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Monetary policy normalisation and mortgage arrears in a recovering economy: The case of the Irish residential market

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Abstract: In this paper we examine the sensitivity of mortgage arrears for Irish households to changes in mortgage interest rates under a series of plausible monetary policy normalisation scenarios. Using panel data over the period 2004 - 2016 we exploit information on current income and current mortgage repayments to link arrears to the level of, as well as shocks in, households' current debt service ratio. In doing so we address gaps in the existing literature on modelling default and stress testing. Both are found to be strong drivers of arrears indicating the level of indebtedness, as well as changes to repayment capacity, matter for households. We find that a 100 basis point increase in policy rates would lead to a 0.5 percentage point increase in new default flows. We also test for heterogeneous effects across households and find younger, low income households and those on tracker mortgage rate loans are most at risk following rate rises. This has important consequences for the distributional impacts of monetary policy.

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1 Introduction

The recent global financial crisis highlighted the importance of managing vulnerabilities in the mortgage market. House price falls, income shocks and unemployment spells for households who initiated mortgage loans during periods of relatively loose credit conditions have all been documented as playing a causal role in the post 2007 period of financial instability (Gerardi et al., 2008; Foote et al., 2008; Duca et al., 2011). Ensuring households have sufficient buffers to withstand economic shocks is the cornerstone of new financial stability measures adopted since the financial crisis such as bank stress testing and the adoption of macroprudential limits on borrower leverage (Claessens, 2014; Kashyap et al., 2011; Cerutti et al., 2017; Duca et al., 2010).

In this context, considerable work has been undertaken to determine the drivers of mortgage default since the financial crisis in the US and Europe. Much of this research has drawn on the increasing access to loan-level data available since the onset of the financial crisis. The research generally finds that defaults are triggered by unemployment shocks and house price declines (Elul et al., 2010; Kelly and O'Malley, 2016; Mayer et al., 2009; Gyourko and Tracy, 2014; Schelkle, 2018) and are exacerbated by the quality of underwriting practices at point of loan origination (Anderson et al., 2011; Jiang et al., 2013, 2014). Additionally, recent research has put forward a range of economy-wide stress testing approaches to model the impact of systemic shocks to housing and labour markets on mortgage default (Simons and Rolwes, 2009; Vazquez et al., 2012; Borio et al., 2014).

While providing a considerable contribution to the recent literature, a limitation of loan-level datasets is that they typically do not contain information on current affordability, in particular the current income of the household. This presents an important omitted variable which may bias estimates. By not having information on income and, hence, the current debt service ratio (DSR), the ratio of the current payment to net monthly income, many of these studies are not able to capture the impact of this aspect of affordability shocks on mortgage default. In dealing with the absence of current information on income, a number of studies rely on regional level unemployment data, or income information at the point of loan origination as a best approximation to the current income position.

Furthermore, much of the literature on mortgage default has focused on labour market channels, with the impact of interest rate changes receiving less attention. However, potential interest rate shocks are of critical importance at present given the historically low period of global policy rates experienced internationally post 2007/08. The low interest rate environment has provided a considerable benefit to mortgage holders where reductions in interest rates have been passed through to households, thereby reducing payment burdens. Nonetheless, as the global economy has begun to recover, and inflation begins to move towards target levels, pressure will inevitably build on Central Banks to normalise the policy environment. Indeed, the Federal Reserve and Bank of England have already begun the process of raising rates while the ECB has begun to unwind extraordinary measures

and indicated policy rate normalisation is on the horizon.[1] This will pose an affordability risk to the many mortgage holders who are exposed to increases in rates. Two recent papers do focus on the affordability channel of mortgage default by assessing the interest rate (payment) and income channels (Fuster and Willen, 2017; Byrne et al., 2017). However, no study to date has linked the current debt service ratio to mortgage default using household panel data and attempted to stress test the market to the effects of monetary policy rate changes.

To address this gap in the literature, in this paper we use data from the Irish Survey of Income and Living Conditions (SILC) over the period 2004-2016 to estimate a discrete time logit survival model of mortgage arrears. Our survey data contain information on default, current income and current repayment as well as a range of other household characteristics which are unavailable in many loan-level datasets. Crucially, the model allows arrears to be determined by the current debt service ratio. We allow the debt-service ratio to impact households both in level terms, to capture the degree of indebtedness, as well as in changes to capture shocks to income or interest rates.

The benefit of this approach is that it allows us to test the impact of both labour market changes and interest rate effects on default. Furthermore, it then provides us with a stress testing framework at the household level to explore the implications of a series of interest rate rises for mortgaged households. Using the empirical estimates from this model, we examine the impact of a series of interest rate rises, ranging from a moderate 25 basis points to 100 basis points, on the predicted one year probability of arrears for Irish households. Finally, we explore the distributional consequences of changes in interest rate by examining the different sensitivity to mortgage arrears across the socio-economic characteristics of households. These impacts provide important insights into our understanding of both how to model the effects of an interest rate increase for stress testing purposes, and the heterogeneous impacts of policy developments across the economy.

Our paper, therefore, makes a threefold contribution to the literature. First, we complement the recent research on labour market shocks and default by directly linking arrears to the current debt service ratio. We allow the debt service ratio to impact arrears both in terms of the levels of the ratio, to capture the impacts of indebtedness, and the change in the ratio to capture shocks to the repayment capacity of the household. Second, we contribute to the literature on the interest rate effects on mortgage default by linking repayment directly with the ability to pay in a panel data setting. Third, we complement the recent macro research on testing the impact of monetary policy on financial stability, and the literature on stress testing mortgage markets to interest rate changes, by exploring how interest rate normalisation by the ECB, would impact mortgage arrears at the household level.

A number of papers are close to our research. First, in relation to the literature on the use of current income and mortgage arrears, Gerardi et al. (2017) use US data to test the

[1]Speech by Peter Praet, Chief Economist ECB, available at:http://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp180606.en.html

ability to pay channel. Our research builds on this study by separately allowing a level effect and a shock effect of the current debt service ratio on arrears. Mocetti and Viviano (2017) test the impact of current income on mortgage default using Italian administrative data, but their study does not have information on the level of repayment, which is also absent in Aller and Grant (2018). Our paper also contributes to the broader US and European literature on the impact of unemployment on arrears, by exploiting information on the current employment status of the head of household, rather than the standard approach of using regional unemployment data as a proxy, as critiqued in Gyourko and Tracy (2014) and Schelkle (2018).

Second, in a similar manner to the research on labour market shocks, our paper contributes to the literature that identifies the impact of interest rates or repayment levels on default by dealing with the omitted variable bias due to the absence of information on current income levels. These data are absent from Fuster and Willen (2017), Byrne et al. (2017), and certain studies testing the impact of mortgage modifications on default risk (Tracy and Wright, 2016). By considering the link between monetary policy normalisation and default, we also complement the research which explores the link between monetary policy and financial stability (Smets, 2014; Rubio and Carrasco-Gallego, 2014) by providing a direct micro-data example of one of the interest rate channels.

Finally, by developing a micro-level stress testing tool which can explore the impact of interest rate shocks on arrears at the household level, our research complements the existing macro-level stress testing models of default (Piffer, 2018; Borio et al., 2014; Simons and Rolwes, 2009; Vazquez et al., 2012; Buncic and Meleck, 2013). Using aggregate data, Drehmann and Juselius (2012) show the importance of the debt service ratio as a predictor of systemic banking crises. By modelling the debt service ratio at a household level, we are able to explore the distributional impact of higher interest rates across households.

Assessing the impact of monetary policy normalisation in the Irish mortgage market is of particular interest. First, due to the severity of its mortgage arrears crisis and the highly indebted nature of the Irish domestic economy; the credit boom observed during the latter stages of the "Celtic Tiger" saw underwriting practices in the banking sector loosened considerably, which led to an unsustainable extension of credit to households who borrowed large volumes of credit at high loan-to-value and loan-to-income ratios (McCarthy and McQuinn, 2017). When the Irish economy was particularly impacted by the financial crisis in 2008/09, resulting in house price declines and sharp increases in unemployment many households had few buffers with which to absorb these shocks. This led to a wave of defaults that have adversely impacted the household and financial sector since. At the peak of the arrears crisis in 2013, one fifth of Irish mortgages were in default.

Second, despite, or maybe because of the relatively large impact of the international crisis, the Irish economy has, since 2013, recovered in a spectacular fashion. However, while the overall economy has enjoyed growth rates at least double the European average since 2013, vulnerabilities remain in the Irish mortgage market. Irish private sector debt, as a

ratio of GDP[2], is still one of the highest levels across the Euro area. Vulnerabilities are also accentuated by the structure of the domestic mortgage market which has a large number of contracts on variable rates. In 2013 85 per cent of mortgage loans in Ireland were on variable rates, compared to less than 10 per cent in France and Belgium and less than one quarter in Germany, the Netherlands and the UK (European Systemic Risk Board, 2015). The high proportion of variable rate mortgages, and the high level of indebtedness, means that Irish households are particularly vulnerable to a rise in interest rates.

The key findings of this paper can be summarised as follows. We find a household's repayment capacity, measured by the current debt service ratio, to be a major determinant of mortgage arrears. Both the level of the debt service ratio, as well as the change in the debt service ratio are found to have strong impacts on arrears. These findings are important as they indicate that it is not only the size of the shock that matters but also the level of indebtedness of households when the shock occurs.

In terms of scenario analysis, we show that increases in the euro area policy rate leads to increases in the arrears rate, but that the severity of the shock depends on the magnitude of the rise in a non-linear way. Initially we stress the interest rates for all households. However, we then allow for different pass-through relationships between the policy rate and the individual household mortgage rate. There are two main variable rate contract types in Ireland: standard variable rates (SVRs) whose level is set at the discretion of the bank but normally follows the policy rate; and "tracker rates" which have a fixed contractual mark-up over a reference rate. To capture these differences, we undertake a scenario that assumes a zero pass-through for those mortgages secured at fixed rates, a partial pass-through for households on a standard variable rate (SVR) and full pass-through for so-called "tracker mortgages".

With differential pass through by interest rate type, our estimates of the percentage point increase in the arrears flow of Irish mortgages range from 0.1 percentage points for a 25 basis points shock, to 0.2 for a 50 basis points rise and 0.5 percentage points for a 100 basis points shock. These represent between a 4 per cent and 18 per cent increase in the flow of mortgages into arrears. The relative variance in the estimates reflects the non-linear nature of the impact of interest rates as well as the uncertainty about the sensitivity of lending rates to changes in the policy rate for non-tracker borrowers.

