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Macro-Financial Linkages in a Structural Model of the Irish Economy

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Abstract

We specify and estimate a system of macro-financial linkages that incorporate transmission channels for both borrower- and lender-based macroprudential instruments. We then embed these linkages in a structural macro model of the Irish economy. To illustrate the usefulness of the model for policy analysis, we simulate several scenarios. We first show that regulatory changes to LTI and LTV ratios have a relatively large impact on the real economy, primarily through consumption. We next examine the stabilising properties of the countercyclical capital buffer. We find that releasing this buffer in response to an adverse real and financial shock can partially attenuate of the ensuing contraction in credit and output. Finally, we consider the impact of an exogenous fall in commercial real estate prices and demonstrate that this sector can generate significant macro-financial volatility.

JEL classification: E5, E53, E52, G21

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Non-Technical Summary

The experience of the Irish economy over the last two decades has emphasised the importance of understanding how the banking system interacts with the rest of the economy. Indeed, Ireland is perhaps the exemplar of how financial distortions can generate high levels of volatility by amplifying the impact of both positive and negative shocks to the real economy. In this context, it is particularly apposite to enhance the Central Bank's macro-econometric modelling framework by incorporating the key relationships that drive this volatility.

In this paper, we embed an estimated system of macro-financial linkages in a structural model of the Irish economy. At its core, it comprises supply and demand equations for different types of credit. Firms and households demand loans taking into consideration income or activity levels, the cost of borrowing, and the value of the collateral they can offer. On the supply side, banks set lending rates as a markup over deposit and wholesale funding costs. The markup is determined by various risk, structural, and policy related factors.

From a financial stability perspective, our model shows that indicators of stress in the household and corporate sectors such as mortgage arrears and corporate insolvency rate depend on both real and financial factors. Moreover, we show that price fluctuations in the residential and commercial property sectors are an important source and propagator of this stress. The Central Bank has several macroprudential policy levers that it can use to mitigate the systemic risk that originates from exposure to these fluctuations. A core contribution of the paper is to outline and quantify the channels through which both borrower- and lender-based instruments affect the economy. The impact of each policy instrument varies according to how it changes banks' lending behaviour and the structure of their balance sheets, firm and household borrowing, property prices, investment and consumption.

We simulate several scenarios to illustrate the transmission channels of various shocks in the model and to demonstrate its usefulness for policy and financial stability analysis. Our first two scenarios consider the impact of borrower-based macroprudential instruments on the economy. We show that lower loan-to-income and loan-to-value ratios have a relatively strong negative impact on mortgage demand and house prices. This reduces the profitability of residential investment and generates a negative housing wealth effect, which lead to lower residential investment and consumption, respectively. However, arrears decline in the long run due to the fall in household indebtedness.

Our third scenario examines the extent to which the release of the cyclical component of banks' capital buffers could cushion the impact of a severe real and financial shock to the Irish economy. Lower capital requirements allow banks to obtain a greater share of their funding from sources that are cheaper than equity. The concomitant reduction in banks' average cost of capital is subsequently passed through to firms and households in the form of lower borrowing costs. This results in higher consumption, investment, and asset prices than would have prevailed if capital requirements did not fall. Our final scenario illustrates how a shock to commercial real estate prices can generate considerable macro-financial volatility. This is due both to the importance of CRE prices in determining the level of investment in that sector and their role in determining firms' collateral values. We also show that these shocks spillover to the residential sector as they affect the relative profitability of investment between the two sectors.

1 Introduction

Ireland represents the prototypical example of an economy in which distortions in the banking sector and in the real economy can interact to generate extreme volatility. The Irish experience starkly illustrates the importance of understanding how balance sheet vulnerabilities in one sector can be propagated to other parts of the economy, both directly and indirectly. Moreover, this is particularly apposite from a financial stability perspective given the tail risks that are embedded in the Irish macro-financial system (Lane, 2019).

In this context, the Central Bank of Ireland has introduced a number of measures to enhance the resilience of the financial system (Donnery, 2019). These macroprudential instruments are designed to mitigate systemic weakness so that banks' balance sheets can absorb, rather than amplify, financial stress and adverse economic shocks. However, given the novelty of these instruments, there is still considerable uncertainty about their quantitative impact and the relative strength of the different channels through which they are transmitted to the economy. Accordingly, having a model of the Irish economy that incorporates a wide range of macroprudential and real-financial linkages is particularly important in terms of understanding how macro-financial volatility can arise, the joint-dynamics of different variables in response to a shock, and the calibration of the appropriate macroprudential response.

In this paper we present an empirical framework within which the bi-directional linkages between the banking sector and real economy are formalised and quantified. We specify and estimate a structural model that explicitly characterises the dynamic direct and indirect nature of the interactions between macroprudential policy, banks, households and firms. These real-financial linkages are then embedded in a macro model of the Irish economy, which allows us to consider the full range of transmission channels and feedback mechanisms concomitant with different types of shocks.

Our model incorporates supply and demand equations for four types of credit: consumer, mortgage, commercial real estate (CRE), and other corporate. The demand for credit is a function of the level of income or economic activity, the cost of credit, and collateral values. In terms of the supply of credit, a central focus of the macro-modelling literature since the 2008 financial crisis has been the integration of frictions into models that generate a role for the financial sector. These frictions generate a cost that is reflected in the spread between intermediaries' lending rates and their funding costs (Woodford, 2010). We adopt a framework similar to that first outlined by Klein (1971) and Monti (1972) in which banks are monopolistically competitive and set lending rates as a spread over funding costs. They can access any quantity of funding at the prevailing interest rate so that the supply of bank credit is perfectly elastic. The spread between lending rates and funding costs depends on several factors reflecting credit risk and policy factors.

From a financial stability perspective, our model shows that typical aggregate indicators of financial stress in the household and corporate sectors such as mortgage arrears and insolvency rates have both real and financial triggers, which then feedback into banks' loan-pricing decisions through the lending spreads. This mechanism can generate accelerator effects similar to those in, for example, Bernanke et al (1999). In addition, as bank capital is endogenous in the model it provides a link through which the impact on banks' balance sheets and profitability of fluctuations in the macro-financial environment is also passed through to the lending spread.

Despite the burgeoning literature on the impact of macroprudential policy on the housing market and the wider economy, there is still considerable uncertainty regarding the strength and interaction of the transmission channels of different macroprudential instruments (Galati and Moessner, 2018). Moreover, relatively little is known about their dynamic and spillover effects, and their feedback into the financial system. Accordingly, an important feature of our model is that it incorporates several borrower- and lender-based macroprudential instruments. On the borrower side, the central bank can impose loan-to-income (LTI) and loan-to-value (LTV) restrictions on new mortgage lending, which constrain the amount of credit that households can obtain for a given level of income and house prices. On the lender side, the central bank can raise liquidity requirements or it can activate a countercyclical capital buffer (CCyB). These regulations impose a cost on banks and raise their weighted-average cost of capital. These costs are then passed through to borrowers in the form of higher lending rates. Having a fully integrated framework allows us to illustrate the importance of feedback from the real economy to the banking sector following innovations to macroprudential policy. In this respect, our framework can capture the full transmission mechanism of macroprudential policy, as well as sectoral spillovers and spillbacks.

We simulate four scenarios to demonstrate the model's functionality for financial stability and macroprudential policy analysis. The first two scenarios consider how changes to borrower-based instruments can affect macro-financial volatility. We then explore the extent to which countercyclical capital regulation in the form of the CCyB can be used to stabilise lending in a downturn. Finally, we illustrate the usefulness of the model for financial stability risk analysis by examining the impact on the Irish economy of an exogenous fall in CRE prices.

We find that instruments that directly constrain household leverage and income-gearing are particularly effective in limiting credit growth and, indirectly, house price appreciation. This emphasises the important role that these instruments can play in mitigating macro-financial risks and dampening the Irish financial cycle. Conversely, and notwithstanding its role in enhancing the resilience of banks' balance sheets, the impact of capital regulation on the real economy is relatively weak. This is mainly due to capital instruments operating through the financial intermediary rather than on the borrower and accordingly exerting a more indirect effect on the real economy. We also show that fluctuations in CRE prices can generate substantial real and financial volatility. This is due to their dual role in the model as a determinant of the profitability of investment in the CRE sector, and as an approximation of collateral values and firms' balance sheet strength.

