survey of consumer expenditures involving between 5,000-8,000 households per year. Households are asked to record high-frequency expenditures in spending diaries over a two-week period. Recall interviews are used to obtain spending on information on big-ticket items (such as holidays or large durables) as well as standing costs on items such energy and water, internet bills and magazine subscriptions. The survey also collects information on incomes, demographic

around 5% of owner-occupiers in England reported owning a second home (MHCLG, 2020).

characteristics and, since 1992, on the value of households' mortgages (but not on other aspects of household balance sheets such as home values).

The second dataset we use is the British Household Panel Survey and its successor Understanding Society (both of which we shall refer to as the BHPS) (University of Essex. Institute for Social and Economic Research (2010); University of Essex. Institute for Social and Economic Research. (2016)). The BHPS is available in 18 waves from 1991 to 2008. Understanding Society began in 2009 and incorporated the original BHPS sample members from 2010 onwards. Both surveys include limited information on household spending on food and drink, as well as self-reported house values. The BHPS contains data on total mortgage debt from 1993 onwards, while Understanding Society dropped these variables in its second wave in 2010. In the remaining years, we continue to observe whether households own their homes outright, and details on the length and type of their mortgage if they have one. We use these along with past information on mortgages values to impute mortgages in years following 2010 (see Appendix C for details). Loan to value ratios are calculated by dividing the value of mortgages by the (self-reported) value of homes. We trim those in the top percentile of the leverage distribution, and those with negative equity in our regression samples. The BHPS and Understanding Society also contain information on whether households own a second home.

We need to use two UK surveys because consumption spending is observed in the LCFS, but leverage is not, whereas the BHPS includes information on leverage but not on consumer spending. Hence, we use two-sample methods that combine the information contained in both datasets, as we describe below.

For house prices, we use regional/state-level data on the prices of transacted houses published by the Office for National Statistics.

In all of what follows, we drop households where the head is aged under 25 or over 65. To avoid problems of measurement error, we also drop households who have a lagged housing portfolio share in the top 1% of the distribution and those who have negative equity. We also drop households resident in Northern Ireland from both the BHPS and the LCFS samples, as these were only introduced into the BHPS sample in later years. Finally, for most of our analysis, we drop households who have lived in their home for less than one year. Appendix A provides some descriptive statistics for our two samples.

Non-durable spending is the largest component of expenditure (accounting for 77%). Residential investment spending, which includes extensions, renovations, household repairs, large furniture, carpets, and large household appliances, accounts for roughly 7.1% of total spending. The remainder is accounted for by spending on non-residential durables.

For the borrow-to-invest mechanism to operate on the intensive margin of home improvements, a substantial share of the costs of home improvement spending must be recouped through increased home values. *Realtor* magazine conducts an annual survey of the costs and value added associated with different home improvement projects in different US housing markets to estimate of the proportion of costs of different projects that homeowners can expect to recoup through higher re-sale values.[5] In 2016, the average value-cost ratio of investments made on properties sold within a year was 64%. Investments in attic insulation had the most cost-effective effects on resale values, with 117% of costs recouped through higher home values. Bathroom additions had the lowest returns, with 56% of costs being recouped.[6]

The fact that homeowners can expect to recoup a significant fraction of the costs of home improvement means that investment motives are likely to play an important role in households' decisions to make such expenditures. Moreover, the returns to investments in one's own home appears to increase along with local home values, suggesting that this is indeed a way that households can increase the importance of housing in their overall portfolios. Gyourko and Saiz (2004) find that home improvement spending responds strongly to the ratio of local house values to construction costs, which is consistent with a rational investment motive for such projects that responds to house price growth. Choi, Hong, and Scheinkman (2014) investigate the impact of local house price growth on the average ratio of costs recouped as measured by the *Realtor* survey, controlling for other factors such as local unemployment and income growth. They also find that the investment value of home improvement projects is positively associated with local house price growth. Benmelech et al. (2023) analyse building permits data in the US, and find that home-sellers increase spending on home-improvements by $485 in the two years before a sale. This behaviour is also consistent with home improvement spending increasing sale values.

3.2 Borrowing and House Price Increases

Figure 3 shows that greater household borrowing coincided with periods of high house price growth. The top panel in Figure 3 shows average real house price growth in the UK over time. The middle panel shows how leverage varies over the same time period among both younger (aged 25-45) and older (46-65) households. The bottom panel shows the proportion of existing homeowners taking out additional mortgage debt over this period.

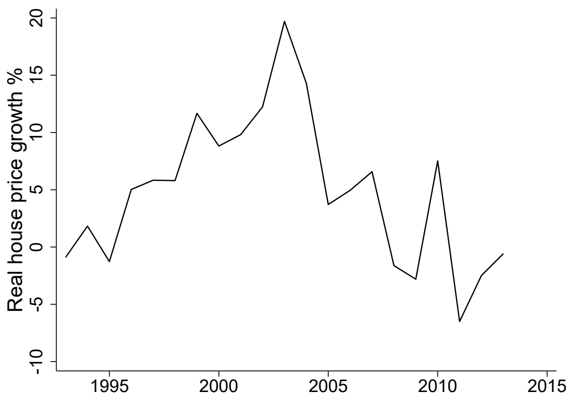
For most of this period, UK house prices were increasing, with annual falls only observed

[5] Real estate agents are asked to the expected value different projects are expected to add to a home's sale price, while professionals in the remodelling industry are asked to provide estimates of their likely cost. http://www.remodeling.hw.net/cost-vs-value/2016/

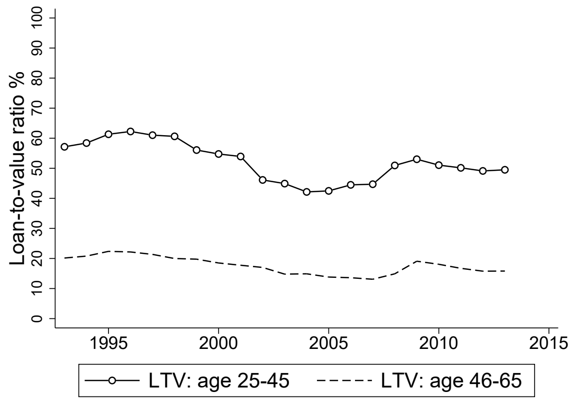
[6] Similar surveys exist in the UK, for example the insurance company GoCompare provides a property investment calculator which provides estimates of the costs and returns associated with different projects. This suggests greater returns to home improvement spending in the UK, although the methodology behind the calculator has not been published. As in the US, Energy-saving investments have the highest returns, while net bathrooms have negative returns (https://www.gocompare.com/home-insurance/property-investment-calculator/).

Figure 3: LTV ratios and house price growth rates

(a) House price growth (UK), 1993-2013



(b) Loan-to-value ratios, 1993-2013



(c) New mortgage loans, 1993-2013

Notes: House prices for are national averages taken from the Office for National Statistics HPI deflated using the CPI. Loan-to-value ratios and new mortgage loans are calculated using data from BHPS and Understanding Society.

in 1994-1995 and 2007-2009. In the period in between these years, house prices grew rapidly. Average loan-to-value ratios fell with rising prices, but UK households were also borrowing more over this period. Annual price increases peaked in 2003 at a rate of almost 20%. If homeowners had responded passively to this increase, and the set of homeowners had been fixed, average loan-to-value ratios should have fallen by the same percentage. Instead, they fell by just 7% in that year. Over the whole of the period of greatest house price growth, LTVs among the under 45s fell from 62% in 1995 to 43% in 2004 before climbing again as house price growth moderated (the over 45s saw smaller changes in their average leverage).

