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Macroprudential Policy, Banking and the Real Estate Sector

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Abstract

We develop and estimate a structural model that explicitly characterises the dynamic nature of the interactions, feedbacks and spillovers between macroprudential policy, and the banking and real estate sectors. Using Irish data we find that borrower-based macroprudential instruments such as LTI and LTV ratios significantly affect credit demand, while intermediary-based instruments such as LTD and capital ratios are important determinants of credit supply. We simulate two counterfactual scenarios to demonstrate the model's usefulness for policy analysis. We show that the boom-bust dynamics in Irish credit growth and property prices could have been significantly dampened if a macroprudential regime that managed credit conditions through a credit-based LTV rule had been in operation. Finally, notwithstanding its enhancement of banks' balance sheet resilience, we show that the implementation of a countercyclical capital buffer would have had a relatively weak impact on real and financial volatility.

JEL classification: E5, E53, E52, G21
Keywords: Banking, Credit, Macroprudential, House Prices

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1. Introduction

The recent financial crisis highlighted the necessity of developing models of financial intermediation that can capture the importance of financial sector shocks to the real economy (Blanchard et al, 2010; Linde et al, 2016). Although research on the role of financial factors in investment and consumption dynamics had a rich history prior to 2007, the scale of the disruption generated by distortions that had manifested in the pre-crisis expansion and that were amplified by the downturn, has given new impetus to the formal modelling of macro-financial linkages. In particular, recent models have focused on the nature of credit supply disruptions, especially those arising through the capital channel, and have integrated new policy instruments that specifically target the maintenance of financial stability (Gertler and Kiyotaki, 2010; Benes et al, 2014).

A modelling framework that can elucidate or quantify the nature of the interaction between the banking system and the real economy and that can demonstrate the potential effectiveness of macroprudential policy is particularly apposite in the case of Ireland. From 2003 to 2008 the balance sheet of the domestically-relevant Irish banking sector tripled in size driven mainly by lending to Irish households and non-financial corporations, and enabled by significant structural change in the funding environment facing banks over the period.[1]

Non-intrusive financial regulation and the absence of a macroprudential policy regime in particular, created distortions that allowed banks to relax non-

[1]This structural change was primarily reflected in the large increase in the share of non-domestic funding in the pre-crisis period as Irish banks became increasingly reliant on wholesale rather than retail funding to finance the growth in lending. Irish banks also engaged in extensive mortgage securitisation during the period through the issuance of covered bonds. These new sources of funding drained rapidly from the banking system with the onset of the financial crisis which initiated the process of balance sheet deleveraging (Coates and Everett, 2013).

interest credit conditions through variations in loan maturities, loan-to-income (LTI) and loan-to-value (LTV) ratios (Honohan, 2010; McCarthy and McQuinn, 2017).[2] The resulting shift in the relation between the volume of credit on one side, and income levels and asset values on the other, led to banks, firms and households becoming highly leveraged.[3]

By 2015, however, the total assets of this sector had fallen to approximately half of its 2008 level. The most calamitous effects originated from banks' large exposures to commercial real estate (CRE).[4] Irish banks faced an average write-down on these loans of 58 percent when they were transferred to the asset management agency, or "bad bank", established by the Irish government prior to being recapitalised, with losses on these loans accounting for approximately half of the recapitalisation requirements (ESRB,2015).

Ireland provides the prototypical example of how this leverage cycle amplifies cycles in the real economy. In the decade prior to onset of the financial crisis, Ireland experienced the largest increase in real house prices across all OECD economies with an average annual appreciation rate of over ten percent (Duffy et al, 2016). The strong concordance between the residential and commercial property sectors was reflected in a similar rate of growth in real commercial capital values. The rising returns to real estate investment generated a construction

[2] The distortions which lead to excessive leverage may be driven by externalities in the financial system. First, each individual bank may not consider that their portfolio or lending decisions may increase the likelihood of asset sales by all banks in the future which may depress collateral values and ultimately restrict lending through the banking system. Second, strategic complementarities may generate incentives to imitate the lending behaviour of other more profitable banks due, for example, to reputational concerns (Giese et al, 2013).

[3] Gerlach-Kristen and McInerney (2014) find that the relation between mortgage credit and house prices had become statistically explosive by mid-2003.

[4] The real estate sector has also been a primary source of financial distress in other crises such as the Savings and Loans crisis in the US in the late 1980s and the Scandanavian crisis of the early 1990s (Davis and Zhu,2011).

boom that expanded the total stock of dwellings by almost 50 percent during this period. However, the financial crisis precipitated a collapse in Irish property prices that was the largest across all advanced countries with house prices falling by a half relative to the pre-crisis peak and a peak-to-trough decline in commercial property prices of over 60 percent. Construction activity effectively came to a halt. The ensuing recession and rise in the unemployment rate led to a spike in corporate insolvencies, and a steep and protracted increase in household mortgage arrears, which still remain elevated.

In this paper, we present an empirical framework within which the bidirectional linkages between the banking and real estate sectors are formalised and their relative strength quantified. In particular, we develop a structural model that explicitly characterises the dynamic nature of the interactions, feedbacks and spillovers between macroprudential policy, bank's lending behaviour, household and corporate borrowing, and fluctuations in property prices. Although the model is estimated using Irish data, the underlying specification is sufficiently general that it can be easily estimated using a similar dataset for other countries. Importantly, our sample covers a period of significant real and financial volatility in the Irish economy. While this poses its own econometric challenges, it allows us to capture more completely how distortions for example originate and propagate, particularly in terms of generating potential accelerator effects.[5]

There are relatively few studies that examine the behaviour of the banking sector and credit markets from a structural econometric perspective. At their

[5] A common criticism of structural econometric models is that the parameters are not truly "structural" as they are not invariant to changes in policy (the Lucas critique). Our model is estimated over a sample period that includes phases of quite differing volatilities and rates of structural change in the banking and real estate sectors. However, by specifying equations that incorporate these characteristics so that the estimated parameters are stable over time, we argue that our results are considerably insulated from this critique.

core, these models comprise demand and supply equations for different types of credit. Here, our model is similar to those of Liadze and Davis (2012) and Nobili and Zollino (2012) in that, in order to isolate supply from demand factors, we must use the identifying assumption that loan quantities do not enter the supply equations. This is consistent with our theoretical framework in which banks are monopolistically competitive due, for example, to switching and monitoring costs as well as informational asymmetries that generate market power (Freixas and Rochet, 2008). This assumption implies that banks set the price of lending (the interest rate) as a markup over the cost of funding and also that banks can accommodate any level of credit demand at this interest rate.[6]

Importantly from a financial stability perspective, our model shows that usual indicators of distress in the household and corporate sectors such as mortgage arrears and insolvency rates have important financial triggers, which then feedback into banks' loan-pricing decisions through this markup. This mechanism can generate accelerator effects similar to those in, for example, Bernanke et al (1996).

The primary contribution of our model is to incorporate several macroprudential instruments into a model of the banking and real estate sectors. One of the key drivers behind the renewed focus on integrating the financial sector into macroeconomic models is the increasing emphasis placed by policymakers on macroprudential tools that aim to mitigate systemic risk by dampening the source and propogation of financial volatility. However, the channels through which these tools affect the behaviour of banks, households and firms are still

[6]This suggests that the supply curve for each type of credit is perfectly elastic. See Gerlach-Kristen and McInerney (2014) for an alternative framework in which the price of credit rises with the quantity of credit supplied due, for example, to implicit constraints on leverage.

uncertain (Galati and Moessner, 2017). We outline a unifying empirical framework within which the transmission, interaction and spillover mechanisms of several macroprudential instruments can be explicitly and jointly specified and quantified.

As far as we are aware, we are the first to introduce borrower- and liquidity based instruments, in addition to capital ratios, into a structural econometric model. In this respect, our model contributes to the literature on the effectiveness of macroprudential instruments.[7] In the case of those that target credit demand, several studies have used reduced-form single-equations (Duca et al, 2011), vector autoregressions (Kuttner and Shim, 2013), and panel methods (IMF, 2011) to examine how these instruments affect rates of credit growth and house price appreciation. However, these studies do not explicitly specify how changes in the LTV and LTI ratios are transmitted through the banking sector or real economy. Moreover, they do not allow these effects to feedback into banks' balance sheets, to interact with intermediary-based instruments and consequently, to affect banks' lending behaviour.[8]

We also show how instruments that affect the liability structure of this sector such as the loan-to-deposit (LTD) ratio and the capital ratio affect banks' lending behaviour. The financial crisis starkly illustrated how liquidity mismatch between assets and liabilities can increase the vulnerability of the sector to a sys-

[7]A recent exception is Davis et al (2018) who incorporate the LTV ratio into the necessarily parsimonious house price equations of several countries in the NiGEM global macroeconometric model. However, this specification is not "structural" in the sense that it does not explicitly capture the direct impact of collateral (or downpayment) constraints on new mortgage lending, which is the role of this type of borrower-based macroprudential instrument.

[8]Duffy et al (2016) estimate an econometric model of the Irish mortgage and housing markets in which LTV and LTI ratios affect the demand for new mortgage lending. However, they do not consider feedbacks to banks' balance sheets, spillovers to other property markets, or interactions with other macroprudential instruments.

temic bank run (Uhlig, 2010; Gertler and Kiyotaki, 2015). Basel III has sought to address these liquidity issues with the introduction of the Liquidity Coverage Ratio and the Net Stable Funding Ratio. In the Irish case, the central bank in 2011 introduced constraints on banks' ability to fund balance sheet expansion through short-term wholesale funding by imposing restrictions on the LTD ratio. As deposit funding is less subject to roll-over risk and less "flighty" relative to short-term debt or money market funding (Shin and Shin, 2011), the higher the share of lending that is financed by deposits the lower should be the associated exposure of banks to systemic liquidity risk. In our model, the LTD ratio acts as a macroprudential instrument that reflects the cost of mitigating liquidity risk. In contrast to the borrower-based instruments that target credit demand, restrictions on the LTD ratio affect banks directly by raising the marginal cost of funding and thus shifting the credit supply schedule.

In addition to funding risk, the financial crisis also highlighted the importance of bank capital in the transmission of real and financial shocks (Jermann and Quadrini, 2012). In response to this, central banks and prudential authorities through the Basel III accord have raised required levels of capital adequacy significantly in an effort to manage systemic risk. One of the key components of this new regulatory architecture is the introduction of a counter-cyclical capital buffer (CCyB) that is activated during periods of high credit growth.

However, although higher levels of capital can enhance financial stability, they may also be associated with higher economic costs. One important feature of our modelling framework is that it allows us to quantify these costs in terms of the price and volume of different types of credit. Accordingly, we also contribute to the literature on the impact of changes in capital requirements on banks' lending and pricing behaviour.[9] In contrast to many of these studies which examine the impact of higher capital ratios on a representative lending rate and total credit growth, we decompose this impact for each lending rate and ultimately, for each credit stock.[10] In this respect, we identify the margins along which the Irish banking sector adjusts to higher capital requirements. This also allows us to simulate the impact of macroprudential policy by raising the capital ratio in accordance with the CCyB.

We demonstrate the usefulness of the model for macroprudential policy analysis by simulating the model under two counterfactual scenarios. As Ireland provides an exemplar of a quintessential credit-fuelled property market boom and bust, an interesting question is what would the path of the banking and real estate sectors have been if a macroprudential regime had been in operation during this period. We construct "alternative histories" by imposing certain assumptions about the reaction function of the macroprudential authority. This allows us to compare the effectiveness of different macroprudential instruments in maintaining financial stability.

First, we examine how credit and real estate markets would have evolved under different countercyclical rules for the LTV ratio and find that a rule that targeted credit growth would have achieved the greatest degree of macrofinancial stabilisation. We then consider how the introduction of the CCyB would have affected banks' behaviour and ultimately, the volatility of real estate markets. Our results suggest that the real impact of instruments that work through the intermediary are relatively small when compared to that of instruments that directly

[9] See Dagher et al (2016) for an overview of this literature.

[10] The structural models of Liadze and Davis (2012) and Nobili and Zollino (2012) also allow capital ratios to have a differential impact on each lending rate.

affect credit demand.

The remainder of the paper is structured as follows. Section 2 outlines our model of the Irish banking and real estate sectors. Section 3 presents and discusses the econometric results. Section 4 outlines several counterfactual scenarios to illustrate the model's usefulness for macroprudential policy analysis. Section 5 concludes.

2. A Model of the Irish Banking Sector

2.1. Mortgage Credit

One of the primary contributions of this paper is the formal modelling of the interaction between the property market and borrower-based macroprudential instruments such as the LTI and LTV ratios. These ratios are increasingly being viewed as an important tool in the management of financial stability (Claessens, 2015). However, there is a critical absence of a structural econometric framework within which the transmission of these instruments to the banking sector and real economy, and the dynamic responses of banks, households and firms can be analysed or quantified.

In the Irish case, higher LTI and LTV ratios in the pre-crisis period relaxed affordability and collateral constraints which lead to a surge in mortgage lending (McCarthy and McQuinn, 2017). This relaxation in credit conditions meant that the relation between house prices and mortgage credit became statistically explosive from 2003 onwards (Gerlach-Kristen and McInerney, 2014). Understanding how variations in these ratios affect housing supply and demand and their concomitant impact on banks' behaviour is crucial to understanding how the Irish property bubble and crash developed. It also allows macroprudential policymakers to draw important lessons from the Irish experience.

The recent empirical literature on the impact of borrower-based macroprudential instruments on the aggregate housing market has tended to be either reduced-form or single-equation panel data studies. These reduced-form specifications typically include the LTV ratio or time dummies as indicators of credit conditions in a traditional house price equation (Fernandez-Corugedo and Muellbauer, 2006; Duca et al). The panel data studies tend to examine the impact of various macroprudential instruments such as the LTI, LTV and debt-service-to-income (DSTI) ratios on credit or house price growth in a single-equation setting that does not allow interaction between, or feedbacks from, housing and credit markets (IMF, 2011; Kuttner and Shim, 2016).

In order to understand the dynamic impact of these macroprudential instruments on the real economy and the corresponding feedback to balance sheets and bank behaviour, policymakers require a structural model which specifies and quantifies each transmission and feedback channel. There are few studies that try to isolate demand from supply factors in relation to the (aggregate) volume of credit extended. Some of these, such as Nobili and Zollino (2012), Liadze and Davis (2012), and Gerlach-Kristen and McInerney (2014) estimate structural models of the mortgage and housing markets, but these studies do not incorporate the impact of credit conditions or macroprudential policy. Others such as Avouyi-Dovi et al (2014) use a relatively parsimonious model to analyse the impact of changes in lending criteria, as captured by the debt service to income ratio, on credit demand and the housing market.

The borrower-based instruments we focus on in this paper are, along with the countercyclical capital buffer (CCyB), the key components of the macroprudential policy framework in Ireland. In 2015, the Central Bank of Ireland in its capacity as the domestic macroprudential authority introduced caps on the LTI and LTV ratios on mortgage lending to first time buyers.[11] As these borrower-based instruments affect new mortgage lending rather than the stock of existing lending, we focus on estimating a behavioural equation for mortgage demand in terms of the former rather than the latter.[12]

In our framework the demand for new mortgage lending is modelled as a function of real personal disposable income, the real mortgage interest rate and real house prices.[13]

In addition to these conventional drivers of mortgage demand, we seek to elucidate and quantify the channels through which fluctuations in mortgage credit conditions affect borrower behaviour. It is through its impact on the latter that macroprudential policy can be used to directly stabilise credit growth. Credit conditions act as an accelerator in that they amplify the impact of income and collateral effects on house prices (Almeida, Campello and Lu, 2006).[14]

[11]The LTI cap was set at 3.5, while the LTV ceiling was set at 90 percent of the value of the house up to 220,000 euro and 80 percent thereafter. Banks were also allowed to exempt 20 percent of all new mortgage lending from the LTI limits and 15 percent from the LTV limit. See CBI (2015) for details.

[12]Duffy et al (2016) estimate a similar equation for mortgage demand using different data.