Our simulation of several macroprudential policy shocks contributes to the literature on the macroeconomic impact of these policies. This literature has tended to use a DSGE framework to examine the impact of macroprudential instruments. Some studies find that constraints on borrower indebtedness in terms of LTI restrictions (Gelain et al, 2013) or borrower leverage in terms of LTV restrictions (Turdaliev and Zhang, 2019) are the most effective tools for enhancing welfare by dampening the volatility that arises from financial shocks or non-rational expectations. Within a monetary union, welfare can be further enhanced if leverage restrictions are imposed across countries (Rubio and Carrasco-Gallego, 2016). Other studies consider the impact of countercyclical capital regulation, particularly its interaction with monetary policy. The benefits of capital-based macroprudential policy tend to be larger when the economy is driven by financial rather than supply shocks (Angelini et al, 2014) and when the steady-state level of capital requirements is sufficiently high (Clerc et al, 2015). However, while the long-run benefits of capital policies in terms of macroeconomic stabilisation tend to be positive, there can be substantial transition costs, particularly if monetary policy is constrained and the implementation period of the increase in requirements is short (Mendicino et al, 2019).

In the case of Ireland, studies of macro-financial linkages and the macroeconomic impact of macroprudential policy have predominantly used DSGE models. Clancy and Merola (2016) calibrate a small open economy DSGE model with a financial sector using Irish data and show that countercyclical capital regulation can enhance welfare by dampening extreme swings in the financial cycle driven by over-optimistic expectations. Lozej et al (2018) use a similar model to compare welfare under countercyclical capital rules that alternately respond to a credit gap and a house price gap. They find that the latter is optimal as it does not require a policy trade-off between the stabilisation of fluctuations that originate in the housing market and those caused by foreign demand shocks. Lozej and O'Brien (2018) also use this model to show that early activation of the CCyB can enhance bank resilience without substantially reducing an economic expansion. The macroeconomic cost of the CCyB is also lower the larger are banks' capital buffers in excess of regulatory requirements. This model is also used by Lozej and Rannenberg (2018) to examine the impact of restrictions on LTI and LTV ratios on the Irish economy. They find that, while these restrictions do lower economic activity in the short run, they improve welfare in the longer term by reducing household leverage and subsequent levels of default.

Semi-structural models can complement the analysis provided by a DSGE framework by using their flexibility to incorporate a broader range of macro-financial linkages and macroprudential instruments with the corresponding sectoral spillovers, spillbacks, and dynamic interactions that are specific to a particular economy. However, there are relatively few studies that use semi-structural models to analyse these issues. Davis and Liadze (2012) embed a banking sector for several countries in the NiGEM model that includes a series of supply and demand equations for different types of credit and a capital adequacy variable for banks that can be used to analyse prudential policy. Davis et al (2018) augment this model with a LTV ratio in the credit demand and house price equations and a systemic risk index to which the LTV and capital ratios respond. They show that macroprudential policy that targets the LTV ratio mainly affects the housing market whereas capital-based policies have a much broader impact on the economy. Berben et al (2018) embed a banking sector in a semi-structural model of the Netherlands, in which macroprudential policy mainly operates by changing the gap between banks' actual capital ratio and their desired or target ratio. Shocks to the latter have a broad-based effect as they raise interest rates on all types of lending.

The development of semi-structural models to examine the transmission of macro-financial shocks and macroprudential policy in the Irish economy is also relatively novel. Existing models have limited their analysis to the interaction of the banking and real estate sectors. Duffy et al (2016) estimate a five-equation model of the Irish housing and mortgage markets and examine how changes in mortgage LTI and LTV ratios affect credit and house price growth. McInerney (2019) estimates a model of the banking and real estate sectors but does not consider how shocks originating in these sectors affect the wider economy. Bergin et al (2017) incorporate a parsimonious version of the banking model outlined in McInerney (2019) into the same macro model we use in this paper but do not outline the estimation of real-financial linkages or demonstrate how macroprudential policy is transmitted in the model.

In this paper we estimate a new model of macro-financial linkages for the Irish economy. Importantly, we motivate our system of real-financial linkages from a theoretical and empirical perspective, and provide a detailed discussion of the estimation results. We also illustrate how both borrower- and lender-based macroprudential policy shocks are transmitted to the real economy, emphasising the dynamic spillovers and spillbacks between sectors. Finally, we highlight a particularly novel feature of our model by showing how shocks to the CRE sector can generate significant macro-financial risks.

The remainder of the paper is structured as follows. Section 2 outlines the estimation of macro-financial linkages in the model. Section 3 discusses how these linkages operate in a macro model of the Irish economy. Section 4 simulates several scenarios to illustrate the impact of different macroprudential and financial stability shocks. Section 5 concludes.

2 The Banking Sector and the Real Economy

In this section we estimate a system of macro-financial linkages, which provide the channels through which the banking sector and the real economy interact. We first estimate supply and demand equations for each type of credit in the model, using the identifying assumption that loan quantities do not affect the former. We next present our models of property prices and investment in both the residential and CRE sectors, emphasising the role of credit in both the supply and demand for real estate. We then show how the indicators of financial stress in the model, the mortgage arrears and corporate insolvency rates, are driven by both real and financial factors. Finally, we discuss the estimation of the bank capital equation and outline how we use the results to derive a long-run target for banks' capital ratios.

Mortgage Credit

Mortgage Demand

One of the key features of our model is the incorporation of borrower-based macroprudential instruments that act as quantitative restrictions on the demand for mortgages. In particular, sector-specific instruments that directly limit borrower leverage and income-gearing are an important tool in the management of systemic risk and dampening of the financial cycle (Claessens, 2015).

High LTI and LTV ratios were a key driver of the surge in mortgage lending in Ireland over the 2003-2007 period (McCarthy and McQuinn, 2017). From a modelling perspective, the variation in these ratios over this period significantly changed the bivariate relationship between house prices and mortgage credit, which became statistically explosive after 2003 (Gerlach-Kristen and McInerney, 2014). Given the disruptive macro-financial dynamics that variations in these ratios can generate, the Central Bank of Ireland is one of many central banks and regulatory authorities that have introduced caps on LTI and LTV ratios as part of their macroprudential toolkit. Therefore, identifying and quantifying the transmission channels of these instruments is particularly important from a policy perspective.

As these borrower-based instruments act as constraints on new mortgage lending rather than the stock of existing lending, we estimate a behavioural equation for mortgage demand in terms of the former rather than the latter. In our framework the demand for new mortgages is modelled as a function of real personal disposable income, the real mortgage interest rate, real house prices, and housing completions.[1,2] As mentioned, an important contribution of our framework is that we incorporate the impact of credit conditions on mortgage demand. By relaxing leverage and affordability constraints, changes in credit conditions act as an accelerator by amplifying the impact of income shocks on house prices and there is some empirical evidence that the impact of changes in income on house prices is stronger in countries with high LTV ratios (Almeida et al, 2006; IMF, 2011).

The LTI and LTV ratios we use are the mean values for first-time buyers. However, these observed ratios do not solely capture changes in credit conditions or exogenous shifts in the supply of credit. They also incorporate demand-side or cyclical factors that affect borrowers' ability to obtain higher LTI and LTV ratios (Fernandez-Corugedo and Muellbauer, 2006). To construct ratios that reflect exogenous changes in credit conditions, we isolate the variations in the ratios that are due to expected changes in interest rates, income, and house prices (Cameron et al, 2006; Duca et al, 2011).[3] Once the ratios are adjusted for these factors, they will capture shifts in affordability and leverage constraints at each income and price level, similar to the shifts that occur under borrower-based macroprudential policy.

The demand for new mortgage lending therefore has the following form:

$$\begin{aligned}NewMortgages_t = \alpha + \beta_1 NewMortgages_{t-1} + \beta_2 RMorRate_t + \beta_3 LTV_t \\ + \beta_4 LTI_t + \beta_5 \Delta HP_{t-1} + \beta_6 \Delta Income_{t-1} + \beta_7 HCompl_{t-1} + \varepsilon_t \end{aligned} \quad (1)$$

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, $HCompl$ is the volume of housing completions, and LTV and LTI are the respective ratios net of demand-side factors. The lagged dependent variable is included to capture persistence in new mortgage lending, while ε is the error term.[4] All variables, except for the mortgage interest rate, are in logs. We first difference income and house prices so that there is a common order of integration among the regressors. Nominal variables are deflated by the consumer expenditure deflator to obtain real values.

All equations in the model are estimated over the period Q1 1997 to Q2 2018. Table 1 presents the results of the mortgage demand equation. New mortgages exhibit moderate persistence with a coefficient of 0.644 on the first lag. Our dependent variable is the volume of new mortgages that are drawn down so this persistence may be capturing the lag between when the explanatory variables change and new mortgages are approved and when they are actually drawn down.

The coefficients on the mortgage rate and income indicate that, for a given LTI ratio, repayment capacity is a binding constraint on the size of the mortgage that

[1] Other structural models of mortgage credit relate mortgage demand to affordability in terms of income and interest rates and to collateral, as measured by house prices (Duffy et al, 2016; Nobili and Zollino, 2017; Davis et al, 2018). Davis et al (2018) also model the mortgage stock as a function of the LTV ratio.