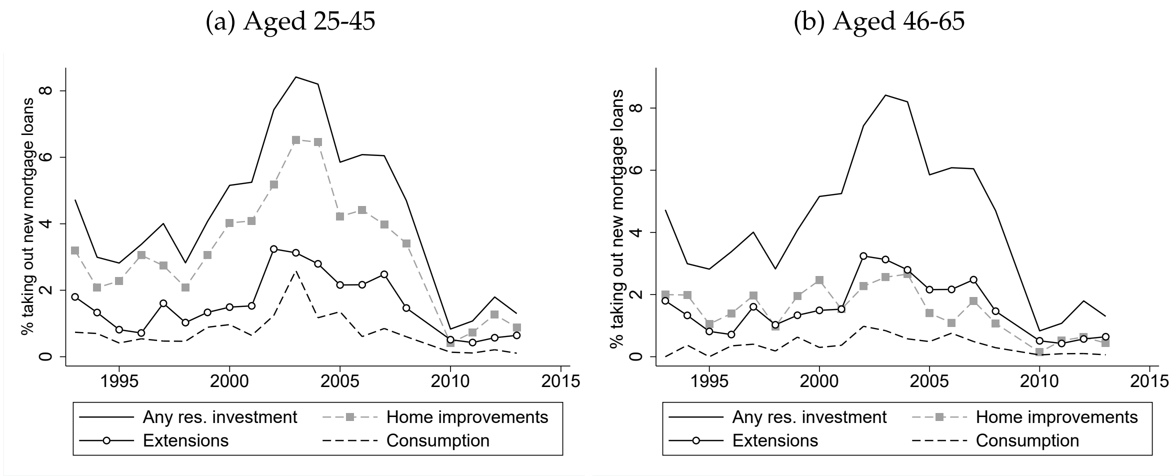
Changes in mortgage debt could be driven by changes in the amount of borrowing used to purchase new homes, or through new borrowing by those remaining in their current homes. Panel (c) in Figure 3 shows that homeowners who did not move were actively engaged in new mortgage borrowing as prices rose. The proportion of home-owning households aged 25-45 observed taking out additional mortgage debt in the UK increased to exceed 10% in the period of most rapid house price growth. We quantify the extent of new borrowing in our data for both movers and non-movers through panel regressions in Appendix B, that corroborates evidence in Figure 3. Amongst non-movers, each £ increase in home values is associated with 7p of extra borrowing over two years. This is smaller than other estimates for the UK. Cloyne et al. (2019) use panel data and differences in house prices at the pre-specified points (typically 2-5 years into a mortgage) when interest rates on households' mortgages tend to increase, and therefore homeowners tend to refinance. They find a marginal propensity to borrow out of house price differences at this point of 0.11 (implying that each £1 increase in house prices increases borrowing by 11p), although the marginal propensity to borrow may be greater around refinancing events.

The evidence in this subsection highlights that households increase their borrowing in response to house price changes.

3.3 Expenditure Responses

A natural question is to ask what this new borrowing was used for. Households in the BHPS are asked whether new mortgage loans, taken out on current properties, were used for extensions, home improvements, car purchases, other consumer goods, or some other reason (households could give more than one answer). We class the first two of these responses as "residential investment" and the second two as "consumption" and plot the proportions reporting new mortgage loans for each motive for home-owning household heads aged 25-45, and 46-65 in panels (a) and (b) of in Figure 4. Both younger and older households are roughly four times more likely to report taking out a loan for residential investment than for consumption spending. Overall, when we condition on taking out a new loan, 62% of new loans were taken out for a residential investment purpose compared to 11.5% for some consumption purpose in the UK.[7] Young people were more likely to used these loans for home improvements. Households with older heads were roughly as likely to use loans for extensions as for home improvements.

Figure 4: Purpose of new mortgage loans, 1993-2013



Note: Authors' calculations using British Household Panel Survey/Understanding Society. Sample is homeowners who did not move relative to previous wave.

This evidence suggests that households respond to house price increases by borrowing more and changing their household investment spending. This is consistent with the borrow-to-invest motive, which we now test more formally.

4 Testing the Borrow-to-Invest Motive

In this section, we use regressions for different spending categories to test explicitly an implication of the borrow-to-invest motive. We focus on the prediction that the investment spending response to a house price realisation will vary more with leverage than the consumption spending responses. As discussed in Section 2, this prediction follows from equations (17) and (19).

4.1 Empirical Strategy

To test the specific hypothesis that more leveraged households will disproportionately increase housing investment in response to house price increases, we estimate the equation

[7] There is suggestive evidence on the same lines for the US. Brady, Canner, and Maki (2000) use a "reason for loan" question in the Federal Reserve Board Survey of Consumer Finances and find that home improvements were a more important self-reported motive for home equity withdrawal than consumption spending, as in Figure 4. Further, Cooper (2010) reports a significant association between home equity extraction and the binary indicator of residential investment in the PSID.

$$\widetilde{C}_{i,t} = \gamma_{c,t,r} + \theta_1(\omega_{i,t-1} - 1) + \theta_2\left\{(\omega_{i,t-1} - 1) \times \left(\frac{p_{r,t}}{p_{r,t-1}} - 1\right)\right\} + \theta_3 X_{i,t} + e_{i,t} \qquad (21)$$

where C_{it} are expenditures by household i in period t (either consumption or investment) and $\widetilde{C}_{it}$ is the inverse-hyperbolic sine transformed value of C_{it} discussed below; $\omega_{i,t}$ is as before the household portfolio share in housing (we subtract one so that the interaction term is zero for an outright owner); $X_{i,t}$ is a set of control variables including education, family size, characteristics of the home and years spent at the current address; $\gamma_{c,t,r}$ are interacted fixed effects for cohort, time, and region.[8] Equation (21) is our preferred specification, but we also report results for specifications that only include separate region and cohort effects and that additionally include a main effect for regional house price growth.

We transform expenditure using the inverse hyperbolic sine (IHS) transformation rather than the log, as a significant fraction of households has zero investment spending. The IHS transformation approximates log values at high values of spending, but remains defined at zero (Burbidge, Magee, and Robb (1988)). A disadvantage of the IHS specification is that the coefficients can no longer be readily interpreted as elasticities or semi-elasticities. To calculate elasticities of spending with respect to house prices changes, and how these vary with leverage, we use Duan's smearing statistic (Duan (1983)) as suggested by Norton (2022). Further details of how these are calculated are provided in Appendix D. We use a similar approach to estimate the marginal effects of house price changes (changes in £ spent) for different categories of spending.

One concern about directly estimating equation (21) is that leverage (portfolio choice) is a choice variable and so endogenous. The conventional approach to estimating leverage effects is to use individuals' once-lagged leverage (uninstrumented), but this is unlikely to be adequate when lagged leverage is a choice of forward-looking households. As we document below, once-lagged leverage is correlated with gross house values and income from non-housing assets. In order for our empirical application to identify the effects of independently varying leverage, these other variables ought to be held constant. We therefore need an instrument for leverage.

A second concern is that house prices changes across regions may be driven by factors that also drive consumption or investment spending. Recall that our test relies on identifying the role of leverage in explaining *differences* in the reactions of households' to a given house price shock. This means our main worry would be that factors driving regional growth disproportionately affect more leveraged households. By including fixed effects for

[8] The inclusion of cohort-region-year fixed effects means that we will only identify the *relative* effects of house price changes across different households within each region-cohort-year cell. Common effects of house prices changes affecting all households (and any general equilibrium effects on either national or regional housing markets) will be absorbed by our fixed effects.

cohort-year-region groups, we already capture average differences in shocks across young and old or across different regional labour markets that might be correlated with leverage.[9]

To further account for regional shocks that might both affect local house prices and differentially affect households spending by leverage (for example, differences in regional credit supply), we use a "Hausman" relative price instrument for house price changes. To implement this, we calculate a leave-one-out average of changes in house prices outside households' own-regions, and use this to instrument for regional house price changes. This instrument captures changes in local house prices that are driven by national trends, alleviating concerns of endogeneity that arise from using purely regional shocks.