[13]The few existing structural models of mortgage credit relate the mortgage stock to affordability in terms of income and interest rates and to collateral, as indicated by house prices (Nobili and Zollino, 2012; Liadze and Davis, 2012; Gerlach-Kristen and McInerney, 2014; and Duffy et al, 2016). This is analagous to DSGE models of mortgage credit, in which affordability depends on the (lifetime) budget constraint that incorporates future income and interest rates and in which collateral depends on house prices (Iacoviello, 2005). In addition, our model of mortgage demand allows affordability and collateral constraints to be relaxed via changes in the LTI and LTV ratios, respectively. This is similar to recent DSGE models which treat the LTV ratio as an exogenous collateral constraint that is used to reflect lending conditions (Iacoviello and Neri (2010), Gerali et al (2010); Benes and Kumhof, 2015)

[14]For example, IMF (2011) finds empirical evidence that high LTV ratios strengthen the impact of real GDP growth on house price growth, with a coefficient that is half of the direct effect of real GDP growth.

Our measures of the LTV and LTI ratios are constructed using aggregate data on new mortgage approvals. Using these "raw" ratios as indicators of credit conditions in a mortgage equation would clearly be endogenous as they depend on several factors such as interest rates, income and house prices (Fernandez-Corugedo and Muellbauer, 2006). We address potential endogeneity concerns in using these constructed variables to reflect exogenous changes in credit conditions (or collateral and affordability constraints) by isolating variations in the LTI and LTV ratios that are orthogonal to changing expectations about house prices, income, interest rates and the unemployment rate (Cameron et al, 2006; Duca et al, 2011).[15] The resulting ratios represent shifts in the quantity of credit available at each income and house price level and so are ideal instruments for gauging the impact of macroprudential policy that imposes restrictions on these ratios. The demand for new mortgage lending therefore has the following form:

$$NewMortgages_t = \alpha + \beta_1 NewMortgages_{t-1} + \beta_2 RMorRate_t + \beta_3 LTV_t + \beta_4 LTI_t + \beta_5 \Delta HP_{t-1} + \beta_6 \Delta Income_{t-1} + \varepsilon_t \quad (1)$$

where $NewMortgages$ is the volume of real new mortgage lending, $RMorRate$ is the real mortgage interest rate, $Income$ is real personal disposable income, HP is the real house price, and LTV and LTI are the respective ratios adjusted for cyclical factors. The lagged dependent variable is included to capture persistence in new mortgage lending. ε is the error term. All variables, except for the mortgage interest rate, are in logs. We use the changes in income and house prices rather than their levels given the differences in the order of integration among the regressors. Nominal variables are deflated by the consumer expen-

[15] See Duffy et al (2016) for more details on this procedure.

diture deflator to obtain real values. We assume that inflation expectations are extrapolative and therefore that real interest rates are calculated as the current nominal rate minus the annualised lagged quarterly change in the consumer expenditure deflator.[16]

Although macroprudential policy affects the volume of new mortgage lending, it is the total outstanding stock of mortgage credit which affects households' and banks' balance sheets. We allow the volume of new mortgage lending to accumulate on the previous period's capital stock similar to the perpetual inventory method used to characterise the evolution of the housing stock below:[17]

$$MorStock_t = \beta_1 MorStock_{t-1} + NewMortgages_t + \varepsilon_t \tag{2}$$

where $MorStock$ is the (notional) mortgage stock in real terms and ε_t is the error term. β_1 indicates the rate of net mortgage repayment and is analagous to the depreciation rate in the housing stock equation. It is important to emphasise that we use notional stocks based on transactions data rather than balance sheet stocks to model demand for each credit aggregate as the former incorporates the impact of securitisation, valuation effects, asset disposals and other factors that drive a wedge between stocks and the accumulation of net flows.[18] However, banks' lending behaviour and capital position are driven by actual stocks of each type of lending held on balance sheet. We model these balance sheet stocks as a simple linear function of their notional counterparts and adjust for statistical breaks where necessary.[19]

[16]Our results are not sensitive to other specifications of expectation formation which incorporate information from a longer time horizon.

[17]See also Duffy et al (2016).

[18]I thank Martin O'Brien for this suggestion.

[19]These results are available on request. It is worth noting that modelling the drivers of the

In terms of mortgage supply, we follow the literature and assume that banks are monopolistically competitive (Freixas and Rochet, 2008). This implies that banks set interest rates as a markup over funding costs. The assumption that the quantity of credit does not enter the supply equation is necessary for the separate identification of supply and demand factors (Davis and Liadze, 2012; Nobili and Zollino, 2012).

Funding costs are represented by the deposit rate and the money market rate. The latter is approximated by 3-month Euribor and is the main channel through which monetary policy affects interest rates.[20] The markup set by banks over these marginal funding costs is time-varying and dependent on macroeconomic and sector-specific risk, internal capital management, and the liquidity composition of liabilities.

As the majority of Irish banks' assets have historically been in the form of loans, risk in the model primarily reflects credit risk which is driven by factors that affect borrowers' debt-servicing capacity and collateral values. The riskiness of lending to the household sector therefore reflects the implied loss given default as well as the repayment capacity of households. The former can be captured by the undrawn equity of households given by the residual proportion of housing wealth net of mortgage debt, while we use the unemployment rate to capture the latter.[21]

As discussed below in relation to our model of bank capital, we assume that the Modigliani-Miller theorem does not hold, so that banks find it relatively costly

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wedge between notional and actual stocks is not possible given data availability.

[20]See ECB (2009) for evidence that Irish banks used three-month Euribor as the base rate off which the standard variable mortgage rate was priced.

[21]Both housing equity and the unemployment rate have been shown to be significant predictors of household mortgage arrears. See the model of mortgage arrears below for further discussion.

to raise capital.[22] Consistent with the empirical evidence on the behaviour of banks since the crisis, the main channel through which banks raise capital in the model is through higher retained earnings (Cohen and Scatigna, 2016). Banks achieve this through higher lending rates, which subsequently lead, depending on the elasticity of demand for each type of credit, to a decline in lending and to a fall in risk-weighted assets.[23]

Finally, we also allow macroprudential policy to enter the supply of credit through the constraints on the composition of funding via the LTD ratio. Variation in the share of wholesale funding was a significant driver of changes in the supply of credit in the Irish case (Addison-Smyth et al, 2009; Coates and Everett, 2013). Deposits tend to be one of the least "flighty" sources of funding and are generally subject to much lower rollover risk than wholesale funding. Indeed, rising LTD ratios are one of the most robust early warning indicators of impending financial distress (Shin and Shin, 2011). The Basel III regulatory framework aims to reduce the vulnerability of the banking system to liquidity shortages by implementing targets for the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR).[24] In the case of Ireland, the post-crisis regulatory focus in terms of liquidity requirements has been on the LTD ratio.[25]

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[22]In other words, we assume that the Modigliani-Miller offset is incomplete so that the cost of raising finance through equity rather than debt exceeds the reduction in the cost of capital arising from the increase in the share of liabilities that comprise equity capital. Empirically, the offset if found to be small. For example, Gambacorta and Shin (2016), using a sample of international banks over the period 1994-2012, show that a one percentage point increase in the ratio of equity to total assets reduces average (debt) funding costs by 4 basis points.

[23]Risk-weighted assets are constructed using risk-weights for each type of lending under the Basel I accord as this was the regulatory regime that was in place for most of our sample period.

[24]The LCR is the ratio of high quality liquid assets to net cash outflows over the next 30 days. The NSFR measures the amount of stable funding relative to the required amount where the former is defined as the portion of capital and liabilities expected to be reliable over a particular horizon. See BCBS (2010) for details.

[25]The *Financial Measures Programme* (CBI, 2011) introduced by the Central Bank of Ireland in

Accordingly, we estimate the supply of mortgage lending within an error-correction framework with the nominal mortgage rate adjusting over time to the following long-run relation:

$$MorRate_t = \alpha + \beta_1 MMRate_t + \beta_2 DepRate_t + \beta_3 HHEquity_t + \beta_4 URate_t + \beta_5 CAP_t + \beta_6 LTD_t + \varepsilon_t \qquad (3)$$

where $MorRate$ is the nominal mortgage rate, $MMRate$ is the money market rate, $DepRate$ is the deposit rate, $HHEquity$ is the residual proportion of housing wealth net of mortgage debt, $URate$ is the unemployment rate, CAP is the ratio of capital to risk-weighted assets, LTD is the LTD ratio and ε is the stationary equilibrium error. In the short run, we allow persistence in the mortgage rate to be driven by contemporaneous and lagged changes in the variables in (3).

2.2. Consumer Credit

There is a vast literature investigating the effects of housing and financial wealth on consumption, with the general consensus that these effects tend to increase the lower are credit and liquidity constraints (Muellbauer, 2007; Carroll et al, 2011). We follow this literature and assume that the drivers of consumption and the demand for consumer credit are similar. Accordingly, we assume that the stock of consumer credit is a function of disposable income, interest rates and wealth effects, with the latter conditional on the net position of households in relation to both housing and financial investments.

Housing equity can affect consumer credit demand through the "housing

2011 set an upper limit on the LTD ratio of 1.22 and banks have subsequently been encouraged to reduce the ratio further. The LTD ratio had fallen to 0.8 by 2015Q4.

wealth effect". Abstracting from credit constraints, a perceived permanent increase in the net housing wealth of home owners may generate an increase in demand for credit to finance non-housing related consumption. This balance sheet channel may be important from a credit worthiness perspective depending on the extent to which households can leverage their net worth (Nobili and Zollino, 2012). In addition, financial deregulation and greater competition in the Irish banking sector enabled households to obtain loans backed by housing equity (Lydon and O'Hanlon, 2012; Lydon and O'Leary, 2013). Higher house prices allow households to increase debt or refinance existing debt at lower interest rates. The availability of home equity loans increases the "spendability" of housing wealth and can magnify the strength of the housing wealth effect (Muellbauer, 2007).

The literature on wealth effects and consumption also finds evidence that the latter responds to changes in net financial wealth, although the size of the impact varies considerably across countries (Case et al, 2005; Barrell et al, 2015). However, the direction of the effect of higher net financial wealth on the demand for consumer credit is an empirical question and likely depends on the liquidity of financial assets. For example, if financial wealth mainly comprises relatively liquid instruments such as stocks and bonds, then if net financial wealth increases, households may choose to divest financial assets to finance consumption rather than obtain bank credit. However, if financial wealth is mainly in the form of technical reserves or pensions, then households may instead finance consumption using bank loans. We model the demand for consumer credit in an error-correction framework that allows adjustment to the following long-run relation:

$$
\begin{aligned}
ConsCredit_t = {} & \alpha + \beta_1 RConsRate_t + \beta_2 Income_t + \beta_3 HHEquity_t \\
& + \beta_4 NFW_t + \varepsilon_t
\end{aligned} \tag{4}
$$

where $ConsCredit_t$ is the (notional) stock of consumer loans in real terms, $RConsRate_t$ is the real interest rate on consumer loans, NFW_t is real net financial wealth and ε is the equilibrium error.

As with the mortgage rate, the supply of consumer loans is represented by the interest rate on consumer lending. Similar to the mortgage rate, the latter is modelled as a variable mark-up over deposit and money market funding costs, while the mark-up itself is a function of risk, liquidity and banks' internal capital management.

We relate the risk associated with this type of unsecured lending to both macroeconomic and sector-specific factors. We allow the unemployment rate to capture the former and the ratio of consumer credit to income to capture the latter. These variables reflect the debt-servicing capacity and income gearing of households with respect to consumer credit.[26]

The consumer lending rate also depends on the structure of banks' balance sheets in terms of the composition of liabilities. Both the capital and LTD ratios have a qualitatively similar impact on the consumer lending rate to that on the

[26] As this type of lending is unsecured we also considered a number of risk factors that might distinguish this type of lending from mortgage credit such as income and interest rate expectations, stock market volatility as an approximate measure of economic uncertainty, and the spread between three-month Euribor and the three-month yield on treasury bills. These variables however were statistically insignificant. In addition, we considered whether banks incorporate the total income gearing of households by including secured and unsecured household lending. This variable was also insignificant.

mortgage rate. However, an important contribution of our analysis is to show how these impacts differ quantitatively for unsecured relative to secured household lending and household relative to corporate lending. We therefore allow the nominal consumer interest rate, $ConsRate$, to adjust over time to the following long-run relation:

$$
\begin{aligned}
ConsRate_t = \alpha + \beta_1 MMRate_t + \beta_2 DepRate_t + \beta_3 URate_t \\
+ \beta_4 (ConsCredit_t / Income_t) + \beta_5 CAP_t + \beta_6 LTD_t + \varepsilon_t
\end{aligned}
\tag{5}
$$

where ε is the stationary equilibrium error. In addition to error-correction, short-run dynamics in the consumer rate depend on lagged and contemporaneous changes in the variables in 5.

2.3. Corporate Credit

2.3.1. Demand for Corporate Credit

Bank-intermediated credit is the primary source of external financing for Irish non-financial firms, which are almost entirely small and medium enterprises (Lawless et al, 2013). However, treating corporate credit as a homogenous category would ignore significant heterogeneity across different types of corporate lending in terms of their impact on the economy and on financial stability.

In particular, the spike in corporate insolvencies and collapse of Irish commercial property prices in the aftermath of the financial crisis was on such a scale that government intervention was necessary to prevent several banks from failing due to losses on CRE lending.[27] This type of lending tends to be signif-

[27] See Schoenmaker (2015) for an overview.

icantly more cyclical and volatile than other components of banks' loan portfolios (ESRB, 2015). In addition, default rates on these loans tend to be higher than on residential mortgages as the former are often limited-recourse and commercial premises fulfil a purely economic purpose rather than a social purpose as in the case of housing.[28] Given the importance of CRE lending from a financial stability perspective, we therefore distinguish this type of lending from other corporate credit.

The stock of CRE loans includes lending to firms engaged in the construction of both residential housing and commercial real estate. Although this type of lending is typically staggered with different stages of development, we assume that that real housing wealth (or alternatively the real value of the housing stock) can be used as an approximation for the collateral against lending for housing construction, while the real value of commercial property can be used to approximate the collateral used to construct and invest in commercial real estate. The value of commercial property can influence the availability of credit through improving a firm's net worth, as in Bernanke and Gertler (1989), or raising the value of the collateral that firms provide against bank loans, as in Kiyotaki and Moore (1997).[29]

Analagous to the models of household credit demand outlined above, the demand for CRE loans is also a function of activity levels and the cost of credit. We approximate the derived demand for this type of credit from higher levels of employment and investment using real GDP, which captures the cyclical volatility that has characterised this lending historically.

[28] As ESRB (2015) notes, in contrast to commercial real estate, housing is both an investment and consumption good as households purchase residential real estate to live in.

[29] See Gan (2007) and Chaney et al (2012) for evidence of a positive relation between collateral values and the volume of credit and investment.

In terms of the cost of bank financing, individual interest rates on different types of corporate credit are unfortunately not available. Instead, we use the representative interest rate on corporate lending to approximate the cost of credit to the CRE sector.[30] The demand for CRE credit is modelled in an error-correction framework with the following long-run equilibrium:

$$\begin{aligned} CRE_t = \alpha_1 + \beta_1 RCorpRate_t + \beta_2 RGDP_t + \beta_3 ComProp_t \\ + \beta_4 HWealth_t + \varepsilon_t \end{aligned} \tag{6}$$

where CRE is the (notional) stock of real commercial real estate loans, $RCorpRate_t$ is the real interest rate on corporate lending, $RGDP$ is real GDP, $ComProp_t$ is the private capital stock revalued in terms of commercial property capital values, $HWealth$ is real housing wealth (or the value of the housing stock), and ε_t is a stationary error term.

The demand for non-property corporate credit follows a similar functional form to that specified for CRE credit in (6). In particular, a common factor driving both types of corporate lending is commercial property as the primary collateral against which credit can be secured. Therefore, the Kiyotaki-Moore (1997) channel may be important for both types of credit. To reflect this credit rationing and given the difficulties of measuring the net worth of firms at the aggregate level, we again use the the private capital stock revalued in terms of commercial property capital values as an approximate indicator.