[2] We use completions to approximate the demand for housing. The latter will also depend on turnover in the market for existing houses but this variable is excluded due to insufficient data.

[3] See Duffy et al (2016) for further details on this procedure.

[4] As ε denotes the error term in each of the equations below, we define it here for all equations.

households can obtain. For example, a one percentage point fall in the mortgage rate would raise the demand for new mortgages by approximately seven percent, holding all else constant.[5] We find that collateral constraints are also important. Higher house prices allow households to obtain higher levels of mortgage credit for a given LTV ratio. Similarly, higher demand for housing, as indicated by the level of completions, is a strong driver of mortgage demand with a one percent increase in completions raising mortgage demand by 0.4 percent, ceteris paribus.

The above discussion highlights the importance of affordability and collateral constraints in mortgage demand. These constraints are relaxed when LTI and LTV ratios, that are adjusted for demand-side factors, increase. Table 1 shows that these adjusted LTI and LTV ratios have a positive and significant effect on the demand for mortgage credit. Our results are particularly interesting from a macroprudential perspective as they suggest that a change in the average LTV ratio for first time buyers has a considerably larger effect on the volume of new mortgage credit than a similar change in the LTI ratio. For example, a one percent increase in the adjusted LTV ratio raises the volume of new mortgages by almost 2.5 percent while a similar increase in the adjusted LTI ratio raises this volume by one percent, in the long run. This suggests that the LTV ratio has been the more binding constraint for mortgagors over the estimation period. Overall, our results suggest that imposing restrictions on these ratios is effective in terms of limiting borrower leverage and indebtedness. We discuss this further in the scenarios section below.

The total stock of mortgages is assumed to follow a perpetual inventory-type process, whereby new mortgage credit in the current period accumulates on the previous period's mortgage stock net of redemptions:

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

where $MorStock$ is the (notional) mortgage stock and unitary coefficient is imposed on new mortgages.[6] The rate at which the mortgage stock falls due to mortgage repayment is given by (1-β_1). The estimate for β_1 in the right panel of Table 1 shows that this rate is over one percent per quarter.

The notional mortgage stock measures the amount of mortgage credit in the economy but may not coincide with the amount that is actually held on banks' balance sheets due to several factors including asset disposals, valuation effects and securitisation. However, it is the stock held on balance sheet that constrains banks' lending behaviour in the presence of capital and liquidity requirements. We abstract from these issues and assume that actual credit stocks are a linear function of their notional counterparts so that in model simulations, the former will simply track the latter.

Mortgage Supply

In terms of mortgage supply, we follow the literature and assume that banks are monopolistically competitive[7]. In this framework, banks set interest rates as a markup

[5] This is calculated by dividing the coefficient on the mortgage rate by one minus the coefficient on the lagged dependent variable i.e. 0.025/(1-0.64)=0.07

[6] The "notional" stock is calculated using transactions data and therefore excludes factors that affect the stock of credit, but not the flow.

[7] This literature generally models bank behaviour within the Monti-Klein framework (Klein, 1971; Monti, 1972). See Freixas and Rochet (2008) for a textbook treatment of these models.

over funding costs so that banks supply any quantity of credit at the prevailing interest rate. The assumption that the quantity of credit does not enter the interest rate equation is necessary to separately identify factors that affect credit demand and supply (Nobili and Zollino, 2017; Davis et al, 2018).

Funding costs are represented by the deposit rate and the money market rate. The latter is the main channel through which monetary policy affects interest rates, while the former is assumed to follow the long-term government bond rate due to deposit insurance. The markup or spread over funding costs is a function of macroeconomic and sector-specific risks that affect repayment capacity and borrower default rates, internal capital management or regulatory requirements, and the composition of banks' liabilities. For mortgages, macroeconomic risk is captured by the unemployment rate, while we use "undrawn" housing equity to approximate the risk associated with lending to households.[8] As discussed below, both of these variables are key drivers of mortgage arrears.

In contrast to the prediction of the Modigliani-Miller theorem (Modigliani and Miller, 1958), the majority of empirical studies on the costs of higher capital find that higher capital ratios are associated with larger lending spreads.[9] This implies that the required return on equity in response to lower leverage does not fall sufficiently to prevent banks' weighted average cost of capital from rising. Accordingly, when banks increase their capital ratios, whether for regulatory or internal management reasons, we assume the increase in costs is passed through to higher lending spreads. Capital-based macroprudential policy in our model therefore operates through the spread and this is the primary channel through which banks can generate the retained earnings necessary to meet higher capital requirements.

The final component of the spread relates to the liquidity profile of banks' balance sheets. It is well documented that the large expansion in lending by Irish banks over the 2003-2007 period was primarily financed by wholesale rather than deposit funding (Addison-Smyth et al, 2009; Coates and Everett, 2013). As the ensuing financial crisis starkly illustrated, over-reliance on short-term money market funding can expose banks to substantial rollover-risk (Honohan, 2010). To mitigate this risk, the Basel III regulatory framework has introduced liquidity requirements in the form of the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR). In the case of Ireland, restrictions on banks' LTD ratios have been in operation since 2011. We therefore use the LTD ratio to measure the cost to banks of liquidity-based macroprudential policy measures. Similar to capital-based instruments, requiring banks to fund more of their lending from deposits raises their weighted average cost of funding which will subsequently be passed through to lending rates.

We model the nominal mortgage rate in an error-correction framework with adjustment to the following long-run equilibrium:

$$\begin{aligned} MorRate_t = \alpha + \beta_1 MMRate_t + \beta_2 DepRate_t + \beta_3 HHEquity_t \\ + \beta_4 URate_t + \beta_5 CAP_t + \beta_6 LTD_t + \varepsilon_t \end{aligned} \tag{3}$$

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

[8] "Undrawn" housing equity is the residual proportion of housing wealth net of mortgage debt (Whitley et al, 2004).

[9] See McInerney et al (2020) for an overview of this literature.

of mortgage debt, $URate$ is the unemployment rate, CAP is the ratio of capital to risk-weighted assets, LTD is the LTD ratio. We allow short-run persistence in the mortgage rate to be driven by contemporaneous and lagged changes in the variables in (3). We also test whether the short-run behaviour of the mortgage rate depends on the gap between banks' actual capital ratio and their target ratio so that changes in the mortgage rate are larger when this gap is large.[10]

The top panel of Table 2 presents the estimates of the long-run relationship given by (3) and the bottom panel presents the short-run model. We impose the restriction that the coefficients on the deposit and money market rates sum to unity.[11] The parameter values suggest that three-quarters of the change in money market rates is passed through to mortgage rates while only 25 percent of the change in deposit rates is passed through. Our results suggest that risk factors are significant determinants of the mortgage rate in the long run. Higher levels of housing equity are associated with lower borrower default, which reduces the risk component of the lending spread. Similarly, lower unemployment generates lower repayment risk which reduces the spread.

We also find evidence that changes in the capital and liquidity structure of banks' balance sheets are important drivers of the mortgage rate in the long run. This suggests that lender-based macroprudential policy that raises capital or liquidity requirements increases the lending spread and accordingly, mortgage borrowing costs for households. For example, the coefficient on the (log) capital ratio suggests that a one percentage point increase in this ratio will raise the mortgage rate by approximately 11 basis points in the long run.

In terms of the short-run model, the coefficient on the error-correction term suggests that most of the adjustment to the long-run equilibrium takes place within one year. The mortgage rate also responds to changes in the money market rate and to the gap between banks' actual and target capital ratio. Although the impact of the latter is small, it is an additional consideration when determining how additional capital requirements should be sequenced.

Consumer Credit

Demand for Consumer Credit

The empirical literature on household consumption has generally focused on the reduced-form relationship between consumption and its underlying drivers, which typically include income, interest rates, and financial and housing wealth effects (Muellbauer, 2007). However, recent studies have emphasised the importance of credit in determining the impact of these variables on consumption (Carroll et al, 2011). In the case of Ireland, the sharp rise in consumption over the 2003-2007 period coincided with a marked increase in bank lending to households in the form of both mortgages and consumer credit (Clancy et al, 2014). Accordingly, it is important from a macro-financial perspective to understand the sensitivity of consumer credit demand to both real and financial factors.

[10] We also tested whether the gap should be included in the long-run model of each of the lending rate equations but we found it was statistically insignificant in all specifications.

[11] A Wald test suggests this restriction is valid for the mortgage and consumer interest rates but not for the corporate interest rates. These results are available on request from the author.