A third issue is data availability. Long-running surveys that contain balance sheet data on wealth and leverage rarely contain comprehensive spending measures. A panel survey is also required in order to know the consumer's lagged leverage position $\omega_{i,t-1}$. Previous studies have addressed this problem by either using available proxies for spending (such as borrowing, Mian and Sufi (2011)), subsets of spending that are observed (e.g. Lehnert (2004)) or measures backed out from the consumer's budget constraint (using the difference between observed income and wealth changes, as in Cooper (2013)). These approaches do not decompose total spending into consumption spending and investment spending.[10] Using total spending may lead to the misinterpretation of an investment spending response as being a consumption response. Distinguishing between the two is crucial for testing the importance of the borrow-to-invest motive.

For these reasons, we use a two-sample IV approach (Angrist & Krueger, 1992) to combine spending data in the LCFS with data on leverage in the BHPS. This approach allows us to simultaneously impute and instrument for leverage in our (cross-sectional) expenditure dataset using balance sheet data taken from the BHPS. The instrument we use is the credit conditions households faced at the time they moved into their current residences. In theory, the use of this instrument requires financial frictions or transaction costs, of the kind we discussed in Section 2, that prevent households from reaching their optimal leverage for some time after they move. We discuss the strength and validity of our instrument, as well as alternative instruments, further below.[11] We adopt the two-sample two stage least squares

[9]One such shock is to future income expectations, which would be expected to boost the consumption of younger cohorts by more. If effects such as these are not controlled for, they could lead to spuriously large estimates of house price wealth effects for younger (and so more leveraged) households (Attanasio, Blow, Hamilton, & Leicester, 2009).

[10]There are a few other potential drawbacks to these approaches. Credit card borrowing, which is used as proxy in Mian et al. (2013), may also be more cyclical than other forms of spending. This point was made in Aladangady (2017). The use of the budget constraint identity to impute consumption can also lead to biased estimates of wealth effects in the presence of measurement error (Browning, Crossley, & Winter, 2014). If reported wealth in the previous period is smaller than actual wealth, then leverage as observed by the researcher in that period will be too high and consumption in the current period be too large, biasing estimates upward.

[11]In principle, in the US we could investigate these questions using the PSID, which in its later years contains information on both spending and leverage. However, the number of waves in which the PSID includes

approach, which is asymptotically more efficient than two-sample IV (Inoue & Solon, 2010). We correct standard errors for the two-step procedure using the approach of Pacini and Windmeijer (2016).

4.2 Instrument Relevance and Validity

For our proposed method, we require a source of variation in leverage that explains why some households took out larger loans than others that is common to both the BHPS and the LCFS. For this purpose, we exploit variation in the average price to income ratios for new loans at the time households moved into their current residences (denoted $(P/Y)_i$). This variable is often used as a measure of the cost of credit (for example, loan-to-income ratios are included in the credit conditions index of Fernandez-Corugedo and Muellbauer (2006)). In our case, it indicates the cost of borrowing in the years house prices were made, and so the degree to which households would have been able to leverage their housing purchases at the time they moved. We discuss results using alternative instruments, including the credit conditions index, regional house prices and price-to-income ratios when the household head turned 25 alongside our main results.

The solid line in Figure 5 (Panel (a)) shows how this instrument varies over time in the UK. There is a gradual upward trend in the price to income ratio, suggesting that credit has become looser over time. In 2013, average loans were almost five times greater than the incomes of buyers. This compares to a ratio of 2.5 in 1969. This provides one source of identification. Importantly, however, there is also cyclical variation in this variable, with for example evidence of credit tightening following the 2008 financial crisis. Movements in other measures of credit conditions, such as the average deposit on new homes (Figure 5, Panel (b)) show similar patterns.

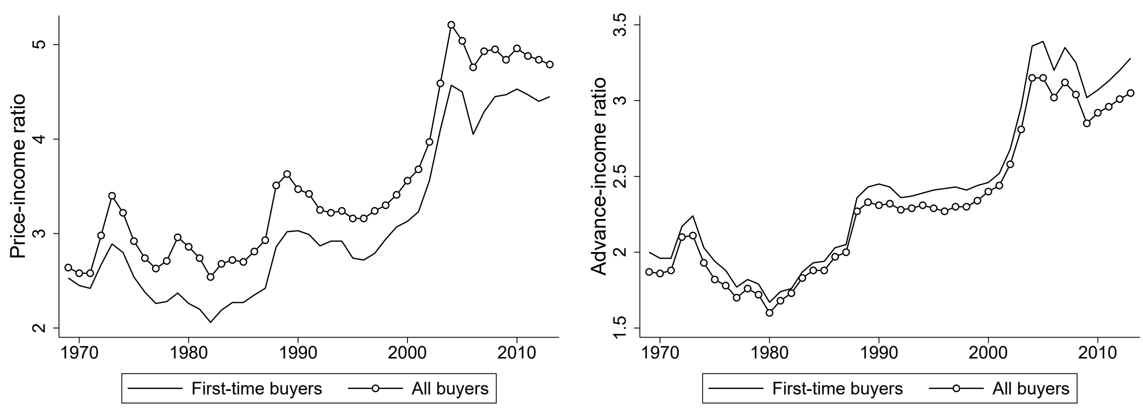
Our instrument is only available from 1969 onwards, and so in what follows we drop households who moved into their homes before this. This constitutes roughly 0.5% of the total number of observations in our LCFS sample.

As our regression model includes cohort fixed effects, what matters is within-cohort variation in households' leverage. Figure 6 shows how our instrument relates to loan-to-value ratios within a given cohort (those born in the 1960s). This is the only ten-year birth cohort that we observe for almost our entire sample period. We plot loan-to-value ratios for households who moved into their homes in three different years: 1989, 1996, and 2004. These three years represent peaks and troughs in price-to-income ratios on new housing purchases from

comprehensive consumption data is relatively short, as are other US panel surveys, such as the HRS, used by Christelis, Georgarakos, and Japelli (2015) to study questions around leverage. In addition, US households tend to re-leverage rapidly in response to house price increases. As a result, the leverage of US households is far less dependent on past circumstances than it is for UK households, and so our instrument does not have power in the US. In what follows, we therefore focus on UK results.

Figure 5: Credit conditions, 1969-2013

(a) Price-income ratios (b) Advance-income ratios



Note: Office for National Statistics UK House Price Index.

Panel (a) in Figure 5. Price to income ratios reached a temporary high of 3.7 in 1989 before falling to a low of 3.2 in 1996. Thereafter, they increased to a peak of 5.2 in 2004. As Figure 6 shows, households that moved when price-to-income ratios were relatively high in 1989 tended to have higher leverage than those in the same cohort who moved in 1996. This is true not only at the point they moved in to their current homes, but also long-afterward. Loan-to-value ratios are also persistently higher for those who moved in when credit conditions were even looser in 2004.

Figure 6: Loan to value ratios by age and year moved in (1960s birth cohort)

Note: Authors' calculations using the British Household Panel Survey/Understanding Society

This relevance of our instruments can be more formally tested by looking at the results of first stage regressions. We do this in Table 2. To match our preferred specification, we report first stage results including fully interacted cohort, region and time effects.

We have two first stage regressions, one for leverage and one for leverage interacted with house prices. Our two instruments are credit conditions at the point of households' last move, and the interaction of these with the leave-one-out average to instrument for regional house price growth (denoted $\frac{1}{R}\sum_{r'\neq r}\frac{p_{r't}}{p_{r',t-1}}-1$). In both cases, the F-statistics are greater than the value of 10 suggested as a rule of thumb by Staiger and Stock (1997) for IV estimated using a single sample. Two sample IV methods may suffer less of a bias than standard 2SLS estimators, as errors in the first stage estimation will be unrelated to errors in the second stage equation. This is the rationale for estimators that run first and second stages in split samples (Angrist & Krueger, 1995)). Nonetheless, weak instruments may still result in coefficients being biased towards zero in finite samples. The relatively strong first stage we obtain is reassuring. Kleibergen-Paap statistics for the first stage also heavily reject the hypothesis of underidentification.[12]

[12] A further 'first stage' check we can conduct is to test for a positive association between our instrument and total mortgage debt in the LCFS. This would demonstrate that the association between our instrument and leverage is not limited to our first sample. Regressing mortgage debt on $(P/Y)_i$ and our controls yields a positive coefficient with a t-statistic of 24.07.