As mentioned, Irish firms are mainly small and medium enterprises and thus are likely subject to an external financing premium on bank-intermediated bor-

[30] We note that it is likely given the historical volatility of this sector that the interest rate on CRE lending carries a risk premium over other types of corporate lending.

rowing (Bernanke and Gertler, 1989; Holton and McCann, 2016). For these firms, it is relatively cheaper to first use retained earnings to finance investment before turning to external sources of funding. Accordingly, the demand for bank credit should, all else equal, be negatively related to the level of retained earnings. Given data availability, we use the aggregate level of after-tax profits to approximate the latter.

Finally, we also relate the demand for non-property corporate loans to the level of economic activity and the cost of credit. As in (6), we use the real GDP to capture the derived demand for credit from higher levels of investment and from working capital requirements. However, in contrast to the strong cyclical volatility of property-related corporate lending, other types of corporate lending has tended to grow more in line with GDP. [31] As discussed above, the data do not allow us to distinguish between the costs of different types of corporate lending and therefore we use the representative interest rate on all corporate lending as an approximation for the cost of non-property corporate credit.

The stock of other (non-property) corporate loans therefore adjusts over time to the following long-run relation:

$$
\begin{aligned}
OCorp_t = \alpha + \beta_1 RCorpRate_t + \beta_2 RGDP_t + \beta_3 ComProp_t \\
+ \beta_4 Profits_t + \varepsilon_t
\end{aligned}
\tag{7}
$$

where $OCorp$ is the (notional) real stock of non-property corporate lending, $Profits$ are the real after-tax profits of non-financial corporations, and ε_t is the equilibrium error term. In addition to error-correction, the short-run dynamics of non-

[31] The share of non-property corporate lending in GDP has been relatively constant over the last three decades.

property corporate lending are driven by lagged and contemporaneous changes in the variables in (7).

2.3.2. Supply of Corporate Credit

The supply of corporate credit is represented by the interest rate on loans to non-financial corporations. To preserve consistency with our models of the supply of mortgage and consumer credit, the corporate rate is specified as a markup over funding costs, with the markup itself determined by the risk associated with corporate lending and the structure of banks' balance sheets.

Importantly, we use the risk component of the markup to establish links between the cost of credit and the balance sheets of non-financial corporations in a mechanism similar to that outlined in Bernanke and Gertler (1989). These links are both direct and indirect. First, we use the corporate gearing ratio as indicated by the share of total corporate credit in GDP to reflect the debt burden of non-financial firms and thus the capacity of these firms to service their debt. Second, we include the corporate insolvency rate to capture general repayment risk associated with lending to firms. However, a key driver of the insolvency rate is the value of commercial property, which we use to approximate the strength of firms' balance sheets. We therefore incorporate an indirect channel between the latter and the interest rate on corporate lending.

The remaining components of the markup reflect banks'capital and liquidity management. The sensitivity of the corporate lending rate to changes in the capital ratio is important in determining how significant this margin of adjustment is to banks in meeting particular targets for macroprudential capital buffers.

Similarly, liquidity constraints through restrictions on the LTD ratio lead to banks using proportionately more relatively expensive deposit funding at the margin. As with the capital ratio, the difference in the elasticity of each of the lending rates with respect to changes in the LTD ratio is an important determinant of how banks may adjust to the changes in the composition of funding required under the Basel III framework. The equation for the corporate rate therefore has the following long-run form:

$$\begin{aligned} CorpRate_t &= \alpha + \beta_1 MMRate_t + \beta_2 DepRate_t + \beta_3 Insolv_t \\ &+ \beta_4 (CorpCredit_t / GDP_t) + \beta_5 CAP_t + \beta_6 LTD_t + \varepsilon_t \end{aligned} \tag{8}$$

where $CorpRate$ in the nominal interest rate on corporate lending, $Insolv$ is the corporate insolvency rate, $CorpCredit$ is total lending to non-financial corporations, GDP is nominal GDP and ε is the stationary equilibrium error. The error-correction model allows adjustment to this long-run relation and short-run dynamics from contemporaneous and lagged changes in the variables in (8).

2.4. Housing

As previously discussed, the residential housing market has propagated significant macroeconomic and financial volatility in the case of Ireland. As housing is the primary asset of Irish households (Lawless et al, 2015), fluctuations in house prices have a significant impact on both households' and, through mortgage lending, on banks' balance sheets.

In traditional housing models, the housing demand function is inverted so that (real) house prices are a function of the demand for housing services with the latter typically approximated by the per-capita housing stock. Variables that shift the demand schedule for housing include household income, rental yields and demographic factors. In equilibrium, the user cost of housing capital in terms of house prices will equal the rental yield.

However, the ability of these models to explain the behaviour of house prices across countries declined during the period of rapid appreciation that began in the early 2000s and continued up to the onset of the financial crisis (Muellbauer, 2012). One factor driving the poor empirical performance of traditional house price equations was the omission of variables that could account for the impact of changing credit conditions (Duffy et al, 2016).

In this context, recent house price models have sought to complement the user cost measure with an indicator that reflects shifts in the supply of credit. For example, Duca et al (2011) show that including the median LTV ratio for first-time buyers in a quite traditional house price model significantly improves its ability to explain pre-crisis house price dynamics in the US. However, as mentioned previously, these studies tend to use either reduced-form single-equation or VAR models.

One of the central contributions of this paper is to develop a structural framework that elucidates the interactions, feedbacks and spillovers between credit and housing markets. To this end, equations (1) and (2) show how changes in credit conditions, as reflected for example in a higher LTV ratio, directly affects the availability of credit. In a structural model it is the availability of credit rather than the LTV ratio itself which should enter the house price equation in some form. However, simply including the stock of mortgages in the latter would not reflect the extent to which the volume of outstanding credit has deviated from the level that would be implied for example by income levels. Therefore, the stock of credit needs to be normalised by a variable so that the resulting ratio can indicate how this "excess" credit stock is changing over time.

Here, we draw an analogy with the credit-to-GDP ratio that is the key indicator of excessive credit growth in the Basel III regulatory framework (BCBS, 2010; Drehmann and Tsatsaronis, 2014). The counterpart to this ratio at the household level is the mortgage debt-to-income (DTI) ratio and therefore we use this variable to link changes in credit availability in the mortgage market to changes in house prices.[32]

The second channel through which the mortgage market affects house prices is the user cost of housing. The latter is constructed as the difference between the mortgage rate and expected house prices appreciation so that lower interest rates raise the return on housing investment. We approximate house price expectations using a moving average of lagged annual house price inflation over the previous eight quarters.[33]

Finally, we also relate house prices to the other determinants of house prices in standard models as represented by disposable income and the demand for housing services. We use the ratio of the housing stock to the population of 25 to 39 year olds to approximate the latter. This variable incorporates the impact of demographic factors on house prices. A decline in this ratio implies that the ex-

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[32]The mortgage DTI ratio more accurately reflects a relaxation in borrowing constraints than a LTV constraint, as income is less subject to distortions from asset bubbles. Gelain et al (2013) show that LTV ratios in US during the housing boom of the mid-2000s did not indicate a significant increase in household leverage as house prices rose with mortgage credit in a self-reinforcing cycle. The extent of household leverage subsequently became clear when house prices collapsed. In contrast, the DTI ratio rose rapidly during the boom period and clearly signalled that household were becoming excessively leveraged. In addition, as the focus here is on the role mortgage credit availability plays in the determination of house prices, we exclude consumer credit from this ratio. In any case, the latter comprises a relatively small share of total household debt. Finally, note that the DTI ratio differs from the LTI ratio in that the former refers to the outstanding stock of mortgage credit while the latter refers to new mortgage lending.

[33]Our results are not sensitive to using alternative lag lengths to approximate expectations formation.

isting housing stock is becoming scarce relative to desired household formation and is thereby exerting upward pressure on house prices.

We therefore specify house prices as following an error-correction process with adjustment to the following long-run equilibrium:

$$HP_t = \alpha + \beta_1 User_t^h + \beta_2 Income_t + \beta_3(MorStock_t/Income_t) + \beta_4(HStock_t/Pop2539_t) + \varepsilon_t \quad (9)$$

where $user^h$ is the real user cost of housing, $HStock$ is the stock of housing units, $Pop2539$ is the population of 25 to 39 year olds, and ε is the equilibrium error. In the short run, we allow house prices to be driven by lagged and contemporaneous changes in the variables in (9), as well as by changes in the unemployment rate.[34]

On the supply side, we follow Poterba (1984) and Topel and Rosen (1988) and adopt a Tobin's Q approach to modelling residential construction. In this framework housing construction is a function of real house prices, construction costs and credit availability.[35] We model the completion of new housing units as a flow variable that accumulates on the existing housing stock through a perpetual inventory process (Mayer and Sommerville, 2000; Duffy et al, 2016). Our measure of Tobin's Q relates the value of housing to its replacement cost. We approximate this value of Q with the ratio of house prices to building costs, which reflects the profitability of housing construction (Kenny, 1999). Similar to housing demand, the housing supply model incorporates two credit channels. We capture the cost

[34]See Gerlach-Kristen and McInerney (2014) and Kelly and McQuinn (2014) for evidence of the impact of the unemployment rate on Irish house prices.

[35]More recent models have also included either farmland or residential land prices. Unfortunately, a representative continuous series for either is not available in the Irish case.

of credit by the change in the real corporate lending rate and credit availability by the growth rate of CRE lending. The latter approximates non-interest rate-related changes in credit conditions for construction firms.

Although these variables do exhibit procyclicality, housing investment itself is highly correlated with the economic cycle (Davis and Heathcote, 2005; Leamer, 2007). One potential explanation for this residual cyclicality in the housing completions equation is fluctuations in uncertainty, which tend to be countercyclical (Miles, 2009; Bloom, 2014). Housing construction is subject to uncertainty due to high fixed costs and concomitant irreversibility of investment. Periods in which there is higher uncertainty about the future profitability of construction raises the real option of waiting so that firms may postpone current investment projects. Accordingly, we include both the output gap and insolvency rate to capture cyclical variation in uncertainty about the future path of housing demand.[36]

Finally, we also include an indicator of population trends to reflect any demographic factors that may affect housing construction. These are captured using the change in the share of the population of 25 to 39 year olds in the total population. Our equation for housing completions therefore has the following form:

$$\begin{aligned} HCompl_t = \alpha + \beta_1 HCompl_{t-1} + \beta_2 Tobin_t + \beta_3 \Delta RCorpRate_t \\ + \beta_4 \Delta CRE_{t-1} + \beta_5 GAP_t + \beta_6 \Delta GAP_t + \beta_7 \Delta (Pop2539_t / Pop_t) + \varepsilon_t \end{aligned} \quad (10)$$

where $HCompl$ is the number of housing units completed in each quarter, $Tobin$

[36]The output gap is constructed as the deviation of real GDP from a Hodrick-Prescott filtered trend. The insolvency rate is included as a second indicator of cyclical variation in aggregate demand due to the difficulty of estimating the potential output of an economy that has experienced significant real volatility over much of our sample period.

is Tobin's Q given by the ratio of house prices to building costs, GAP is the output gap, Pop is the total population, and ε is a stationary error term. Property-related corporate lending, the corporate lending rate, the insolvency rate and the population variable are first-differenced to induce stationarity. The first lag of the dependent variable is included to capture persistence in the construction process (Duffy et al, 2016).

As mentioned above, we assume the housing stock (11) follows a perpetual inventory process with the current level of the housing stock depending on the depreciated level from the previous period and on new housing completions:

$$HStock_t = \delta^h HStock_{t-1} + HCompl_t \tag{11}$$

where δ^h is the rate of depreciation of the existing housing stock. Following Duffy et al (2016) we assume that the annual depreciation for dwellings is approximately 2 percent.

2.5. Commercial Real Estate

As discussed above, the primary channel through which commercial real estate affects financial stability in our model is through CRE loans. These loans are mainly secured using commercial property as collateral. It follows that fluctuations in commerical property markets have a potentially important impact on banks' balance sheets through losses-given-default on corporate lending. Therefore, a central contribution of our framework is to outline the transmission and feedback mechanisms that connect the banking and commercial real estate sectors. Further, equations (6) and (7) show how developments in the commercial property market affect the rest of the corporate sector through its role as collateral. For example, as commercial property rises in value firms may be able to obtain higher levels of credit through the typical Kiyotaki and Moore (1997) channel.

The literature on the drivers of commercial rents or capital values relates the return on commercial property investment to the stock of commercial property, the derived demand for this type of investment, and to the returns on alternative investments (Ball et al, 2010). Limitations on data availability, particularly in relation to the stock of commercial property, lead to different specifications across studies. In general however, the derived demand for commercial space is approximated by real GDP and is expected to be positively related to (real) capital values.

Our measure of the user cost of commercial property incorporates both an interest rate and capital gain component. Similar to the house price equation, the user cost variable represents the primary procyclical channel through which endogenous cycles in capital values are generated as expectations of appreciation follow an extrapolative rule. This rule is based on the moving average of lagged annual changes in capital values over the previous eight quarters.[37] We use the corporate lending rate to reflect the cost of credit used to finance investment in commercial property.

The previous section outlined how the house price equation needed to be augmented with a measure of credit availability given that interest rates are a poor indicator of credit conditions. Analagous to the mortgage credit-to-income

[37]We are therefore assuming that households and commercial real estate firms use similar rules to form expectations about the future appreciation of house prices and commercial capital values.

ratio for households used above and the private sector credit-to-GDP ratio for the aggregate economy used in the Basel III framework, we argue that the corporate credit-to-GDP ratio can similarly be used to reflect changes in the credit conditions facing firms.

Finally, the main challenge in modelling commercial property values in the case of Ireland is the absence of time series data on the supply of commercial property. In this respect, we follow Whitley and Windram (2003) and use the private capital stock per employee to approximate the effective stock of commercial property.[38] *A priori*, we expect that higher levels of the stock of commercial property are associated with lower capital values. We model commercial capital values in an error-correction framework with the following long-run equilibrium:

$$\begin{aligned} ComVal_t = \alpha + \beta_1 User^c_t + \beta_2 RGDP_t + \beta_3 (CorpCredit_t/GDP_t) \\ + \beta_4 (KStock_t/Emp_t) + \varepsilon_t \end{aligned} \tag{12}$$

where $ComVal$ are real commercial property capital values, $User^c$ is the user cost of investment in commercial property, $KStock$ is the private sector capital stock, Emp is private sector employment, and ε is the equilibrium error.

Importantly, as construction firms are likely to engage in the development of both commercial and residential property, we allow house prices to affect commercial capital values in the short run. House prices reflect demand pressures from the residential sector so that higher house prices attract resources away from commercial real estate construction, thereby raising the value of commer-

[38]The 2015 data for the Irish private capital stock displayed a level shift relative to previous years due to corporate restructuring and international asset transfers, which also generated outsized levels of depreciation. Accordingly, we construct a private capital stock for 2015 that is consistent with previous years by using investment data that excludes investment in intangibles and aircraft. The latter rose significantly as a result of this activity.

cial property due to relatively lower supply. In this context, house prices represent the opportunity cost to construction firms of commercial real estate development (Whitley and Windram, 2003).

The short-run capital values model also incorporates dynamics from changes in the variables in (12) and in the corporate insolvency rate. The latter is included as an indicator of investor sentiment similar to the unemployment rate in the house price equation.

2.6. Mortgage Arrears and Corporate Insolvency

From a financial stability perspective, a key indicator of household financial distress is the level of mortgage arrears. The empirical literature on mortgage default and borrower payment delinquency tends to support the "double trigger" modelling approach which posits that these events occur, not only because of a weak net equity position, but also because of changes in affordability caused by high debt service ratios, unemployment and lower expected income growth (Bajari et al, 2008; Gerardi et al, 2010).[39]

The international evidence on the drivers of mortgage arrears tends to point to both economic and financial factors as being important. For example, Gerardi et al (2015) examine the relative importance of liquidity and equity factors in mortgage distress among US households and show that job loss has an impact on mortgage default equivalent to a 35-50 percent fall in home equity.