We follow Davis and Liadze (2012) and assume that the demand for consumer credit is a function of both the cost of credit and household income. These variables influence the affordability of a particular consumer loan. In addition, we allow housing equity to affect credit demand through the housing "wealth effect", whereby households respond to an increase in net housing wealth by increasing demand for credit to finance non-housing consumption. For households that face liquidity constraints, this balance sheet channel may also be important as an indicator of credit worthiness depending on the extent to which households can leverage their net worth (Nobili and Zollino, 2017). Higher house prices allow households to increase debt or refinance existing debt at lower interest rates. The availability of home equity loans thus raises the "spendability" of housing wealth and may drive differences in the estimated housing wealth effect across countries and over time (Muellbauer, 2007).[12]

The second wealth effect in our model of consumer credit demand relates to household's net financial assets. The literature on impact of the latter on consumption finds considerable cross-country heterogeneity in the size and direction of the effect (Case et al, 2005; Barrell et al, 2015). This heterogeneity is potentially driven by differences in the composition of assets. If financial wealth is mainly in the form of relatively liquid assets such as stocks and bonds, then in response to capital gains, households may choose to divest a proportion of these assets to finance any desired increase in consumption. However, if financial wealth is mainly in the form of relatively illiquid assets such as technical reserves or pensions, then households may instead borrow to finance consumption. The direction of this effect is therefore an empirical question.

We model the demand for consumer loans in an error-correction framework with the following long-run equilibrium:

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

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

The first two columns of Table 3 present the estimation results for (4). We find that the income elasticity of demand for consumer credit is close to unity, with a one percent increase in income increasing the stock of consumer loans by approximately 1.2 percent. We also find that both the financial and housing wealth variables have a significant effect on consumption but that they have opposite signs. The coefficients imply that a one percent increase in housing equity raises consumer credit demand by 0.25 percent, while a similar increase in net financial wealth reduces consumer credit demand by 0.4 percent. The latter indicates that households are likely to reduce deposits or sell assets in response to net capital gains on financial assets rather than borrow against these capital gains. We also find that the cost of borrowing has a negative and significant impact on consumer credit demand. For example, a one percentage point increase in the consumer rate reduces demand by over 2.5 percent. This has implications for the transmission of lender-based macroprudential policy as the interest elasticity of credit demand will partly

[12] See Lydon and O'Hanlon (2012) and Lydon and O'Leary (2013) for an overview of how financial deregulation and greater competition in the Irish banking sector enabled households to obtain loans backed by housing equity.

determine the size and composition of banks' balance sheets in response to a change in either liquidity or capital requirements.

The error-correction model suggests that adjustment to the long-run equilibrium is quite slow, although this is consistent with the typical dynamic behaviour exhibited by stock variables. We also find that changes in household income and in consumer credit itself are important drivers of consumer credit in the short run.

Supply of Consumer Credit

In terms of the supply of consumer credit, we model the consumer rate as a markup over deposit and money market funding costs. Similar to the mortgage rate, the markup is a function of risk, liquidity and banks' internal capital management. As this lending is unsecured, the credit risk associated with this type of credit is higher than for mortgages. An important factor that generates repayment risk among households is job loss, which is reflected at the aggregate level by the unemployment rate. In addition, repayment risk is also a function of the indebtedness or income-gearing of households (Luzzetti and Neumuller, 2014; Nakajima and Rios-Rull, 2019). We use the ratio of consumer credit to income to capture the risk associated with the size of the repayment burden.[13]

The remaining components of the consumer lending rate spread relate to banks' capital and liquidity structure, which are indicated by banks' capital and liquidity ratios, respectively. As in the case of the mortgage rate, these components represent a cost to banks, which raises their weighted average cost of capital. However, an interesting dimension of our analysis is that we estimate whether the degree of pass-through of these costs varies across lending rates. Differences in pass-through have implications for the transmission of lender-based macroprudential policy and illustrate how banks can be expected to adjust to changes in liquidity and capital requirements.

We therefore allow the long-run level of the consumer rate to be determined by the following relationship with variables that capture funding costs and drivers of the lending spread:

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

where $ConsRate$ is the nominal consumer rate. The short-run behaviour of the consumer rate is determined by error-correction, as well as by lagged and contemporaneous changes in the variables in 5. We also test whether the gap between the actual and target capital ratio affect the dynamics of consumer rate in the short run.

The last two columns of Table 3 present the estimation results of the consumer equation. In terms of funding costs, a particularly interesting result is that the elasticity of the consumer rate with respect to cost of deposit and wholesale funding is approximately the same. The coefficients suggest that a one percentage point increase in the money market rate raises the consumer interest rate by 46 basis points, whereas a similar increase in the deposit rate raises the consumer rate by 54 basis points. This contrasts with our estimates for the mortgage and corporate (discussed below) rates, which suggest that the elasticity with respect to the money market rate is significantly

[13] We also considered whether it is the total debt (secured and unsecured) of households relative to income that drives the risk premium component of the consumer rate. The variable was statistically insignificant and so only the ratio of consumer credit to income is included.

higher for these lending rates. As we outline in section 3, our macro model uses the money market rate to reflect changes in the ECB's policy rate. The differential elasticities of lending rates with respect to the money market rate will thus affect how changes in money policy are transmitted to the economy.

Both indicators of lending risk are statistically significant and quantitatively important. For example, a one percentage point increase in the unemployment rate raises the consumer rate by approximately 20 basis points, all else equal. Banks also price lending according to how much unsecured debt households already owe relative to income, and therefore how default risk might rise in the case of adverse macroeconomic shocks.

The long-run response of the consumer lending rate to changes in both lender-based macroprudential instruments is strongest across all lending rates. Banks therefore appear to respond to higher capital and liquidity requirements by passing through a greater share of these costs to more unsecured borrowers. In the case of capital requirements, this may be due to the high risk weight attached to consumer lending in the calculation of regulatory capital ratios. We find that a one percentage point increase in the capital ratio is associated with a 17 basis point increase in the consumer rate, compared to 10 and 11 basis points for the corporate and mortgage rates, respectively.

The large coefficient on the LTD ratio suggests that Irish banks have tended to rely relatively more on deposits when setting consumer lending rates. Deposits have historically been a more expensive source of funding compared to borrowing on wholesale markets. This is also consistent with the comparatively high elasticity of the consumer rate with respect to the deposit rate. 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.

The results of the error-correction model show that adjustment to the long-run equilibrium is slightly slower than for the mortgage rate. Importantly, we also find that capital-based macroprudential policy affects the short-run behaviour of the consumer rate through the gap between the actual and target capital ratio. Finally, persistence in the consumer rate is also driven by changes in funding costs and in the consumer credit-to-income ratio.

Corporate Credit

Demand for Corporate Credit

The primary source of external financing for Irish small and medium enterprises (SMEs) is bank-intermediated credit (Lawless et al, 2013). However, both the pre- and post-financial crisis periods highlighted the differential cyclical dynamics of credit demand that characterises different components of corporate lending. For example, the stock of CRE loans held on Irish banks' balance sheets rose from 19 billion euro in Q1 2003 to a peak of 115 billion euro in Q3 2008, before falling to its current level of approximately 13 billion euro. This contrasts strikingly with the evolution of other (non-CRE) corporate credit, which rose from 29 billion euro in Q1 2003 to a peak of almost 60 billion euro, before falling to its current level of close to 30 billion euro.[14]

[14] See the Central Bank of Ireland's *Credit and Banking Statistics*. Note that here we use the stock of lending held on balance sheet rather than the notional stock to illustrate the relative

Accordingly, treating corporate credit as a homogeneous category would ignore significant heterogeneity across different types of corporate lending in terms of their impact both on the economy and on financial stability. Across countries, CRE lending tends to be one of the most volatile components of banks' loan portfolios and the component that is subject to one of the highest rates of default (ESRB, 2015). Therefore, given that the origin and propagation of macro-financial risk can differ between the CRE- and non-CRE components of corporate lending, we estimate separate equations for each of these types of credit.

We model the demand for CRE loans in terms of the notional stock of CRE lending that is outstanding. This variable will also include lending to firms engaged in the construction of both residential housing and commercial real estate. We assume that demand for these loans is partly driven by the return on investment or profitability of construction in both the housing and CRE sectors (Davis and Zhu, 2011). We approximate these returns using real house and CRE prices.

Similar 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 capture the derived demand for this type of credit from higher levels of employment and investment using the level of real output in the non-traded sector.[15] This is a more appropriate indicator of activity-related credit demand in the case of Ireland than a more aggregate measure such as real GDP, which also includes the output of the traded sector. Irish firms are predominantly SMEs, whereas the Irish traded sector is dominated by MNEs.[16] The latter are generally not bank-dependent and tend to raise funding through internal and international capital markets (Desai et al, 2004).

