04/RT/2017

Páipéar Taighde Teicniúil
Research Technical Paper

How does monetary policy pass-through affect mortgage default? Evidence from the Irish mortgage market

David Byrne, Robert Kelly and Conor O'Toole

Banc Ceannais na hÉireann
Central Bank of Ireland
Eurosystem

How does monetary policy pass-through affect mortgage default? Evidence from the Irish mortgage market

David Byrne[a], Robert Kelly[a] and Conor O'Toole[b*]

[a] Monetary Policy Division, Central Bank of Ireland
[b] Financial Stability Division, Central Bank of Ireland

March 2017

Abstract

One channel through which monetary policy can affect loan default in the mortgage market is by altering the affordability of borrower repayments. Quantifying the exact impact of this relationship is complex as it depends on both the structure and pass-through of a given mortgage market. This paper uses a quasi-natural experiment to identify the impact of changes in interest rates on mortgage default. Using a panel of loan level administrative data for Ireland, we deal with selection bias that is inherent in identifying the impact of interest rates by exploiting the variation between two types of adjustable rate mortgage that were offered to Irish borrowers for a particular period in the mid-2000s. We map changes in interest rates to default by quantifying the direct effect through changes in borrower installments. Using a pass-through approach, we find a strong and highly statistically significant impact of interest rates on mortgage default, with a 1 per cent reduction in installment associated with a 5.8 per cent decrease in the likelihood of default over the following year. We also find evidence that negative equity offsets the some of the gains arising from lower policy rates indicating an interaction between monetary policy and asset price shocks in the mortgage market.

JEL Classification: E52, E58, G01, G21
Keywords: Monetary Policy, Mortgage Default

[*] E-mail: david.byrne@centralbank.ie; robert.kelly@centralbank.ie & conor.otoole@centralbank.ie. The views presented in this paper are those of the authors alone and do not represent the official views of the Central Bank of Ireland or the European System of Central Banks. Any remaining errors are our own.

Non-Technical Summary

After the global financial crisis, central banks loosened monetary policy considerably. This paper examines the extent to which the decline in monetary policy rates caused default rates on mortgages to be lower, through decreases in the interest rates on mortgages.

Quantifying the exact nature of the relationship between monetary policy affects mortgage default rates is challenging. This is due to the fact that the relationship depends on the type of mortgages products which are prevalent in the market, and the extent to which the mortgage contracts allow the mortgage interest rate to change when the monetary policy rate changes. A further difficulty arises from concerns that the type of mortgage product chosen by a borrower may be linked to how credit-worthy the borrower is, and thus bias later analysis of differences in default rates between mortgage types.

The Irish mortgage market provides a unique opportunity to examine this question. For a limited time, two similarly-priced variable rate mortgage contracts were offered, which experienced different interest rate paths since origination. For research purposes, these developments are closer to the idealised randomised interest rate changes than previously studied in the literature. Using a comprehensive loan level dataset of Irish mortgages, for each borrower we calculate the changes in monthly installment resulting from changes in interest rate. We then identify how changes in installment affect the likelihood of default, mitigating bias which could arise from borrowers' choice of mortgage type. We find that a 1 per cent reduction in mortgage installment is associated with a 5.8 per cent decrease in the likelihood of default over the following year. We find that this effect is diminished somewhat when the loan is in negative equity.

These findings have a number of implications for the functioning of monetary policy and financial stability policy. While the main objective of monetary policy is not to deal with legacy mortgage issues, it is nonetheless an important channel through which rate changes can impact economic activity. This paper shows that default rates are impacted by pass-through of lower rates. An accommodative monetary policy is therefore pro-stability through this channel reducing the risk of mortgage delinquency and the resulting impairment of bank balance sheets. The net effect is enhanced functioning of the bank lending channel, aligned with the aim of a period of expansionary monetary policy.

1 Introduction

A combination of housing booms and a concentration in property lending has called into question the health of bank balance sheets in many OECD countries such as Spain, Ireland and the United States. One potential relief is the extensive monetary policy loosening undertaken by Central Banks in most major economies since the onset of the global financial crisis in 2007. The direct impact of these accommodative measures is reduced bank funding costs but another important channel is the potential impact on loan delinquency, particularly in the mortgage market.

It is empirically challenging to test the link between mortgage distress and monetary policy as it depends on both the structure and pass-through of a given mortgage market (Hancock and Passmore, 2011). For example, quantifying the impact of Federal Reserve monetary policy actions post-crisis is difficult as the nature of the US mortgage market, characterised by 30 year fixed loans, suffers a severe selection bias. This arises as refinancing is required to take advantage of the lower debt servicing cost and policy rate changes are not automatically passed through to borrowers. The ability to refinance is limited to customers with no deterioration in credit score and/or negative equity; arguably the individuals with must to gain from reduced installments. Ideally, accurate assessment of this channel requires a market operating with full pass-through of policy rate changes for a random selection of borrowers and the remainder unaffected by the policy rates as a control group.

While no mortgage market will ever meet this criteria, the structure of the Irish mortgage market provides a unique opportunity as two similarly priced variable rate mortgage contracts were offered at the same time for a limited period and, since origination, have experienced very different rate paths. In this paper, we exploit the quasi experiment variation between these two variable rate contracts to identify the impact of changes in interest rates on mortgage default. We use a panel of loan level administrative data for Ireland and deal with selection bias that is inherent in identifying the impact of interest rates by exploiting the variation between these two types of adjustable rate. We map changes in interest rates to default by quantifying the direct effect through changes in borrower installments.

Our paper is linked to the broad body of research considering the triggers of mortgage default. Given the role played by housing finance in the global crisis (Mian and Sufi, 2009, 2011), a number of papers have considered such triggers focusing on both unemployment and house price declines (Haughwout et al., 2008; Gerardi et al., 2008; Jiang et al., 2013, 2014). In general, this research finds a role for both equity and income channels. Elul et al. (2010) find an impact of both illiquidity and equity in driving default. Mayer et al. (2009) assess loan performance for sub-prime borrowers in the US following the 2007 crisis and find that housing equity played a considerable role in driving default. Foote et al. (2008) also find negative equity to be a driving factor while Gyourko and Tracy (2014) note the income channel, and it's measurement, is important. Irish-specific studies include Kelly and O'Malley (2016) and Lydon and McCarthy (2013) who also identify equity and unemployment shocks in mortgage default models. Additionally, the paper is linked to the very extensive literature of pass-though of policy rates to lending rates. Ciccarelli et al. (2014) show from 2000 to 2007 euro area monetary policy pass-though is relatively homogenous across countries. Hristov et al. (2014) document how this almost complete pass-though pre-2007, became significantly distorted in the period thereafter, hampering the effectiveness of monetary policy. This distortion is typified by the divergence in mortgage interest rates between the two groups of Irish mortgage holders.