As our scenarios are partial equilibrium in nature, an interesting question arises as to whether the increase in incomes due to a growing economy would offset the higher interest rates. To address this issue, we obtain an estimate of the long term growth rate in Irish income levels, adjusted for the general equilibrium effects of higher interest rates. This is achieved with a structural macroeconomic model of the Irish economy (Bergin et al., 2017). We then examine to what extent the increase in income levels would offset the reduction in affordability of the higher interest rates. We find that even fairly substantial income growth would not fully offset the effects of interest rate rises on Irish mortgage

[2]At the end of 2017, this ratio was 260 per cent, whereas the EU Commission has set an indicative threshold of 160 per cent for member countries.

holders. This is because the increase in the mortgage payment due to an interest rate shock would significantly outweigh the impact of income growth for households. Overall, notwithstanding the strong expected growth path of the Irish economy, the debt service ratio for many households would still deteriorate.

Finally, we explore the heterogeneity of these results across household types. Our findings show that in particular young households, low income households and those early in the loan age distribution are most at risk of falling into arrears on their mortgage payments as a result of a rise in interest rates. These findings highlight the precarious nature of repayment burdens for non-fixed rate borrowers and suggest a number of implications for policy. Fixing interest rates may be appropriate for certain at risk groups, particularly younger households. Expanding the share of fixed rate loans in the Irish market, and the length of the fixed term could therefore help to minimise the risk confronting those groups most exposed to interest rate shocks.

The rest of the paper is structured as follows: Section 2 provides an overview of both the Irish mortgage arrears crisis and monetary policy in the aftermath of the crisis. Section 3 introduces the data and methodology used in the analysis, while Section 4 presents the empirical results and tests the performance of the model. In Section 5 we test the sensitivity of households' repayment capacity to a series of interest rate shock scenarios. Section 6 summarises our findings and discusses policy implications.

2 Mortgage Arrears and the Irish Crisis

Following the onset of the financial crisis in Ireland in 2008, the mortgage market experienced a rapid deterioration in loan performance. During the latter stages of the "Celtic Tiger", underwriting practices in the banking sector loosened markedly and households borrowed large volumes of credit at high loan-to-value and loan-to-income ratios. Mortgage terms also lengthened on average which reduced the effective repayment burdens. McCarthy and McQuinn (2017) document the loosening of Irish credit conditions for households, noting in particular the more liberal lending channel in relation to incomes.

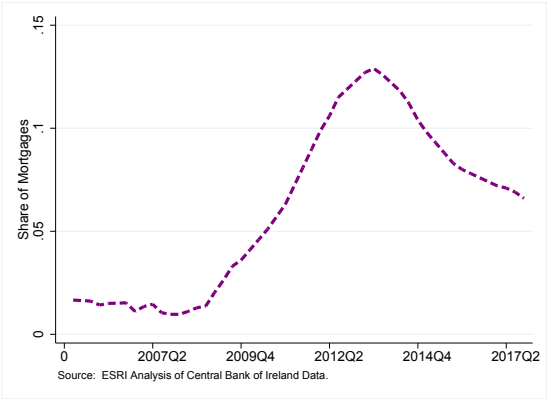
The extension of loans at loose credit conditions left households with few buffers available to withstand shocks once the banking crisis began to propagate through the real economy. Figure 1 presents the trend in mortgage arrears, unemployment, house prices and interest rates from just prior to the crisis in 2005 to end-2017. The data on mortgage defaults relate to mortgages collateralised on owner-occupied principal dwelling home (PDH) properties. Default in this market increased from below 1 per cent of loans in 2007 to peak at 13 per cent of loans in 2013[3]. The scale of the shock to the labour market was just as stark; the unemployment rate increased from under 5 per cent in 2007 to 16 per

[3]These figures relate to mortgage accounts greater than 90 days past due on their obligations which is the standard Basel definition of loan delinquency. This differs from our definition of arrears in the SILC survey micro data which relates to any missed payments. Some differences in magnitude for aggregate charts may therefore be evident.

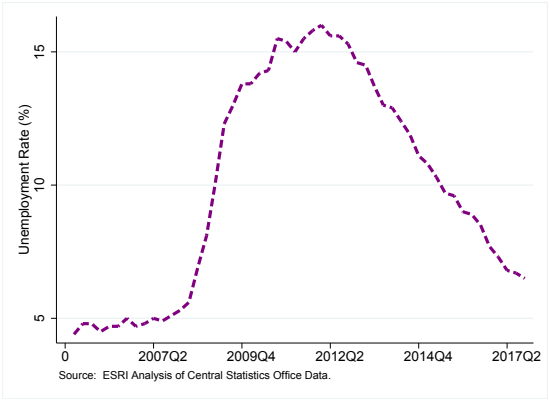
cent at the height of the bust in 2012. Real incomes also fell markedly in each year from 2009 to 2013 (CSO SILC data).

Figure 1: Mortgage Default Backdrop Ireland

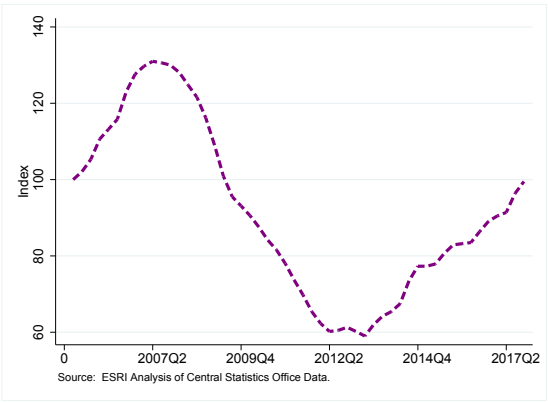
(a) Trend in Mortgage Default



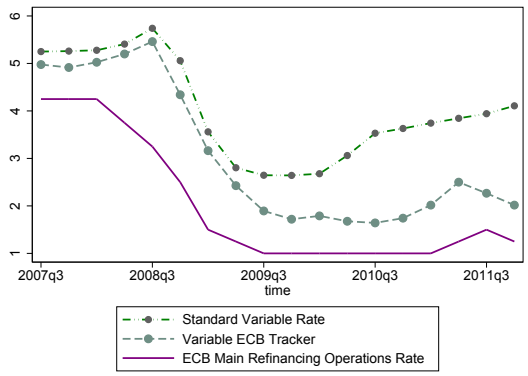
(b) Trend in Unemployment (%)



(c) House Prices Developments



(d) Interest Rate Differences



The correction in house prices was even more dramatic; from the peak in Q2 2007 to the trough in Q2 2013, prices fell by 55 per cent on a nominal basis. This led to a large share of households experiencing negative equity. Thus, the Irish mortgage market after the crash, saw borrowers hit simultaneously with severe affordability (unemployment and falling incomes) and equity shocks (house prices reversals). Indeed, Fahy et al. (2018) show a change in the type of households experiencing arrears before and after the crisis, highlighting the systemic nature of the shock. More recently mortgage arrears have begun to decline, in part driven by the economic recovery but also driven by an extensive programme of mortgage modification which has attempted to provide sustainable solutions for borrowers looking to engage with banks to resolve their mortgage difficulties. McCann (2017) and Donnery et al. (2018) document the steps taken to resolve the Irish mortgage crisis including the extensive programmes of mortgage resolution.

A large body of research has explored the determinants of mortgage arrears since the Irish crisis, with a particular emphasis on disentangling the relative magnitude of the affordability and equity shocks. An early study using EU SILC data up to 2009 by McCarthy and McQuinn (2011) explored a range of scenarios examining the implications for

Irish mortgage affordability of an interest rate shock. They define the mortgage repayment to income ratio (MRTI) and examine the distributional implications for Irish mortgaged households of an increase in interest rates. More specifically, they find that an increase in the variable mortgage rate of 150 basis points results in a 26 per cent increase in the number of households in the top decile range of the MRTI (30 to 80 per cent) for that year. A decline of the same magnitude, on the other hand, results in a 35 per cent reduction in those in the same range. While this study was informative, it was completed at a time which pre-dated the worst years of the crisis and an updated study which formally models arrears as a function of affordability complements and updates this research.

Lydon and McCarthy (2013) use 2010 loan level data to examine the effect of both equity and income shocks on arrears. They find a considerable role for both channels, but as their loan level data do not contain current income or labour market status, they capture income shocks by using regional unemployment rates as a proxy for income shocks.

As part of the stress testing framework developed by the Central Bank of Ireland, a range of research papers focused on determining the drivers of mortgage default using transition models. Kelly (2011), and subsequently Kelly and O'Malley (2016), present a transition matrix model of the Irish mortgage market which determines flows into arrears as a function of unemployment, loan-to-value ratios and other loan and dwelling characteristics. This research has subsequently been outlined further in Gaffney et al. (2014b), Gaffney et al. (2014a) and applied to the UK mortgage market by McCann (2014). This research is critically important to understanding the development in mortgage arrears in an Irish case. They formed the basis for the ongoing stress testing and financial vulnerability analysis that are undertaken in the Irish mortgage market. They were also used in the Prudential Capital Adequacy Review (PCAR) process which assessed the recapitalisation requirements of the Irish banks after the economic crisis. These models find a large effect of loan-to-value and unemployment on arrears. Other factors have also affected the default rate in Ireland. O'Malley (2018) uses a judicial ruling to also highlight the impact of the removal of repossession risk on the Irish default rate following the crisis. As these papers rely on loan-level data they do not have access to up-to-date information on household income which we explore in this paper.

One paper which does bridge the gap between loan-level data and current information on income is McCarthy (2014) which uses survey data appended to the Central Bank of Ireland loan level data. It combines the results of an income survey (see McCarthy and McQuinn (2017) for details) of Irish mortgaged households conducted in 2012 with information on the corresponding loan level data for the same households. This research finds an important role for income volatility and labour market shocks in explaining default activity. Our research builds on this paper by estimating the impact on arrears of current income affordability using a panel setting.

While mortgage arrears in Ireland have fallen in recent quarters, continued vulnerabilities remain given the indebted nature of many households. Indeed, an inevitable risk for the domestic economy are the implications of future Euro area policy rate increases.

The interest rate on the main refinancing operations (MRO), which provides the bulk of liquidity to the banking system has, since 2009, been kept at historically low rates as a response to the international financial crisis. As evidence of economic recovery gathers throughout Europe, the highly accommodative nature of Euro area monetary policy is unlikely to last past the short to medium-term. ECB policy makers have recently pointed towards a gradual removal of the extraordinary monetary accommodation and a potential normalisation of policy rates.[4] Therefore, as the significance of the debt service ratio in influencing Irish mortgage arrears demonstrates, the sensitivity of Irish mortgage holders to interest rate changes is a significant policy concern.