We approximate the cost of CRE loans using the average interest rate on loans to non-financial corporations. Unfortunately, more disaggregated data on interest rates by corporate lending category are not available. We note that the average corporate rate is likely to underestimate the cost of CRE finance, as lending to the CRE sector is likely to carry a higher risk premium relative to other types of corporate lending due to its volatility.

The demand for CRE loans is modelled in an error-correction framework with the following long-run equilibrium:

$$CREL_t = \alpha_1 + \beta_1 RCorpRate_t + \beta_2 YNT_t + \beta_3 CP_t + \beta_4 HP_t + \varepsilon_t \tag{6}$$

where $CREL$ is the (notional) stock of real commercial real estate loans, $RCorpRate_t$ is the real interest rate on corporate lending, YNT is the real output of the non-traded sector, and CP_t is the real price of CRE. The short-run model also incorporates additional dynamics from lagged and contemporaneous changes in these variables.

volatility of each loan type as the former incorporates the impact of demand factors, loan losses, and asset transfers.

[15]The traded, non-traded and government sectors in COSMO are defined using the CSO's Supply and Use Input-Output tables. The non-traded sector includes those sectors in which less than 50 percent of output is exported, and those sectors in which less than 50 percent of output is part of government consumption.

[16]Outside of these conceptual reasons for using non-traded output rather than GDP we also find that models that use non-traded output have a superior in-sample and out-of-sample statistical fit.

We model the demand for non-CRE corporate credit analogously. An important common factor driving the demand for both types of corporate credit is the price of commercial real estate. CRE prices signal the return or profitability of investment in commercial property. They also indicate the value of the collateral against which corporate credit can be secured and can be used to approximate the strength of firms' balance sheets. CRE prices can therefore influence the availability or rationing of credit by affecting firms' net worth as in Bernanke and Gertler (1989), or by affecting collateral values, as in Kiyotaki and Moore (1997).

As Irish firms are primarily SMEs, they must likely pay a premium on external sources of finance (Bernanke and Gertler, 1989; Holton and McCann, 2017). This premium means that firms typically use internal funds such as retained earnings to finance investment before turning to external sources. Firms' demand for bank credit should therefore be negatively related to the level of retained earnings. We approximate the latter with the level of (real) after-tax corporate profits. As the external financing premium mainly affects SMEs, our profit variable excludes corporate profits in the traded sector.

We also relate the demand for non-CRE corporate loans to the level of economic activity and the cost of credit. Similar to our model for CRE loans, we use the output of the non-traded sector to capture the derived demand for credit from higher levels of investment and from working capital requirements. As time series data on lending rates by type of corporate loan are relatively short, we use the average interest rate on all corporate lending to approximate the cost of non-CRE loans.

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

$$OCorpL_t = \alpha + \beta_1 RCorpRate_t + \beta_2 YNT_t + \beta_3 CP_t + \beta_4 NTProfits_t + \varepsilon_t \tag{7}$$

where $OCorpL$ is the real notional stock of other corporate loans, and $NTProfits$ are real after-tax corporate profits in the non-traded sector. In addition to error-correction, the short-run dynamics of non-property corporate lending are driven by lagged and contemporaneous changes in the variables in (7).

The first two columns of Table 4 present the results of the equation for CRE loans, while the last two columns show the results of the equation for other corporate loans. We find that the demand for both types of credit is sensitive to the cost of borrowing. A one percentage point increase in the corporate rate is associated with a stock of CRE loans that is approximately 2.5 percent lower in the long run and a stock of other corporate loans that is over four percent lower. These elasticities are an important component of the transmission mechanism of lender-based macroprudential policy to the real economy, which we discuss in Sections 3 and 4.

Our results indicate that demand for both types of corporate loans is highly procyclical with coefficients on non-traded output that exceed unity. CRE credit is more responsive to changes in CRE prices, which reflects the role of both investment returns and collateral in the demand for that type of credit. By contrast, the role of CRE prices in the equation for other corporate loans is mainly in terms of determining collateral values only. The coefficient on house prices is close to that on CRE prices in the CRE loan equation. Construction and other real estate firms therefore respond to increasing returns in both sectors by obtaining more CRE loans to finance their investment.

Importantly, we find that the demand for non-CRE loans is inversely related to non-traded sector profits. This suggests that firms prefer to first use internal sources to fund investment before seeking external sources such as bank credit. The estimated unitary elasticity also indicates that this channel is quantitatively important and is consistent with the empirical results in Holton and McCann (2017).

Table 4 also shows the results of the error-correction models. We find that the adjustment of both types of credit to the long-run equilibrium is relatively slow, although this is generally expected with stock variables. The short-run behaviour of CRE loans is also affected by changes in CRE prices, while that of non-CRE corporate loans is mainly determined by growth in non-traded output. Finally, there is some evidence that both types of credit respond to changes in the corporate rate in the short run but that the impact is quite weak.

Supply of Corporate Credit

The supply of corporate credit is represented by the interest rate on loans to non-financial corporations. Similar to the mortgage and consumer rates, the price of corporate lending is a time-varying spread over deposit and wholesale funding costs. The spread itself depends on risk factors and on the structure of banks' balance sheets.

We use the risk component of the spread to link firms' borrowing costs with the condition of their balance sheets in a mechanism similar to that outlined in Bernanke and Gertler (1989) and (Bernanke et al, 1999). These links are both direct and indirect. We use the ratio of corporate credit to GDP to reflect corporate income gearing and thus firms' repayment burden. We also include the corporate insolvency rate to capture default risk associated with lending to firms. As discussed below, the value of commercial property is a key driver of the corporate insolvency rate. Fluctuations in the value of commercial property will therefore affect the corporate lending rate indirectly through the insolvency rate.

The remaining components of the spread reflect costs arising from the capital and liquidity structure of banks' balance sheets. Banks' capital ratios reflect both internal capital management decisions and regulatory requirements. The sensitivity of the corporate rate to changes in the capital ratio is important in determining the extent to which banks use this margin of adjustment in responding to changes in capital-based macroprudential policy. Similarly in the case of liquidity-based policy measures, the elasticity of the corporate rate with respect to the LTD ratio will determine how banks use the corporate rate to pass through changes in their weighted-average cost of capital due to greater reliance on deposit funding at the margin.

The equation for the corporate rate therefore has the following long-run form:

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

where $CorpRate$ in the nominal interest rate on corporate lending, $Insolv$ is the corporate insolvency rate, $CorpL$ is total lending to non-financial corporations, and GDP is nominal GDP. 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). Similar to the mortgage and consumer rate equations, we also test whether the gap between the actual and target capital ratio influences the short-run behaviour of the corporate rate.

Table 5 presents the results of the long-run and short-run models for the corporate rate. The long-run elasticities of the corporate rate with respect to the money market and deposit rate are similar to those for the mortgage rate. This suggests that the pass-through of monetary policy is relatively high for both of these rates.

Our indicators of financial stress both indicate that credit or default risk is an important component of price-setting on corporate loans. The corporate credit-to-GDP ratio is used to approximate corporate income-gearing, while the insolvency rate is a more direct measure of default. In terms of the latter, our results suggest that a one percentage point increase in the insolvency rate raises the corporate rate by over 1.5 percentage points, all else equal. As mentioned above, the insolvency rate provides an indirect link between the corporate rate and the strength of firms' balance sheets. Through this mechanism we can generate "accelerator" effects when these relationships are embedded in a macroeconomic model and subject firms' asset values to adverse shocks.

The coefficients on the capital and LTD ratios are close to those for the mortgage rate. Excluding consumer loans which are a small share of household debt, this suggests that the impact of lender-based macroprudential policy on borrowing costs for firms and households will be broadly similar. For example, a one percentage point increase in capital requirements would raise the corporate rate by 10 basis points. As discussed above, this compares to 11 basis points for the mortgage rate.

Table 5 also presents the results of the short-run model. The speed of error-correction is similar to that of the mortgage and consumer rates, with most of the adjustment to the long-run equilibrium occurring within a year. In addition to error-correction, changes in the unemployment and money market rates mainly drive the short-run dynamics of the corporate rate. Finally, we find that the gap between the actual and target capital ratio also influences these dynamics and that its impact on the corporate rate is broadly equivalent to that on the mortgage and consumer rates.

Residential and Commercial Property

Demand for Residential and Commercial Property

The residential and commercial property markets have been the source and conduit of substantial macro-financial volatility in the case of Ireland. From a modelling perspective, this volatility is difficult to generate within traditional specifications of property demand and supply. For example, in traditional models of house prices the inverted demand for housing is related to the demand for housing services. The latter is usually approximated by the ratio of the stock of existing housing to the population. Variables that shift this relationship include household income, demographic factors, and the rental yield or user cost of housing.[17] Therefore, in the context of the transmission of financial or credit shocks, only the user cost will reflect changes in the mortgage finance environment.