However, none of the aforementioned studies identify the impact of interest rate shocks on default. Given the very extensive loosening of monetary policy globally, understanding the interest rate channel in the default story is important. This is particularly the case given its ability to potentially offset income or equity shocks. One difficulty for researchers identifying this channel using micro data has been the selection bias arising from the type of mortgage interest rate contract into which they enter. The broad literature on mortgage contract choice highlights that borrowers' self select into the type of interest rate contract (usually choosing between fixed or adjustable rates) depending on their risk tolerance, personal characteristics and expectations about the path of inflation and nominal interest rates (Campbell and Cocco, 2003; Bacon and Moffatt, 2012). Research also indicates that this selection can be correlated with ex-post loan performance (Campbell and Cocco, 2015); From a credit risk perspective, the endogenous selection into rate types can reveal the risk tolerance of the borrower which impacts their future decision to default. This leads to biased estimates of the coefficients on interest, unemployment and equity shocks. Furthermore, within the group of adjusting mortgages, lenders typically pass official rate changes through to all loans in a similar fashion making measuring the potential impact of rate changes difficult.

One paper which attempts to isolate the impact of the interest rate channel for the US is Fuster and Willen (2013). For a group of loans with interest rate resets[1], they exploit the timing of rate resets to test the impact of payment size reductions on default. However, the upward only rate resets leads to a stark increase in prepayments before the reset and factors determining prepayment and default are closely (negatively) associated (Sengupta and Bhardwaj, 2015). By comparison, the dominance of variable rate contracts in Ireland removes this prepayment incentive.

Within this context, our contribution is as follows. Using administrative loan level data covering the majority of Irish mortgages, we exploit a specific aspect of the Irish mortgage market to deal with selection bias into rate types. For a very specific period (2003-2008) in the Irish mortgage market, two different groups of adjustable rate mortgage contracts were offered to borrowers. The first group

[1] These loans are commonly referred to as Hybrid ARM (adjustable rate mortgage) contracts, with a typical initial period of fixation of 1 to 5 years followed by rate change. They account for approximately 8 per cent of US mortgages (source: Monthly Interest Rate Survey of the Federal Housing Finance Agency) and Elliehausen and Hwang (2010) discuss their popularity during the 2000s growth of the sub-prime lending.

hold "standard variable rate" (SVR) mortgage contracts which have a floating interest rate set at the discretion of the bank. The second group hold "Tracker" interest rates which have a fixed margin above the ECB monetary policy base rate. Normally, both of these rates follow developments in the policy rate and borrowers interest rate expectations at origination would have been similar for both. However since the crisis, SVR rates have not fallen in line with policy rates while Tracker rates, by design, have. This provides an empirical context whereby two variable rate holders have experienced considerably different interest rate paths since the crisis: SVRs are paying significantly higher interest rates compared to the Tracker group.

While the selection between trackers and SVRs is potentially not truly random (being determined by borrower and bank factors), our empirical strategy uses inverse probability weighting to mitigate the selection bias between mortgage contract type. For a panel of borrowers, it is possible to estimate the impact of changes in the interest rate on mortgage default. From negligible differences at origination, the rate gap between the two groups shows an average difference of 290 basis points and a 4.3 percentage point difference in default rates having controlled for potential selection criteria such as originating loan to value and borrower income. In terms of the role played by lower rates, a 1 per cent reduction in installment lowers the annual transition to default from 2.3 to 2.1 per cent. We find evidence for the "double trigger" of affordability and equity shocks, with negative equity offsetting the some of the gains of lower policy rates.

The rest of this paper is structured as follows: Section 2 presents the data and an overview of the Irish mortgage market. Section 3 outlines the empirical strategy. Section 4 presents the results while section 5 concludes.

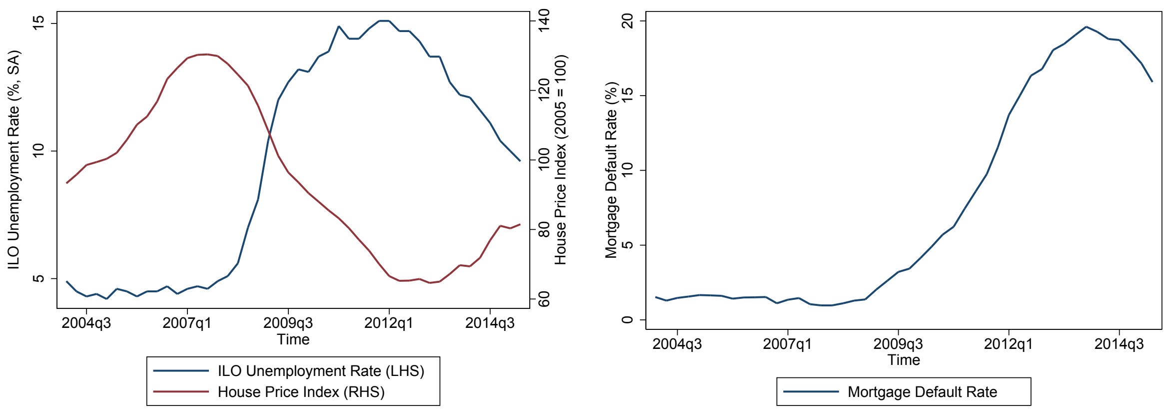
2 The Irish Mortgage Market As a Quasi-Natural Experiment

2.1 The Irish Market: An Overview

The Irish mortgage market provides an interesting case study with which to evaluate the impact of interest rate shocks on mortgage default. Ireland suffered a severe banking and sovereign debt crisis following the global financial difficulties in 2007. Real economy shocks were severe with considerable declines in disposable incomes, stark increases in the unemployment rate and large house price declines. Figure 1a presents the increase in the unemployment rate juxtaposed with the evolution of the house price index to provide some context as to their severity.

Such shocks to the "triggers" of mortgage default led inevitably to a large increase in the number of loan delinquencies. Figure 1b uses data from the Moody's RMBS pools to provide an overview of the evolution of mortgage default in Ireland. While these data do not correspond to the whole

(a) Evolution of House Prices and Unemployment (b) Residential Mortgage Defaults



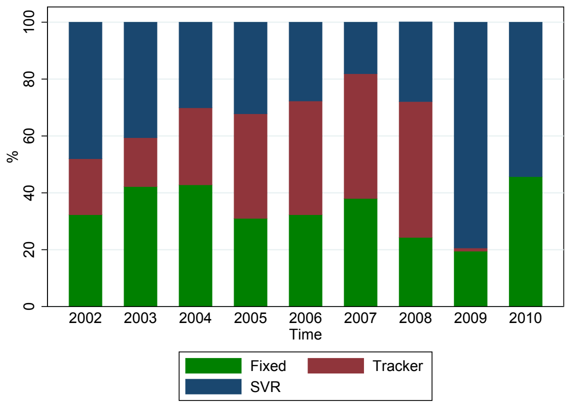
market, the are representative of the broader trends and highlight the scale of the deterioration in the Irish residential housing loan market. At the peak, approximately 17 per cent of the total stock of outstanding residential mortgages were in arrears.[2]

Coupled to these income and affordability shocks in Ireland, current mortgage holders experienced very divergent impacts of the interest cost of their liabilities depending on the type of interest rate they held. In Ireland, three main types of loan contract were issued to borrowers at origination: a) standard variable rates (SVRs) b) "Tracker" rates and c) fixed rates mortgages. The shares of each rate type which were allocated at mortgage origination are presented in Figure 2a and a detailed discussion can be found in Kelly et al. (2015). The Irish market traditionally used SVR interest rates whereby the borrower agreed to pay a floating interest rate which could be changed at the discretion of the lending institution but nominally followed the policy rate. A special "Tracker" rate was introduced into the market by one particular bank early in the 2000s. Due to competitive pressures other banks began to follow suit and provide this product, however, since the onset of the crisis, it is no longer available to new mortgage customers.