3 Data and Methodology

3.1 Data and Descriptive Statistics

SILC provides a comprehensive micro-level dataset surveying income and living conditions across different types of households. As a survey of private households, it is voluntary and is carried out under EU legislation. In Ireland, the survey is conducted on an annual basis by the CSO and, while it is primarily focused on collecting information used to derive indicators of poverty, deprivation and social exclusion, the survey also contains a significant amount of information for each individual on home ownership, details of mortgage debt, monthly mortgage instalments and arrears. The data do not capture information on the balances outstanding for equity releases or top-ups so households who hold such products may have their debt balances underestimated by SILC.[5]

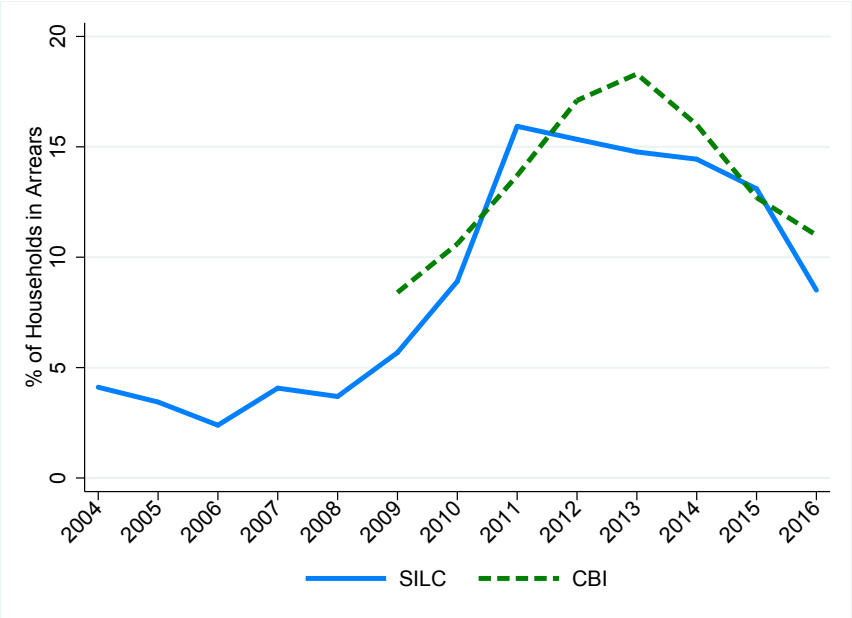
A key attraction in using SILC to examine the issue of household mortgage stress is the availability of timely economic data for the household. Much of the literature on mortgage arrears indicates affordability issues such as declines in household disposable income and or shocks to the employment status of household members are key determinants. However, the majority of studies used to examine the issue of arrears use loan level administrative data usually compiled by Central Banks and or Regulatory authorities. While these data have accurate and timely information on the nature of the loan, they rarely have timely information on the household's current economic status. The only economic data such datasets typically have is income and employment information at the time of loan origination. However, in a labour market such as Ireland's, where unemployment rapidly increased from just over 5 per cent in at the start of 2008 to just under 16 per cent in mid-2010, such information can very quickly become outdated. As mentioned in the previous section, McCarthy (2014) sought to address this using survey data appended to CBI loan-level data. However, owing to the one-off nature of the survey, this information was

[4] Speech by Peter Praet, Chief Economist ECB, available at:http://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp180606.en.html

[5] As we cannot capture data on these products, any shocks and scenarios that we calculate using these data cannot take this debt into account. Our estimates only provide shocks based on the primary dwelling mortgage.

only available on a one year, cross-sectional basis.

Figure 2: Comparison of SILC and CBI Arrears Data



CBI data refer to the % of PDH loans that are in arrears (of any length). We report the average across 4 quarters. In SILC households are asked to report if they have failed to make a mortgage payment on their principal dwelling home in the last 12 months. The correlation coefficient is 0.88.

Figure 2 plots a comparison between the percentage of Irish households in mortgage arrears in SILC[6] and the percentage of PDH loans in arrears of any length from the Central Bank of Ireland (CBI) loan level dataset[7]. While the CBI loan level data are only available from 2009 onwards, for the period 2009-2016 there is a 88 per cent correlation between the two datasets, allaying concerns of under-representation of households in arrears in this instance. Figure 2 also highlights the scale of the mortgage arrears crisis in Ireland.

In Figure 3a we plot the mean current mortgage loan to value (CLTV) ratio between 2004 and 2016. It shows that in our sample, household mortgage debt relative to the value of the property increased hugely from 30 per cent in 2005 to a peak of 80 per cent in 2013, coinciding with the sharp decline in house prices. In Figure 3b we see the corresponding increase in households in negative equity, with virtually no households in negative equity up until 2008 and a sharp increase thereafter, peaking at just over 30 per cent of households in 2013.

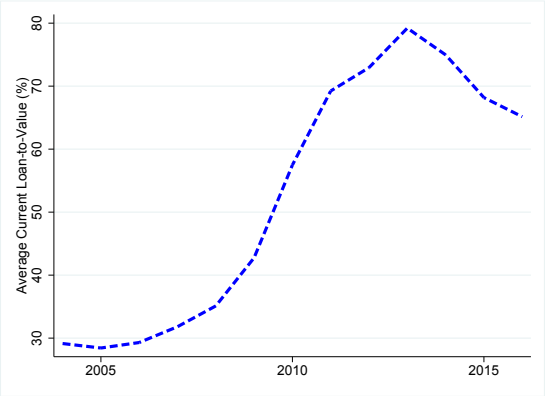
Figure 4 documents the rise in the average household Debt Service Ratio (DSR), with the proportion of income spent on mortgage instalments increasing from 14 per cent in

[6]In SILC respondents were asked whether "In the last 12 months, did it happen that the household was unable to make a mortgage repayment for the main dwelling on time, due to financial difficulties?". The analysis in this paper therefore only focuses on the primary dwelling home arrears and not on the buy to let or second homes markets.

[7]CBI loan level data contain data for the five largest mortgage lenders in Ireland, covering approximately 90% of the PDH market in 2015.

Figure 3: CLTV and Negative Equity 2004-2016

(a) Mean CLTV Ratio



(b) % Households in Negative Equity

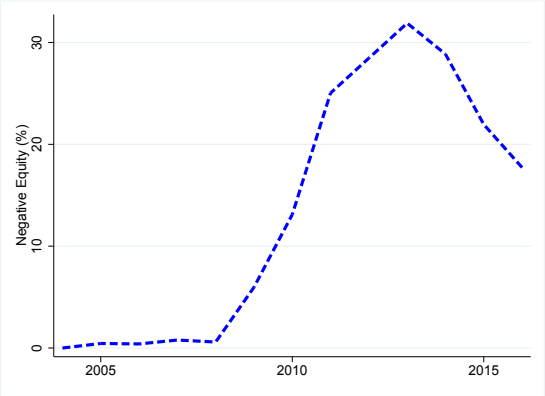
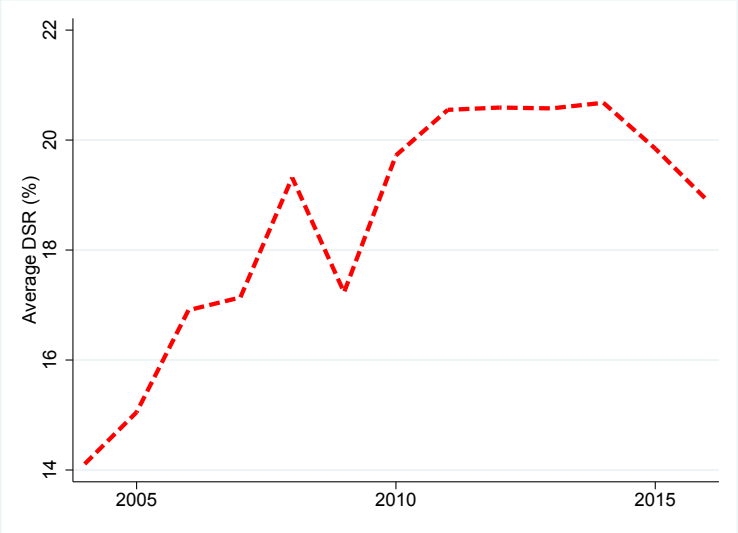


Figure 4: Mean Debt Service Ratio 2004-2016



2004 to approximately 20 per cent in 2010 and remaining at a similar level through to 2014 before beginning to decrease. Taking Figures 2-4 together, it is clear that the huge increase in households falling into arrears on their mortgage payments coincided with both the deterioration in housing equity and the increase in the repayment burden faced by households. We will test these channels empirically in the next section.

In Table 1 we report summary statistics for the key demographic (top panel) and mortgage variables (bottom panel) of households in our sample. Beginning with demographic variables, we see that mortgaged households are likely to be employed, married, between 36-50 years of age and with either secondary or tertiary level education. With regards to household formation, approximately 90 per cent of the sample is composed of households with at least two adults, and three quarters of the sample belong to the top 40 per cent of the income distribution. From the bottom panel of Table 1 we see that on average households in our sample pay €835 per month on their mortgage repayments and have

€140,886 outstanding on their mortgage loan.

Table 1: Summary Statistics 2004-2016

	Share of Households
Marital Status	
Married	0.71
Single	0.18
Divorced/Separated/Widowed	0.11
Age Group	
18-35	0.26
36-50	0.55
51+	0.19
Employment Status	
Employed	0.78
Unemployed	0.04
Other	0.18
Education	
Primary	0.06
Secondary	0.42
Tertiary	0.52
Household Composition	
1 adult, no children	0.10
1 adult, with children	0.02
2+ adults, no children	0.33
2+ adults, with children	0.55
Income Distribution	
Q1	0.02
Q2	0.06
Q3	0.16
Q4	0.32
Q5	0.43
Region	
BMW	0.22
Dublin	0.33
ME MW SE SW	0.44
Mortgage and Economic Indicators	
Original Loan (€)	156248.60
Outstanding Principal (€)	140886.40
Monthly Payment (€)	835.33
Mortgage Term (Years)	25
Debt Service Ratio	0.19
Change in DSR	-0.00097
Current Loan to Value Ratio	0.54
$CLTV < 80$	0.74
$CLTV 80 - 100$	0.10
$CLTV > 100$	0.16
Negative Equity	0.14
Arrears	0.09
Real Disposable Income (€)	59164.70
Ln(real disposable income)	10.88
Regional Macro Controls	
Unemployment	0.1
GVA growth	0.06
GDPpc (€)	42513.39
Ln(GDPpc)	10.59
No. Obs	4749

3.2 Methodology

In determining the drivers of mortgage default, the standard literature suggests two key triggers; equity shocks and affordability shocks. An important contribution of this research is to measure affordability shocks using the current debt servicing capacity of the household as measured by the current debt service ratio (DSR) and changes in the debt service ratio.