Table 2: First stage results

	Dependent variable	
	$\omega_{i,t-1} - 1$	$(\omega_{i,t-1} - 1) \times (\frac{p_{rt}}{p_{rt-1}} - 1)$
$(P/Y)_i$	0.405***	-0.008***
	(0.041)	(0.002)
$(P/Y)_i \times \frac{1}{R} \sum_{r' \neq r} \frac{p_{r't}}{p_{r',t-1}} - 1$	0.871**	0.638***
	(0.354)	(0.049)
Shea partial R^2	0.008	0.023
F-stat (p-value)	48.54	152.40
	(<0.001)	(<0.001)
Kleibergen-Paap (p-value)	94.07	
	(<0.001)	
N	30,947	
Clusters	8,250	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the individual level. $(P/Y)_i$ is average the price-to-income ratio on properties purchased in the year when the household first moved into their current address.

There may be concerns that those who move home in years with higher price-income ratios will have spending patterns that are different to those who moved in other years for reasons other than the degree of their leverage. The most obvious challenge is that since price-income ratios have tended to increase over time, those households with higher values of our instrument will tend to have moved more recently. They may be more likely to be furnishing a new home. We address these concerns directly by including a control for the number of years households have spent in their current address (in addition to a dummy variable for households having moved in in the last year to account for first year 'setting up' expenses). We also run regressions excluding those who did not move in the last five years (rather than just the last year). Results from this alternative sample are very similar to our main results (see Appendix E).

There are further possible challenges to identification. To be fully excludable, households current spending decisions should not be correlated with the timing of their past moves. This could be violated, if, for example, households are more likely to move when house prices are high because greater unobservable wealth made them less price sensitive. They may also have moved into larger houses. This would create a spurious association between our instrument and consumption. Households who moved at times when credit was loose may be more likely to move in response to economic shocks and drop out of our sample, introducing a selection bias. The assumption that such omitted factors do not induce a correlation between instruments and the error term is usually something which cannot be verified. Omitted variables are typically omitted because they are unobserved. However, when using a two sample approach, such tests are possible. Some variables may be observed in the sample in which we run our first stage regressions even if they are not present in our main sample.

To address these concerns, we test for an association between our instruments and gross house values, asset incomes, the probability of being a mover, log gross household earnings and log earnings growth (over three years) in the BHPS and Understanding Society panels conditional on our covariates. The two-sample instrumental variable approach allows for this kind of exogeniety, testing where potential omitted variables are observed in the second data set. Panel (a) of Table 3 reports results from regressions of these potential sources of endogeneity on our instruments and our other covariates. The instruments are both jointly and individually insignificant in all models, suggesting that they are plausibly orthogonal to these omitted variables.[13]

[13] In additional unreported results, we also regress unsecured debt-to-income ratios and an indicator for whether households have positive debts on our instruments. Debts are only observed in 3 of the 18 waves of the BHPS survey, and so these tests are necessarily conducted on a much smaller sample. The instruments are again individually and jointly insignificant in these regressions.

Table 3: Exogeneity tests for Instruments

Dependent var.	$\log(HValue)$	Invest inc. > 1000	Invest inc.$= 0$	Mover$_{t+1}$	$\log(Earn)$	$\Delta_{t+3}\log(Earn)$
Panel (a)	Instrument: Credit Conditions					
$(P/Y)_i$	0.012	-0.001	0.0002	-0.0005	0.00775	-0.0185
	(0.011)	(0.007)	(0.012)	(0.003)	(0.0128)	(0.0441)
$(P/Y)_i \times \frac{1}{R}\sum_{r' \neq r} \frac{p_{r't}}{p_{r',t-1}} - 1$	-0.008	-0.009	0.017	0.040	-0.151	0.429
	(0.096)	(0.067)	(0.095)	(0.033)	(0.120)	(0.367)
F-test: p-values	0.492	0.397	0.801	0.463	0.349	0.418
N	30,626	28,282	28,282	23,531	28903	10872
Clusters	8,116	7,735	7,735	6,618	8210	2271
Panel (b)	Instrument: Lagged Leverage					
LTV_{t-1}	-0.193***	-0.161***	0.317***	0.002	0.312***	0.147**
	(0.0184)	(0.012)	(0.020)	(0.007)	(0.0225)	(0.0687)
$LTV_{t-1} \times \frac{1}{R}\sum_{r' \neq r} \frac{p_{r't}}{p_{r',t-1}} - 1$	-0.596***	-0.045	0.110	0.002	0.472**	-1.105
	(0.196)	(0.116)	(0.192)	(0.076)	(0.240)	(0.762)
F-test: p-values	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.0800
N	30,626	28,282	28,282	23,531	30936	12426
Clusters	8,116	7,735	7,735	6,618	8249	2350

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Controls for education, cohort-region-year dummies, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. Standard errors are clustered at the individual level. $\log(Earn)$ is household gross earnings.

An alternative source of variation used by a number of previous studies (e.g. Disney, Bridges, and Gathergood (2010), Dynan (2012), Mian et al. (2013)) is household leverage lagged one period. We report in Panel (b) of Table 3 correlations between the potential omitted variables assessed in Panel (a) and households' lagged LTV ratios (leverage). There is strong evidence that those with higher lagged leverage have fewer financial assets, tend to live in less valuable homes and to have higher earnings, which invalidates its use as an instrument. The point of Table 3 is to show that our instrument (which is both a grouping instrument and further back in time) does much better than once-lagged household leverage on these exogeneity tests.

To further ensure that our results are not driven by unobserved differences in spending correlated with the timing of moves, we use an alternative instrument that relies on credit conditions when household heads turn 25. Using this instrument, we are not able to separately control for cohort fixed effects. We show that results using this instrument are qualitatively very similar to those from our main specification.

4.3 Main Results

Having established the relevance and exogeneity of our instrument, we now show in Table 4 the results of estimating equation (21) for residential investment, and total (non-durable and durable) consumption spending.

We consider three versions of equation (21). The first includes regional house price changes and controls for region and cohort fixed effects (but not time effects). The elasticity of consumption spending is large at 0.60, in line with the estimates of Mian and Sufi (2011), though we note that even with our leave-one-out instrument for house prices, consumption growth and national house price growth may be driven by common factors.

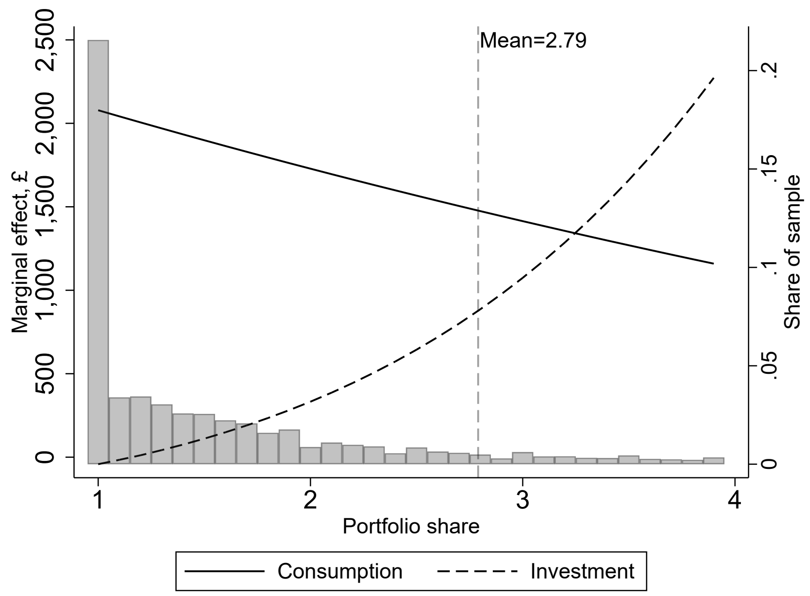
More importantly, the residential investment behaviour of more leveraged households however rapidly increases in response to house price gains, while their consumption spending is no more sensitive than that of other homeowners. Figure 7 plots the marginal effects of a doubling of house prices for weekly spending on consumption and residential investment evaluated at different values of the housing portfolio share (and at average values of the other covariates). The expected increase in consumption spending falls for higher values of the portfolio share, while the effects of property price increases on residential investment rises quickly. Spending on residential investment accounts for the majority of the household spending response once the housing portfolio share exceeds 3.25 (corresponding to an LTV of 69%).