To understand the link between monetary policy and mortgage default, our interest focuses on borrowers who chose either standard variable rate mortgages or Tracker rates. Traditionally, both of these rate types would experience "pass through" of monetary policy rate changes to the borrower, in the Tracker case this was contractually specified. As fixed rate customers do not experience such a pass through, they are not the focus of our analysis. Our identification using a "quasi" natural experiment is motivated by two aspects of the market. First, the fact that two variable rate mortgages were in existence in the market for a short period and second the divergent path of the interest rate on these two products since the crisis.

[2]See the Central Bank of Ireland's *Household Credit Market Report* for more details.

(a) Interest Rate Types at Origination



(b) Interest Rates by Mortgage Type

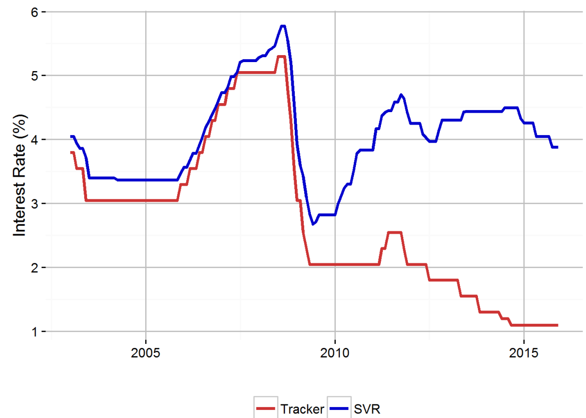


Figure 2b presents the weighted average interest rate on new SVR lending between 2003 and 2015. We also include an indicative interest rate for Tracker mortgage lending, calculated as the sum of the ECB MRO rate and the average Tracker rate premium over the MRO throughout the sample, which is approximately 1 per cent. It can be seen that the Tracker and SVR rates were similar and moved in tandem through the early part of the sample, but diverged in the later period, with SVR rates decoupling from both Tracker rates and the MRO. With SVRs, the banks are not contractually obliged to pass through monetary policy developments. In recent periods, due to a confluence of factors such as low competition, a desire to boost profitability and a lack of switching influenced by negative equity[3] banks have not passed through the reductions in the policy rate to SVR holders, while Tracker mortgage holders automatically experience such pass through. Consequently, the borrowers holding these two mortgage contract types have experienced divergent shocks to their mortgage affordability with Tracker holders seeing affordability increase as interest payments have fallen while SVR borrowers have seen rates rise and affordability decrease. This setting provides an ideal quasi-natural experiment to test the impact of rate changes on these two groups of borrowers.

2.2 Data and Summary Statistics

This research uses a population of loan-level data from four major banking institutions in Ireland: Allied Irish Banks (AIB, including EBS Building Society), Bank of Ireland (BoI), and Permanent TSB (PTSB). These institutions account for approximately 66 per cent of the Irish residential mortgage market. These loan-level data (LLD) were first provided by the institutions to the Irish Central Bank

[3]The Central Bank of Ireland explored the drivers of the changes in SVRs in a report entitled "Influences on Standard Variable Rate Mortgage Pricing in Ireland" published in 2015. Please see this report for more detail.

following the Financial Measures Programme which assessed bank restructuring, recapitalisation and conducted stress testing following the recent systemic banking crisis. The LLD contain full information on the originating characteristics of each mortgage at these institutions, e.g. the balance drawn-down, LTV & LTI ratio, mortgage term and interest rate type; a range of borrower-specific information such as borrower age, income at origination, marital status and whether they were joint or single-assessed; and data on the dwelling the loan is used to acquire, such as the county of location, purchase price and whether the property is an apartment or house. Data is also available on the employment status of the borrower at origination (employed, self-employed, other).

Our data are in quarterly panel form, including up-to-date information on collateral valuations, the performance status of each loan and the interest rate on the loan. We limit the sample to loans originating between 2003 and 2008 with loan performance as of December 2015. Due to legal complications, repossession was not possible in Ireland in this period.[4] As a result, repossessions are not a source of survival bias in our data. In total, the sample contains 157,352 loans, with the panel comprising 3,618,558 observations. Figure 3 displays the quarterly transitions into default over the sample period, conistent with the worsening of the Irish housing market until 2013 and the lower levels of new defaults since, with an average of 2.3 per cent of loans defaulting over a 12 month period.

Figure 3: Transitions to Default by Quarter

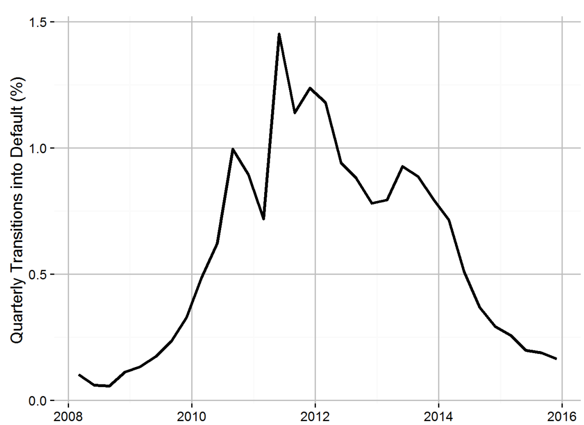


Table 1 contains summary statistics from the LLD, with the developments since origination calculated as of the end of our sample. As of December 2015, the default rate among SVR loans was 9.36 per cent, with the default rate among Tracker loans 3.36 percentage points lower at 5.99 per cent. The average change in interest rate for SVR loans, between origination and December 2015, was a decrease of 15 basis points. The corresponding decrease for Tracker loans was 305 basis points. These map

[4] On July 25th 2011, Justice Dunne ruled that a lending institution cannot apply for a repossession order on a mortgage created before 1st December 2009. In early 2013, the Irish Government published new legislation, allowing banks to take possession of properties attached to delinquency loans.

into average installment changes of -0.39 per cent and -29.92 per cent for SVR and Tracker mortgages, respectively.