Using UK data, Whitley et al (2004), Figueira et al (2005), and Aron and Muell-

[39]Another approach to modelling mortgage default or delinquency uses an option pricing model in which households choose to default once they have fallen into negative equity by a certain amount (Deng et al, 2000). In the Irish case, such strategic default is limited by mortgage contracts which give the lender full-recourse to the total amount outstanding.

bauer (2010) find that income gearing and "undrawn equity" are important determinants of arrears.[40] In virtually all studies, unemployment is significantly associated with higher rates of delinquency.

In the case of Ireland, several microeconomic studies use confidential regulatory loan-level data to investigate the drivers of mortgage arrears. Lydon and McCarthy (2013) using loan-level data over the period 2008 to 2010 find that the key drivers of arrears are unemployment and the debt service to income ratio. Kelly and McCann (2016) examine the determinants of a mortgage being in long term arrears using loan-level data for the period 2012 to 2013. They find that the key economic factors that influence mortgage distress are again unemployment and income gearing but show that mortgage interest rates and household equity are also important.

Following the literature, we model mortgage arrears as a function of both ability-to-pay and equity variables, with error-correction to the following long-run relation:

$$\begin{aligned} Arrears_t = \alpha + \beta_1 HHEquity_t + \beta_2 MorRate_t + \beta_3 URate_t \\ + \beta_4 (MorStock_t / Income_t) + \varepsilon_t \end{aligned} \tag{13}$$

where $Arrears$ is the household mortgage arrears rate and ε_t is the stationary equilibrium error term subsequently included in the short-run model, along with lagged and contemporaneous changes in the variables in (13).

Financial distress among non-financial corporations is captured by the cor-

[40]Undrawn equity is the residual proportion of housing wealth net of mortgage debt. Note that the variable capturing income gearing in these studies is typically the debt service ratio, which incorporates the impact of both mortgage size and the mortgage interest rate. Recall that in our framework, mortgage credit and the mortgage interest rate are endogenous variables and therefore we include them separately in the arrears equation.

porate insolvency rate. The literature on firm default and insolvency suggests that financial factors such as indebtedness are important determinants of firms' survival rate.[41] However, real factors that reflect overall demand conditions such as the unemployment rate are also important.

Vlieghe (2001) examines the determinants of the corporate liquidation rate in the UK and finds that aggregate corporate indebtedness, as approximated by the corporate debt-to-GDP ratio, interest rates, the output gap and collateral values (captured by an index of property prices) all play an important role. Liu (2009) also looks at the relation between corporate failure and macroeconomic factors in the UK and shows that profits and GDP growth, in addition to interest rates and credit, have a significant impact on the former.

Cross-country studies tend to yield similar results. For example, Hazak and Mannasoo (2007) investigate which variables best predict company failure using data for the European Union. Among the financial factors they consider, corporate leverage and real interest rates are positively associated with the probability of insolvency. On the real side, higher rates of GDP growth are associated with a lower probability of insolvency in 'old' member states.

There are few studies on the macroeconomic drivers of corporate insolvencies in the Irish context, particularly in terms of the role of financial factors. One exception is Kelly et al (2015) who examine the impact of both macroeconomic factors and credit conditions on Irish firms' probability of survival. Consistent with the international literature their results confirm that unemployment and

[41] That indebtedness should matter to a firm's solvency is clearly a violation of the Modigliani and Miller (1958) theorem, which as discussed in the next section in relation to bank capital, suggests that the ratio of debt to equity in a firm's funding structure should be irrelevant to the value of the firm. However, two of the conditions necessary for this theorem to hold and which are not supported empirically, are that firms can borrow at the prevailing market interest rate and that there is no bankruptcy.

credit growth have a significant impact on the insolvency rate. They also construct a "credit gap", similar to one we construct in section 4 according to the Basel III regulatory framework, as an indicator of credit conditions and find that new firms established during boom periods when credit conditions are relaxed are less likely to survive than those established when credit conditions are relatively tight.

Following these studies, we relate the corporate insolvency rate to both real and financial factors. The unemployment rate is used to capture demand factors that affect profitability, while the interest rate on corporate loans and the stock of corporate credit relative to GDP capture the cost of credit and the indebtedness of firms, respectively. In addition to these indicators of debt service costs and income gearing, changes in collateral values can affect firms' ability to rollover existing debt and access short-term working capital (Kiyotaki and Moore, 1997). Declining property values may lead to tighter credit constraints and thus increase vulnerability to adverse shocks for firms who cannot borrow to smooth the temporary decline in income. We allow commercial property values to affect the corporate insolvency rate to capture these constraints.

We model the corporate insolvency rate as error-correcting to the following long-run relation:

$$
\begin{aligned}
Insolv_t = \alpha + \beta_1 ComVal_t + \beta_2 RCorpRate_t + \beta_3 URate_t \\
+ \beta_4 (CorpC_t / GDP_t) + \varepsilon_t \qquad (14)
\end{aligned}
$$

where ε_t represents the stationary equilibrium error. The short-run behaviour of the insolvency rate is governed by lagged and contemporaneous changes in the variables in (14).

2.7. Bank Capital

In addition to liquidity requirements, the second channel through which macro-prudential policy can affect credit supply is through banks' capital structure. Theoretically, the Modigliani-Miller "irrelevance proposition" (Modigliani and Miller, 1958) posits that under certain conditions there is no optimal relationship of equity to debt finance in the funding structure of a firm. In reality, these conditions are rarely present for firms in general and for banks, in particular. For example, debt financing tends to incur more favourable tax treatment in most countries (De Mooij, 2012). In the case of banks, minimum capital requirements are necessary to mitigate the potential moral hazard concerns associated with holding publicly insured deposits. Given the higher cost of equity relative to debt, banks may however be expected to hold no more than these minimum requirements. Therefore, the typical corporate finance determinants of firms' capital structure outside of regulation should have little explanatory power in relation to banks (Gropp and Heider, 2010).

To the contrary, banks actually tend to manage their capital ratios and maintain capital buffers in excess of the regulatory minimum (Flannery and Rangan, 2008). Theoretically there may be several reasons for this.[42] First, banks may maintain these buffers so as not to trigger regulatory intervention if they accidentally allow capital levels to fall below the regulatory minimum (Repullo and Suarez, 2013). Also, due to asymmetric information, banks face significant costs in issuing new equity at short notice and accordingly may hold buffers to avoid these adjustment costs (Myers and Majluf, 1984). Second, banks may set capi-

[42]Under the Basel III framework, the minimum requirement for equity capital (CET1) is 4.5 percent of risk-weighted assets. In addition, the "capital conservation buffer" of 2.5 percent should comprise CET1 capital. This means that total CET1 capital must comprise at least 7 percent of risk-weighted assets ratio.

tal ratios according to economic needs rather than as a consequence of purely regulatory requirements. For example, banks may hold higher levels of capital due to perceived risk exposures, earnings volatility, to signal soundness to credit markets, or to be able to quickly avail of investment opportunities as they arise. Finally, the ‘pecking order’ theory of the capital structure suggests that banks’ capital holdings may simply reflect a period of high profitability and thus the recent path of retained earnings. Moreover, dividend payouts may signal to potential investors that the bank is unable to exploit growth opportunities (Maurin and Toivanen, 2012).

Empirically, capital ratios tend to be inversely correlated with banks’ size. This may reflect greater diversification by large banks, economies of scale in risk management, and easier access to equity finance due to lower informational asymmetries (Gropp and Heider, 2010). This is also the case for larger banking systems, as measured by the ratio of assets-to-GDP (Caprio et al, 2005). We use the latter to proxy for lower capital adjustment costs, and thus greater ability to manage capital ratios, that result from an expanding banking sector.

Microeconomic evidence also suggests that capital ratios are positively related to profitability indicating that retained earnings are an important source of recapitalisation, which is consistent with the pecking order theory (Berger et al, 2008; Mehran and Thakor, 2011). Unfortunately in the case of Ireland, data on the profitability of the aggregate banking sector is limited. However, there is a strong positive and robust relation between the slope of the yield curve and bank profitability with the former in particular reflecting the returns from maturity transformation (Alessandri and Nelson, 2015; Borio et al, 2017)[43]. In our

[43]A positive relation between the slope of the term structure and bank profitability suggests that the positive impact of the term structure on net interest income is larger than the negative

framework, these returns are given by the difference between lending rates and funding costs.[44] Accordingly, we use the spread between the weighted-average of lending rates and the money market rate to reflect the profitability of the aggregate banking sector.

There is considerable evidence that capital ratios are strongly procyclical (Drumond, 2009). For some banks this may be due to a decline in the measured Value-at-Risk (VaR) of assets during upswings as in Adrian and Shin (2014), while for others it may indicate myopic management whereby capital buffers fall during periods when equity is relatively cheap (Estrella, 2004; Jokipii and Milne, 2008). In terms of the latter, imbalances may accumulate during cyclical upturns and thus increase the likelihood of incurring large losses during downturns (Borio et al, 2001, Brei and Gambacorta, 2016). Similar to Akram (2014), we use the unemployment rate to capture these fluctuations in the capital ratio that are attributable to the economic cycle and thus to changes in the perception of economic risk.

Capital ratios also tend to be positively related to indicators of credit risk even after controlling for cyclical factors (Ayuso et al, 2004; Milne and Jokipii, 2008). Measuring credit risk at the banking sector level is difficult and although some expost measures of this risk such as the rate of non-performing loans may serve as suitable proxies, a sufficiently long series for this variable is not available for Ireland. Instead, we focus on portfolio risk related to the concentration of lend-

impact on loan loss provisions (due to higher debt-servicing costs and probability of default) and other non-interest income (via lower asset prices).

[44]Including the yield curve spread on government bonds in the bank capital equation would mean that bank profitability would be exogenous in simulations. We are therefore endogenising bank profitability by instead using the difference between lending rates and funding costs. We use the money market rate to approximate the latter due to the large elasticities with respect to lending rates estimated in the next section.

ing in real estate as this is the loan category which tends to be the most volatile. Following Martin-Oliver et al (2013) we use a simple measure of the exposure to this risk given by the share of real estate lending in total lending. In addition, we allow risk in the short-run to be reflected by fluctuations in asset values in the household sector, as given by changes in house prices, and by the corporate insolvency rate.[45]

As in the case of credit risk, measuring the impact of "market discipline" on banks' capital ratios at the aggregate level is difficult from both a definitional and data availability perspective. However, some studies suggest that this impact operates through the share of funding that is uninsured or that does not comprise deposits (Nier and Baumann, 2006; Francis and Osbourne, 2010). For a given increase in bank risk, non-deposit investors will demand higher yields, which will accordingly reduce bank profitability. This effect rises with the share of liabilities that are uninsured. To mitigate the pressure from market discipline, banks may raise their capital ratio to reduce leverage and to signal lower solvency risk to potential investors. The bank capital equation in our model uses the share of deposits in total liabilities to capture this disciplinary impact of the market.

In summary, we model the capital ratio as adjusting to a long-run equilibrium that depends on a number of factors related to the size of the banking sector, profitability, cyclicality, risk exposure and market discipline:

$$\begin{aligned} CAP_t = \alpha + \beta_1(Assets_t/GDP_t) + \beta_2 URate_t + \beta_3 Spread_t \\ + \beta_4(CRE_t/Loans_t + \beta_5(Deposits_t/Liabilities_t) + \varepsilon_t \end{aligned} \tag{15}$$

[45]We also included house prices and the corporate insolvency rate in the long-run relation but both were statistically insignificant.

where CAP_t is the ratio of capital to risk-weighted assets, $Spread_t$ is the difference between a weighted-average of lending rates and the money market rate, $Assets$ and $Liabilities$ are, respectively, the total assets and liabilities of the banking sector, and ε_t is the stationary equilibrium error.[46] We allow for an error-correction process to reflect the adjustment costs associated with raising new equity. As mentioned above, the short-run model also allows the capital ratio to respond to changes in house prices and the corporate insolvency rate, in addition to changes in the variables included in the long-run relation.

3. Results

We estimate the model presented in the previous section as a system using three-stage least squares (3SLS) over the period 1988 Q1 to 2015 Q4.[47] This estimator allows us to capture contemporaneous spillovers between sectors and to instrument for potentially endogenous variables.[48] Although the equations are estimated jointly, we discuss each individually here for expository reasons.

3.1. Mortgage Credit

Table 1 presents the results of the mortgage demand equations. All variables are statistically significant at the 5 percent confidence level. The demand for new mortgages exhibits moderate persistence with a coefficient of 0.715 on the first lag. The dependent variable is the volume of new mortgages that are drawn

[46] Clearly, total assets must equal total liabilities. They are included separately here for intuition.

[47] One exception is the mortgage arrears equation, which is estimated separately due to a shorter sample length. Unit root test results for each variable are available from the author.

[48] We use lags of the potentially endogenous variable as instruments.

down rather than approved. Therefore, past conditions in the mortgage market when mortgages were approved can affect the current volume of new mortgage credit actually obtained by households.

Our results suggest that affordability constraints or repayment capacity are particularly important determinants of mortgage demand. The mortgage rate has a negative impact indicating that the cost of credit is a statistically significant contributing factor to the debt-service burden. However, it is real household disposable income that appears to be the main factor driving mortgage affordability. We find that collateral constraints also play a role. Higher house prices allow households to obtain higher levels of mortgage credit for a given LTV ratio. In our model this introduces procyclicality to mortgage lending similar to the accelerator mechanism outlined in Almeida et al (2006) and provides motivation for our simulations of countercyclical LTV rules in section 4.1.

The central motivation of this paper is to specify and quantify the channels through which macroprudential policy operates. In this context, changes in borrower-based instruments alter the credit conditions facing households. As we have concentrated out the impact of cyclical factors on these instruments, higher (lower) values for the LTI and LTV ratios imply a relaxation (tighening) of affordability and collateral constraints, respectively.

Table 1 shows that these adjusted LTV and LTI ratios have a positive and significant effect on the demand for mortgage credit. For example, a 1 percent increase in the adjusted LTV ratio raises the volume of new mortgages by over 2.5 percent while a similar increase in the adjusted LTI ratio raises this volume by over 1.5 percent in the long run.[49] From a macroprudential perspective, these

[49]The long-run impact of each ratio is calculated by dividing the short-run coefficient in Table 1 by (1-0.715), where 0.715 is the coefficient on the lagged dependent variable. Duffy et al (2016)

results suggest that imposing restrictions on these ratios would potentially be very effective in constraining credit growth in the case of Ireland. We discuss this further in section 4.

The right panel of Table 1 shows how the volume of new mortgage credit accumulates on the outstanding stock of credit. The coefficient of 0.982 indicates how much of the latter remains after net mortgage repayments. We impose the unitary coefficient on new mortgage credit in the current period to reflect a perpetual inventory process.

Table 2 presents the results of the mortgage supply equation. The top panel shows the coefficients on the variables driving the nominal mortgage interest rate in the long run while those in the bottom panel are the coefficients of the error-correction model. Both indicators of funding costs have a positive and significant effect on the mortgage rate, although the long-run elasticity of the latter with respect to the money market rate is much higher than with respect to the deposit rate. A one percentage point increase in the money market rate raises the mortgage rate by 77 basis points in the long run compared to 18 basis points for a similar increase in the deposit rate.

The variables representing macroeconomic risk and risk specific to lending to the household sector are also significant. Higher rates of unemployment generate greater repayment risk which leads to a compensatory increase in mortgage rates. Similarly, higher levels of home equity imply lower rates of loss given default which allows banks to reduce mortgage rates.