To test the impact of these variables on mortgage arrears we therefore estimate two specific models: 1) a standard logit model on the stock of mortgage arrears; and 2) a discrete time survival model on the flow of mortgages into arrears using a logit specification. We exploit the panel nature of our dataset to deal with a number of econometric concerns such as simultaneity and the determinants of arrears transitions in the flows model. To begin, the following specification is presented for the arrears stock:

$$Pr(D_{it} = 1) = f(\Delta DSR_{it}, DSR_{it-1}, CLTV_{it-1}, lnY_{it-1}, EmpStatus_{it}, \mathbf{X_{it}}, \mathbf{Z_{rt-1}}) \quad (1)$$

where D_{it} is the censored underlying latent propensity to delinquency for household mortgage i in period t as is common in the existing literature (Jiang et al., 2013, 2014; Haughwout et al., 2008). The DSR enters the baseline specification as a lagged level. As in Elul et al. (2010), the CLTV enters as a series of dummy variables: households with CLTV less than 80, households with a CLTV between 80 and 100 and households with negative equity (CLTV greater than 100). This allows for the fact that equity shocks should only really determine arrears once the borrower moves into negative equity and the underlying "put" value of the default option that any mortgage holder has moved "into the money" i.e. when the value of the house is worth less than the underlying collateralised loan, the borrower has negative net worth and discontinues repayments. We include these indicators with a one period lag to remove any possible simultaneity bias.

In addition to the DSR as a control for current affordability, we exploit the richness in the economic variables in our survey by also including the log level of income lnY_{it-1} and indicator variables for those households who are unemployed or not in the workforce in the vector $EmpStatus_{it}$. These controls are important as they capture aspects of affordability over and above the debt service ratio. Controlling for income as a covariate as well as the debt service ratio ensures that the DSR coefficient captures the variation in indebtedness across households, the sensitivity to repayment shocks and the relative affordability of the current payment for a given income level. Also including a dummy for unemployed households ensures that those households who face a large shock event are separately controlled for. We feel the suite of affordability indicators leads to a saturated specification and ensures that any debt service ratio effect we find is robust and correctly captures the repayment burden.

Finally, and most critically, we include in our specification the change in the debt-service ratio ΔDSR_{it} to capture the channel through which households would be exposed to shocks to their mortgage payment or changes in their after tax income. This is the

critical channel when trying to understand the impact of policy rate rises on arrears, as changes in the household's ability to repay are due to variations in the current affordability of the loan. We therefore include in our specifications the ΔDSR_{it} as well as the level of the DSR in the previous period to ensure we account for the size of the shock as well as the starting level of the repayment burden. These aspects have not to date been explored in the literature.

To further saturate our specification, we include a vector of household characteristics which include the age of the household head, education, martial status and household composition. To capture macroeconomic time varying effects, we include the NUTS3 regional unemployment rate, change in gross value added, and gross value added per capita. These controls capture macroeconomic variation and business cycle fluctuations at the regional level. This is in line with existing research in this area (McCann, 2017; Kelly and O'Malley, 2016). These factors are included with a lag to avoid simultaneity bias. In the robustness checks, we remove these factors and instead include region year fixed effects.

For the arrears flows model, we are able to estimate a survival model on the transitions into arrears. In this model, the dependent variable D_{it}^{f} takes the value of 1 if a household first missed a payment within that period. Only incidents where households are observed to transition over time from a non-delinquent to delinquent state are used in the analysis. For households with a transition but then a number of years of arrears following this point, they are marked as having experienced a delinquency after the first year of missed payments with subsequent observations omitted.

Given the annual nature of our data, we estimate the discrete time version of the standard hazard model. We use the common logistic specification of the discrete time hazard function for household i at time t, $h((\mathbf{G}))_{it}$, as in Jenkins (1995):

$$h((\mathbf{G}))_{it} = \frac{1}{[1 + exp(-\lambda(t) - \beta\mathbf{G})]} \tag{2}$$

which the survival function in log format simplifies for specification purposes to:

$$log(\frac{h_{it}}{1 - h_i t}) = \lambda(t) + \beta\mathbf{G} \tag{3}$$

The vector, G, contains all the controls specified earlier in equation 1 including the DSR, income, household controls and the time-region varying macroeconomic factors. An important aspect for such discrete time models is the choice of the functional form for time, $\lambda(t)$. This is complicated in our setting as our mortgages originated in different years and the latent exposure to risk differs across households and time periods (left truncation). To deal with this issue, we follow Kelly et al. (2015) who specify the functional form for time as a polynomial of the loan vintage (the number of years since the loan was originated). We therefore append this variable to equation 3. Previous literature on mortgage default and the time of exposure at risk would suggest that the vintage controls should follow a hump shape with the default risk high in the early years of the loan and then declining through the term (Haughwout et al., 2008).

$$log(\frac{h_{it}}{1-h_it}) = \alpha_1 v_{it} + \alpha_2 v_{it}^2 + \beta \mathbf{G} \tag{4}$$

In terms of the key parameters in our baseline specification for either the stocks model or the survival model, we would expect that the probability of arrears is increasing in the debt service ratio (both in levels and in shocks). These expectations are outlined in Table 2.

Table 2: A-Priori Parameter Expectations

$\beta \Delta DSR$	> 0
$\beta(DSR)$	> 0

4 Empirical Analysis

4.1 Baseline Empirical Findings

In Table 3 we present the results from estimating the baseline mortgage arrears (Stocks) and discrete time survival model of transitions into mortgage arrears (Flows) models outlined in Section 3.2. We report average marginal effects from logit regressions with standard errors in parentheses. All regressions reported in Table 3 control for household characteristics, loan vintage and regional macroeconomic controls. In columns 1 and 2 we first focus purely on the housing equity channel by including indicator variables for three bands of the current loan to value ratio (CLTV). We only find a positive, statistically significant effect on the arrears rate in our stocks specification for households with a CLTV>100 i.e. households in negative equity. This would indicate that it is not a higher level of the loan to value ratio per se that is important in determining arrears, but rather, whether a household is in negative equity or not.

In columns 3 and 4 we instead include the first component of the affordability channel: employment status.[8] Being unemployed is unsurprisingly associated with a higher probability of arrears and this holds in both the stocks and flows specifications. Columns 5 and 6 include disposable household income and show that higher incomes are associated with a lower probability of arrears. In columns 7 and 8 we include the CLTV indicators, employment status and household income jointly and the coefficient estimates and significance levels remain similar.

In columns 9 and 10 we add the household's Debt Service Ratio (DSR) as our main measure of household repayment capacity. The positive, statistically significant coefficient in our stocks specification indicates that households who pay a higher proportion of their

[8] Our employment status refers to the household head.

Table 3: Baseline Results

	(1) Stocks	(2) Flows	(3) Stocks	(4) Flows	(5) Stocks	(6) Flows	(7) Stocks	(8) Flows	(9) Stocks	(10) Flows	(11) Stocks	(12) Flows
Regional Macro Variables												
L.Unemployment Rate	1.002***	0.569***	1.159***	0.593***	1.150***	0.582***	0.891***	0.531***	0.867***	0.519***	0.838***	0.498***
	(0.171)	(0.142)	(0.161)	(0.139)	(0.164)	(0.136)	(0.165)	(0.144)	(0.168)	(0.146)	(0.170)	(0.148)
L.GVA Growth	-0.0990*	-0.124**	-0.0152	-0.0986**	-0.104*	-0.129***	-0.109**	-0.119**	-0.100*	-0.115**	-0.109**	-0.119**
	(0.0579)	(0.0505)	(0.0529)	(0.0454)	(0.0582)	(0.0496)	(0.0555)	(0.0473)	(0.0555)	(0.0474)	(0.0554)	(0.0474)
L.Log GDP per capita	0.0822	0.0904*	0.0483	0.0763	0.0925	0.0897*	0.0875	0.0864*	0.0778	0.0805	0.0769	0.0785
	(0.0630)	(0.0529)	(0.0580)	(0.0501)	(0.0607)	(0.0524)	(0.0587)	(0.0502)	(0.0589)	(0.0502)	(0.0597)	(0.0509)
LTV Channel												
L.CLTV <80 (Base Group)	-	-					-	-	-	-	-	-
L.CLTV $80-100$	0.0207	0.00303					0.0233	0.00316	0.0179	0.00144	0.0173	0.00204
	(0.0195)	(0.0137)					(0.0185)	(0.0131)	(0.0179)	(0.0128)	(0.0179)	(0.0129)
L.CLTV >100	0.0837***	0.0161					0.0822***	0.0188	0.0683***	0.0141	0.0667***	0.0146
	(0.0185)	(0.0116)					(0.0175)	(0.0118)	(0.0175)	(0.0113)	(0.0171)	(0.0113)
Affordability Channel												
Employed (Base Group)			-	-			-	-	-	-	-	-
Unemployed			0.177***	0.0850**			0.128***	0.0748**	0.130***	0.0767**	0.110***	0.0624**
			(0.0383)	(0.0374)			(0.0356)	(0.0365)	(0.0357)	(0.0372)	(0.0316)	(0.0308)
Other			0.0864***	0.0297**			0.0662***	0.0252*	0.0669***	0.0248*	0.0589***	0.0211
			(0.0175)	(0.0136)			(0.0182)	(0.0150)	(0.0182)	(0.0149)	(0.0174)	(0.0141)
L.Log Real HH Income					-0.0903***	-0.0272***	-0.0657***	-0.0165	-0.0469***	-0.00909	-0.0508***	-0.0124
					(0.0116)	(0.00856)	(0.0127)	(0.0103)	(0.0139)	(0.0104)	(0.0137)	(0.0103)
L.Debt Service Ratio									0.131***	0.0569	0.233***	0.100***
									(0.0459)	(0.0369)	(0.0485)	(0.0387)
Δ Debt Service Ratio											0.239***	0.122***
											(0.0564)	(0.0475)
Loan Vintage	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Household Characteristics	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,749	4,239	4,749	4,239	4,749	4,239	4,749	4,239	4,749	4,239	4,749	4,239

Mortgage arrears is defined as being unable to make a mortgage repayment in the last 12 months, due to financial difficulties. Loan vintage is defined as years since mortgage origination. Household characteristics: Age, Marital Status, Education, Household Composition, Region. Standard errors reported in parentheses and significance level displayed as * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

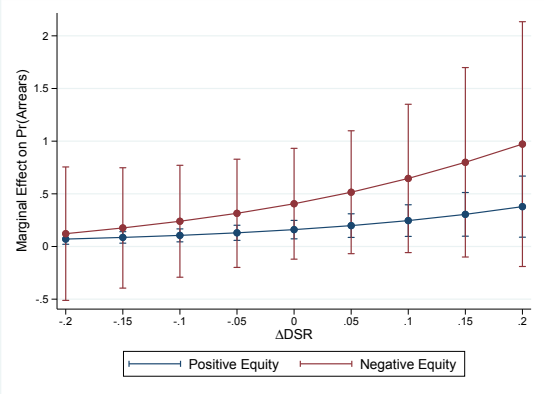
income on mortgage payments are associated with higher levels of mortgage arrears. However, as we are interested in identifying the role that income shocks play in mortgage arrears, we are interested not only in the level of indebtedness, but also in the change in the debt servicing requirement. Although in many cases our employment status indicator will capture the effects of a severe income shock from becoming unemployed, there is evidence that in Ireland during the crisis that incomes declined even for those who remained in employment. In columns 11 and 12 of Table 3 we therefore include both the lagged level and the change in the DSR in the same specification. Both the level and the shock to the DSR are highly statistically significant in both the stocks and flows models. In the flows model, the magnitude of the coefficient on ΔDSR is slightly larger than the level effect, while the magnitudes of the two coefficients are virtually identical in the stocks model.