Table 1: Loan Level Data Summary Statistics

	SVR	Tracker	Difference
Default Rate (%)	9.36	5.99	3.36***
Originating Characteristics			
Interest Rate (%)	3.49	4.21	−0.72***
Income (€,000)	62.26	75.24	−12.97***
DSR (%)	17.18	20.90	−3.72***
OLTV	57.39	63.25	−5.85
Loan Size (€,000)	169.52	232.22	−62.70***
FTB (%)	35.13	39.57	−4.44***
Age (years)	36.73	36.07	0.66***
Dublin (%)	22.31	25.41	−3.09***
2003 (%)	13.41	1.94	11.47***
2004 (%)	13.41	8.61	4.81***
2005 (%)	19.23	18.02	1.21***
2006 (%)	21.12	26.01	−4.89***
2007 (%)	15.62	23.67	−8.05***
2008 (%)	17.21	21.76	−4.56***
Developments since Origination			
ΔRate (pp)	−0.15	−3.05	2.90***
ΔInstallment (%)	−0.39	−29.92	29.53***
Negative Equity (%)	19.85	20.80	−0.95***
N	66736	56744	

Note: Significant differences based on t-tests on the equality of means.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3 Empirical Model and Identification Strategy

A key aim for our research is to identify the impact of mortgage interest rate differentials on the probability of mortgage default. We focus on loans originating in the six-year period between 2003 and 2008 in which two variants of adjustable-rate mortgages were offered to Irish borrowers: Tracker mortgages, which follow movements in the interest rate on Main Refinancing Operations (MRO) at a fixed margin, and Standard Variable Rate (SVR) mortgages. Given the path of the MRO rate between the origination period and 2015, a divergence emerged in the interest rates on Tracker and SVR mortgages. We use this divergence to identify the impact of changes in interest rates on the probability of default. Our data allows us to derive, for each individual loan, how a change in interest rate maps into a change in the installment of the loan. This is important given that the change in installment is a non-linear function of the change in interest rate, and depends on the size of the loan amongst other factors. This allows us to identify how an interest rate change, which may be common to many loans, affects the affordability of each individual loan. Throughout the following, we make use of the individual-specific installment changes rather than changes in mortgage interest rate.

3.1 Assignment Model

To make the cleanest causal inference, random assignment of individuals between the two contracts is required. Given the dataset contains common factors upon which selection may occur, a test of whether mortgage type is not randomly assigned takes the form of a model predicting Tracker selection, as follows:

$$Pr(Tracker_i = 1) = \mathbf{F}(Income_i, LTV_i, Age_i, FTB_i, LoanSize_i) \tag{1}$$

where $Income_i$ is the household income at origination, LTV_i is the originating loan-to-value ratio, Age_i is the age of the borrower, FTB_i is a dummy variable representing First Time Buyer status, and $LoanSize_i$ is the size of the loan balance at origination. This formulation allows us to capture both an income channel and a proxy wealth channel, i.e., via the equity share of the borrower. If any of these factors are found to significantly explain selection, assignment is not as good as random.

This same test, however, also provides us with a method to correct for non-random assignment. For each loan in our sample, we may estimate the predicted probability, or the propensity score, p_i, of assignment to a Tracker mortgage contract. Propensity score matching methods then allow us to estimate the impact of monetary policy on mortgage default by exploiting the divergence in interest rates between the treatment group (Tracker mortgages) and control group (SVR mortgages). Ex-ante, we expect to find a negative Average Treatment Effect on the Treated (ATT); the treatment group should have a significantly lower default rate.

Next, to quantify the relative importance of interest rate and equity shocks, we estimate a mortgage default model. Using the predicted probabilities from the assignment model, we can mitigate selection bias in the default model by constructing appropriate probability weights (Wooldridge, 2007; Imbens and Wooldridge, 2009). For each loan in the loan-level data, we define a weight, w_i, as follows:

$$w_i = \begin{cases} 1/p_i & \text{if Tracker mortgage;} \\ 1/(1-p_i) & \text{if SVR mortgage.} \end{cases} \tag{2}$$

3.2 Default Model

Our empirical approach uses a standard model of default which is common in the existing literature (Jiang et al., 2013, 2014; Haughwout et al., 2008). Let NP_i^* be the censored underlying latent propensity to delinquency for mortgage i. An observed indicator of default, NP_i, then takes the values:

$$NP_i = \begin{cases} 1 & \text{if } NP_i^* \geq 0; \\ 0 & \text{if } NP_i^* < 0. \end{cases} \tag{3}$$

Our baseline default model is a survival panel in the form of a Cox regression with both time-invariant and time-varying covariates. We model the hazard of household mortgage default as a function of the change in the mortgage installment in response to an interest rate shock within the last year, the cumulative change in installment due to rate movements since origination, the equity position, unemployment, and of loan and borrower characteristics both at loan origination, as follows:

$$Pr(NP_{it} = 1) = \mathbf{F}(\mathbf{X}_i, \mathbf{Z}_{i,t}; w_i) \tag{4}$$

$$\{\Delta Installment_{i,t-j}, \sum_{t=0}^{t-5} \Delta Installment_{it}, LTV_{i,t-1}, Unemployment_{t-1}\} \in \mathbf{Z}_{i,t} \tag{5}$$

where $\mathbf{X}_i$ contains a vector of loan and borrower variables measured at origination, including household income, interest rate, term, borrower age, originating LTV, originating LTI, the debt service ratio and binary indicators for first time buyer status, whether the loan was based on a joint application, bank of origination and mortgage type. $\mathbf{Z}_{it}$ contains a vector of time-varying controls, including the variables of interest as outlined in equation (5), and lags and interactions of the key variables. As discussed above, we use Inverse Probability Weighting methods, with w_i being the probability weight variable.

In equation (5), $\Delta Installment_{i,t-j}, j \in \{1, 4\}$ represents the change in installment on the mortgage resulting from an interest rate shock within the last 4 quarters, $\sum_{t=0}^{t-5} \Delta Installment_{it}$ represents the cumulative change in installment for loan i due to the monetary policy stance since mortgage origination and $LTV_{i,t-1}$ is the equity position of the mortgage. We lag all variables by one quarter given that it takes non-performance for 90 days for a loan to be classified as being in default. Our a-priori expectations for the signs on these variables are:

- H1: $\beta_{\Delta Installment_{i,t-j}} > 0$
- H2: $\beta_{\sum_{t=0}^{t-5} \Delta Installment_{it}} > 0$
- H3: $\beta_{LTV_{i,t-1}} > 0$.
- H4: $\beta_{Unemployment_{t-1}} > 0$

H1 states that default is increasing in changes in the installment due to interest rate shocks, H2 states that default is increasing in the cumulative change in installment, H3 states that default is increasing in changes in equity, i.e. through falling house prices, and H4 states that default is increasing in the unemployment rate, equivalently that default is decreasing in changes in household income. In our default model, equation (4) takes the functional form given by (6):

$$h(t) = h_0(t)exp\{\beta\mathbf{X}_i + g(t)(\gamma\mathbf{Z}_i)\} \tag{6}$$

where $h_0(t)$ is the baseline hazard function and $g(t)z_i = z_i(t), \forall i \in \{1, m\}$ are time-varying covariates.