We also find evidence that macroprudential policy could have a significant impact on the pricing of mortgage lending. Restrictions on the LTD ratio lead to banks substituting away from wholesale funding at the margin towards relatively

find similar results using different data.

more expensive deposits with these higher costs "passed-through" to higher mortgage rates. The introduction of higher capital buffers would also raise lending rates as banks try to generate earnings through higher net interest margins to achieve the required capital ratios. The coefficient on the (log) capital ratio implies that a one percentage point increase in this ratio raises the mortgage interest rate by approximately nine basis points. This is within the range of estimates found in the literature.[50]

The coefficient on the error-correction term indicates that the mortgage rate adjusts quite quickly (within a year) to the long-run equilibrium. Changes in the money market rate, the deposit rate and in the capital ratio contribute additional dynamics to the mortgage rate in the short run. We also included changes in the unemployment rate, LTD ratio and household equity in the short-run model but these were insignificant.[51]

3.2. Consumer Credit

Table 3 presents the results for the supply of and demand for consumer credit. The long-run demand for consumer credit is mainly driven by income and household equity. Recall that the dependent variable in the demand equation is the (notional) stock of consumer credit so that a one percent increase in income is associated with a 0.5 percent increase in this stock. The coefficient on house-

[50]Estimates of the impact of a one percentage point increase in capital requirements on lending rates range from 2 to 20 basis points. See Dagher et al (2016) for a survey of the literature on the pass-through of changes in capital to lending rates. We discuss this literature further in section 4.2.

[51]Most of the equations include time dummies for particular quarters that are clear outliers such as during the ERM crisis of 1992-1993 or the financial crisis. These are periods of exceptional volatility that are unrelated to changes in the underlying determinants of the variable but which affect the coefficient estimates if their impact is not controlled for.

hold equity is quite large but reflects the rising “spendability” of housing wealth over our sample period. Interestingly, the long-run coefficient on net financial wealth is much smaller and only weakly significant. One potential explanation for this finding is that housing represents Irish households’ main asset so that the “wealth effect” of housing is much greater than for financial assets. In addition, financial assets mainly comprise pensions and technical reserves and so are relatively illiquid.

We also find that the interest (semi-) elasticity of consumer credit demand is relatively low. In our model, this has implications for the strength of the transmission of intermediary-based macroprudential instruments to the household and corporate sectors and, ultimately, for the size and composition of banks’ balance sheets. As these instruments operate through lending rates, a low interest elasticity of credit demand will weaken the impact of these instruments, all else equal.

The error-correction model is characterised by adjustment to the equilibrium given by the long-run coefficients above and by additional dynamics from housing wealth and income. We also find that shocks to consumer credit itself generate persistence in its behaviour in the short run.

On the supply side, we find evidence that funding costs, risk and balance sheet or macroprudential factors all drive the consumer lending rate in the long run. A particularly interesting finding is that the elasticity of the lending rate with respect to the deposit rate is much higher than with respect to the money market rate. For example, a one percentage point increase in the latter raises the consumer interest rate by 33 basis points, whereas a similar increase in the deposit rate raises the consumer rate by 66 basis points. As we use the money market rate to reflect changes in the central bank’s policy rate, our results suggest that the pass-through of monetary policy changes is much lower for the consumer rate than for either the mortgage or corporate lending (discussed below) rates.

In terms of risk, the consumer credit-to-income ratio appears to be a more important factor in the pricing of consumer lending than the unemployment rate. Both variables are used to approximate repayment capacity but the more specific measure of lending risk may more accurately capture the debt-service burden or income-gearing ratio that influences bank lending.

The elasticity of the consumer lending rate with respect to both lender-based macroprudential instruments is the largest across all lending rates. This result would be expected a priori in the case of the capital ratio, as consumer lending is unsecured and is potentially the riskiest type of lending. For example, a one percentage point increase in this ratio increases the consumer lending rate by approximately 11 basis points in the long run. The large coefficient on the LTD ratio reflects our finding that Irish banks tend to rely on relatively more expensive deposit funding when setting consumer lending rates. Holding all other variables constant, a higher LTD ratio implies that banks are using proportionately more wholesale funding at the margin and this leads to lower lending rates than would otherwise prevail.

Similar to the mortgage rate, the consumer lending rate exhibits relatively fast error-correction, with adjustment to the long-run equilibrium occurring after approximately one year. Short-run dynamics in the consumer rate are mainly determined by changes to funding costs and to the capital ratio.

3.3. Corporate Credit

Table 4 presents the results for the demand for each type of corporate credit. We find that the long-run demand for construction and real estate credit is more procyclical than that for non-property related corporate credit and is more sensitive to the value of collateral. For example, a one percentage rise in the value of commercial property is associated with 0.83 percent rise in the stock of corporate lending to the real estate sector but only a 0.35 rise in corporate credit to other sectors.

The demand for credit by construction and real estate firms is also more sensitive to the cost of credit than that by other firms. As discussed above, the interest elasticity of credit demand is an important determinant of the strength of the impact of macroprudential instruments that directly affect the behaviour of financial intermediaries. In this case and holding all other variables constant, any given increase in the corporate lending rate due to changes in these instruments will affect the stock of property related corporate credit more than the stock of non-property corporate credit in the long run. Ultimately, they will affect both the size and composition of the stock of total corporate lending on banks' balance sheets.

As construction firms supply both residential and commercial real estate, the value of the housing stock is included along with the value of commercial property to indicate the value of both types of collateral. The long-run coefficients on both variables are broadly similar with demand elasticities close to unity.

We find that the demand for non-property related credit is inversely related to firms' profits in the long-run. One obvious explanation for this is that Irish firms are predominantly small and medium enterprises for which external borrowing is relatively expensive due to information asymmetries. The pecking-order theory of the liability structure suggests that firms will prefer to first use retained profits to finance investment before turning to external sources.

The error-correction models for both credit aggregates are characterised by significant but relatively slow adjustment to the long-run equilibrium relation. Short-run persistence in construction and real estate credit is mainly due to own shocks, although there is some evidence that changes to the cost of credit also play a role. The short-run behaviour of non-property corporate credit is influenced by both its own shocks and shocks to corporate profits, real GDP and the value of commercial property

In terms of supply, Table 5 shows that funding costs, corporate risk and the two macroprudential instruments are all significant determinants of the interest rate on loans extended to non-financial corporations. The elasticity of the corporate lending rate with respect to the money market rate is the highest across all three lending rates and is correspondingly the lowest with respect to the deposit rate. A one percentage point increase in the money market rate raises the corporate rate by 81 basis points, while a similar increase in the deposit rate raises the latter by 16 basis points.

Our indicators of financial stress in the corporate sector suggest that credit risk is also an important factor that banks consider when setting interest rates on corporate loans. The corporate credit-to-GDP ratio represents an approximate measure of the firms' income gearing and reflects the impact of a higher debt service burden on repayment capacity. Recall also that we relate the corporate insolvency rate to indicators of firms' balance sheet strength so this variable provides an indirect channel through which the latter affects the cost of borrowing. Higher interest rates in turn lead to lower credit demand and ultimately, to lower commercial capital values. This link between balance sheet strength and the cost of credit generates similar "accelerator" effects to those outlined in, for example, Bernanke et al (1996).

It is particularly interesting to compare the coefficients on capital and LTD ratios with those of the mortgage and consumer credit supply equations. Taken together, they indicate the relative strength of each margin along which banks adjust to potential changes in regulatory policy. The elasticity of the corporate lending rate to changes in the LTD ratio is between that of the mortgage and consumer rates while the elasticity of the corporate lending rate to changes in the capital ratio is the lowest across all lending rates. Comparing the latter elasticities across lending rates, a one percentage point increase in the capital ratio raises the consumer, mortgage and corporate rates by eleven, nine and seven basis points, respectively.

Table 5 also shows that the short-run dynamics of the corporate rate are mainly determined by error-correction and by shocks to the money market rate and capital ratio. The speed of adjustment to the long-run equilibrium relation is broadly similar to the other lending rates, which suggests that it generally takes approximately one year for nominal interest rates to fully respond to shocks in the variables that drive their long-run behaviour.

3.4. Housing and Commercial Property

Table 6 presents the results of the equations for the demand for both housing and commercial property. All variables are statistically significant with the expected signs. The equations have similar functional forms that relate the price of each type of property to corresponding measures of user cost of capital, income, credit conditions and property supply. The user cost of capital appears to have an almost identical impact on the demand for each type of property, although the coefficient is quite small. The main impact of credit markets on house prices and commercial capital values appears to operate through the credit conditions channel, as captured by the mortgage credit-to-income and corporate credit-to-GDP ratios. For example, a one percentage point increase in the mortgage credit-to-income ratio raises real house prices by approximately 1.3 percent, while a one percentage point increase in the corporate credit-to-GDP ratio raises commercial capital values by approximately 2 percent.

We also find evidence consistent with the literature that property prices are strongly procyclical. This is particularly the case for commercial property with a unitary elasticity on the real GDP coefficient and partially explains the steep rise and decline in capital values over the last two decades. From a stress-testing and financial stability perspective, the derived demand for both commercial space and residential housing are therefore significant contributors to fluctuations in the asset prices that secure much of Irish banks' lending.

Table 6 also shows how the value of each type of property varies inversely with its supply. A larger housing stock relative to the number of people wishing to form households implies that the residential housing stock is expanding relative to demand and this increase in the effective supply exerts downward pressure on house prices. Similarly, an increase in the stock of commercial property relative to the number of employees expands the effective supply of commercial space and dampens the appreciation in capital values. We emphasise however, that we are using the total private capital stock as an approximation for the stock of commercial property and therefore the coefficient on this variable should carry this caveat.

The short-run models of house prices and capital values show that the error-correction tends to occur at a similar speed to each of the credit stocks. Short-run persistence in house prices is mainly driven by own shocks with additional dynamics from changes in income, the unemployment rate and credit conditions. House prices also affect capital values in the short-term as construction firms in both the residential and commercial property sectors compete for the same resources. Similar to the unemployment rate in the house price error-correction model, the corporate insolvency rate is included in the model of commercial capital values to capture investor sentiment and uncertainty. The coefficients on these variables suggest that their effects tend to be quite small.

Table 7 presents the results of our housing supply model.[52] Housing completions display a high level of persistence, which is unsurprising considering the lags that are intrinsic to the construction process.

We find that the Tobin's Q model is an empirically valid representation of residential investment in the Irish case. One of the key drivers of housing construction is the ratio of house prices to building costs, which we use to reflect the value of the housing stock relative to its replacement cost. Higher values of Q indicate that the profitability of construction is increasing so that a one percent increase in this ratio leads to a 1.6 percent increase in the supply of new housing units in the long run.

Both the cost and growth rate of credit are significant and have the expected signs. As the interest rate on construction credit is likely to be higher than the representative corporate rate, the coefficient on the latter likely constitutes a

[52] Recall that as we use the total private sector capital stock as an approximation of the supply of commercial property we treat the latter as exogenous. Endogenising the private capital stock would require a much larger macroeconomic model and is therefore beyond the scope of this paper.

lower bound on the effects of interest rates on housing supply. Measuring changes in the availability of construction credit is difficult given data availability. However, as we control for both the cost of credit and cyclical factors affecting housing completions, the growth rate of property-related corporate credit should provide an approximate indicator of general credit conditions facing construction firms. Accordingly, we find that higher growth rates are associated with higher levels of building activity by these firms.

The coefficients on the output gap and insolvency rate suggest that uncertainty and sentiment also play a role on the supply side. These indicators are used to reflect mean-preserving shifts in the distribution of future housing prices and thus changing perceptions about the future profitability of residential investment. We interpret our results as suggesting that construction firms' uncertainty falls as the macroeconomic environment improves and as the level of corporate distress falls. This consequently generates an increase in the number of new housing units.

Finally, we include the growth in the share of 25 to 39 year olds in the total population to capture desired levels of household formation and to provide a demographic context to interpret shifts in the quantity of completions over time.[53] We find that the change in this share has a positive and significant effect on the supply of new housing units. Clearly, this is a slow-moving variable and is therefore more likely to explain underlying trends rather than any higher frequency fluctuations in housing supply.

[53]We also considered alternative specifications in which the level of completions is itself scaled by a demographic indicator. These specifications yielded an inferior out-of-sample fit to that outlined in Table 7.

3.5. Mortgage Arrears and Corporate Insolvency

We now turn to the indicators of stress in the household and corporate sectors. Table 8 highlights the role of financial factors in determining the rate of household mortgage arrears and corporate insolvencies. In particular, the debt-to-income ratio, which together with the cost of credit, reflect the debt-service burden, appears to be the key driver of both measures of economic distress. For example, a one percentage point increase in the mortgage credit-to-income ratio raises the household mortgage arrears rate by approximately 18 basis points, while a similar increase in the non-property corporate credit-to-GDP ratio raises the corporate insolvency rate by approximately three basis points. Importantly, these results suggest that financial regulators and macroprudential policymakers need to pay particular attention to the income gearing of both households and firms when assessing risks to financial stability.

In addition, adverse shocks to the value of assets used to secure lending can lead to higher rates of delinquency. For households, we find that a one percent fall in home equity raises the mortgage arrears rate by 12 basis points. Recall that mortgages extended by Irish banks are typically full-recourse so that in the event that home equity becomes negative households cannot simply exit the mortgage contract by surrendering the collateral to the lender. As we control for factors that affect debt-servicing capacity, our results may provide some evidence however that households engage in strategic default when home equity falls. For firms, fluctuations in the value of commercial property are more likely to reflect changes in net worth and the concomitant ability to obtain working capital when they are liquidity constrained. Interestingly, our results suggest that this channel is quite weak with a one percent increase in the value of commercial property (net of corporate bank credit) reducing the corporate insolvency rate by less than one basis point.

The final long-run determinant of both arrears and insolvencies is the unemployment rate. The latter is included to reflect changes in the macroeconomic environment and the impact this has on the debt repayment capacity of households and firms. We find that the unemployment rate has a positive significant long-run effect on both stress indicators. Further, the results of the error-correction model show that changes in the unemployment rate also have a significant effect on the arrears and insolvency rate in the short term.

We find that the adjustment of household arrears to the long-run equilibrium occurs at approximately one-third of the speed of the insolvency rate, although the shorter sample length of the former likely makes it more difficult to estimate this coefficient accurately. The short-run dynamics of mortgage arrears are also affected by shocks to the mortgage interest rate and household equity, while the insolvency rate is driven by its own shocks and those to the value of commercial property.

3.6. Bank Capital

Table 9 presents the estimation results of the bank capital equation. Banks' capital ratios tend to decline as the banking sector expands. The most obvious explanation for this is that banks find it easier to raise capital at short notice in larger banking systems, perhaps due to lower information asymmetries and more liquid capital markets. We also find that banks maintain higher levels of capital when unemployment is rising. For example, a one percentage increase in the unemployment rate is associated with a 50 basis points increase in the ratio of capital to risk-weighted assets. This indicates that the capital ratios of Irish banks are strongly procyclical as banks raise precautionary buffers and increase provisions against potential loan impairment. It is this feature of capital ratios that the Basel III regulatory framework seeks to address by requiring banks to increase capital buffers in "good" times when it is relatively less expensive to do so. We discuss this procyclicality further in section 4.2.

Our results suggest that the capital ratio is positively related to the spread between interest rates and funding costs. This reflects the ability of banks to raise capital through retained earnings consistent with the pecking order theory of the capital structure. We also find that capital ratios are increasing in the exposure of banks to the real estate sector. This is mainly due to the greater volatility of this sector relative to other types of lending which leads to banks holding higher levels of capital as a precaution.

The composition of banks' liabilities is also an important driver of capital holdings in the long run. We find that the capital ratio is inversely related to the share of deposit funding in total liabilities. As banks with a falling share of deposit relative to wholesale funding are more vulnerable to rollover or liquidity risk, "market discipline" may require these banks to hold higher levels of capital. The estimated coefficient suggests that a one percentage point fall in the share of deposits in total liabilities raises the capital ratio by approximately 16 basis points.

Table 9 also shows that bank capital exhibits significant but relatively slow error-correction. The speed of adjustment reflects the presence of adjustment costs that generate inertia in the capital ratio. These rigidities may need to be considered by regulators and macroprudential policymakers when changing capital buffer requirements. In addition to persistence arising from the growth of the banking sector, the short-run behaviour of bank capital is also driven by shocks to the riskiness of lending and collateral values, as indicated by changes in the corporate insolvency rate and house prices, respectively.