These findings are consistent with predictions of the borrow-to-invest framework.

Our second regression model (columns (3) and (4)) shows results when include a full set of time-cohort-region interactions, controlling for shocks that may vary in their impacts across locations and age groups. With this specification, the direct effect of prices is no longer identified, but the interaction between house prices and leverage is identified and this is the basis of the test of our mechanism. In these columns, we leave regional house price growth uninstrumented. We once again find that the residential investment spending of more leveraged households is much more responsive to house price increases, while consumption spending is not. The impact of leverage on the estimated elasticity of residential investment spending is around half the size in this specification, which, unlike the specfications used in columns (1) and (2), does not make use of differences in the differences in house price growth over time or across regions for identification.

Columns (5) and (6) present our preferred specification in which we instrument house price growth using our leave-one-out average. The results are similar to those when house price growth is uninstrumented. Our results imply that a 10% increase in house prices results in an 8.8% greater increase in residential investment for a household with a housing portfolio share of 3.79 (LTV of 73%) relative to a household with a portfolio share at the sample average value of 2.79 (LTV of 64%). These imply increases in annual consumption spending by £57, and investment spending by £210 more for the more leveraged household (evaluated at average values of the other covariates).

Figure 7: Marginal effects of house price increases on spending: consumption vs residential investment



Note: Figure plots the marginal effects from the specifications in columns 1 and 2 in Table 4 at different values of households' housing portfolio shares. The grey bars show the fractions of the sample in each portfolio share bin.

One concern with our interpretation of these results may be that the residential investment response reflects the durability or luxuriousness of housing, rather than an investment motive. In Table 5 we examine how responses to house price increases vary for subcate-

Table 4: Consumption and residential investment responses to house price changes: differential responses by leverage

	(1) Res inv.	(2) Cons.	(3) Res inv.	(4) Cons.	(5) Res inv.	(6) Cons.
Interaction effects: Changes as $\bar{\omega}_{t-1} \to \bar{\omega}_{t-1}+1$						
Δ Elasticity	1.77***	-0.08	0.73**	0.00	0.88**	0.02
	(0.23)	(0.05)	(0.27)	(0.07)	(0.34)	(0.08)
Δ Marg. effect	1212.48***	-288.18*	170.97**	8.36	209.60**	57.26
	(130.62)	(121.02)	(63.19)	(156.11)	(80.16)	(199.41)
Main effects at $\bar{\omega}_{t-1}$						
Elasticity	2.89***	0.60***				
	(0.22)	(0.05)				
Marginal effect	877.26***	1477.38***				
	(65.70)	(119.10)				
Controls						
Region effects	Y	Y				
Cohort effects	Y	Y				
Coh. $\times$ Reg. $\times$ Year			Y	Y	Y	Y
Instruments						
IV for leverage	Y	Y	Y	Y	Y	Y
IV for house prices	Y	Y			Y	Y
N	60,342	60,342	60,342	60,342	60,342	60,342
R^2	0.06	0.34	0.08	0.36	0.08	0.36

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls for education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. The dependent variables are transformed using the Inverse Hyperbolic Sine transformation. The first two rows show the change in the estimated elasticity (at average spending) and average marginal effect on annual spending of a 10% increase in house prices, when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second two rows show elasticities and marginal effects when ω_{t-1} is evaluated at the average portfolio share, $\bar{\omega}_{t-1}$

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gories of total consumption spending. First, we run regressions separately for non-durable and durable spending. We do not find evidence that leveraged households' spending on either of these subcategories is more sensitive to house price increases than other households' (although the effects on durable spending is imprecisely measured). Second, we report spending effects for 'luxuries' (a subset of non-durables, defined as spending on recreation and food out). We do not find evidence of stronger spending responses among leveraged households for these goods, lending additional support to our hypothesis that the relatively greater increase in residential investment spending by more leverage households reflects a desire to rebalance investment portfolios rather than a pure consumption motive.

In the final two columns of Table 5 we investigate whether our results depend on our chosen measure of residential investment. The measure of residential investment used in column 1 includes certain white goods such as cookers, refrigerators and washing machines which are often capitalised into property values but which would not necessarily be considered residential investment spending in, for instance, a national accounting framework. In column 4 we restrict our definition to purer investment goods such as electric tools, floor coverings and the costs of installing or repairing heating and air conditioning units (along with spending on household extensions). The effects of increases in prices for more leveraged households are very similar to those obtained for our broader measure of residential investment. In column 5, we show results from a linear probability model in which the dependent variable takes a value of 1 if the household is observed spending a positive amount on household extensions. This is probably the purest measure of residential investment in that it only includes structural modifications to the home. Again, we find that the investment spending of more leveraged households is significantly more responsive to house price changes than the spending of other home-owners. A household with a portfolio share one unit greater than the average is 1.7 percentage points more likely to spend on extension following a 10% increase in house prices that a household with the average portfolio share.

4.4 Robustness Checks and Additional Evidence

Alternative instruments for leverage

In this section, we consider how our results are affected when we use alternative instruments in place of the price-to-income ratio at the time individuals moved into their current residences.

The first of these is the Credit Conditions Index (CCI) assembled in Fernandez-Corugedo and Muellbauer (2006). This index contains 10 indicators of credit conditions. Two are aggregate measures of unsecured and mortgage debts. The remaining 8 are fractions of mortgages for first time buyers that are above given loan-to-value and loan-to-income ratios for

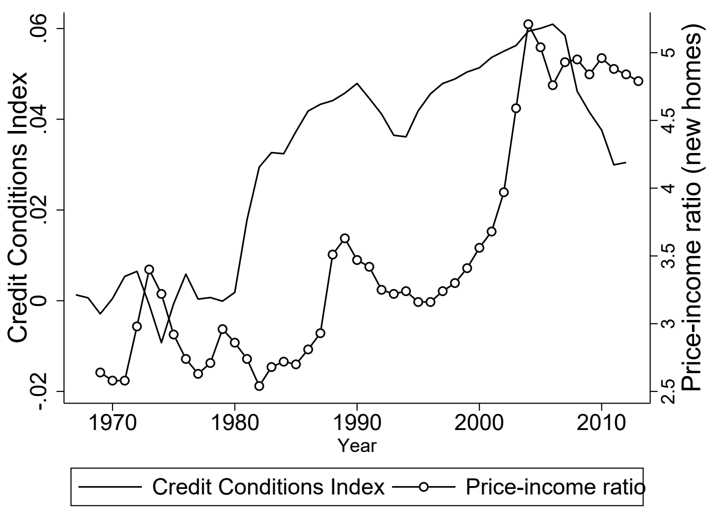
Table 5: Responses of categories of consumption: differential responses by leverage

	(1) Res inv. IHS	(2) Non-durables IHS	(3) Durables IHS	(4) Luxuries IHS	(5) Narrow inv. IHS	(6) Extensions LPM
Interaction effects: Changes as $\bar{\omega}_{t-1} \rightarrow \bar{\omega}_{t-1} + 1$						
Δ Elasticity	0.88**	0.01	0.01	-0.02	0.83*	
	(0.34)	(0.08)	(0.27)	(0.16)	(0.33)	
Δ Marg. effect	209.60**	12.88	4.67	-6.99	183.98*	0.017*
	(80.16)	(159.81)	(100.44)	(76.52)	(74.12)	(0.005)
R^2	0.08	0.38	0.11	0.21	0.08	0.04
N	60,342	60,342	60,342	60,342	60,342	60,342

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls cohort-region-year fixed effects, education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. We instrument for leverage and house price changes following the specification in columns 5 and 6 of Table 4. The first row shows the change in the estimated elasticity (at average spending) of annual spending with respect to house prices when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second row shows the change in average marginal effects for a 10% increase in house prices on annual spending for the same increase in leverage (except for column 6 which shows the per cent increase in households building extensions).

different age groups and regions. The index is constructed controlling for various determinants of credit demand to ensure the index reflects credit supply conditions.[14] The series is plotted alongside our instrument in Figure 8. The CCI shows a discontinuous increase in 1981. Because this is not matched by a similarly discontinuous increase in leverage for those moving in these years in our sample, when we include households who moved before this date we find the instrument to be weak and our results imprecise. The first two columns of Table 6 present results for consumption spending and residential investment (conditional on moving in 1981 or after). As before we instrument house price growth using our leave-one-out average. The results are very similar to what we obtain in our main specification, with change in the implied elasticity for residential investment by leverage much greater than for other forms of spending.