We undertake a range of robustness checks to test for stability in our estimates of the impact of changes in installment on default, presented in Table 4 and Table 5. We include a number of specifications of the equity channel on default and include the originating debt-service-to-income ratio, to capture the interaction between the originating risk factors on which it is based. We also include interactions of a dummy for being in negative equity, and the continuous equity measure, to investigate "double trigger" effects between the equity position and affordability position of a loan.

In Table 5 we use a survey of a representative sub-sample of borrowers which provides us with up-to-date data on household income, to examine the relationship between income shocks and interest rate pass-through. This allows us to investigate a potential source of bias from a correspondence between income shocks and periods of interest rate resets. We then re-estimate the default model on this sub-sample of borrowers, to show that our findings are robust to the inclusion of income shock data.

4 Results

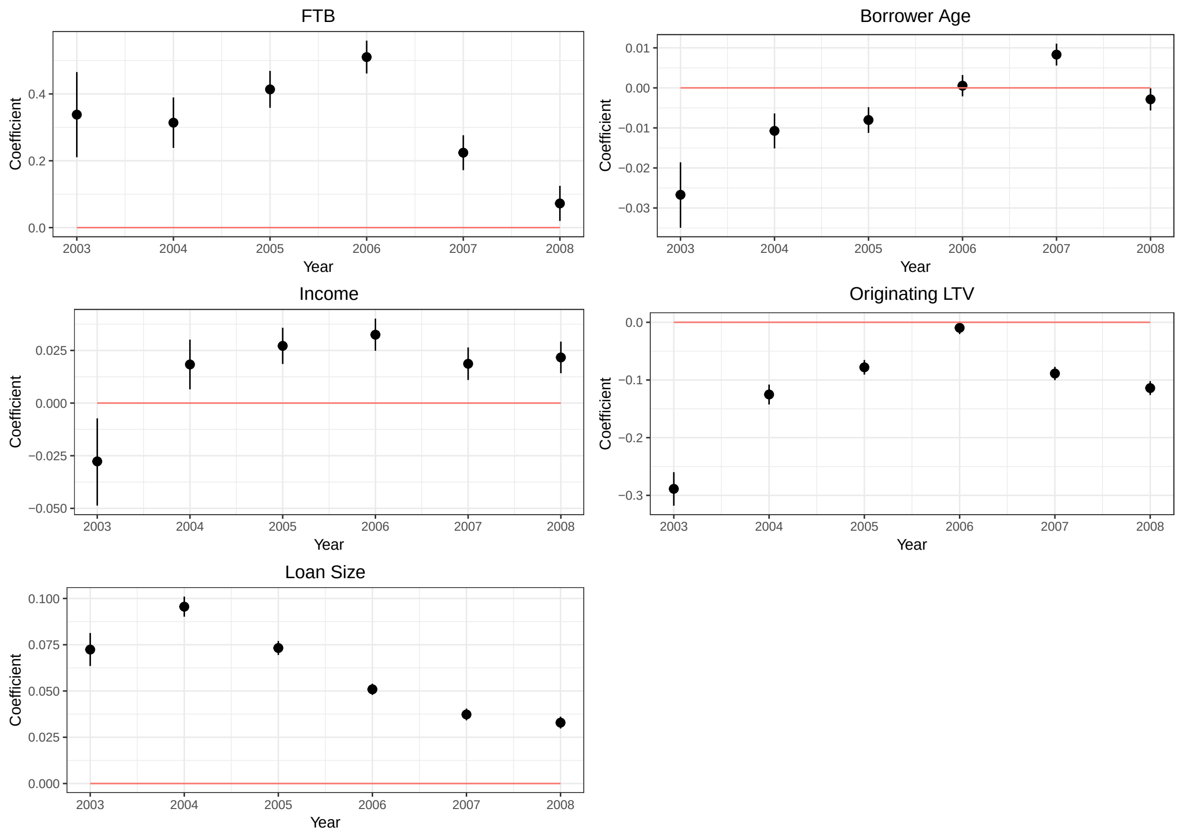
4.1 Assignment Model Estimates

The assignment model outlined in Section 3.1 focuses firstly on the randomness of selection into the Tracker mortgage group and secondly, provides a method to control any non-random assignment. Only origination loan characteristics can be considered. We estimate the model on the full administration loan level dataset. We estimate the model separately for each year between 2003 and 2008, to allow for the fact that the relationships between the explanatory variables and tracker mortgage status may differ through time[5]. Figure 4 includes plots of the coefficients, and the associated 95% confidence interval, for each variable and year.

From Figure 4, we observe that first time buyers have a significantly higher probability of having Tracker mortgage type in each year. The magnitude of this premium varies between 7 and 50 percentage points. For each year, we find that larger loan balances at origination are correlated with Tracker status;

[5] As a robustness check, we also estimate the assignment model in a pooled regression over years, including a full set of year dummies and their interactions with the explanatory variables. The results remain unchanged.

Figure 4: Coefficients from Assignment Model on Tracker Probability by Year



a €10,000 increase in loan size results in an increase in Tracker probability by between 3.3 and 9.6 percentage points, by year. The originating LTV ratio, frequently used as a proxy for borrower wealth through the ability to provide greater down-payments, also has a significant impact in all but one year. We find that a 10 percentage point increase in the originating LTV ratio is associated with an average decrease of 11.7 percentage point decrease in Tracker mortgage probability. In all but one year, income is associated with a significant increase in Tracker probability, with an average magnitude of the 2 percentage points for an increase of €10,000.

Having modelled the probability of selection into the mortgage contract type, we use this assignment model to match borrowers and then provide an estimate of the ATT using nearest-neighbour matching. The results are presented in Table 2. As of December 2015, the default rate in the Tracker group was 5.99 per cent, while the default rate for the SVR group was 9.36 per cent. Matching on the propensity score, we find that the difference in default rates between the two groups increases from 3.4 to 4.4 percentage points, and remains highly statistically significant.

Given the results of the test for biases into the selection of contract type from the assignment model in Figure 4, one may infer that assignment into the Treatment (Tracker) and Control (SVR) groups is not random. Furthermore, from the estimated treatment effect in Table 2, one may infer the following: the selection bias inherent in choosing between these mortgage types resulted in an ex-post lower default rate for the SVR group. Ex-ante, it appears that more creditworthy borrowers chose to take out SVR mortgages. The consequence of this is a default differential between groups which understates the impact of the divergence in interest rates across the mortgage types. We thus correct for this selection bias in estimating the impact of the interest rate divergence on default rate divergence below.