Finally, as a complement to the R^2 as a measure of goodness-of-fit that is presented in each table, Figure 1 shows the fitted values for each variable as predicted by the model relative to each variables actual historical value. The in-sample fit of each variable corresponds closely to actual values over the sample, although there is some evidence of instability in the housing completions equation during the late 1990s and early 2000s.[54]

We now illustrate how our model and broader framework could be used by a macroprudential authority to examine the potential impact of different instruments on the banking and real estate sectors.

4. State Dependence and Counterfactual Scenarios

Given the calamitous impact of the collapse of the housing bubble on the Irish economy, and on the banking sector in particular, an important question from a policymaker's perspective is the extent to which this could have been mitigated had a different financial regulation framework been in operation. Through the counterfactual scenarios that our model can generate, we can create "alternative histories" that highlight and quantify how targeting distortions through macroprudential policy might have significantly reduced real and financial volatility in the Irish case. We focus on one borrower-based instrument, the LTV ratio, and one lender-based instrument, the CCyB, to illustrate their differential real

[54]Formal statistical tests for a structural break do not indicate that this instability significantly changes the relation between completions and its covariates.

effects.

4.1. Countercyclical Rules for LTV Ratios

To simulate these counterfactual scenarios, we need to assume a likely reaction function for the macroprudential authority, one that is countercyclical and rules-based.[55] The effectiveness of borrower-based macroprudential instruments are likely to be state-dependent as regulatory restrictions on maximum LTV and LTI ratios may only bind at certain stages of the economic (or financial) cycle. A passive macroprudential stance in terms of this cycle can generate strong procyclicality in credit and house price (Almeida, 2006). As discussed below, the Basel III framework aims to dampen the financial cycle with the introduction of instruments, such as the countercyclical capital buffer (CCyB), that aim to mitigate the growth of systemic risk that follows the procyclical expansion of the balance sheets of financial intermediaries. Thus, a macro

In addition, the rules-based aspect to macroprudential instruments, such as that specified for the CCyB, are attractive from a financial stability perspective as they are transparent, easy to understand, and predictable. While the CCyB is focused on the procyclical leverage of the institutions that supply credit, similar countercyclical rules that seek to limit the procyclical indebtedness of borrowers through adjustment of the ceiling on the LTV ratio could also be considered to be an effective tool in maintaining financial stability.[56]

Several studies have examined the welfare impact of different types of LTV

[55]Our simulations focus on countercyclical rules for the LTV ratio only. However, similar rules could also be specified for the LTI ratio.

[56]The Basel Committee on the Global Financial System has emphasised the potential role of a countercyclical LTV ratio as an automatic stabiliser in maintaining financial stability (CGFS, 2010).

rules using calibrated DSGE models. For example, Christensen and Meh (2011) examine the behaviour of a countercyclical LTV rule in a DSGE model with housing providing the main source of collateral. In their model, the regulator controls the LTV specified in mortgage contracts and adjusts the ratio according to the deviation of mortgage credit from its steady state value. Thus, the policymaker lowers the LTV ratio during periods of excessive credit growth and raises the ratio when credit growth is relatively weak. Similarly, Lambertini et al (2013) consider a macroprudential policy rule for the LTV ratio that behaves countercyclically. They find that LTV rules that respond to credit growth lead to higher welfare than rules that respond to house prices or GDP growth as the former generate a more stable supply of credit.

Our framework can be used to evaluate the stabilising properties of different types of LTV rules, as well as to make some inferences about their impact on welfare. Accordinly, we now consider scenarios in which the LTV ratio follows a rule whereby it varies inversely with a particular indicator of the economic or financial cycle. We follow Lambertini et al (2013) and specify rules for the LTV ratio with the following form:

$$LTV_t = \nu_m LTV_{t-1} + (1 - \nu_m)LTV_{ss} - (1 - \nu_m)\phi_x(x_t - x_{t-1}) \tag{16}$$

where ν_m is an autoregressive parameter that is set to 0.5, LTV_{ss} is the steady-state value of the LTV ratio, which is set to the average LTV over the sample period, and ϕ_x is the response of the LTV to the cyclical indicator x_t, which can represent house price, credit or GDP growth.[57] Note that the final term on the

[57]The results are qualitatively similar for different values of the autoregressive parameter and are available on request. We include GDP growth as a cyclical indicator for completeness although it is exogenous in each scenario. Thus, the scenarios based on this indicator show the

right-hand side is negative so that the rule is countercyclical. Similar to Lambertini et al (2013), we consider the rule for different values of ϕ_x between 1 and 7. These models are solved over the period 2000 Q3 to 2015 Q4 and we compare the results to the baseline scenario in which the LTV ratio is exogenous.

Although our framework does not explicitly specify utility functions as is typical in DSGE models, we can compare the different rules along dimensions that matter for household welfare. In this respect, the relative impact on household welfare of each rule could be assessed via the level of the housing stock, housing equity, and mortgage arrears that are generated by each rule. The housing stock is often used to approximate the consumption of housing services (Duca et al, 2011), while household equity and mortgage arrears have been shown to be a key driver of non-housing consumption (Mian and Sufi, 2011; Kaplan et al, 2015).

Table 10 shows the percentage change in the mean and standard deviation (in parenthesis) relative to the baseline of the key mortgage and housing markets variables under each type of rule and for different values of the sensitivity parameter ϕ_x.[58] In terms of welfare, the credit-based rule for the LTV ratio achieves the greatest reduction in the average level of mortgage arrears and the largest increase in average levels of household equity. However, to the extent that home ownership or the consumption of housing services matters for welfare, an LTV rule that targets house price growth leads to the smallest reduction in the housing stock relative to the baseline. This is a result of the fall in house prices being lower relative to that under the other rules. However, it is impor-

impact of these rules on credit and housing markets, conditional on the historical evolution of GDP.

[58]We focus in these variables to simplify the exposition. The mean and standard variation under each rule for all other variables in the model are available from the author on request.

tant to note that the differences between the rules in terms of the housing stock are relatively small (approximately one percentage point) while those in terms of arrears and household equity are much larger. Therefore, our analysis suggests that the smallest reduction in welfare relative to the baseline of not adopting rules for the LTV ratio, is achieved by those rules that target credit growth.

Of primary interest from a macroprudential perspective are the stabilisation properties of each rule in terms of the extent to which each rule reduces the volatility of particular prices and quantities and thus dampens boom and bust cycles in credit and house prices. Table 10 shows that, among the three types of rules, the credit rule leads to the lowest variability, or fall in standard deviation, across all variables. In particular, LTV rules that target credit growth achieve greater stability in house prices when compared to rules that explicitly target house prices. In our framework, this is due to weaker feedback from house prices to credit growth relative to the impact of credit growth on house prices. More stable house prices lead to greater stability in housing supply via Tobin's Q in the housing completions equation, which accordingly generates more balanced growth in the housing stock.

Table 10 also highlights how targeting credit growth significantly reduces the volatility of mortgage arrears relative to other cyclical indicators. Stabilising the growth of mortgage credit also stabilises income gearing and household equity, which are the key determinants of mortgage arrears in the model. The variability of the latter falls significantly under all rules, but particularly those that directly respond to credit growth.

We now illustrate how the path of credit and housing markets might have evolved during the 'boom' and 'bust' periods had the credit-based rule for the LTV ratio been in operation in an Irish context. Figure 2 shows the counterfactual path of the housing and mortgage market variables in percent or percentage point deviation from the actual path. If the Irish macroprudential policy authority had adjusted the LTV ratio in response to credit growth from 2002 onwards, it is clear that the build-up of mortgage debt would have been much lower in the pre-crisis period.

Our model suggests that, depending on the value of ϕ_c, new mortgage lending would have been between 35 and 75 percent lower in 2007 resulting in a mortgage stock that was between 20 and 50 percent lower prior to the onset of the global financial crisis. As a result, house price growth would have been between 10 and 20 percent lower in the pre-crisis period but would have been significantly higher after the onset of crisis. Lower house prices reduce the profitability of housing investment and thus would have precipitated significantly lower housing construction. As a result, the overhang of residential properties that developed as a result of the construction boom in Ireland would likely not have materialised.

The lower level of housing construction would also have significantly reduced the demand commercial real estate credit by between 10 and 23 percent, depending on the parameterisation of ϕ_c. The spillovers between both commercial and residential real estate markets in the mode are also evident as commercial capital values fall between 7 and 15 percent. The fall in collateral values further generates a decline in the demand for non-property corporate credit, while the fall in house prices relative to their historical baseline would have led to a lower demand for consumer loans through the wealth effect.

The counterfactual lower levels of collateral values also implies that interest rates would have been higher. The simulation results suggest that, if the Irish macroprudential authority had followed a credit-based rule for the LTV ratio, mortgage rates could have been up to 20 basis points higher, corporate rates up to 40 basis points higher, and consumer rates up to 80 basis points higher prior to the onset of the financial crisis. Lending rates subsequently fall back to baseline values in-line with collateral values.

From a financial stability perspective however, perhaps the most important impact of the rules would have been on household mortgage arrears. Our simulations show, that a credit-based LTV rule would have prevented much of the build-up of arrears in the post-crisis period and that for intermediate to high values of ϕ_c, would have eliminated arrears almost completely.

4.2. Countercyclical Capital Buffer

A key component of the Basel III regulatory framework is the introduction of a countercyclical capital buffer (CCyB) that is proportional to the difference between the private sector credit-to-GDP ratio and its long-run trend. The European Systemic Risk Board (ESRB) has outlined a standardised approach for calculating this gap for euro area economies. The credit-to-GDP ratio is defined as the ratio of private non-financial sector credit to nominal GDP, while the trend ratio is estimated by the Hodrick-Prescott (HP) filter.[59] The "credit gap" is the deviation from trend and the buffer is activated once the gap exceeds 2 percentage points. The size of the buffer increases linearly from 0 to 2.5 percentage points until the credit gap exceeds 10 percentage points, above which the 2.5 percentage point maximum is applied.

Figure 3 shows the "real-time credit gap" that Irish policymakers would have been able to contemporaneously estimate prior to and in the aftermath of the

[59] The trend in the credit-to-GDP ratio is estimated using a one-sided HP filter with the smoothing parameter, λ, set to 400,000.

financial crisis. The credit gap exceeded the lower threshold of the CCyB in 1998 and remained at or close to the upper threshold until early 2003, after which it stayed above this threshold until mid-2010. As previously mentioned, the period since 2010 has coincided with substantial private sector deleveraging, which is reflected in the sharp decline in the gap.

We now consider what the impact on credit and housing markets might have been if the CCyB component of the Basel III framework had been in operation during the boom and bust episode. We simulate a counterfactual scenario in which the capital ratio is raised by 2.5 percentage points from 2000 Q1 to 2010 Q2, by 1.5 percentage points in 2010 Q3, and falls back to its baseline value thereafter.[60]

Figure 4 illustrates the impact on the banking and property sectors of these higher capital requirements. Banks respond to the latter by raising lending rates. As discussed in section 3, a particularly interesting result from the estimation of the model is the differential rates of pass-through from changes in the capital ratio to different lending rates. Pass-through is highest for the lending rate on consumer loans, which rises by up to 30 basis points relative to the baseline of no change in capital requirements over the simulation period. This is followed by the mortgage interest rate, which increases by up to 25 basis points and by the corporate interest rate, which rises by 20 basis points over the period. Each interest rate returns to baseline approximately 1.5 years after the CCyB has fallen to zero.

[60]Clearly, such sharp movements in the CCyB are not realistic as macroprudential authorities are likely to smooth changes in capital requirements given the uncertainty in measuring the credit gap and the adjustment costs incurred by banks in meeting these requirements. Thus, these simulation results are more illustrative of the long-run impacts of the CCyB rather than the short-term dynamics it might have generated.

The impact of higher capital requirements on the volume of credit depends not only on the change in interest rates, but also on the estimated interest elasticity of demand for each type of credit. Figure 4 shows that new mortgage lending is on average 2 percent lower relative to baseline at the credit gap's peak, which results in a mortgage stock that is approximately 1.4 percent lower. The difference in the estimated interest elasticity of demand for different types of corporate credit is highlighted by the significantly weaker response of non-property related credit relative to CRE loans. The former is 0.3 percent lower at the onset of the crisis, while the latter is almost 1.4 percent lower. Similarly, while consumer loan interest rates are most sensitive to higher capital ratios, the demand for consumer loans falls 0.5 percent less relative to baseline than CRE loans and mortgages.

These findings are broadly similar to other studies on the impact of capital requirements on lending rates and credit growth. For example, BCBS (2010) uses a number of different models to assess the impact of higher capital requirements on the economy using data for 15 countries and finds, depending on the model and country, that a 1 percentage point increase in the capital ratio raises lending rates by between 5 and 26 basis points. This increase in lending rates results in a reduction in the volume of credit of 1.5 percent. De Resende, Dib and Perevalov (2010) use a sample of Canadian banks to assess the impact of higher capital requirements. Their results suggest that a 2.5 percentage point increase in capital requirements would reduce lending volumes by approximately 1 percent. Farook (2014) findings suggest that a 2.5 percentage point increase in capital requirements raises lending rates by approximately 25 basis points in the case of Norway with credit to households and firms falling by 0.6 and 0.9 percent, respectively in the long term.

In terms of the real effects of higher capital requirements, Figure 4 shows that the impact of the CCyB on the property sector is also quite weak. Both commercial property capital values and house prices are approximately 0.5 percent lower by the onset of the financial crisis. The small decline in house prices relative to baseline generates a weak response from housing supply with the completion of new housing units and the housing stock falling by 3 percent and 0.3 percent, respectively, by 2008. The sharp recovery in property values once the CCyB has fallen to zero is due to the higher demand for housing services that results from the lower level of the housing stock relative to demographics.[61] This feeds back into the mortgage and construction lending equations and ultimately into the housing supply component of the model.

Finally, Figure 4 indicates that the impact of the CCyB in terms of reducing the rate of mortgage arrears and corporate insolvency is significantly weaker than that of borrower-based macroprudential instruments such as limits on LTI and LTV ratios. Mortgage arrears are approximately 1.5 percentage points lower relative to baseline by the end of the simulation period, while the impact on the corporate insolvency rate is negligible.

Raising capital buffers as lending expands may be important from a financial stability perspective in terms of enhancing the resilience of banks' balance sheets to lending that becomes impaired in a downturn. Our simulation results indicate that the economic cost of higher capital requirements in terms of raising the cost of credit and reducing the volume of credit extended by the banking sector appears to be small. However, in terms of dampening the financial cy-

[61] Recall that the demand for housing services is captured by the ratio of the housing stock to the population of 25 to 39 year olds. The latter is exogenous in the model and therefore remains at historical values in these simulations.

cle, our counterfactual scenarios suggest that borrower-based instruments such as limits on the LTI and LTV ratios are more effective in terms of generating a stable path for credit and house price growth. This stability by itself could mitigate the macroprudential necessity for increasing capital buffers as lower asset and income gearing by households (and non-financial corporations) reduces the frequency and magnitude of adverse shocks to the asset side of banks' balance sheets.

5. Conclusion

We develop a structural model that formalises and quantifies the bidirectional linkages between the banking and real estate sectors. Our framework explicitly characterises the dynamic nature of the interactions, feedbacks and spillovers between macroprudential policy, bank's lending behaviour, household and corporate borrowing, and fluctuations in property prices. Importantly from a financial stability perspective, our model shows that the usual indicators of distress in the household and corporate sectors such as mortgage arrears and insolvency rates have important financial triggers, which subsequently feed back into banks' loan-pricing decisions.

We find that both intermediary- and borrower-based macroprudential instruments can a significant impact on the supply of credit and demand for credit, respectively. On the demand side, the LTV and LTI ratios determine credit conditions in the mortgage market by relaxing or tightening collateral and affordability constraints. On the supply side, the capital and LTD ratios constrain banks' liability structure and ultimately affect the cost of credit. We find that there is a differential response to changes in these ratios across lending rates, which reflects how banks adjust to changes in macroprudential policy.