Figure 8: Credit Conditions Index vs price-income ratio



Note: Credit Conditions Index from Fernandez-Corugedo and Muellbauer (2006). Price to income ratio is taken from Office for National Statistics UK House Price Index.

The second alternative instrument we consider is the average regional price at the point homeowners moved into their homes (as used as an instrument for mortgage debt in Chetty et al. (2017). This makes use of interregional variation as well as intertemporal variation in house prices. Because of this, our first stage is underpowered if we instrument house price growth with our leave-one-out average, and so we use regional house price growth. We report results for this approach in Table 6. We find that they are again very similar to our main results.

[14]These controls are: nominal and real interest rates, a measure of interest rate expectations and of inflation and interest rate volatility, mortgage and housing return, 36 risk indicators, house prices, income, a proxy for expected income growth, the change in the unemployment rate, demography, consumer confidence, portfolio wealth components, proxies for sample selection bias and institutional features.

Table 6: Results with alternative instruments

	(1) Res inv.	(2) Cons.	(3) Res inv.	(4) Cons.	(5) Res inv.	(6) Cons.
Interaction effects: Changes as $\bar{\omega}_{t-1} \to \bar{\omega}_{t-1} + 1$						
Δ Elasticity	0.94*	0.05	0.72*	0.07	0.58***	0.04
	(0.43)	(0.10)	(0.29)	(0.07)	(0.17)	(0.04)
Δ Marg. effect	152.68*	131.71	260.84*	198.07	91.89***	109.95
	(69.87)	(268.62)	(104.46)	(192.86)	(27.92)	(109.85)
Controls						
Reg. × Year					Y	Y
Coh. × Reg. × Year	Y	Y	Y	Y		
Instrument set						
Credit Conditions Index	Y	Y				
Reg. house prices at move			Y	Y		
Price-income ratio age 25					Y	Y
R^2	0.09	0.36	0.08	0.36	0.07	0.34
N	52,143	52,143	60,342	60,342	52,722	52,722

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls for education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. The dependent variables are transformed using the Inverse Hyperbolic Sine transformation. The first row shows the change in the estimated elasticity (at average spending) of annual spending with respect to house prices when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second row shows the change in average marginal effects for a 10% increase in house prices on annual spending for the same increase in leverage.

Finally, we examine how our results are affected when we instrument leverage at the time household heads reach age 25 (around the time many households make their first purchase) rather than the date of their last move. This latter strategy means we do not rely on possibly non-random variation in the timing of moves; however, it also means we cannot separately control for cohort effects in household spending. As a result, we only include region-year interactions when using this instrument. The results using this specification are shown in columns (5) and (6) of Table 6. The elasticity of residential investment spending is still much larger for more leveraged households.

Results with different samples

We also carry out additional analysis with different subsamples. For reasons of space, we discuss the results of these briefly here, reporting the full set of results in Appendix E.

We exclude households who moved within the previous year from our analysis, but concerns may remain that our spending effects are driven by more recent movers, who are likely to be the most leveraged, possibly at credit a constraint, and may be more likely to have higher spending due to the expenses of setting-up and customising new properties (Benmelech et al. (2023)). We therefore consider results from an alternative sample, where we exclude those who moved into their homes within the previous five years. Results are similar to those in Table 4.

We also separately consider results for a younger subsample of households (those with heads aged 25-45). If the relaxation of credit constraints were an important explanation for our findings, we would expect the magnitude of effects to be greater for this subsample. However, we find that the results are similar to those in Table 4. As in the case of our full sample, there is no evidence of a differential response in consumption spending between leveraged and non-leveraged households.

Extensive Margin: Other property investments

Households may invest in housing by purchasing additional properties or by up-sizing their main residence. In this section, we examine whether more leveraged households are more likely to make such investments in response to house price increases than other households, as our model would predict.

To test this prediction of the borrow-to-invest motive, we estimate the following equation using the BHPS

$$\Delta Y_{t,t+10} = X\delta_0 + \delta_1 \left(\frac{p_{rt+10}}{p_{rt}} - 1 \right) + \delta_2 \left[(\omega_{i,t-1} - 1) \times \left(\frac{p_{rt+10}}{p_{rt}} - 1 \right) \right] + u_t \tag{22}$$

where Y is some outcome of interest (second homeownership or the number of rooms in the household's main residence). We consider changes in these outcomes over a period of 10 years. This is to account for the possibility that, as a result of transaction and search costs, consumers may be slow to make new home purchases in response to increases in their housing wealth.

Table 7 shows results for the change in second homeownership. We include other controls for year, region, 10-year birth cohort, a quadratic in age and the years the household head has been living at the current address. The latter control accounts for the fact that households who have moved recently will likely be closer to their desired leverage, and so less likely to need to rebalance their portfolios. As above, we instrument leverage with the price to income ratio at the time households moved into their current residence, and regional house price growth is instrumented using the leave-one-out average of growth in regions outside the household's current one. We find that the second home purchases of more leveraged households are more responsive to house price increases than the purchases of other households. Our results imply that each unit increase in the portfolio share leads to a 0.07 percentage points increase in the likelihood households purchase a second home following a 10% appreciation in house prices.

Table 7 includes results for whether more leveraged households are more likely to upsize their main residences (as measured by changes in the number of rooms in their primary residence). While the pattern of results is similar to that for second homes, the coefficient on the interaction of leverage and house price changes is not statistically significant.

Table 7: Effects of leverage on second homeownership and home size

	Δ *Second home*$_{t,t+10}$	Δ *No Rooms*$_{t,t+10}$
	(1)	(2)
Change in marg. effect$_{\bar{\omega}_{t-1}\to\bar{\omega}_{t-1}+1}$	0.007**	0.007
	(0.003)	(0.011)
First stage F-stat	22.37	27.09
(p-value)	(<0.001)	(<0.001)
N	3,599	4,627
Clusters	1,393	1,440

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at the individual level. Controls are year dummies, dummies for 10-year birth cohorts, age, age squared, years at current address and a dummy for having just moved in. The estimates show the difference in the change in the proportions of households purchasing a second home following a 10% increase in house prices for a one unit increase in leverage.

5 Conclusion

It is well known that households releverage and increase spending in response to house price gains. One point we stress in this paper is that spending does not mean consumption spending: spending includes investment in housing. We introduce a new "borrow-to-invest" motive whereby households want to increase their borrowing to releverage in response to house price gains, but where the borrowing is disproportionately used to increase investment in housing. This motive arises in a life-cycle portfolio choice framework with rational consumers and i.i.d. house price changes.

We provide an empirical test of the borrow-to-invest motive by focusing on one prediction of the model, that the investment spending response to a house price realisation will vary more with leverage than the consumption spending responses. In particular, more leveraged households will respond to a greater extent to a house price increase, but this difference in response will be in their investment spending not consumption spending. We show this to be the case by regressing different categories of spending on house price realisations interacted with leverage.