Table 2: Treatment effect estimation

	Treated	Controls	Difference	Standard Error	T-stat
Unmatched sample	0.0599	0.0936	−0.034	0.0015	−22.00
ATT	0.0599	0.1039	−0.044	0.0024	−17.99

Note: ATT estimated by nearest-neighbour matching.

4.2 Baseline Default Model

In this sub-section, we present the results of our panel Cox model of mortgage default. Table 3 presents a number of default model specifications, differing in their treatment of the rate divergence. The first models the rate gap as a dummy for Tracker loans, showing a 38 per cent lower hazard, consistent with Table 2 findings. Columns (2) - (5) map rate changes to installment changes to capture the greater gain for larger loans. Column (2) defines this gain as the cumulative change in installment since origination. This provides a proxy for the total impact of having a Tracker mortgage, with default hazard adjusting by twice the cumulative installment percentage change.

Columns (3) and (4) attempt to isolate the direct effect of a rate change, using a pass-through approach, controlling for the path of rates since origination. Taking account of previous rate movements allows estimation of the impact of the rate movement over a year, with yearly hazards growing by 5.8 per cent respectively for a 1 per cent rate rise. To give context, this lowers the annual transition rate (see Figure 3) of 2.3 per cent to 2.1 per cent. Unweighted results in column (4) are consistent with Table 2 showing lower pass-through (5.1 compared to 5.8 per cent).

Table 4 investigates the robustness of the above findings (repeating column (3) of Table 3) to different specifications of originating leverage risk and housing equity. Column (2) replaces the common measures of origination risk (rate, term, loan size, income), with the originating debt service ratio to capture the combination of these risk factors. A one percentage point increase in originating DSR is reflected 1.5 times in the probability of a default transition. Column (3) attempts to control for the non-linear impact of the current loan to value ratio. We first split current LTV in categories, showing a stark increase in risk for loans with a current LTV above 130 per cent.

Table 3: Panel Default Model of Irish Mortgages Jan 2008 - Dec 2015

	Pr(Default)			
	(1)	(2)	(3)	(4)
FTB	0.681***	0.689***	0.689***	0.690***
	(0.012)	(0.012)	(0.012)	(0.016)
Single Assessment	1.007***	1.009***	1.009***	1.029***
	(0.011)	(0.011)	(0.011)	(0.016)
Dublin	0.802***	0.810***	0.810***	0.799***
	(0.014)	(0.014)	(0.014)	(0.020)
Origin Interest Rate	1.197***	1.198***	1.200***	1.194***
	(0.004)	(0.004)	(0.004)	(0.006)
Term	1.006***	1.006***	1.006***	1.007***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
oLTI	1.058***	1.054***	1.054***	1.032***
	(0.003)	(0.003)	(0.003)	(0.005)
Loan Age	1.001***	0.994***	0.994***	0.997***
	(0.0003)	(0.0004)	(0.0004)	(0.001)
Borrower Age	1.036***	1.035***	1.035***	1.035***
	(0.001)	(0.001)	(0.001)	(0.001)
cLTV	1.001***	1.001***	1.001***	1.001***
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Unemployment$_{t-1}$	1.028***	1.027***	1.027***	1.027***
	(0.003)	(0.003)	(0.003)	(0.004)
Tracker	0.619***			
	(0.011)			
Cumul ΔInstall$_{t-1}$		1.018***		
		(0.0005)		
$\sum_{i=t-1}^{i=t-4} \Delta\text{Install}_i$			1.058***	1.051***
			(0.003)	(0.004)
Cumul ΔInstall$_{t-5}$			1.019***	1.016***
			(0.001)	(0.001)
Bank FE	Yes	Yes	Yes	Yes
PSIW	Yes	Yes	Yes	No
Observations	3,456,860	3,451,809	3,450,038	3,450,038

Notes: Mortgage default, defined at 90+ days past due with the model taking the form $h(t) = h_0(t) exp\{\beta \mathbf{X}_i + g(t)(\gamma \mathbf{Z}_i)\}$, where $h_0(t)$ is the baseline hazard function and $g(t)z_i = z_i(t), \forall i \in \{1, m\}$ are time-varying covariates and columns with PSIW indicating inverse probability weighting using the model described in section 4.1. Standard errors are in parentheses and signifcance level displayed as *p<0.1; **p<0.05; ***p<0.01

In the existing literature, negative equity or equity shocks are a very commonly cited cause of mortgage default. To provide some insight into how the interest rate channel interacts with equity shocks, column (4) models the impact of negative equity and the possible interaction between equity and installment changes. A negative equity dummy, defined as loans with current LTV above 100, is used to show a 2.5 times increase in default hazard compared to loans with positive equity. One must consider the estimation period of falling rates to assess the interaction of negative equity with rate pass-through. The negative equity default incentive is offset by the release valve provided by falling installments. In contrast, rate hikes, coupled with house price falls, would cause negative equity to amplify the default effect of rate pass-through. Column (4) shows that the presence of negative equity lowers the yearly pass-through from 6.7 to 4 per cent. Finally, in column (5), we interact the continuous measure of current LTV with interest rate shocks over the past year. We again find that falling interest rates offset the incentive to default which arises from impairment of the equity channel of the loan.

4.3 Robustness Checks: Additional Survey Evidence

The above model specification depends crucially on the relationship (or lack thereof) between income shocks and interest rate pass-through. If income shocks are not random accross SVR and Tracker groups, a bias exists in estimates of the impact of identification of payment size and default. To further investigate, we draw on a second dataset, a survey of income and economic circumstances which was undertaken by the Central Bank of Ireland to understand the drivers of the Irish mortgage arrears crisis. This survey went to the field during the period May 2012 to February 2013 and targeted mortgaged households which could be linked back to the loan-level data described in Section 2.2. Approximately 1,800 households were surveyed to collect current information on employment circumstances, current income, current marital and household status, and household demographics. The survey has been used extensively in the analysis of the mortgage arrears crisis in Ireland (McCarthy, 2014; McCarthy and McQuinn, 2013) and provided the first link between mortgage arrears are current income. From our perspective, having these data allow us to disentangle income shocks from interest rate shocks in our assessment of the impact of affordability on default.

The cross-sectional nature of the survey results, with one update of individual income and unemployment status, does not provide for a robust estimate of the pass-through of rate changes. The survey information is more suited to understanding how income and unemployment shocks are distributed across groups of variable rate mortgages. Columns (1), (2) and (3) of Table 5 show no impact of significant difference across mortgage types for either individual-level unemployment or income shocks.