4.2 Do We Find A Double Trigger?

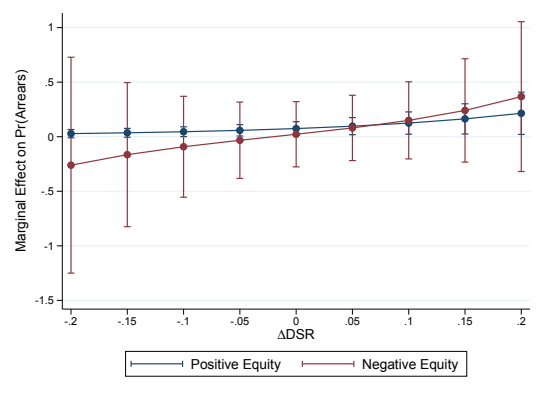
The analysis in this section is motivated by the double-trigger theory of mortgage default, discussed in Foote et al. (2008) amongst others, which states that it is the combination of an income shock and negative equity which leads to default; the borrower runs out of liquid financial resources and is unable to either continue making mortgage payments or to sell the property and pay off the outstanding mortgage debt. As we are particularly concerned with the implications of monetary policy shocks, it is also important to examine whether equity shocks attenuate repayment shocks as this would affect the pass through of monetary policy rate changes.

Figure 5: The Impact of Debt Service Ratio Shocks on Arrears by Housing Equity Status

(a) Stocks



(b) Flows



In Figure 5 we present the marginal effects of arrears at discrete values of the repayment capacity shock, ΔDSR, by housing equity status. We find no evidence of the presence of a double trigger in either our stocks or flows specifications, which means that we find no evidence that for CLTV>100, increases in the debt service ratio have more pronounced effects on delinquency. However, it is important to note that one limitation of our data is that our measure of housing equity is based on the level of the CLTV ratio being greater than 100. Ideally, in order to test the presence of a double-trigger, we would model transitions into negative equity, particularly in our flows specification which models the determinants of delinquency at the point where households transition into arrears. Unfortunately we do not have a sufficient number of observations in our data to allow us to model the transition into negative equity. This limitation could potentially provide an explanation for why we find no evidence of a double-trigger. In the analysis from this point, we model arrears on the basis of two dual, but independent, triggers (i.e. no interaction between equity and affordability shocks).

4.3 Testing the Model's Performance

As we noted in Section 2, despite the fall in mortgage arrears amongst Irish households in recent quarters, likely increases in Euro area policy rates will inevitably put pressure on mortgage holders which may exacerbate continued vulnerabilities due to the highly leveraged nature of Irish households by international standards. Before we use the model developed in Section 4.1 to stress test the impact of potential policy rate rises on Irish households, it is important to test the model's performance.

In Table 4 we report the key variables of interest from our benchmark stocks and flows models presented in columns 11 and 12 of Table 3. In addition, we report two standard measures of model performance, the area under the Receiver Operating Characteristic (ROC) curve and the percentage of correctly classified predictions. In Figure 6 we present the ROC curves graphically. ROC curves present the trade-off between sensitivity (the true

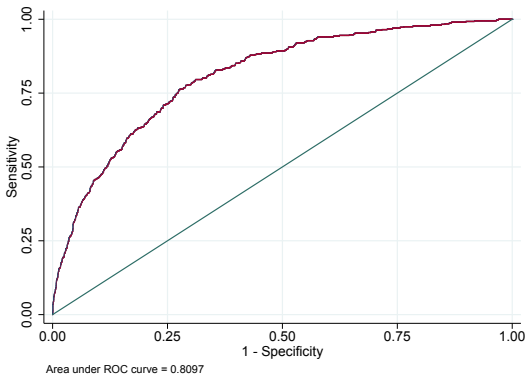
positive rate) and specificity (the false positive rate) and the closer the curve is to the top and left hand axes, the better the model's performance. From Table 4 we also see that the stocks and flows models correctly classify 91 and 96 per cent of households respectively. Both of these measures indicate that our models are reasonable at correctly classifying which households are and are not in mortgage arrears. We are therefore satisfied that the model is suitable to use for the stress testing exercises that we conduct in Section 5.

Table 4: Testing the Model

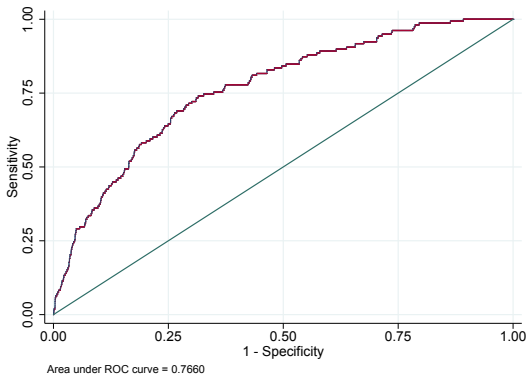
	(1) Stocks	(2) Flows
LTV Channel		
L.CLTV < 80 (Base Group)	-	-
L.CLTV $80 - 100$	0.0173	0.00204
	(0.0179)	(0.0129)
L.CLTV > 100	0.0667***	0.0146
	(0.0171)	(0.0113)
Affordability Channel		
L.Debt Service Ratio	0.233***	0.100***
	(0.0485)	(0.0387)
Δ Debt Service Ratio	0.239***	0.122***
	(0.0564)	(0.0475)
Area under ROC Curve	0.8097	0.766
% correctly classified	91.66	96.25
Observations	4,749	4,239

Figure 6: Testing Model Performance - ROC Curves

(a) Stocks



(b) Flows



4.4 Robustness Checks

In this section we perform a number of robustness checks to ensure that our findings are robust to alternative specifications of the model. In Table 5 we explore alternative ways of modelling the LTV channel. In our baseline specifications, repeated for convenience in columns 1 and 2 of Table 5, we model the LTV channel using three buckets: CLTV<80,

CLTV 80-100 and CLTV>100. Instead, in columns 3 and 4 we model the LTV continuously and show that the coefficients are similar to those for CLTV>100 in the baseline specification. In addition to the level of the LTV, in columns 5 and 6 we also test whether the change in the LTV is a key determinant of arrears. The coefficient on ΔCLTV is statistically significant in the stocks model. Finally, in columns 7 and 8 we include a dummy variable for a household being in negative equity, in addition to the continuous CLTV and ΔCLTV measures. We find no additional effect on the negative equity dummy having already controlled for the continuous LTV and ΔLTV measures. These alternative ways of modelling the LTV channel have no impact on the estimates of our key affordability variables, the DSR and ΔDSR, reported in each of columns 3-8.

Table 5: Modelling the LTV Channel

	(1) Stocks	(2) Flows	(3) Stocks	(4) Flows	(5) Stocks	(6) Flows	(7) Stocks	(8) Flows
L.CLTV < 80 (Base Group)	-	-	-	-	-	-	-	-
L.CLTV 80 – 100	0.0173	0.00204						
	(0.0179)	(0.0129)						
L.CLTV > 100	0.0667***	0.0146						
	(0.0171)	(0.0113)						
L.CLTV			0.0648***	0.0117	0.0913***	0.0182*	0.0897***	0.0139
			(0.0113)	(0.00957)	(0.0134)	(0.0103)	(0.0221)	(0.0185)
Δ CLTV					0.0574***	0.00668	0.0571***	0.00618
					(0.0194)	(0.0175)	(0.0194)	(0.0174)
L.Negative Equity							0.00210	0.00550
							(0.0216)	(0.0187)
L.DSR	0.233***	0.100***	0.204***	0.0979**	0.174***	0.0937**	0.175***	0.0943**
	(0.0485)	(0.0387)	(0.0490)	(0.0417)	(0.0517)	(0.0438)	(0.0519)	(0.0441)
Δ DSR	0.239***	0.122***	0.235***	0.122**	0.250***	0.139***	0.250***	0.139***
	(0.0564)	(0.0475)	(0.0570)	(0.0478)	(0.0601)	(0.0479)	(0.0601)	(0.0479)
Observations	4,749	4,239	4,749	4,239	4,316	3,861	4,316	3,861

Mortgage arrears is defined as being unable to make a mortgage repayment in the last 12 months, due to financial difficulties. Regressions also include loan vintage, household characteristics (age, marital status, education, household composition, region), regional macro variables, employment status and income. Standard errors are reported in parentheses and significance level displayed as * p < 0.1, ** p < 0.05, *** p < 0.01.

In Table 6 we perform a number of additional robustness checks. Our baseline regressions show that households with children, either single or double parent households, are associated with a higher likelihood of delinquency (see Table 13 in the Appendix). In columns 1 and 2 we therefore replace the log of real household income with the log of real equivalised household income, which gives each household member a weighting to account for the composition of the household. The coefficients on equivalised income are very similar to those on income in the baseline models, while the coefficients on other key variables remain unchanged.