Our findings have relevance for understanding the impact of restricting loan-to-value ratios and debt-to-income ratios. These interventions aim to restrict the growth of debt in the face of house price increases. However, constraints on loan-to-value are themselves relaxed by house price increases and this leads to greater borrowing and greater investment in housing. By contrast, loan-to-income constraints will restrict debt responses to house price increases, but our framework highlights that these restrictions come at a cost: they limit the extent of wealth accumulation and access to leveraged returns, rather than simply limiting consumption spending.

Our results on the impact of house price changes have further implications for the literature on consumption pass-through (which follows Blundell, Pistaferri, and Preston (2008)). That literature focuses largely on the pass-through of income shocks to non-durable consumption, but the realisations of house prices also matter, as noted by Etheridge (2019). We show that the extent of the pass-through from house price realisations will depend on the leveraged position of households, and also that it is important to distinguish between a consumption response and an investment spending response.

A final implication of our findings is that they suggest potentially important feedback mechanisms following house price increases. As house prices rise, the desire of households to re-leverage may lead to greater demand for housing. The aggregate implications of the greater demand for housing depends on whether the household desire to borrow-to-invest results in investment in new housing stock, which includes additions to existing homes and expands the supply of housing, or in purchasing existing housing stock. If the response is in purchasing existing stock, this would generate further price increases - increasing households' exposure to future house price changes and amplifying housing booms.

Our analysis leaves open several questions for future research. One important area for future study is a direct quantification of the macroeconomic importance of borrow-to-invest motives, and its importance in driving business cycles. A second question is whether lender behaviour may encourage new borrowers to use funds for residential investment purposes by, for example, imposing restrictions on the uses of loaned funds. Such restrictions are hard to enforce because of the fungibility of spending.

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Appendix A Descriptive Statistics

In Table 8 we report descriptive statistics for 1993-2013. The proportion of those owning their own homes and the average tenure among homeowners are similar across the the LCFS and BHPS surveys, at around 70% of households. Focusing on homeowners, the average loan-to-value ratio in our BHPS sample is 0.33.

Table 8: Descriptive statistics, BHPS and LCFS 1993-2013

	BHPS	LCFS
Age	44.7	44.5
% Own home	70.6%	69.5%
Homeowners		
Years at address	10.7	10.2
LTV ratio	0.33	-
ω_t (housing share)	2.79	-
Total spend (£ ann.)	-	30,500
Non-durable	-	23,372
Durable	-	4,199
Residential inv.	-	2,928
% Res inv. > 0	-	78.8%

Notes: See text for details of what is included in each spending category.

Appendix B Household Level Dynamics of House Prices and Borrowing

The average changes in loan-to-value ratios displayed graphically in the text confound individuals responses with compositional changes as households enter and leave homeownership. In this Appendix, we turn to examining household level responses in panel data. In Table 9 we report results from a regression of changes in mortgage debt on changes in regional home values. That is, we estimate the regression:

$$\Delta d_{i,t} = \delta \Delta p_{r,t} + \epsilon_{i,t} \tag{23}$$

on a sample of homeowners. As before, $d_{i,t}$ is the mortgage debt of household i in period t. $p_{r,t}$ are average house prices in region r and period t. We use regional home values rather self-reported home values, which may be subject to greater measurement error.[15] If mortgage debt did not adjust as house prices increased, leaving LTV ratios to fall passively with house prices, then we would expect the coefficient on house values to equal 0.

Column (1) shows results for households who have not moved in the previous 2 years. Household mortgage debt and house price changes are positively correlated. Each pound increase in regional home values is associated with in an additional 7 pence of borrowing for UK households.

In columns (2) and (3) we look for evidence in asymmetries of responses when households are re-leveraging versus de-leveraging by splitting the sample according to whether regional house prices rose or fell relative to the previous wave. The coefficient on the effect of house price falls is insignificant and imprecisely estimated, as our sample only includes a few years of falling house prices.

Column (4) shows results when we include households who may have moved in the previous 2 years. The average change in debt associated with each pound increase in house prices is 9 pence. This indicates that up-sizing and down-sizing are important means by which households adjust their leverage as house prices change.

Table 9: Panel Correlations between Debt and Average Regional House Prices

	(1)	(2)	(3)	(4)
Δp_{rt}	0.065***	-0.027	0.072***	0.099***
	(0.019)	(0.461)	(0.022)	(0.029)
N	27,543	1,652	25,891	30,291
Clusters	5,056	1,143	4,933	5,222
Restrictions				
Including movers				Y
House price growth<0		Y		
House price growth>0			Y	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Standard errors clustered at the individual level. The correlations are defined over two-year periods. House prices are average house price within the region.

[15] An alternative approach is to instrument self-reported home values with regional house values. This yields very similar results.

Appendix C Mortgage Imputation in Understanding Society Survey

The BHPS contains data on mortgage values from 1993 (wave 3) onwards, while Understanding Society dropped these variables in its second wave in 2010 except for households who had newly moved. However, in all years of the BHPS and Understanding Society the data contains a great deal of information on household mortgages, including whether households are outright owners, the mortgage type, the value of any additional loans, and the years left to pay on the mortgage. So as to avoid throwing data out unnecessarily, we use this information to impute mortgages for the remaining three waves of Understanding Society.

For those with interest only or 'endowment' mortgages, we assume no principal repayments. In this case, we take the current value of the mortgage to be its lagged value plus any additional loans the household may have taken out since its previous interview. For those with standard repayment mortgages, we assume the loan is amortised with annual payments (which consist of both interest and principal) determined by

$$\text{Ann. Payment} = M_{t-1} \times i/(1-(1+i)^{-(\ell+1)}) \tag{24}$$

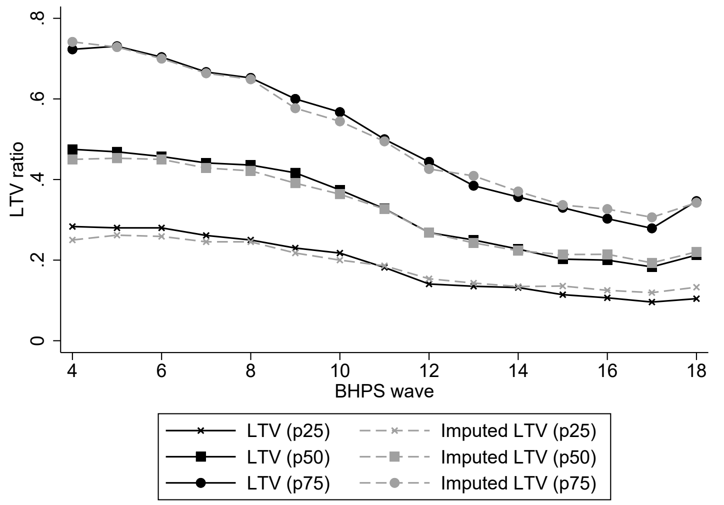
where M_{t-1} is the value of the households' mortgage in the previous year, i is the interest rate and ℓ is the remaining life of the mortgage. This means that the mortgage in any given period is given by

$$M_t = M_{t-1} - \text{Ann. Payment} + iM_{t-1} + M_t^{new} \tag{25}$$

where M_t^{new} is the amount of additional mortgage we observe the household borrowing between periods t and $t-1$.

To assess the accuracy of our imputation procedure, we implemented it on waves of the BHPS for which we observe the true value of households' mortgages. That is, we took a set of households observed in the 3rd wave of the BHPS, and imputed their mortgage values for all subsequent waves. We then plot the LTV ratios implied by our imputation procedure against actual values calculated from the survey for different percentiles of the LTV distribution (25th, 50th and 75th). The results of this exercise are shown in Figure 9. Our imputation procedure appears to work well - accurately predicting households' LTV ratios even after 15 waves.

Figure 9: Imputed and actual LTV values, BHPS



Note: Authors' calculations using the British Household Panel Survey.