Table 4: Robustness Specifications for Mortgage Default Jan 2008 - Dec 2015

	Pr(Default)				
	(1)	(2)	(3)	(4)	(5)
FTB	0.689***	0.874***	0.597***	0.632***	0.595***
	(0.012)	(0.012)	(0.012)	(0.017)	(0.017)
Single Assessment	1.009***	0.941***	1.076***	1.064***	1.100***
	(0.011)	(0.011)	(0.012)	(0.016)	(0.016)
Dublin	0.810***	0.860***	0.601***	0.671***	0.555***
	(0.014)	(0.014)	(0.015)	(0.020)	(0.021)
Origin Interest Rate	1.200***		1.169***	1.171***	1.157***
	(0.004)		(0.004)	(0.006)	(0.006)
Term	1.006***		1.003***	1.005***	1.003***
	(0.0001)		(0.0001)	(0.0001)	(0.0001)
oLTI	1.054***		1.014***	1.006***	0.986***
	(0.003)		(0.004)	(0.005)	(0.005)
oDSR		1.015***			
		(0.001)			
Loan Age	0.994***	0.992***	1.001***	1.001***	1.005***
	(0.0004)	(0.0004)	(0.0004)	(0.0006)	(0.0006)
Borrower Age	1.036***	1.007***	1.037***	1.037***	1.038***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
cLTV	1.001***	1.001***			1.018***
	(0.00002)	(0.00001)			(0.00002)
$70 < \text{cLTV} \leq 90$			1.589***		
			(0.018)		
$90 < \text{cLTV} \leq 110$			2.162***		
			(0.018)		
$110 < \text{cLTV} \leq 130$			3.087***		
			(0.019)		
$\text{cLTV} > 130$			5.695***		
			(0.018)		
NE				2.588***	
				(0.017)	
$\text{Unemployment}_{t-1}$	1.027***	1.023***	1.021***	1.022***	1.018***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Cumul $\Delta\text{Install}_{t-5}$	1.019***	1.007***	1.020***	1.017***	1.017***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\sum_{i=t-1}^{i=t-4} \Delta\text{Install}_i$	1.056***	1.054***	1.044***	1.067***	1.090***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.0001)
$NE * \sum_{i=t-1}^{i=t-4} \Delta\text{Install}_i$				0.973***	
				(0.005)	
$cLTV * \sum_{i=t-1}^{i=t-4} \Delta\text{Install}_i$					0.999***
					(0.0001)
Bank FE	Yes	Yes	Yes	Yes	Yes
PSIW	Yes	Yes	Yes	Yes	Yes
Observations	3,450,038	3,448,463	3,522,196	3,600,454	3,600,454

Notes: Mortgage default, defined at 90+ days past due with the model taking the form $h(t) = h_0(t)exp\{\beta\mathbf{X}_i + g(t)(\gamma\mathbf{Z}_i)\}$, where $h_0(t)$ is the baseline hazard function and $g(t)z_i = z_i(t), \forall i \in \{1, m\}$ are time-varying covariates and columns with PSIW indicating inverse probability weighting using the model described in section 4.1. Standard errors are in parentheses and significance level displayed as *p<0.1; **p<0.05; ***p<0.01

Table 5: Robustness Checks using Additional Survey Information

	(1) Pr(Un)	(2) ΔIncome	(3) ΔIncome	(4) Pr(Tkr)	(5) Pr(Tkr)	(6) Pr(Default)
Tracker	0.007	-5.788	-8.038			
	(0.656)	(5.936)	(10.729)			
Tracker × Income			0.055			
			(0.128)			
Educ, Primary				*Omitted*		
Educ, Secondary				-0.125	-0.135	-0.128^{**}
				(0.093)	(0.0819)	(0.041)
Educ, Third Level				-0.032	-0.103	-0.192^{***}
				(0.095)	(0.095)	(0.051)
FTB					0.121^{*}	-0.072^{***}
					(0.377)	(0.021)
Borrower Age					0.001	0.001
					(0.003)	(0.002)
Income			-0.502^{***}		-0.005	0.001
			(0.112)		(0.004)	(0.001)
oLTV					-0.002^{*}	
					(0.007)	
Loan Size (€,000)					0.001^{***}	
					(0.003)	
cLTV						0.001^{**}
						(0.0003)
ΔIncome						-0.001^{**}
						(0.0002)
ΔInstall						0.002^{**}
						(0.001)
Constant		19.826	39.484			
		(12.665)	(13.504)			
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Origin Year FE	Yes	Yes	Yes	Yes	Yes	No
Observations	352	352	352	352	349	351

Notes: Models (1), (4), (5) and (6) are discrete models estimated using the logit functional form with dependent variables as the probability of unemployment, Tracker group and default respectively. The estimates are marginal effects representing the partial effects for the average observation. Models (2) and (3) are estimated using OLS with dependent variable defined as the change in income since loan origination. ΔIncome and ΔInstall is defined as the per cent difference between loan origination and end 2012 for reported income and installment level. cLTV is the loan to value at December 2012. Standard errors are in parentheses and significance level displayed as *p<0.1; **p<0.05; ***p<0.01

Understanding the potential future differences between Tracker and SVR mortgages contracts requires a high level of financial literacy and if banks acted in a predictory nature, less-informed individuals may have the SVR group. The survey allows us to investigate such potential omission from the selection model by including data on individual education level. Estimates in columns (4) and (5) show education level is not a significant determinant of being in the Tracker group at loan origination.

Finally, column (6) shows the estimates of a cross sectional default model dated December 2012. While these are not directly comparable to the panel specifications in Section 4.2, they do show the impact of cumulative change in installment is robust to the inclusion of income shocks. Comparing the two shocks, cumulative installment changes have twice the effect of income shocks, consistent with a much greater variance on the installment level compared to income.

5 Conclusion

The Irish mortgage market experienced exponential growth over the ten year period preceding the global financial crisis in 2008. Intense competition and low funding costs since the adoption of the euro drove lending margins to historical lows and lead to the creation of new products to attract customers. One outcome of this was a unique opportunity to study how the pass-through of monetary policy affects mortgage default. Two variable rate mortgage contracts were offered at the same time, by the same banks, and have experienced very different interest rate paths since origination. This paper uses administrative loan level data, covering these two groups of mortgages to estimate the impact of monetary policy on mortgage default.

While the selection between rate groups is potentially not truly random (being determined by borrower and bank factors), our empirical strategy uses inverse probability weighting to mitigate the selection bias between mortgage contract type. For a panel of borrowers, it is possible to estimate the impact of changes in the interest rate on mortgage default. From negligible differences at origination, the rate gap between the two groups shows an average difference of 290 basis points and a 4.3 percentage point difference in default rates having controlled for potential selection criteria such as originating loan to value and borrower income. In terms of the role played by lower rates, a 1 per cent reduction in installment is associated with a 5.8 per cent decrease in the likelihood of default over the following year. We also find evidence that negative equity offsets the some of the gains arising from lower policy rates indicating an interaction between monetary policy and asset price shocks in the mortgage market.

These findings have a number of implications for the functioning of monetary policy as well as financial stability policy more broadly. From a monetary policy perspective, the transmission of changes in the interest rate to the real position of borrowers will be confounded by the type of mortgage contract structure in the market. While the main objective of monetary policy is not to deal with legacy mortgage issues, it is nonetheless an important channel through which rate changes can impact economic activity. This paper has shown that default rates are impacted by pass-through of lower rates. An accommodative monetary policy is therefore pro-stability through this channel reducing the risk of mortgage delinquency and the resulting impairment of bank balance sheets. The net effect is enhanced functioning of the bank lending channel, aligned with the aim of a period of expansionary monetary policy.