In our baseline specification we included the NUTS3 regional unemployment rate, GVA growth and GDP per capita to capture macroeconomic variation and business cycle fluctuations at the regional level. However, we may still have concerns over omitted variable bias. In columns 3 and 4 we therefore replace the time varying regional macroeconomic controls with region year fixed effects which capture all regional variation over time. The

Table 6: Robustness Checks

	(1) Stocks	(2) Flows	(3) Stocks	(4) Flows	(5) Stocks	(6) Flows
L.CLTV < 80 (Base Group)	-	-	-	-	-	-
L.CLTV $80 - 100$	0.0217	0.00327	0.0184	-0.00371	0.0148	0.00286
	(0.0185)	(0.0132)	(0.0187)	(0.0148)	(0.0178)	(0.0129)
L.CLTV > 100	0.0710***	0.0163	0.0633***	0.00431	0.0650***	0.0198
	(0.0176)	(0.0117)	(0.0183)	(0.0134)	(0.0174)	(0.0124)
Employed (Base Group)	-	-	-	-	-	-
Unemployed	0.102***	0.0599**	0.115***	0.0710**	0.106***	0.0627**
	(0.0303)	(0.0296)	(0.0314)	(0.0345)	(0.0318)	(0.0304)
Other	0.0497***	0.0187	0.0482***	0.0201	0.0581***	0.0217
	(0.0165)	(0.0138)	(0.0161)	(0.0153)	(0.0172)	(0.0140)
L.Log Real HH Income			-0.0613***	-0.0210	-0.0601***	-0.0163
			(0.0140)	(0.0128)	(0.0142)	(0.0112)
L.Debt Service Ratio	0.216***	0.0931**	0.284***	0.163***	0.203***	0.0895**
	(0.0492)	(0.0392)	(0.0501)	(0.0479)	(0.0481)	(0.0390)
Δ Debt Service Ratio	0.237***	0.125***	0.260***	0.157***	0.231***	0.120**
	(0.0588)	(0.0480)	(0.0619)	(0.0571)	(0.0576)	(0.0474)
L.Log Real Equivalised HH Income	-0.0713***	-0.0198**				
	(0.0130)	(0.0101)				
Mortgage originated 2003-2008					0.0149	-0.00910
					(0.0134)	(0.00961)
Mortgage top-up					0.0381**	0.0192
					(0.0152)	(0.0135)
Loan Vintage	Y	Y	Y	Y	Y	Y
Household Characteristics	Y	Y	Y	Y	Y	Y
Regional Macro Controls	Y	Y	N	N	Y	Y
Region*Year FE	N	N	Y	Y	N	N
Observations	4,735	4,226	4,333	3,289	4,749	4,239

Mortgage arrears is defined as being unable to make a mortgage repayment in the last 12 months, due to financial difficulties. Regressions also include loan vintage, household characteristics (age, marital status, education, household composition, region), regional macro variables, employment status and income. Standard errors are reported in parentheses and significance level displayed as * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

coefficients on our key variables of interest remain unchanged. Finally, in columns 5 and 6 we include two variables to control for legacy effects of the crisis in our data. The first is a control for whether the mortgage was originated during the pre-crisis boom years 2003-2008 when underwriting practices in the banking sector loosened markedly and households borrowed large volumes of credit at high loan-to-value and loan-to-income ratios. The second is an indicator variable which controls for whether the mortgage has been topped-up. We observe that having topped up a mortgage is associated with a higher stock of mortgage arrears, but neither of these variables have any effect on the transition into delinquency.

5 Exploring the Impact of Monetary Policy Shocks at the Borrower Level

5.1 Transmission Mechanism and Scenario Design

In this section we use the empirical estimates from the arrears model presented in Section 4 to examine the implications for Irish households of a possible increase in mortgage interest rates. Despite the decline in cases of arrears in recent quarters, continued vulnerabilities remain given the indebted nature of many households. These policy scenarios provide a stress test of households' ability to cope with mortgage repayment increases that would be associated with any policy rate rise. As we observe both the monthly payment that households face, and their monthly net income, we can directly measure how an increase in interest rates would change their repayment capacity. We can then map this through to arrears using the estimated parameters from our benchmark model in Section 4.

In order to test the sensitivity of Irish mortgage holders to interest rate changes, we use the flows model presented in column 12 of Table 3. We focus on the flows model for two reasons. First, we are interested in households who transition into arrears and second, the stock of households in arrears is affected by both households transitioning into and out of arrears. However, we do not have information on cured loans in our SILC dataset. The analysis conducted in Section 4 focuses on the entire period for which SILC data are available, 2004-2016. However, due to the huge systemic crisis that occurred in 2007/08, we may expect that the parameters on key determinants of mortgage arrears may have changed over time. In Table 7 we show that this is indeed the case; the coefficients on both the Debt Service Ratio and particularly ΔDSR are higher in the post-crisis period (columns 3 and 4) compared to the entire 2004-2016 period (columns 1 and 2). For the purposes of testing the sensitivity of Irish mortgage holders to potential future changes in interest rates, we therefore focus on the post crisis period 2010-2016 only, to ensure that the parameters reflect the most recent period in order to provide the most accurate predictions. Further insights on why parameters might differ between periods of systemic crisis and more normal economic conditions are provided in O'Toole and Slaymaker (2019).

Table 7: Full Sample and Post Crisis Sample Analysis

	(1) Full Sample Flows	(2) Post-Crisis Only Flows
L.DSR	0.100***	0.130**
	(0.0387)	(0.0606)
Δ DSR	0.122***	0.239***
	(0.0475)	(0.0700)
Observations	4,239	2,439

Our simulation procedure is as follows. First, we use the model to calculate a baseline predicted probability of arrears for each borrower. This is a function of all of the charac-

teristics in the regression presented in column 12 of Table 3. We then use the amortisation formula shown in equation 5 to increase the interest rate for each household and calculate a new instalment[9]. The payment for each scenario, s, is then a function of the shocked interest rate, the borrower's mortgage term, and the original loan amount.[10] An important aspect of passing the shock through to borrowers is the fact that the interest rate is non-linear in the term and balance through the amortisation formula.

$$Payment_s = OriginalLoanBalance * \frac{r_s(1+r_s)^\tau}{((1+r_s)^\tau)-1} \tag{5}$$

In equation 5, s relates to the scenario, τ the original term of the mortgage and the original loan balance is as reported. Once the new payment has been calculated, we can then re-calculate the DSR with the shocked payment value:

$$DSR_s = \frac{Payment_s}{NetIncome} \tag{6}$$

The re-calculated DSRs are then combined with the values of other controls, and the estimated parameters from the logit specification, to estimate a new predicted probability of arrears for each household, i in year t.

$$\widehat{Pr(D^s_{it}=1)} = f(\widehat{\Delta DSR^s_{it}}, \overline{DSR^s_{it-1}}, \overline{controls}) \tag{7}$$

We then take the mean predicted probability of arrears across all households in each year, and compare this to the baseline mean to quantify the increase in the average predicted probability of arrears.

$$Deviation = \frac{\sum_{i=1}^{n} \widehat{Pr(D^s_{it}=1)}}{n} - \frac{\sum_{i=1}^{n} Pr(D_{it}=1)}{n} \tag{8}$$

[9]As our SILC dataset only reports an average annual interest rate, we use an amortisation formula and information on the originating loan amount, monthly mortgage payment and original mortgage term to solve for a household specific interest rate which we then shock under each of our six interest rate scenarios. Due to missing instalment data for tracker mortgages in SILC, we use an average quarterly tracker rate, calculated by adding a 1.35 per cent mark-up to the base rate, and then use the amortisation formula and information on the loan amount and mortgage term to calculate the monthly instalment. The mark up 1.35 is derived from using the average tracker rate on all loans from Kelly et al. (2015) Table 4 minus the average policy rate for 2015.

[10]One limitation of our approach is that, in SILC, we do not have information on modified loan amounts if arrears have been capitalised or if a portion of the capital warehoused. This may break the link between originating features of the loan and the current payment and add some additional uncertainty to the magnitude of our shocks. Furthermore, we do not have information on equity release balances but households who have these products may report the component of the payment for these products in the monthly instalment. This would lower the solved interest rate in our analysis and lead to a lower probability of default for these households than if we had this information. Our estimates should be seen as a lower bound in this case.

One important aspect of the Irish market that represents a potential vulnerability is the difference in arrears sensitivity by the type of mortgage interest rate held, and how any policy rate changes would be passed through to borrowers. The vast majority (approximately 85 per cent) of Irish mortgages are variable rate and these can be classified as either "tracker", where the rate tracks the ECB base rate at an agreed margin or "standard variable rate (SVR)", where the SVR lender offers no specific link to an underlying marker or wholesale rate. Crucially, the lender can increase or decrease the rate at its discretion. Irish lenders stopped offering tracker mortgage rates in 2009, when the underlying profitability risk inherent in such products became evident due to the increased funding costs from interbank rates such as the Euribor. Since then all variable rates offered in the Irish market have been standard variable in nature. In our sample we observe 16 per cent of mortgages being on fixed rates, 59 per cent are SVR and 25 per cent are on tracker rates[11].

We conduct three interest rate shocks: 25, 50 and 100 basis points. Each of these scenarios are conducted under the assumptions of both full pass through for all interest rate types and then with a differential pass through to reflect the different interest rate types across the Irish mortgage market. We use this range of values between 25-100 basis points for several reasons. First, ECB policy makers have recently pointed towards a gradual removal of the extraordinary monetary accommodation and a potential normalisation of policy rates. During a speech to the ECB Forum on Central Banking in June 2018, Mario Draghi stated that the ECB "will remain patient in determining the timing of the first rate rise and will take a gradual approach to adjusting policy thereafter." We therefore begin with a very small 25 basis point increment. Second, however, it is important to remember that as our model is annual, it is plausible that we may see a number of small incremental increases over the course of one year, which could add up to a 50 or 100 basis point increase.

In the scenarios with the differential pass through, we make a number of technical working assumptions. For fixed rate mortgages, there is no effect, while the full effect passes through to the tracker mortgages. For the SVR, the issue is complicated due to the breakdown in the pass-through relationship, which has been observed in the Irish market since 2013. Both Goggin et al. (2012) and McQuinn and Morley (2015) examine the breakdown in the pass through relationship in the Irish mortgage market. Amongst other reasons, both studies cite the decline in competition in the Irish mortgage market post 2008 as a reason for this. We take a pass-through coefficient of 0.6, which is estimated from McQuinn and Morley (2015). Using a panel dataset, McQuinn and Morley (2015) estimate the pass-through relationship for Irish credit institutions over the period 1999-2008, the period just before the breakdown in the transmission mechanism. For these final two scenarios with different pass-through, we calculate the predicted probabilities of arrears on the smaller 2013-2016 sample only as the breakdown of SVR and tracker rates

[11] In our SILC data variable rate mortgages are only split into SVR and trackers from 2013 onwards. Prior to this mortgages have been classified simply as fixed or variable (including trackers) rate.

is not available in our data prior to 2013.