Appendix D Elasticities and the inverse hyperbolic sine function

Our estimating equation is

$$sinh^{-1}(y) = X\beta + \theta_1 \left(\frac{p_{rt}}{p_{rt-1}} - 1 \right) + \theta_2 \left((\omega_{i,t-1} - 1) \times \left(\frac{p_{rt}}{p_{rt-1}} - 1 \right) \right) + \epsilon \tag{26}$$

We want to get marginal effects evaluated at average values of the covariates

$$\frac{\partial E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1}]}{\partial \left(\frac{p_{rt}}{p_{rt-1}} - 1 \right)} \tag{27}$$

To do this, first note that

$$y = sinh \left(X\beta + \theta_1 \left(\frac{p_{rt}}{p_{rt-1}} - 1 \right) + \theta_2 \left((\omega_{i,t-1} - 1) \times (\frac{p_{rt}}{p_{rt-1}} - 1 \right) + \epsilon \right) \tag{28}$$

So

$$y = sinh \left(\widehat{sinh^{-1}}(y) + \epsilon \right) \tag{29}$$

where *sinh* is the inverse of the inverse hyperbolic sine transformation

$$sinh(y) = \frac{e^y - e^{-y}}{2} \tag{30}$$

Let

$$\hat{D} = \frac{1}{N}\sum_i e^{\epsilon} \tag{31}$$

Then

$$E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1}] = \frac{1}{2}\left[e^{\widehat{sinh^{-1}}(y)}\hat{D} - e^{-\widehat{sinh^{-1}}}\hat{D}^{-1}\right] \tag{32}$$

So the marginal effect is

$$\frac{\partial E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1}]}{\partial\left(\frac{p_{rt}}{p_{rt-1}} - 1\right)} = \frac{1}{2}\left[\left(\theta_1 + \theta_2\omega_{i,t-1}\right) e^{\widehat{sinh^{-1}}(y)}\hat{D} - \left(\theta_1 + \theta_2\omega_{i,t-1}\right)^{-1} e^{-\widehat{sinh^{-1}}(y)}\hat{D}^{-1}\right] \tag{33}$$

To assess how marginal effects are affected by leverage we calculate the difference

$$\frac{\partial E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1} = 2]}{\partial\left(\frac{p_{rt}}{p_{rt-1}} - 1\right)} - \frac{\partial E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1} = 1]}{\partial\left(\frac{p_{rt}}{p_{rt-1}} - 1\right)} \tag{34}$$

We can also calculate the elasticity in response to house prices (at some initial level of leverage) as

$$\frac{\partial E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1}]}{\partial\left(\frac{p_{rt}}{p_{rt-1}} - 1\right)} \frac{1}{E[y|X, p_{rt}, p_{rt-1}, \omega_{i,t-1}]} \tag{35}$$

from which we can also obtain differences in the elasticities at different levels of leverage.

Appendix E Alternative estimation approaches

E.1 Alternative samples

One concern might that our results for more leveraged households are driven entirely by households who have just moved into their homes (and are thus more likely to be at a credit constraint). Since price-to-income ratios have tended to increase over time, our first stage regressions will tend to predict higher rates of leverage for more recent movers.

To account for this, in our main results we exclude households who moved into their homes in the previous year and control for the number of years at current address. In Table 10 we consider how our results are affected when we exclude households who moved into their homes within the previous five years. The results from this exercise are remarkably similar to our main set of results.

Table 10: Results excluding those who moved in in last 5 years

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Res inv.	Cons.	Non-durables	Durables	Luxuries	Narrow inv.	Extensions
	IHS	IHS	IHS	IHS	IHS	IHS	LPM
Interaction effects: Changes as $\bar{\omega}_{t-1} \to \bar{\omega}_{t-1} + 1$							
Δ Elasticity	1.22*	0.01	0.03	0.08	0.26	0.98	
	(0.54)	(0.13)	(0.13)	(0.52)	(0.27)	(0.54)	
Δ Marg. Effect	272.53*	33.47	54.45	24.91	130.18	189.85	0.021
	(121.04)	(315.01)	(258.21)	(162.05)	(138.69)	(103.84)	(0.011)
R^2	0.08	0.39	0.40	0.12	0.23	0.08	0.04
N	42,276	42,276	42,276	42,276	42,276	42,276	42,276

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls cohort-region-year fixed effects, education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. We instrument for leverage and house price changes following the specification in columns 5 and 6 of Table 4. The first row shows the change in the estimated elasticity (at average spending) of annual spending with respect to house prices when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second row shows the change in average marginal effects for a 10% increase in house prices on annual spending for the same increase in leverage (except for column 7 which shows the per cent increase in households building extensions).

In Tables 11 and 12 we report results for a younger subsample of homeowners (those with heads aged 25-45). These are very similar to our main results (which cover households with heads aged 25-65).

Table 11: Consumption and investment responses to house price changes: differential responses by leverage (age 25-45)

	(1) Res inv.	(2) Cons.	(3) Res inv.	(4) Cons.	(5) Res inv.	(6) Cons.
Interaction effects: Changes as $\bar{\omega}_{t-1} \to \bar{\omega}_{t-1} + 1$						
ΔElasticity	3.24***	-0.79***	0.83***	-0.00	1.16***	-0.04
	(0.35)	(0.10)	(0.20)	(0.04)	(0.28)	(0.06)
ΔMarg. Effect	1264.91***	-2075.47***	165.25***	-5.52	232.80***	-97.27
	(116.71)	(237.30)	(40.37)	(109.62)	(55.94)	(157.12)
Main effects at $\bar{\omega}_{t-1}$						
Elasticity	2.59***	0.59***				
	(0.28)	(0.08)				
Marginal effect	525.27***	1601.43***				
	(57.63)	(221.17)				
Controls						
Region effects	Y	Y				
Cohort effects	Y	Y				
Coh. × Reg. × Year			Y	Y	Y	Y
Instruments						
IV for leverage	Y	Y	Y	Y	Y	Y
IV for house prices	Y	Y			Y	Y
R^2	0.07	0.29	0.09	0.31	0.09	0.31
N	29,553	29,553	29,553	29,553	29,553	29,553

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls for education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. The dependent variables are transformed using the Inverse Hyperbolic Sine transformation. The first two rows show the change in the estimated elasticity (at average spending) and average marginal effect on annual spending of a 10% increase in house prices, when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second two rows show elasticities and marginal effects when ω_{t-1} is evaluated at the average portfolio share, $\bar{\omega}_{t-1}$.

Table 12: Responses of Categories of Consumption: differential responses by leverage (age 25-45)

	(1) Res inv. IHS	(2) Non-durables IHS	(3) Durables IHS	(4) Luxuries IHS	(5) Narrow inv. IHS	(6) Extensions LPM
Interaction effects: Changes as $\bar{\omega}_{t-1} \to \bar{\omega}_{t-1} + 1$						
ΔElasticity	1.16***	-0.05	-0.32	-0.02	1.18***	
	(0.28)	(0.06)	(0.25)	(0.12)	(0.28)	
ΔMarg. Effect	232.80***	-111.82	-119.99	-9.85	222.11***	0.023***
	(55.94)	(125.41)	(92.26)	(56.22)	(52.43)	(0.006)
R^2	0.09	0.32	0.11	0.18	0.09	0.0471
N	29,553	29,553	29,553	29,553	29,553	29,553

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Regressions include controls cohort-region-year fixed effects, education, sex, house type, number of rooms, number of adults, number of children, years at address, and a dummy variable for having moved in in the previous year. We instrument for leverage and house price changes following the specification in columns 5 and 6 of Table 4. The first row shows the change in the estimated elasticity (at average spending) of annual spending with respect to house prices when ω_{t-1} (lagged leverage) goes from $\bar{\omega}_{t-1} = 2.79$ to $\bar{\omega}_{t-1} + 1$ (corresponding to an increase in the LTV from 0.64 to 0.74). The second row shows the change in average marginal effects for a 10% increase in house prices on annual spending for the same increase in leverage (except for column 6 which shows the per cent increase in households building extensions).