We also illustrate the potential use of our model for macroprudential policy and financial stability analysis. We consider two counterfactual scenarios that show how the banking and real estate markets might have evolved if a macroprudential regime had been in operation. First, after showing how the LTV might have been calibrated under different rules and different target variables, we find that an LTV ratio that responded to credit growth would have achieved the greatest degree of macrofinancial stabilisation over the simulation period.

Our second scenario illustrates the potential impact of lender-based instruments. We find that the introduction of a countercyclical capital buffer would have had a much weaker impact on credit and property prices relative to that of borrower-based instruments such as the LTV ratio, primarily due to the low interest elasticity of credit demand. Therefore, notwithstanding the enhancement in banks' balance sheet resilience that the CCyB generates, its impact on real and financial volatility is relatively weak.

Finally, the framework we have outlined in this paper could provide a key input in the design of 'top-down' stress test scenarios for banks' balance sheets. In particular, as we have bi-directional feedback between residential and property markets on one side, and banks' balance sheets and lending decisions on the other. Accounting for these deep real-financial linkages is of crucial importance to the assessment of the financial stability implications of the different scenarios.

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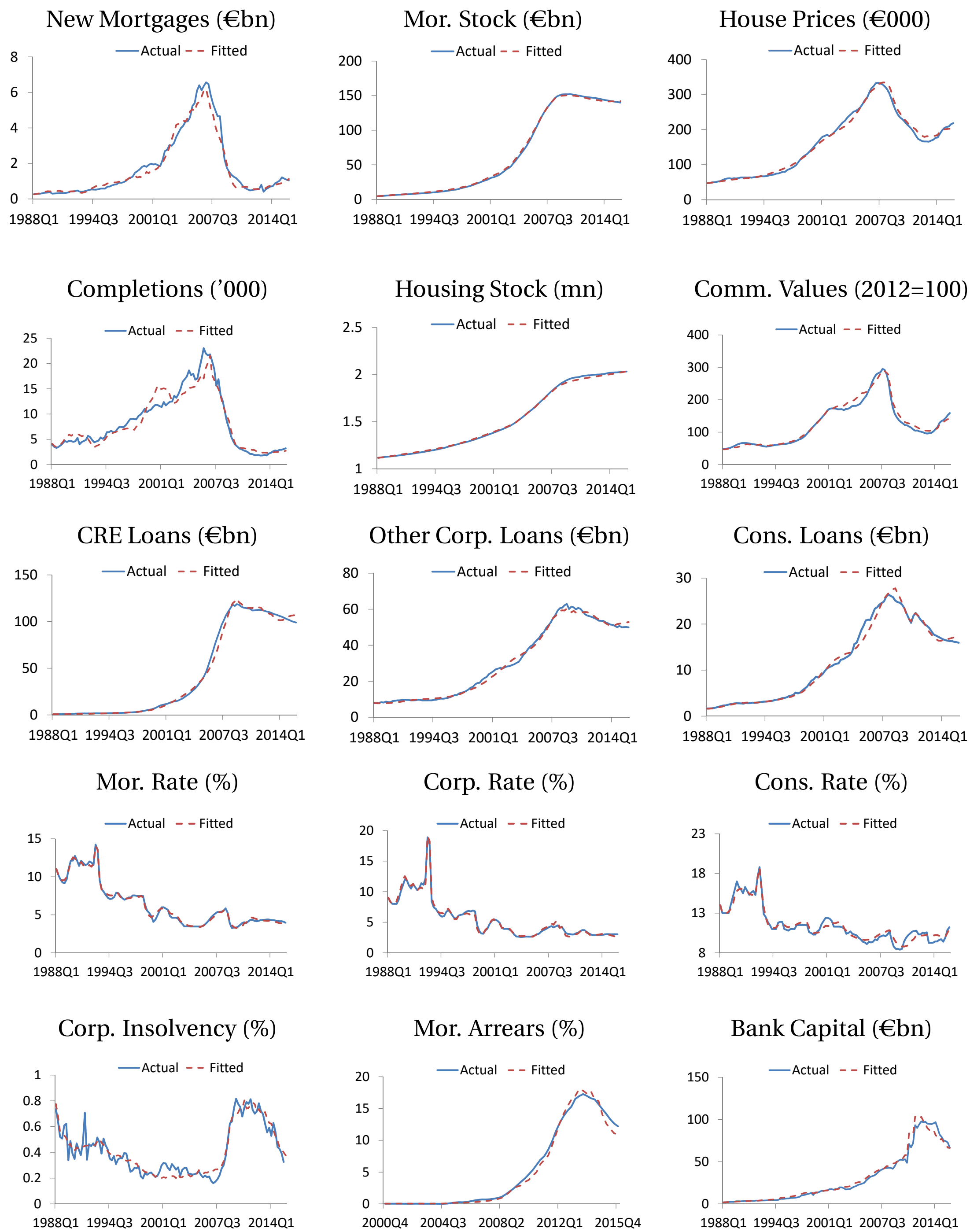
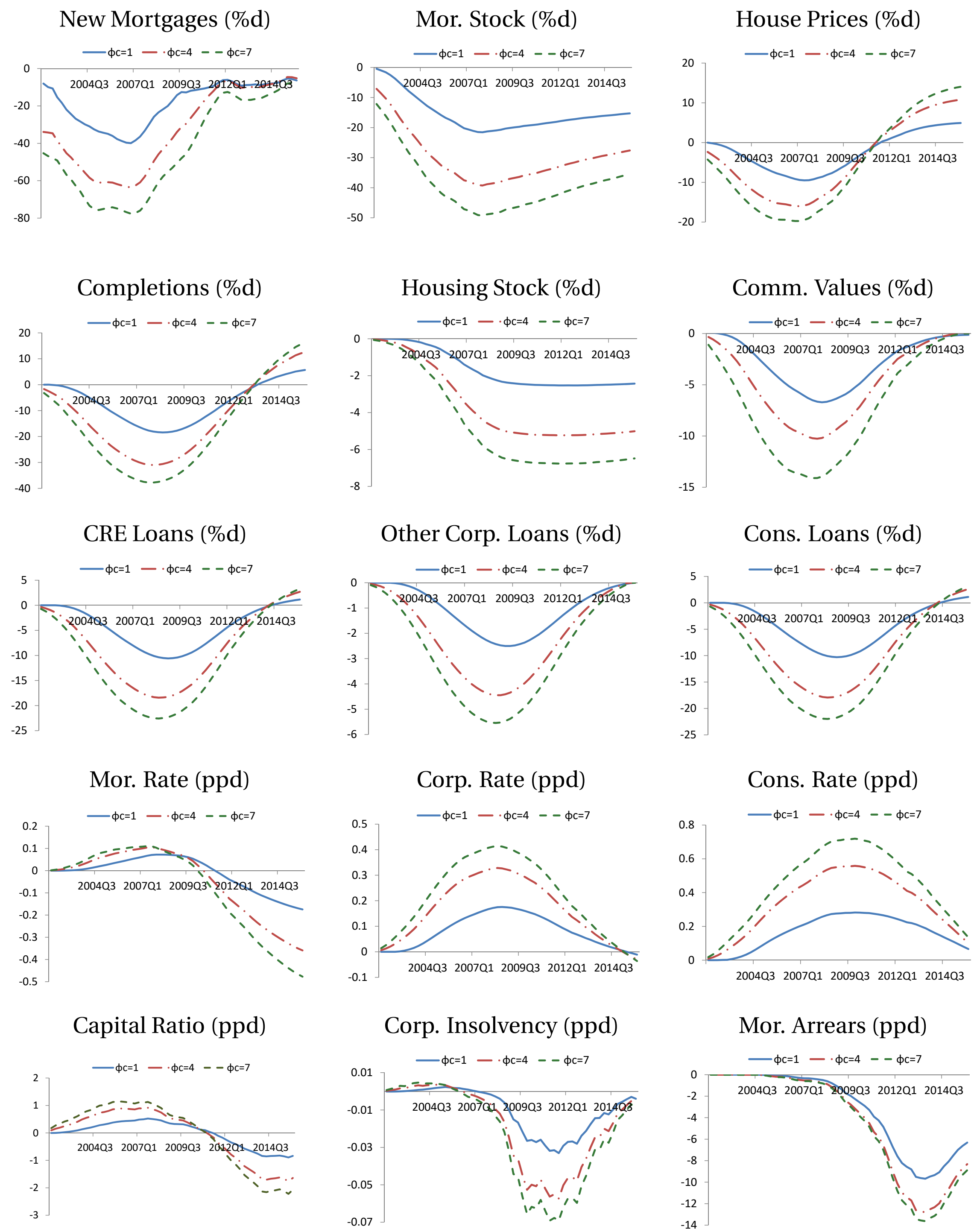
Figure 1: Actual and Fitted Values of Model Variables



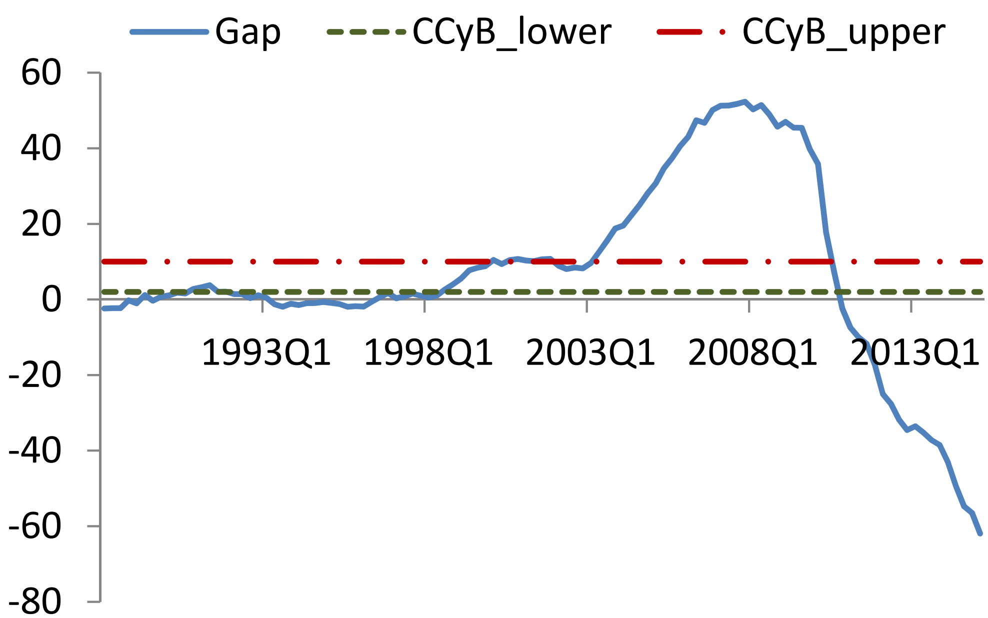
Notes: Figure shows the actual and predicted values from the corresponding model equations. The equations are estimated over the period 1988 Q1 to 2015 Q4 with the exception of mortgage arrears, for which data are only available since 2000 Q4. Note that the stock of mortgages, CRE, OCorp, and consumer lending are notional stocks constructed from transactions series.

Figure 2: Counterfactual Scenario with Countercyclical Credit Rule for LTV Ratio



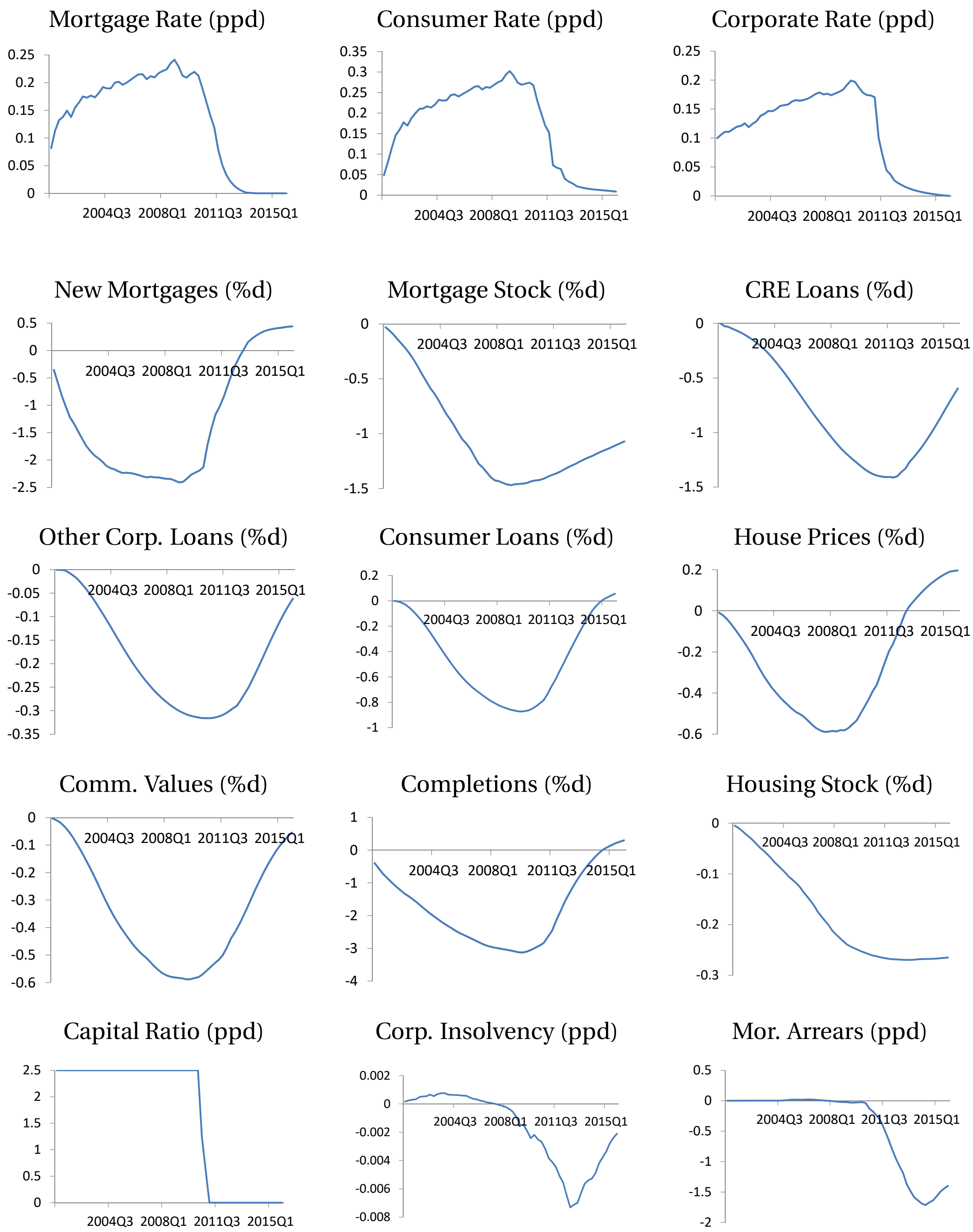
Notes: Figure shows the percent (%d) or percentage point (ppd) deviation of each variable from its historical value under a countercyclical rule for the LTV ratio that targets credit growth. ϕ_c determines the sensitivity of the LTV ratio to credit growth.

Figure 3: Irish Real Time Credit Gap and the CCyB



Notes: The solid line "Gap" is the difference between the credit-to-GDP ratio and its HP-filtered trend. CCyB_lower and CCyB_upper are the 2 percentage point lower bound and 10 percentage point upper bound of the countercyclical capital buffer, respectively. Real-time estimates of GDP are taken from the OECD's Main Economic Indicators database while the stock of private sector credit is from the Central Bank of Ireland. The denominator in the credit-to-GDP ratio is the sum of nominal GDP over the previous four quarters.