As a consequence, these models can be misspecified if there is a change in credit conditions due, for example, to banks lending at higher LTI or LTV ratios. This can primarily explain the failure of these models to accurately forecast house prices in many countries prior to and after the 2008 financial crisis (Muellbauer, 2012). Moreover, the coefficient on the user cost variable in these models was often statistically insignificant or had a positive sign, providing further evidence of misspecification.

[17] In equilibrium, the rental yield (or the ratio of rents to house prices) will equal the user cost of housing.

Recent models have addressed these issues by adding an indicator of credit conditions to the traditional inverted demand function along with the user cost. This indicator should reflect shifts in the supply of credit so that the availability of credit changes at the prevailing levels of income, house prices and interest rates. Some single-equation studies try to capture these changes in credit supply by including an LTV ratio for first-time buyers that is adjusted for demand-side factors. In terms of structural models, Davis et al (2018) include the unadjusted LTV ratio in both the equation for the mortgage stock and the house price equation.

As we have outlined above, the LTV is an important driver of credit conditions. However, including the LTV ratio in the house price equation directly does not provide a structural link between developments in the mortgage market as these may be driven by other factors such as changes in the LTI ratio. In our framework, the volume of new mortgage credit is driven by changes in both the LTI and LTV ratios. We thus have a measure that incorporates changes in credit conditions, which can be included in our house price equation directly as a measure of changes in credit availability. We normalise new mortgage lending by income so that a change in this ratio can be interpreted as a change in credit that is not driven by fundamental factors.[18]

The mortgage market will also affect house prices in the model through the traditional user cost channel. The user cost is calculated as the difference between the mortgage rate and expected house price appreciation. Given the considerable evidence from the empirical literature that expectations in the housing market are extrapolative, we use the moving average of lagged annual house price changes over the previous two years to approximate expectations of capital appreciation.[19] Macroprudential policy will affect house prices through both the user cost and the credit conditions variables. The "price" effect of higher capital requirements will operate through the user cost of capital, while the "quantity" effect of restrictions on the LTI and LTV ratios will operate through the credit conditions variable.

We include the user cost and credit conditions variables in an otherwise standard house price model. Other determinants in our specification are the unemployment rate, disposable income and the demand for housing services.[20] We use the ratio of the housing stock to the population of 25 to 39 year olds to approximate the latter. Note that this variable will also incorporate the impact of demographic trends on housing demand.

We therefore model house prices as error-correcting to the following long-run equilibrium:

$$
\begin{aligned}
HP_t = \alpha + \beta_1 User_t^h + \beta_2 Income_t + \beta_3 (NewMortgages_t / Income_t) \\
+ \beta_4 (HStock_t / Pop2539_t) + \beta_5 URate_t + \varepsilon_t
\end{aligned}
\quad (9)
$$

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 other variables are as previously

[18] We normalise by income rather than by house prices due to the relative volatility of the latter. Moreover, income is less subject to distortions from asset bubbles as house prices rise with mortgage credit in a self-reinforcing cycle (Gelain et al, 2013).

[19] See Glaeser and Nathanson (2015, 2017) for a discussion on expectation formation in the housing market.

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

defined. The short-run model also includes lagged and contemporaneous changes in these variables.

As we model CRE prices analogously, we first outline the specification of that model before discussing the estimation results for both house prices and CRE prices. CRE prices play a particularly important role in our framework in several respects. First, they determine the profitability of CRE investment net of other investment costs. Second, they constrain the volume of CRE loans that are demanded. Third, in a mechanism similar to that outlined in Kiyotaki and Moore (1997), they act as collateral or as a proxy for the value of firms' assets which constrains the demand for other types of corporate credit such as for working capital purposes. Finally, they indirectly affect the risk premium component of the corporate lending rate through their impact on the corporate insolvency rate.

The empirical literature on the determinants of commercial rents and property prices finds that the return on alternative investments, the level of economic activity, and the existing stock of CRE relative to demand, are important drivers of CRE returns in the long run (Ball et al, 2010). In terms of the opportunity cost of CRE investment, we adopt a user cost approach. As in the case of housing demand, the user cost comprises two components: the cost of financing and the expected capital gain. Unfortunately, data on the cost of bank finance for CRE investment specifically are not available and so we use the representative lending rate on corporate lending as an approximation.[21] We assume that households and commercial real estate firms use similar extrapolative rules to form expectations about the future appreciation of house prices and CRE prices. Therefore, expected capital gain is calculated as the moving average of lagged annual changes in commercial property prices over the previous two years. The formulation of expectations in this way introduces a procyclicality to the user cost and can thus generate endogenous cycles in CRE prices if changes in the latter are particularly large.

As discussed above in relation to house prices, interest rates are poor indicators of credit availability when there is a shift in credit conditions. To capture the latter, we augment our model of CRE prices with the change in ratio of corporate credit to GDP, which is conceptually similar to the ratio of new mortgages to household income used in the house price equation. If we assume that corporate income grows approximately in line with GDP, then we interpret an increase in this ratio as indicating credit growth in excess of the underlying driver of demand, which corresponds to a change in credit conditions.

The most common challenge in estimating models of CRE prices found in the empirical literature is the availability of data on the stock of CRE. For example, Whitley and Windram (2003) use the private capital stock per employee to approximate the effective stock of CRE. In the case of Ireland, we use the stock of "other (non-dwelling) buildings and structures including roads" from the CSO and exclude the proportion represented by roads.[22] Following Whitley and Windram (2003) we scale this variable by total employment to calculate the effective CRE stock, which we use to approximate the demand for commercial property services. *A priori*, we expect that higher levels of the stock per employee are associated with lower commercial property prices.

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[21] As the risk premium on bank lending to this sector is likely to be larger than for other sectors, this approximation is likely to underestimate the cost of bank finance for firms in this sector.

[22] We assume a simple linear relationship between the deflator of this stock and our measure of CRE prices.

Finally, similar to the role of the unemployment rate in the house price equation, we include the corporate insolvency rate to capture changes in uncertainty or investor sentiment towards the corporate sector. We model commercial property prices in an error-correction framework with adjustment to the following long-run equilibrium:

$$CP_t = \alpha + \beta_1 User_t^c + \beta_2 RGDP_t + \beta_3 (CorpL_t/GDP_t) + \beta_4 (CREStock_t/Emp_t) + \beta_5 URate_t + \varepsilon_t \quad (10)$$

where CP are real CRE prices, $User^c$ is the user cost of capital in the commercial property sector, $CREStock$ is the stock of commercial property, and Emp is private sector employment. In the short run, we allow house prices to affect commercial property prices. Intuitively, house prices represent the opportunity cost to construction firms of commercial property development (Whitley and Windram, 2003). As house prices rise, construction resources are attracted away from the CRE sector to the residential sector, thereby putting upward pressure on CRE prices. The short-run model also includes dynamics arising from changes in the variables in (10).

The upper panel of Table 6 presents the results of the equations for both housing and CRE prices. We find that the user cost of capital has a negative but quantitatively small impact on house prices. As mentioned, a common finding in pre-crisis empirical studies on house price determination was that the user cost was either statistically insignificant or it had the "wrong" sign (Muellbauer, 2012). One potential reason for this is that these studies did not control for changes in credit conditions. Both the user cost and indicators are significant and have the expected sign in Table 6.

Our results also suggest that property prices are strongly procyclical. The coefficient on real household income of 1.2 is close to the average unity coefficient found in the literature (Malpezzi, 2012). While the literature on CRE prices is more sparse, the coefficient on real GDP is also similar to that found in other studies (Whitley and Windram, 2003; Ball et al, 2010).

Table 6 also shows that property prices are inversely related to their effective supply. The coefficients on the housing and CRE stock variables suggest that there is close to unitary elasticity between prices and total supply in the long run. The strong impact of supply on property prices has important implications for the dynamic response of these sectors to macro-financial shocks.

The lower panel of Table 6 presents the results of the short-run models. We find that the speed of adjustment to the long-run equilibrium is similar for both house prices and CRE prices. We also find that short-run dynamics in both models are mainly driven by changes in the level of economic activity, in investor sentiment, and by own-shocks. Importantly, our results show that house prices affect CRE prices in the short run. One interpretation of this spillover is the opportunity cost mechanism outlined above, whereby an increase in prices in one sector attracts resources towards that sector, resulting in higher prices in the other sector.

Supply of Residential and Commercial Property

In terms of property supply, we adopt the investment or asset market approach originally outlined in Poterba (1984) and Topel and Rosen (1988). While there is an extensive literature on the determinants of residential investment and housing supply in general, studies on the drivers of CRE investment are relatively rare. As with property prices, we assume that investment in each sector can be modelled analogously.