6 Appendix

Table 6: Loan Level Data Summary Statistics, by origination year

	Difference (SVR - Tracker)					
	2003	2004	2005	2006	2007	2008
Default Rate (%)	5.13***	3.66***	4.3***	4.08***	4.18***	3.67***
Interest Rate (%)	−0.07*	−0.27***	−0.31***	−0.56***	−1.04***	−0.35***
Income (€,000)	−6.34***	−18.04***	−15.15***	−12.79***	−9.2***	−9.14***
DSR (%)	−0.92***	−2.63***	−2.57***	−4.06***	−4.13***	−1.52***
OLTV	7.15***	−7.74***	−9.44***	−13.02***	−1.56***	0.72**
Loan Size (€,000)	−21.02***	−78.48***	−72.91***	−74.28***	−36.17***	−27.85***
FTB (%)	−1.62	−4.14***	−8.96***	−13.41***	−0.82	1.87***
Age (years)	0.93***	1.27***	1.54***	1.54***	−0.44***	−0.04
Dublin (%)	0.17	−11.51***	−7.3***	−2.91***	1.77***	−1.63***
ΔRate (pp)	2.53***	2.56***	2.53***	2.76***	2.79***	2.63***
ΔInstallment (%)	26.01***	28.42***	29.44***	30.09***	25.12***	23.06***
Negative Equity (%)	2.05***	1.84***	2.14***	−4.82***	10.57***	10.4***

Note: Significant differences based on t-tests on the equality of means.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

References

Bacon, Philomena M. and Peter G. Moffatt, "Mortgage Choice as a Natural Field Experiment on Choice under Risk," *Journal of Money, Credit and Banking*, 2012, *44* (7), 1401–1426.

Campbell, John and Joao F. Cocco, "Household Risk Management and Optimal Mortgage Choice," *The Quarterly Journal of Economics*, 2003, *118* (4), 1449–1494.

__ **and** __ , "A Model of Mortgage Default," *Journal of Finance*, 2015, *70* (4), 1495–1554.

Ciccarelli, Matteo, Angela Maddaloni, and Jose-Luis Peydro, "Heterogeneous transmission mechanism: monetary policy and financial fragility in the eurozone," *Economic Policy*, 2014, *28* (75), 459–512.

Elliehausen, G. and M. Hwang, "Mortgage Contract Choice in Subprime Mortgage Markets," *Federal Reserve Board Discussion Series*, 2010, *2010-53.*

Elul, Ronel, Nicholas Souleles, Souphala Chomsisengphet, Dennis Glennon, and Robert Hunt, "What "Triggers" Mortgage Default?," *American Economic Review*, 2010, *100* (2), 490–94.

Foote, Christopher, Kristopher Gerardi, Lorenz Goette, and Paul S. Willen, "Just the facts: An initial analysis of subprime's role in the housing crisis," *Journal of Housing Economics*, 2008, *17* (4), 291–305.

Fuster, Andreas and Paul S. Willen, "Payment Size, Negative Equity, and Mortgage Default," NBER Working Papers 19345, National Bureau of Economic Research, Inc 2013.

Gerardi, Kristopher, Andreas Lehnert, Shane Sherlund, and Paul Willen, "Making Sense of the Subprime Crisis," *Brookings Papers on Economic Activity*, 2008, *39* (2 (Fall)), 69–159.

Gyourko, Joseph and Joseph Tracy, "Reconciling theory and empirics on the role of unemployment in mortgage default," *Journal of Urban Economics*, 2014, *80* (C), 87–96.

Hancock, Diana and Wayne Passmore, "Did the Federal Reserve's {MBS} purchase program lower mortgage rates?," *Journal of Monetary Economics*, 2011, *58* (5), 498 – 514. Carnegie-Rochester Conference on public policy: Normalizing Central Bank Practice in Light of the credit Turmoi, 1213 November 2010.

Haughwout, Andrew, Richard Peach, and Joseph Tracy, "Juvenile delinquent mortgages: Bad credit or bad economy?," *Journal of Urban Economics*, September 2008, *64* (2), 246–257.

Hristov, Nikolay, Oliver Hlsewig, and Timo Wollmershuser, "The interest rate pass-through in the Euro area during the global financial crisis," *Journal of Banking & Finance*, 2014, *48*, 104 – 119.

Imbens, Guido W. and Jeffrey M. Wooldridge, "Recent Developments in the Econometrics of Program Evaluation," *Journal of Economic Literature*, March 2009, *47* (1), 5–86.

Jiang, Wei, Ashlyn Aiko Nelson, and Edward Vytlacil, "Delinquency model predictive power among low-documentation loans," *Economics Letters*, 2013, *120* (2), 171–173.

_ , _ , and _ , "Liar's Loan? Effects of Origination Channel and Information Falsification on Mortgage Delinquency," *The Review of Economics and Statistics*, 2014, *96* (1), 1–18.

Kelly, Robert and Terence O'Malley, "The good, the bad and the impaired: A credit risk model of the Irish mortgage market," *Journal of Financial Stability*, 2016, *22*, 1 – 9.

_ , Paul Lyons, and Conor O'Toole, "Mortgage Interest Rate Types in Ireland," Economic Letters 09/EL/15, Central Bank of Ireland 2015.

Lydon, Reamonn and Yvonne McCarthy, "What Lies Beneath? Understanding Recent Trends in Irish Mortgage Arrears," *The Economic and Social Review*, 2013, *44* (1).

Mayer, Christopher, Karen Pence, and Shane Mick Sherlund, "The Rise in Mortgage Defaults," *Journal of Economic Perspectives*, 2009, *23* (1), 27–50.

McCarthy, Yvonne, "Dis-entangling the mortgage arrears crisis: The role of the labour market, income volatility and housing equity," Research Technical Papers 02/RT/14, Central Bank of Ireland 2014.

_ and Kieran McQuinn, "Credit conditions in a boom and bust property market," Research Technical Papers 08/RT/13, Central Bank of Ireland 2013.

Mian, Atif and Amir Sufi, "The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis," *The Quarterly Journal of Economics*, 2009, *124* (4), 1449–1496.

_ and _ , "House Prices, Home Equity-Based Borrowing, and the US Household Leverage Crisis," *American Economic Review*, 2011, *101* (5), 2132–56.

Sengupta, Rajdeep and Geetesh Bhardwaj, "Credit scoring and loan default," *International Review of Finance*, 2015, *15* (2), 139–167.

Wooldridge, Jeffrey M., "Inverse probability weighted estimation for general missing data problems," *Journal of Econometrics*, December 2007, *141* (2), 1281–1301.