Figure 4: Counterfactual Scenario with Countercyclical Capital Buffer



Notes: Figure shows the percent (%d) or percentage point (ppd) deviation of each variable from its baseline value for the period 2001 to 2015. The countercyclical capital buffer is set to its maximum value of 2.5 percentage points from 2001 Q1 to 2010 Q2, to 1.5 percentage points for 2010 Q3, and to zero for the period thereafter.

Table 1: Demand in the Mortgage Market

	NewMortgages_t		MorStock_t
Constant	2.186	MorStock_{t-1}	0.982
	(4.2)		(9.5)
$\text{NewMortgages}_{t-1}$	0.715	NewMortgages_t	1.0
	(10.3)		(n.a)
RMorRate_t	-0.029		
	(-2.9)		
LTV_t	0.751		
	(2.4)		
LTI_t	0.479		
	(2.8)		
ΔHP_{t-1}	0.637		
	(2.8)		
$\Delta\text{Income}_{t-1}$	1.079		
	(2.1)		
Adj. R^2	0.93	Adj R^2	0.99
Sample	1988Q1-2015Q4	Sample	1988Q1-2015Q4

Notes: Table shows the estimation results of the equations for new mortgage lending, *NewMortgages*, and the (notional) mortgage stock, *MorStock*. *RMorRate* is the real mortgage rate. *LTV* is the loan-to-value ratio and *LTI* is the loan-to-income ratio. *HP* and *Income* are real house prices and personal disposable income, respectively. All variables in the equation for new mortgages, except for interest rates, are in logs. t-statistics are in parentheses.

Table 2: Supply in the Mortgage Market

	$MorRate_t$
Constant	15.951
	(3.2)
$MMRate_t$	0.771
	(15.3)
$DepRate_t$	0.182
	(2.9)
$HHEquity_t$	-0.858
	(-2.6)
$URate_t$	0.611
	(4.1)
LTD_t	-1.277
	(-2.9)
CAP_t	0.595
	(2.7)
	$\Delta MorRate_t$
ECT_{t-1}	-0.345
	(-5.9)
$\Delta MMRate_t$	0.538
	(15.0)
ΔDep_t	0.105
	(2.0)
ΔCAP_{t-1}	0.721
	(2.12)
Dummies	1992Q4, 1993Q1
Adj R^2	0.892
Sample	1988Q1-2015Q4

Notes: Table shows the estimation results for the mortgage interest rate, *MorRate*. *MMRate* is the representative money market rate. *DepRate* is the deposit interest rate. *URate* is the unemployment rate. *HHEquity* is household equity. *LTD* is the loan-to-deposit ratio and *CAP* is the ratio of bank capital to risk-weighted assets. All variables, except for interest rates, are in logs. t-statistics are in parentheses.

Table 3: Supply and Demand for Consumer Credit

Demand for Consumer Credit		Supply of Consumer Credit	
	$ConsCredit_t$		$ConsRate_t$
Constant	-18.344	Constant	15.663
	(-12.1)		(5.1)
$RConsRate_t$	-0.006	$MMRate_t$	0.329
	(2.2)		(6.64)
$Income_t$	0.524	$DepRate_t$	0.659
	(2.6)		(8.5)
$HHEquity_t$	0.381	$URate_t$	0.429
	(4.5)		(2.0)
NFW_t	0.079	$ConsCredit_t/Income_t$	1.217
	(1.9)		(2.1)
		CAP_t	0.788
			(2.9)
		LTD_t	-3.131
			(-4.9)
	$\Delta ConsCredit_t$		$\Delta ConsRate_t$
ECT_{t-1}	-0.131	ECT_{t-1}	-0.269
	(-3.2)		(-4.1)
$\Delta ConsCredit_{t-1}$	0.362	$\Delta MMRate_t$	0.297
	(4.5)		(6.2)
$\Delta ConsCredit_{t-2}$	0.236	$\Delta DepRate_{t-1}$	0.199
	(3.0)		(2.4)
ΔNHW_{t-2}	0.258	ΔCAP_{t-1}	0.768
	(2.5)		(2.7)
$\Delta Income_{t-4}$	0.166	$\Delta ConsRate_{t-3}$	0.141
	(2.0)		(2.6)
Dummies	2010Q4	Dummies	1992Q3,1993Q1
Adj. R^2	0.712	Adj. R^2	0.843
Sample	1988Q1-2015Q4	Sample	1988Q1-2015Q4

Notes: Tables shows the estimation results for the consumer credit, *ConsCredit*, and consumer lending rate, *ConsRate*, equations. *RConsRate* is the real consumer lending rate. *NHW* is net housing wealth and *NFW* is net financial wealth. All variables, except for interest rates, are in logs. t-statistics are in parentheses.

Table 4: Demand for Non-Financial Corporate Credit

	CRE_t		$OCorp_t$
Constant	25.981	Constant	-5.934
	(-2.9)		(-8.6)
$RCorpRate_t$	-0.018	$RCorpRate_t$	-0.006
	(-2.8)		(-2.0)
$RGDP_t$	1.723	$RGDP_t$	1.263
	(6.3)		(15.3)
$ComProp_t$	0.831	$ComProp_t$	0.352
	(2.0)		(9.4)
HW_t	1.113	$Profits_t$	-0.665
	(2.1)		(-9.3)
	ΔCRE_t		$\Delta OCorp_t$
ECT_{t-1}	-0.035	ECT_{t-1}	-0.061
	(-4.4)		(-2.9)
$\Delta RCorpRate_{t-2}$	-0.003	$\Delta Profits_{t-2}$	-0.059
	(-3.4)		(-2.1)
ΔCRE_{t-2}	0.272	$\Delta OCorp_{t-2}$	0.182
	(3.1)		(2.2)
ΔCRE_{t-3}	0.174	$\Delta RGDP_{t-2}$	0.192
	(2.3)		(2.0)
		$\Delta ComProp_{t-3}$	0.096
			(2.2)
Dummies	1990Q1, 2009Q1	Dummies	2009Q1
Adj. R^2	0.724	Adj R^2	0.643
Sample	1988Q1-2015Q4	Sample	1988Q1-2015Q4

Notes: Table presents the estimation results of the equations for lending to non-financial corporations, decomposed into commercial real estate lending, *CRE*, and other corporate lending, *OCorp*. *RCorpRate* is the real interest rate on lending to non-financial corporations. *RGDP* is real gross domestic product. *ComProp* is the real value of commercial property and *HW* is the real value of the housing stock. *Profits* relate to the profits of non-financial corporations. All variables are in logs except for interest rates. t-statistics are in parentheses.

Table 5: Supply of Non-Financial Corporate Credit

	CorpRate_t
Constant	2.721
	(4.2)
MMRate_t	0.814
	(18.6)
DepRate_t	0.159
	(2.56)
Insolv_t	0.859
	(6.3)
$\text{CorpCredit}_t/\text{GDP}_t$	0.918
	(2.8)
CAP_t	0.514
	(2.3)
LTD_t	-2.125
	(-3.3)
	$\Delta\text{CorpRate}_t$
ECT_{t-1}	-0.203
	(-2.1)
ΔMMate_t	0.981
	(9.4)
ΔCAP_{t-3}	0.386
	(2.0)
$\Delta\text{CorpRate}_{t-3}$	0.026
	(3.1)
Dummies	1992Q4,1993Q1, 2009Q1
Adj R^2	0.971
Sample	1988Q1-2015Q4

Notes: Table shows the estimation results of the equation for the interest rate on corporate lending, *CorpRate*. *MMRate* is the representative money market interest rate. *DepRate* is the deposit interest rate. *Insolv* is the corporate insolvency rate. *CorpCredit* is total non-financial corporate credit. *CAP* is the capital ratio and *LTD* is the loan-to-deposit ratio. All variables, except for interest rates, are in logs. t-statistics are in parentheses.

Table 6: Demand for Housing and Commerical Property

Housing		Commercial Property	
	HP_t		$ComVal_t$
Constant	24.105	Constant	17.096
	(14.9)		(16.5)
$User^h_t$	-0.008	$User^c_t$	-0.007
	(-7.7)		(-6.3)
$Income_t$	0.701	$RGDP_t$	1.055
	(4.9)		(13.4)
$MorStock_t/Income_t$	0.518	$CorpCredit_t/GDP_t$	0.789
	(8.8)		(8.8)
$HStock_t/Pop2539_t$	-1.282	$KStock_t/Emp_t$	-1.853
	(-5.9)		(-12.0)
	ΔHP_t		$\Delta ComVal_t$
ECT_{t-1}	-0.073	ECT_{t-1}	-0.043
	(-4.0)		(-2.7)
$\Delta Income_t$	0.211	$\Delta Insolv_{t-1}$	-0.035
	(4.4)		(-2.3)
$\Delta URate_{t-1}$	-0.074	$\Delta Insolv_{t-3}$	-0.032
	(-2.4)		(-2.2)
$\Delta(MorStock_{t-1}/Income_{t-1})$	0.157	$\Delta(CorpCredit_{t-1}/GDP_{t-1})$	0.229
	(4.1)		(2.6)
ΔHP_{t-1}	0.338	ΔHP_{t-2}	0.362
	(3.6)		(2.9)
ΔHP_{t-2}	0.188	ΔHP_{t-3}	0.265
	(2.7)		(2.1)
Dummies	2014Q2	Dummies	2008Q4, 2014Q3
Adj. R^2	0.679	Adj. R^2	0.613
Sample	1988Q1-2015Q4	Sample	1988Q1-2015Q4

Notes: Table shows the estimation results of the equations for real house prices, *HP*, and real commercial capital values, *ComVal*. $User^h$ is the user cost of housing. *HStock* is the stock of housing. *Pop2539* is the number of 25 to 39 year olds in the population. $User^c$ is the user cost of commercial property investment. *CorpCredit* is total corporate lending. *KStock* is the private sector capital stock. *Emp* is total private sector employment. All variables, except for interest rates, are in logs. t-statistics are in parentheses.

Table 7: Housing Supply: New Housing Completions

	$HCompl_t$
Constant	0.189
	(0.5)
$HCompl_{t-1}$	0.788
	(23.7)
$Tobin_t$	0.348
	(2.1)
$\Delta RCorpRate_t$	-0.023
	(-5.9)
ΔCRE_{t-1}	0.501
	(3.2)
GAP_t	0.459
	(2.4)
Δ $Insolv_t$	-0.128
	(-1.8)
$\Delta(Pop2539_t/Pop_t)$	1.496
	(2.9)
Adj. R^2	0.972
Sample	1988Q1-2015Q4

Notes: Table shows the determinants of new housing completions, *HCompl*. *Tobin* is the ratio of house prices to building costs. *RCorpRate* is the real interest rate on lending to non-financial corporations. *GAP* is the output gap computed as the deviation of real GDP from a Hodrick-Prescott filtered trend. *Pop* is the total population. All variables are in logs except for the corporate lending rate. t-statistics are in parentheses.

Table 8: Mortgage Arrears and Corporate Insolvencies

	$Arrears_t$		$Insolv_t$
Constant	4.727	Constant	-0.076
	(4.0)		(-0.1)
$HHEquity_t$	-2.448	$ComProp_t$	-0.332
	(-7.1)		(-2.4)
$MorRate_t$	1.281	$RCorpRate_t$	0.010
	(3.7)		(1.8)
$URate_t$	0.538	$URate_t$	0.406
	(2.1)		(4.3)
$MorStock_t/Income_t$	5.557	$OCorp_t/GDP_t$	0.663
	(17.1)		(2.3)
	$\Delta Arrears_t$		$\Delta Insolv_t$
ECT_{t-1}	-0.083	ECT_{t-1}	-0.269
	(1.9)		(-3.4)
$\Delta URate_t$	0.925	$\Delta URate_t$	0.695
	(2.8)		(2.4)
$\Delta MorRate_{t-1}$	0.547	$\Delta Insolv_{t-1}$	-0.267
	(1.8)		(-2.6)
$\Delta HHEquity_{t-2}$	-1.645	$\Delta Insolv_{t-2}$	-0.193
	(2.0)		(-2.2)
		$\Delta ComProp_{t-2}$	-0.971
			(-2.4)
Dummies	2005Q1		
Adj. R^2	0.504	Adj. R^2	0.396
Sample	2000Q4-2015Q4	Sample	1988Q1-2015Q4

Notes: Table presents the estimation results for the households mortgage arrears, *Arrears*, and corporate insolvency, *Insolv*, equations. All variables are in logs except for the real corporate lending interest rate. t-statistics are in parentheses.

Table 9: Determinants of Banks' Capital Ratio

	CAP_t
Constant	0.147
	(0.166)
$Assets_t/GDP_t$	-1.402
	(-4.5)
$URate_t$	0.453
	(4.6)
$Spread_t$	0.025
	(2.3)
$CRE_t/Loans_t$	0.686
	(2.8)
$Deposits_t/Liabilities_t$	-0.769
	(-2.2)
	ΔCAP_t
ECT_{t-1}	-0.074
	(-2.3)
$\Delta Assets_{t-1}/GDP_{t-1}$	-0.479
	(-3.7)
$\Delta Insolv_{t-2}$	0.028
	(2.4)
ΔHP_{t-3}	-0.439
	(-2.4)
Dummies	2010Q4, 2011Q3
Adj. R^2	0.597
Sample	1988Q1-2015Q4

Notes: Table shows the determinants of the balance sheet capital ratio, *CAP*, given by the ratio of bank capital to risk-weighted assets. *Assets* and *Liabilities* are the total assets and liabilities of the banking sector, respectively. *Spread* is the difference between a weighted-average of lending rates and the money market rate. All variables are in logs except for the yield curve spread.

Table 10: Change in Level and Variability under LTV Rules

	Credit Rule			House Price Rule			GDP Rule		
	$\phi_c = 1$	$\phi_c = 4$	$\phi_c = 7$	$\phi_h = 1$	$\phi_h = 4$	$\phi_h = 7$	$\phi_y = 1$	$\phi_y = 4$	$\phi_y = 7$
New Mor.	-25.3	-46.7	-59.9	-18.8	-31.6	-43.9	-18.9	-30.3	-41.5
	(-17.7)	(-35.9)	(-46.4)	(-14.3)	(-28.9)	(-41.2)	(-12.2)	(-22.5)	(-33.4)
Mor. Stock	-16.7	-31.6	-40.5	-12.3	-21.8	-29.2	-12.1	-22.2	-30.8
	(-9.3)	(-14.9)	(-19.2)	(-6.7)	(-6.6)	(-6.6)	(-7.2)	(-7.9)	(-8.2)
H. Prices	-3.2	-5.8	-7.5	-2.3	-3.4	-4.4	-2.4	-3.7	-4.9
	(-19.1)	(-32.7)	(-38.4)	(-14.5)	(-24.7)	(-31.2)	(-13.6)	(-23.9)	(-31.7)
H. Compl.	-8.2	-17.1	-21.9	-6.0	-12.5	-17.2	-5.7	-12.5	-18.2
	(-2.3)	(-6.3)	(-10.2)	(-1.7)	(-6.2)	(-9.1)	(-1.3)	(-5.8)	(-9.6)
H. Stock	-1.7	-3.6	-4.7	-1.2	-2.7	-3.8	-1.1	-2.7	-3.9
	(-8.0)	(-15.9)	(-20.3)	(-5.9)	(-11.6)	(-15.8)	(-5.7)	(-11.7)	(-16.7)
Arrears	-66.6	-89.3	-95.4	-54.4	-76.6	-87.3	-53.8	-77.1	-88.8
	(-5.5)	(-10.2)	(-15.2)	(-3.6)	(-3.1)	(-2.5)	(-4.0)	(-4.4)	(-4.4)
HH Equity	9.8	24.6	36.3	6.8	15.9	24.3	6.5	15.8	25.5
	(-16.6)	(-31.0)	(-40.2)	(-12.1)	(-19.3)	(-25.2)	(-12.1)	(-20.1)	(-27.1)

Notes: Table shows the percentage change in the mean and standard deviation (in parentheses) of variables under each countercyclical LTV rule, where ϕ_c, ϕ_h and ϕ_y indicate the sensitivity of the corresponding rule to credit growth, house price appreciation, and gdp growth, respectively.