In the investment approach, housing supply is a function of Tobin's Q, given by the ratio of house prices to construction costs, with the latter approximating the replacement cost of housing.[23] In empirical specifications of these models, other costs are often included, such as financing costs (Blackley, 1999). In addition, several studies have included measures of credit availability. Credit constraints drive a wedge between actual and desired housing supply, although there is some evidence that credit availability mainly affects speculative residential investment (Chan, 1999; Hedberg and Krainer, 2012).

Following the literature, we relate residential investment to house prices and building costs. A change in either of these factors will affect the profitability of investment. Similar to our model of housing demand (house prices), our housing supply model incorporates two credit channels. We capture the cost of credit by the change in the real corporate lending rate and credit availability by the growth rate of CRE lending relative to GDP.[24] Although these variables do exhibit cyclicality, housing investment is itself highly correlated with the economic cycle (Davis and Heathcote, 2005; Leamer, 2007). One of the potential drivers of this dynamic behaviour may be fluctuations in uncertainty, which tend to be countercyclical (Miles, 2009; Bloom, 2014). Residential investment is particularly subject to uncertainty due to high fixed costs and the irreversibility of such investment. When uncertainty is high, the real option value of waiting rises leading firms to postpone investment. In our model we assume that cyclical variations in uncertainty can be captured by the unemployment rate.

We model residential investment in an error-correction framework and specify its long-run relationship with these variables as follows:

$$\begin{aligned} ResInv_t = \alpha + \beta_1 HP_t + \beta_2 BCosts_t + \beta_3 RCorpRate_t \\ + \beta_4 \Delta(CREL_t/GDP_t) + \beta_5 URate_t + \varepsilon_t \end{aligned} \tag{11}$$

where $ResInv$ is real residential investment, $BCosts$ are real building costs, and other variables are as previously defined. We allow short-run persistence in residential investment to be driven by lagged and contemporaneous changes in the variables in (11).

We model CRE investment analogously. This implies that the same firms engage in both residential and CRE investment, which allows us to generate spillovers between the sectors as these firms respond to changes in relative returns. We therefore assume CRE investment is a function of the profitability of investment and credit availability. We also relate CRE investment to the demand for commercial space, which is approximated by real GDP per employee (Lieser and Groh, 2014). The latter may also capture the cyclical impact of uncertainty.[25] Similar to residential investment, CRE investment follows an

[23] See Kenny (1999) for an earlier application of this model to the Irish housing market.

[24] CRE loans include loans to construction firms. It should be emphasised that our model focuses on bank lending only. However, non-bank institutional investors are becoming an increasingly important source of finance for both the residential and CRE sectors. See Coates et al (2019) for an overview.

[25] We included alternative measures of uncertainty such as the unemployment rate and the corporate insolvency rate but these variables were not statistically significant.

error-correcting process with adjustment to the following long-run equilibrium.

$$CREInv_t = \alpha + \beta_1 CPP_t + \beta_2 BCosts_t + \beta_3 RCorpRate_t + \beta_4 \Delta(CREL_t/GDP_t) + \beta_5 (RGDP_t/Emp_t) + \varepsilon_t \quad (12)$$

where $CREInv$ is real CRE investment. In the short run, we allow persistence in residential investment to be driven by lagged and contemporaneous changes in the variables in (12) as well as the unemployment rate.

The top panel of Table 7 presents the results of the long-run residential and CRE investment models. We find that the price elasticity of investment is higher in the residential sector than in the CRE sector. All else equal, a one percent increase in house prices raises residential investment by 0.8 percent in the long run, while a similar increase in CRE prices raises CRE investment by close to 0.5 percent. We also find that elasticity of investment with respect to building costs is quantitatively similar to that for prices. We therefore view this as evidence in favour of asset market approach to the supply of real estate.

Our results suggest that both residential and CRE investment are particularly interest rate sensitive. This has important implications for the transmission of lender-based macroprudential policy. The coefficients suggest that a one percentage point increase in the corporate rate would, ceteris paribus, lower residential and CRE investment in the long run by approximately two percent and 2.5 percent, respectively. In addition, credit conditions as captured by the growth in CRE lending relative to GDP, also have a strong effect on both types of investment. This is an additional channel through which macroprudential policy will affect these sectors. However, a potentially important caveat to these results is that, as non-bank institutional investors are an increasingly important source of finance for firms in both the residential and CRE sectors, our results may constitute an upper bound for the impact of the domestic banking sector on the supply of housing and commercial property.

The coefficients on the unemployment rate in the residential investment model and real GDP per worker in the CRE investment model, suggest that cyclical factors outside of those captured by the other variables are important. To the extent that this residual cyclicality reflects changes in uncertainty about the future profitability of investment, these results offer a potential explanation for the strong co-movement of real estate investment with the economic cycle. However, given the conceptual and practical difficulties of measuring uncertainty, we simply point to this as one channel through which the macroeconomic environment can affect this type of investment.

The lower panel of Table 7 shows that the speed of error-correction is similar for both types of investment, with most of the adjustment having occurred after two years. These results illustrate the lags inherent in the construction and investment process that are likely related to acquiring land and finance, obtaining planning permission, and building structures. We also find that short-run persistence in residential investment is driven by house prices, the corporate rate, and own-shocks, while persistence in CRE investment is driven by the unemployment rate, the corporate rate and own-shocks.

Finally, we generate the stock of housing and CRE by assuming that each stock follows a perpetual inventory process. For example, in the case of the stock of dwellings we assume that the stock in the current period is the sum of the depreciated stock from the previous period and current residential investment:

$$DStock_t = \delta^h DStock_{t-1} + ResInv_t \quad (13)$$

where $DStock$ is the stock of dwellings and δ^h is the rate of depreciation of the existing dwelling stock.[26] The stock of CRE is assumed to follow an analogous process.[27]

Mortgage Arrears and Corporate Insolvency

We use the household mortgage arrears rate and the corporate insolvency rate as the key indicators of macro-financial risk to which bank's loan pricing models react. As mortgage debt is currently the largest component of Irish banks' lending to the non-financial private sector, an elevated rate of mortgage arrears can have important consequences for banks' profitability and ultimately, their levels of capital. Although Irish banks' lending to non-financial corporations has fallen considerably since the financial crisis, it still comprises approximately one-third of loans held on their balance sheets and continues to represent an important source of finance to Irish firms, which are predominantly SMEs (Lawless et al, 2015). Accordingly, we use the corporate insolvency rate to capture the risks to banks' balance sheets arising from fluctuations in corporate financial stress. We outline our models of mortgage arrears and corporate insolvency before jointly discussing the estimation results of both models.

Mortgage Arrears

Following the empirical literature on mortgage delinquency, we adopt the "double trigger" approach. In this framework, household default occurs due to both a weak equity position and a fall in repayment capacity (Bajari et al, 2008; Gerardi et al, 2010). The latter can arise due to the interaction of high mortgage rates, elevated debt service ratios, unemployment and lower expected income growth.

The empirical evidence on the determinants of mortgage arrears finds that both real and financial factors play a role. In the case of the US, Gerardi et al (2015) illustrate the relative importance of these factors with their estimate that the impact of unemployment on mortgage default is equivalent to a 35-50 percent fall in home equity. For the UK, Whitley et al (2004), Figueira et al (2005), and Aron and Muellbauer (2010) find that the repayment burden and housing equity are important drivers of arrears. Unemployment is associated with higher rates of delinquency in almost all studies.

In the case of Ireland, several studies have used loan-level data collected by the Central Bank of Ireland to investigate the drivers of mortgage arrears. Lydon and McCarthy (2013) analyse these data over the period 2008 to 2010 and find that unemployment and the debt service to income ratio are particularly important. Kelly and McCann (2016) focus on the determinants of long-term arrears using data for the period 2012 to 2013. Unemployment and the repayment burden are also key drivers of mortgages being in long-term arrears, while the mortgage rate and household equity additionally play a role. Finally, Kelly and O'Malley (2016) examine the microeconomic and macroeconomic drivers of the probability of mortgage default and cure transitions.

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[26] The variable $DStock$ is the stock of dwellings estimated by the CSO using national accounts data. The variable $HStock$ is the housing stock based on aggregating the number of housing completions and applying a depreciation rate to the stock at the end of each period. In model simulations, we assume a simple linear relationship between the two variables.

[27] We assume that the rate of depreciation of the dwelling and commercial property stock is the same at 0.8 percent per year.

They show that the deterioration of the labour market played a much stronger role in the rise in Irish default rates following the financial crisis than the decline in housing equity.

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

$$
\begin{aligned}
Arrears_t = \alpha + \beta_1 HHEquity_t + \beta_2 RMorRate_t + \beta_3 URate_t \\
+ \beta_4 (MorStock_t / Income_t) + \varepsilon_t
\end{aligned}
\tag{14}
$$

where $Arrears$ is the household mortgage arrears rate. In the short-run model we include lagged and contemporaneous changes in the variables in (14).