Table 8: Mean Mortgage Payment and DSRs under Interest Rate Shock Scenarios

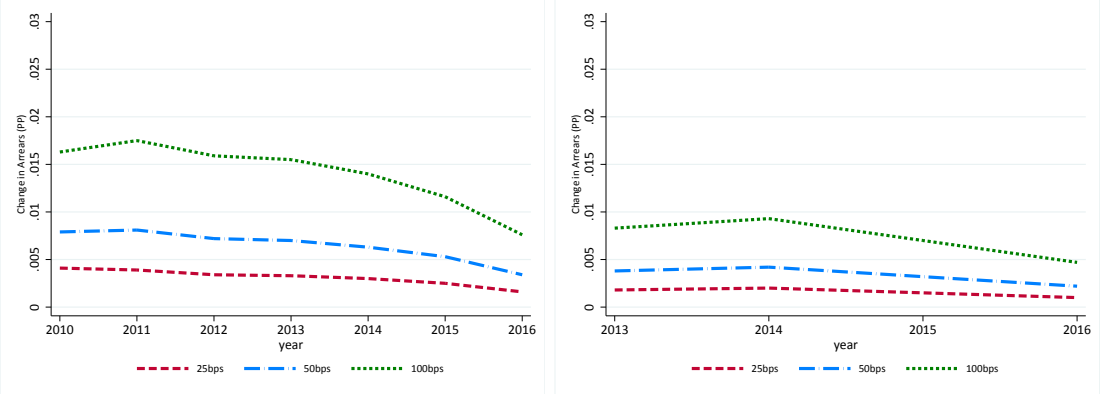
		2010-2016	2013-2016		
		(1)	(2)	(3)	(4)
		All	Fixed	SVR	Tracker
Base	Payment	873	884.22	870.18	968.07
	DSR	0.1885	0.2008	0.1929	0.1871
Shock 25 bps	Payment	971.96	884.22	961.44	1031.08
	DSR	0.1989	0.2008	0.1987	0.1982
Shock 50 bps	Payment	1022.32	884.22	990.87	1090.7
	DSR	0.2096	0.2008	0.2052	0.2093
Shock 100 bps	Payment	1127.27	884.22	1051.26	1215.33
	DSR	0.232	0.2008	0.2183	0.2329
	No. Obs.	2439	266	950	411

5.2 Scenario Outcomes

To begin, we summarise the resulting impacts on the monthly mortgage payment and the DSR under the three different scenarios (Table 8). In column (1) we present the shocks for the full sample with no differential pass through. In columns (2)-(4), where the data are available on the contract types, we disaggregate the impacts. For the full shocks, the debt service ratio increases from a mean of just under 19 per cent in the baseline to just under 20 per cent (just over 23 per cent) under the 25 basis points shock (100 basis points). In the rate type shock, the payment and the DSR are unaffected for the fixed rate mortgages, while the effect is larger for the tracker category than the SVRs.

Figure 7: Deviations from Baseline Predicted Probability of Arrears under Interest Rate Shock Scenarios

(a) All (b) Differential Pass Through



In Figure 7 the implications of the interest rate shock scenarios on the predicted probabilities of arrears are plotted with respect to the baseline level predicted by the original model. The associated probabilities are presented in full in Table 9. The baseline model

predicts a transitions into arrears rate of 2.66 per cent in 2016. Using CBI loan-level data, Figure 3b in McCann (2017) shows an approximately 1.5 per cent six monthly flow of mortgages into any days arrears, indicating that the annual predicted probability of 2.66 per cent predicted by our transitions model is a close fit with the actual data.

Figure 7b shows that for 2016, a 100 basis point increase in the policy rate (with the differing impacts on the three different mortgage rate types) would increase the probability of arrears by approximately 0.5 percentage points. This would represent an increase in the rate of arrears flows of 18 per cent. A smaller 50 basis point increase with differing pass-through would increase the probability of arrears by 0.2 percentage points, an increase of 8 per cent in the flow, while a 25 basis point would increase the probability of arrears by 0.1 percentage points, an increase of 4 per cent in the flow. In all three cases 25 per cent of the mortgage market would observe the full increase in the policy rate (tracker), while 60 per cent of the market would experience 60 per cent of the increase (SVR). The fixed rate customers would not witness any effect on their DSR and consequently the probability of arrears. One potential concern with our SILC data is the accuracy of reported outstanding balances and monthly mortgage payments, and therefore our ability to accurately calculate an interest rate for those households who have topped up their mortgage. To address these concerns we perform a robustness check in which we remove households who have topped up their mortgage. The results remain similar and are reported in Table 14 in the Appendix.

Table 9: Predicted Probabilities of Entering Mortgage Arrears Under Interest Rate Shock Scenarios

Year	Baseline Predicted Probability	Interest Rate Shock 25bps	50bps	100bps	No. Obs.
		Equal Shock for All			
2010	0.0687	0.0728	0.0766	0.0850	318
2011	0.0760	0.0799	0.0841	0.0935	227
2012	0.0630	0.0664	0.0702	0.0789	267
2013	0.0552	0.0585	0.0622	0.0707	369
2014	0.0489	0.0519	0.0552	0.0629	317
2015	0.0429	0.0454	0.0482	0.0545	490
2016	0.0266	0.0282	0.0300	0.0342	451
		Differential Pass Through			
2013	0.0552	0.0570	0.0590	0.0635	369
2014	0.0489	0.0509	0.0531	0.0582	317
2015	0.0429	0.0444	0.0461	0.0499	490
2016	0.0266	0.0276	0.0288	0.0313	451

5.3 Will an Improving Economy Provide any Offset?

In our initial interest rate simulation scenarios presented in Section 5.2, we focus on the partial equilibrium effects of a rise in interest rates on the flow of households falling into mortgage arrears in isolation, keeping all other factors constant. However, it is likely that in an environment where interest rates are rising, that incomes will also be rising, which could therefore potentially offset part of the effect on the arrears rate from increased interest rates.

In order to examine whether taking into account the general equilibrium effects of higher income growth could offset the effects of a rise in interest rates, we use data on personal disposable income from 1970-2017 provided by the Central Statistics Office to calculate an average income growth figure of 3.8% a year. However, a rise in interest rates is likely to lead to lower income growth. In order to address this, we use COSMO, the Core Structural Model of the Irish Economy[12], to test how sensitive income growth is to an interest rate hike and we then moderate the income rise by the sensitivity of income to the policy rate. This results in an annual income growth rate ranging from 3.6-3.7% depending on the magnitude of the interest rate shock.[13]

In Table 10 we present the predicted probabilities of arrears from our model under the three interest rate shock scenarios with accompanying income growth. Comparing these probabilities with the partial equilibrium interest rate shocks presented in Table 9, we show that a rise in household income will do little to offset the effects of a rise in interest rates. For example, for a 50 basis point increase in the interest rate in 2016, our model predicts an arrears flow rate of 2.76%, only marginally lower than the figure of 2.88% predicted in the scenario without any rise in incomes. Our results show that in a highly indebted economy such as Ireland, even fairly substantial income growth would not offset or compensate for the additional stress on Irish households resulting from a rise in interest rates.

Table 10: Predicted Probabilities of Entering Mortgage Arrears Under Interest Rate Shock Scenarios with Rising Incomes

Year	Baseline Predicted Probability	Interest Rate Shock 25bps	50bps	100bps	No. Obs.
2013	0.0552	0.0548	0.0567	0.0608	369
2014	0.0489	0.0488	0.0509	0.0557	317
2015	0.0429	0.0428	0.0444	0.0479	490
2016	0.0266	0.0266	0.0276	0.0300	451

Income growth figures are based on the long run average of CSO personal disposable income data 1970-2017 moderated by COSMO estimates of the sensitivity of income to the policy rate. Income growth of 3.7% under a 25bps or 50bps interest rate shock and 3.6% for 100bps.

To better understand why an increase in household income does not offset the effects of higher interest rates, in Table 11 we take a closer look at what happens to the two

[12] see Bergin et al. (2017) for an overview

[13] For robustness we present results using lower income growth equivalent to the interest rate rise in Table 15 in the Appendix.

components of the debt service ratio, mortgage payments and incomes. Taking the 50 basis point interest rate shock for example, the mean payment for a household on a tracker mortgage would rise from €968 to €1091, an increase of 13%. This means that because incomes increase by a much smaller 3.7%, the increase in the DSR is approximately 8%. For a household on an SVR mortgage a 50bps interest rate shock would increase the DSR by 2.5%. Households with a fixed rate mortgage would see their DSR fall as their payments remain unchanged and their incomes rise, but as variable rate mortgages (tracker and SVR) make up approximately 85% of the Irish mortgage market, this has little impact on the overall predicted arrears rate. It must be noted that in Table 11 the figures presented are mean values for each series. Furthermore, the DSR means are not replicable using a simple amortisation formula. The figures presented are the averages from the distribution of the debt service ratio before and after the shocks. These average figures depend on the shape of the underlying distribution which in turn depend on the distribution of each of the components. In this case, the distribution is a function of interest rates, terms, mortgage balances and incomes. The average of the ratio for these figures does not therefore add to the ratio of the averages. For example dividing the average payment by the average net income will not provide the average DSR.

Table 11: Mean Mortgage Payment and DSRs under Interest Rate Shock Scenarios with Rising Incomes

		Long Run Trend Income Rise		
		(1)	(2)	(3)
		Fixed	SVR	Tracker
Base	Payment	884.22	870.18	968.07
	Income	4751.56	5048.40	5757.06
	DSR	0.2008	0.1929	0.1871
25 bps	Payment	884.22	961.44	1031.08
	Income	4927.37	5235.19	5970.07
	DSR	0.1936	0.1916	0.1911
50 bps	Payment	884.22	990.87	1090.7
	Income	4927.37	5235.19	5970.07
	DSR	0.1936	0.1978	0.2018
100 bps	Payment	884.22	1051.26	1215.33
	Income	4922.62	5230.14	5964.31
	DSR	0.1938	0.2107	0.2248
	No. Observations	266	950	411

Payment and income reported as monthly Euro values.

5.4 Understanding Heterogeneous Policy Impacts

Having established in the previous section that increasing household incomes do little to offset the impacts of rate increases, in this section we turn to exploring the distributional consequences of monetary policy normalisation across households. In previous work analysing the default behaviour of Spanish households, Aller and Grant (2018) show that particular households such as the younger and less educated are more likely to default. In

this section we examine which types of households are most at risk of falling into arrears on their mortgage payments as a result of a rise in interest rates due to monetary policy normalisation.

Table 12: Socio-economic Characteristics of Households by the Severity of Impact of an Interest Rate Shock

	Δ Predicted Probability			
	Q1	Q2	Q3	Q4
Marital Status				
Married	0.77	0.77	0.73	0.70
Single	0.15	0.14	0.19	0.24
Divorced/Separated/Widowed	0.08	0.09	0.08	0.06
Age Group				
18-35	0.16	0.05	0.18	0.35
36-50	0.61	0.77	0.68	0.51
>50	0.23	0.19	0.14	0.14
Employment Status				
Employed	0.89	0.91	0.89	0.69
Unemployed	0.02	0.00	0.01	0.05
Other	0.09	0.09	0.09	0.26
Education				
Primary	0.04	0.02	0.02	0.04
Secondary	0.33	0.28	0.25	0.36
Tertiary	0.63	0.70	0.73	0.60
Household Composition				
No children	0.56	0.45	0.38	0.32
Children	0.44	0.55	0.62	0.68
1 adult	0.11	0.12	0.13	0.14
2+ adults	0.89	0.88	0.87	0.86
Income Distribution				
Q1	0.02	0.00	0.02	0.07
Q2	0.07	0.05	0.08	0.18
Q3	0.28	0.26	0.26	0.40
Q4	0.63	0.69	0.64	0.35
Region				
BMW	0.29	0.26	0.19	0.18
Dublin	0.34	0.36	0.34	0.20
ME MW SE SW	0.37	0.38	0.46	0.62
Vintage				
<10 years	0.45	0.41	0.49	0.61
≥10 years	0.55	0.59	0.51	0.39
No. Obs.	358	358	358	358

We calculate the increase in predicted probability of arrears for each household and split the sample into quartiles (Q1 least severe - Q4 most severe) and then report the share of households by socio-economic groups for each quartile of Δ predicted probability of arrears.

To perform the interest rate shock simulations, we first estimate a baseline predicted probability of arrears and then shock the interest rate and re-calculate a new DSR. The re-calculated DSRs are then combined with the values of other controls, and the estimated parameters from the logit specification, to estimate a new predicted probability of arrears

for each household, i in year t. This enables us to calculate the increase in the predicted probability of arrears for each household and to split these households into quartiles. This gives us a measure of the severity of the increased probability of falling into arrears, with households in Q1 facing the least severe increase in predicted probability of arrears, and those in Q4 facing the most severe impact. In Table 12, using a 50 basis point increase in the interest rate, we examine the share of households in each of these four quartiles by a series of socio-economic characteristics in order to identify which types of households are most vulnerable to a policy rate rise.

Several key findings emerge from Table 12. One of the most striking findings is that the 35 per cent share of young households, those aged 18-35, in Q4 is at least double that in any of the other quartiles, suggesting that young households are likely to be particularly vulnerable to a rise in interest rates. Turning to the income distribution, we see that in general the majority of mortgage holders are typically found in the top quartile of the income distribution, with the share roughly between 60-70 per cent. However, for those most affected by the interest rate shock, Q4, this share falls to 35 per cent, with these Q4 households over-represented in all of the lower quartiles of the income distribution. In terms of household composition, there appears to be little difference across one and two adult households, but households most vulnerable to an interest rate rise are more likely to have children. We also observe a higher share of households in Q4 with a loan vintage of fewer than ten years. However, drawing any conclusions from loan vintage is complicated due to the large number of bad loans issued under loose credit conditions in the early to mid 2000s. In Table 16 in the Appendix we explore the issue of loan vintage further and show that households with a loan vintage$>$10 years actually have a higher predicted probability of arrears, but that households with a loan vintage$<$10 years see the largest increases in their predicted probability of arrears under an interest rate shock. This is consistent with our finding that younger households are particularly vulnerable to a rise in interest rates.

Taken together, the findings on age and a household's position in the income distribution are consistent with a life cycle earnings explanation. Younger households at the beginning of their careers, would likely expect to see their incomes rise in the future, but are likely to currently face higher debt service ratios than an older household which may have seen their debt service ratio decrease through time as a result of rising income. This results in younger households having less capacity to absorb any potential rise in their debt service ratio as a result of a policy rate rise.

6 Conclusions and Policy Implications

In this paper, we use detailed household survey data for Ireland to assess the link between mortgage repayment capacity and arrears. Given the scale of the Irish mortgage market difficulties in recent times, understanding the channels through which vulnerabilities may arise in the market is of considerable importance for financial stability policy.

The high level of indebtedness across Irish households, and the particular interest rate type structure which contains vulnerable tracker borrowers and a high share of variable rate mortgages, leaves specific exposures in the Irish market to potential interest rate reversals. Given the current low interest rate environment, many Irish households, in particular tracker borrowers have benefited considerably from lower rates. However, any potential monetary policy normalisation scenario would certainly higher their repayment burden and reduce their repayment capacity.

Using an empirical model designed to capture current repayment shocks, we test the impact of a range of monetary policy normalisation scenarios on the predicted probability of mortgage arrears for Irish households. We conduct three interest rate shocks: 25, 50 and 100 basis points. Each of these scenarios are conducted under the assumptions of both full pass through for all interest rate types and then with a differential pass through to reflect the different interest rate types across the Irish mortgage market.

Our estimates of the percentage point increase in the arrears flow of Irish mortgages range from 0.1 percentage points for a 25 basis points shock to 0.5 percentage points for a 100 basis points shock with differential pass through. Taking the middle ground of a 50 basis point shock, for 2016 our estimates show a 0.2 percentage point (8 per cent) increase under differential pass through, and a 0.34 percentage point (13 per cent) increase in the arrears flow for a shock applied equally to all households. The relative variance in the estimates reflects the non-linear nature of the impact of interest rates as well as the uncertainty about the sensitivity of lending rates to changes in the policy rate for non-tracker borrowers. We also find that even fairly substantial income growth would not offset or compensate for the additional stress on Irish households resulting from a rise in interest rates because even a moderate rise in the policy rate causes mortgage instalments to rise far more sharply than incomes, causing a deterioration in the debt service ratio. Naturally, rising incomes would be supported by a falling unemployment rate and rising house prices which would further result in lower arrears in a recovering economy but the point remains that debt-service burdens are more sensitive to rate changes than income changes. Finally, we explore the heterogeneous exposure of the shocks across households and find that in particular young households, low income households and those early in the loan age distribution are most at risk of falling into arrears on their mortgage payments as a result of a rise in interest rates.

A number of implications for policy stand out. First, the inevitable monetary policy normalisation that will occur in the medium term poses considerable risk for Irish households and a continued deleveraging process for those with legacy debts is prudent. Second, the scale of the impact on mortgage arrears is large due to the non-linear relationship between interest rates and repayment difficulties. In this regard, increases in the policy rate will be compounding and the impact will increase over time, ceteris paribus. Third, the scenarios highlight the precarious nature of repayment burdens for non-fixed rate borrowers, particularly younger and low income borrowers. Expanding the share of fixed rate loans in the Irish market and the length of the fixed term would provide more stability,

certainty and security in future, by limiting these at risk groups' exposure to policy rate changes.

7 Appendix

Table 13: Baseline Results - Additional Covariates

	(1) Stocks	(2) Flows
L.Unemployment Rate	0.838***	0.498***
	(0.170)	(0.148)
L.GVA Growth	-0.109**	-0.119**
	(0.0554)	(0.0474)
L.Log GDP per capita	0.0769	0.0785
	(0.0597)	(0.0509)
18-35		
36-50	-0.0219	-0.0225**
	(0.0136)	(0.0110)
>50	0.00296	-0.00998
	(0.0232)	(0.0175)
Married		
Single	0.0161	0.00491
	(0.0176)	(0.0161)
Widowed/Separated/Divorced	0.0623**	0.00717
	(0.0249)	(0.0160)
Primary		
Secondary	-0.0152	-0.0116
	(0.0234)	(0.0225)
Tertiary	-0.0235	-0.0185
	(0.0239)	(0.0232)
1 adult, no children		
1 adult, 1+ children	0.0982***	0.0318
	(0.0371)	(0.0227)
2+ adults, no children	0.0329**	0.0112
	(0.0148)	(0.00942)
2+ adults, 1+ children	0.0572***	0.0298**
	(0.0181)	(0.0132)
L.CLTV < 80		
L.CLTV $80 - 100$	0.0173	0.00204
	(0.0179)	(0.0129)
L.CLTV > 100	0.0667***	0.0146
	(0.0171)	(0.0113)
Employed		
Unemployed	0.110***	0.0624**
	(0.0316)	(0.0308)
Other	0.0589***	0.0211
	(0.0174)	(0.0141)
L.Log Real HH Income	-0.0508***	-0.0124
	(0.0137)	(0.0103)
L.Debt Service Ratio	0.233***	0.100***
	(0.0485)	(0.0387)
Δ Debt Service Ratio	0.239***	0.122***
	(0.0564)	(0.0475)
Observations	4,749	4,239

Table 14: Predicted Probabilities of Entering Mortgage Arrears Under Interest Rate Shock Scenarios Excluding Households with Mortgage Top-ups

Year	Baseline Predicted Probability	Interest Rate Shock 25bps	50bps	100bps	No. Obs.
2014	0.0512	0.0531	0.0554	0.0605	235
2015	0.0454	0.0470	0.0489	0.0532	373
2016	0.0276	0.0287	0.0299	0.0327	354

Table 15: Predicted Probabilities of Entering Mortgage Arrears Under Interest Rate Shock Scenarios with Equivalent Rise in Incomes

Year	Baseline Predicted Probability	Interest Rate Shock 25bps	50bps	100bps	No. Obs.
2014	0.0489	0.0507	0.0528	0.0574	317
2015	0.0429	0.0443	0.0459	0.0493	490
2016	0.0266	0.0276	0.0286	0.0309	451

Income growth equivalent to interest rate shock i.e. a 25bps increase in the interest rate is accompanied by a 25bps increase in income.

Table 16: Predicted Probabilities of Entering Mortgage Arrears Under Interest Rate Shock Scenarios by Loan Vintage

Year	Baseline Predicted Probability	Interest Rate Shock 25bps	50bps	100bps	No. Obs.
		Loan Vintage $< 10 years$			
2014	0.0549	0.0575	0.0602	0.0665	165
2015	0.0402	0.0420	0.0439	0.0483	203
2016	0.0232	0.0243	0.0254	0.0282	151
		Loan Vintage $>= 10 years$			
2014	0.0408	0.0420	0.0435	0.0469	152
2015	0.0453	0.0466	0.0481	0.0513	287
2016	0.0288	0.0298	0.0309	0.0332	300

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