Corporate Insolvency

The empirical literature on firm default suggests that financial factors such as leverage are key determinants of firms' survival rate.[28] In addition, overall demand conditions, as reflected for example in the unemployment rate, are an important real factor that affects corporate insolvency .

Using UK data, Vlieghe (2001) finds that aggregate corporate indebtedness (as approximated by the corporate debt-to-GDP ratio), interest rates, the output gap and property prices, all play an important role in determining the corporate liquidation rate. An index of property prices is used to approximate the value of firms' collateral. Liu (2009) also looks at the role of macroeconomic factors in driving the corporate insolvency rate in the UK and shows that higher profits and GDP growth are associated with lower insolvency rates, while higher interest rates and corporate leverage are associated with higher insolvency rates.

These findings are confirmed in studies that use panel data. For example, Hazak and Mannasoo (2007) analyse the drivers of company failure using data for countries in the European union. Similar to single-country studies, they show that higher corporate leverage and real interest rates are associated with higher levels of insolvency. In terms of real factors, they show that higher rates of GDP growth lower the probability of insolvency in 'old' member states.

In the Irish context, the literature on the macroeconomic drivers of corporate insolvency is particularly sparse. One recent contribution is the study by Kelly et al (2015), who examine the role of both macroeconomic factors and credit conditions on Irish firms' probability of survival. Their results highlight the impact of aggregate demand, as captured by the unemployment rate, and credit growth on this probability. Importantly, they also show 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.

Our model of the corporate insolvency rate therefore incorporates the potential impact of both real and financial factors. We use the unemployment rate to capture aggregate demand factors that affect corporate profitability. We include the corporate

[28] As we discuss below in relation to bank capital, one of the central predictions of the Modigliani-Miller theorem is that the value of a firm (or bank) should be independent of how it is financed. The importance of financial factors such as leverage in the determination of the corporate insolvency rate thus implies weak empirical evidence for the theorem. This is likely due to the violation of two assumptions of the model: that firms can borrow at the prevailing market interest rate and that there is no bankruptcy.

lending to capture borrowing costs and the stock of corporate credit relative to GDP to indicate corporate indebtedness. Finally, we construct a measure of firm's net worth to capture changes in collateral or net worth that can affect firms' ability to obtain credit and working capital through the mechanism outlined in Kiyotaki and Moore (1997). To approximate changes in firms net worth we use the ratio of the nominal stock of CRE to total corporate credit. This variable can be interpreted as the corporate equivalent of the housing equity variable in (14).

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

$$\begin{aligned} Insolv_t = \alpha + \beta_1 CEquity_t + \beta_2 RCorpRate_t + \beta_3 URate_t \\ + \beta_4 (CorpC_t/GDP_t) + \varepsilon_t \end{aligned} \tag{15}$$

where $CEquity$ is the ratio of the nominal value of the stock of CRE to total corporate credit, $CorpC_t$. In addition to the error-correction term, the short-run behaviour of the insolvency rate is governed by the first differences of the variables in (15).

The top panel of Table 8 presents the estimation results for the long-run mortgage arrears and corporate insolvency models. Our results highlight the important role of financial factors in determining the rate of both arrears and insolvencies. For households, both the real mortgage rate and the mortgage debt-to-income ratio reflect the repayment burden. The coefficients suggest that both variables have a strong impact on arrears. For example, a one percentage point increase in the mortgage rate will raise the long-run level of mortgage arrears by 30 basis points, all else equal. For firms, both the corporate rate and the ratio of corporate credit-to-GDP indicate that financial factors matter for insolvency rate, although the impact is slightly weaker than for mortgage arrears. As lender-based macroprudential policy is mainly transmitted through lending rates in our model, it can have a potentially important impact on financial stress in both the household and corporate sectors.

In addition, adverse shocks to firms' and households' equity positions 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. In the case of firms, our measure of firms' equity reflects changes in the value of CRE relative to debt. To the extent that this captures fluctuations in firms' net worth, it represents a channel through which constraints on access to finance can become binding. If net worth falls firms may not be able to rollover credit or obtain working capital, which may ultimately lead to insolvency. The estimated coefficient suggests this channel may be relatively weak. For example, a one percent fall in firms' equity raises the insolvency rate by approximately five basis points.

As discussed above, almost all empirical studies find that the unemployment rate is one of the most important drivers of both the mortgage arrears rate and the corporate insolvency rate. The unemployment rate is used to reflect changes in the macroeconomic environment and the impact this has on the debt repayment capacity of households and firms. We find that it has a positive significant long-run effect on both stress indicators. Holding the other variables constant, a one percentage point increase in the unemployment rate will raise the mortgage arrears rate by 80 basis points and the corporate insolvency rate by close to 10 basis points. 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 run.

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. The short-run dynamics of mortgage arrears are also affected by shocks to the mortgage rate and household equity, while the insolvency rate is driven by its own shocks and by economic growth, an alternative indicator of demand conditions.

Bank Capital

The Modigliani-Miller theorem (Modigliani and Miller, 1958) comprises two propositions. The first states that in a perfectly competitive frictionless economy, the value of a firm is independent of how it is financed. The second posits that, given the first proposition holds, the cost of equity for a firm increases linearly with its leverage ratio. As mentioned above, there is little evidence that the theorem holds empirically. This is likely due to a number of distortions that, in response to an increase in its capital ratio, prevent a bank's required return on equity falling sufficiently so that its weighted average cost of capital remains unchanged. These distortions include the favourable tax treatment of debt relative to equity, explicit or implicit public guarantees on banks' debt, and informational asymmetries (Cline, 2015).

Considering the empirical evidence against the Modigliani-Miller theorem, it may be expected that a bank would economise on its holdings of capital and target a capital ratio that is close to the regulatory minimum. However, banks tend to maintain often sizeable buffers over minimum requirements (Flannery and Rangan, 2006).

From a theoretical perspective, there may be several reasons for this. First, buffers provide insurance against capital falling below minimum requirements and the bank incurring a regulatory penalty (Repullo and Suarez, 2013). This can be particularly costly if there are significant short-run costs to adjusting capital ratios quickly due to asymmetric information (Myers and Majluf, 1984). Second, banks may hold buffers for economic capital reasons driven by perceived risk exposures on their lending portfolios, volatility in earnings, a desire to signal soundness to potential investors or to quickly avail of investment opportunities as they arise. Finally, in accordance with the "pecking order" theory buffers may reflect a period of high profitability and therefore the recent path of retained earnings (Myers and Majluf, 1984). A bank may decide not to distribute these profits as dividends as it may signal to potential investors that the bank is unable to exploit growth opportunities (Maurin and Toivanen, 2012).

Empirically, banks' capital ratios are found to be driven by several factors. Capital ratios tend to be lower among large banks and in larger sectors (Caprio et al, 2005; Gropp and Heider, 2010). This is likely due to less asymmetric information and a larger pool of potential investors, which reduce the cost of raising equity. Accordingly, we allow banks' capital ratios in our framework to depend on the size of the Irish banking sector in terms of total assets normalised by GDP.

Capital ratios tend to be inversely correlated with bank profitability as more profitable banks are able to raise capital more easily through retained earnings if they are required to do so at short notice (Berger et al, 2008; Mehran and Thankor, 2011). We use net interest margins as the indicator of profitability in our framework and it is through this channel that banks generate the retained earnings required to meet changes in their capital target.[29] This is consistent with the pecking order theory, which proposes

[29] In practice, a bank could also meet an increase in its target ratio by deleveraging, by changing the composition of its risk-weighted assets, or by issuing equity.

that banks choose to use internal funds first before seeking relatively more expensive external finance (Myers and Majluf, 1984). It is also consistent with the behaviour of capital ratios since the global financial crisis (Cohen and Scatigna, 2016). We use the weighted-average interest differential between assets and liabilities as an approximate measure of retained earnings or bank profits. However, in simulations we allow for losses arising from non-performing loans to reduce bank profits.[30]

In the absence of countercyclical macroprudential policy, there is considerable evidence that capital ratios are strongly procyclical (Drumond, 2009). This may be due to fluctuations in banks' perception of risk or in different quantitative measures of risk, such as Value-at-Risk (VaR), that fall in a cyclical upswing and rise in a downswing (Jokipii and Milne, 2008; Adrian and Shin, 2014). Following Akram (2014), we use the unemployment rate as our measure of the cyclical position of the economy.

Finally, capital ratios are driven by risks related to the structure of banks' balance sheets. On the asset side, these are related to portfolio concentration risk and exposure to relatively volatile sectors. In particular, capital ratios tend to be higher in banks that are more exposed to the real estate sector (Martin-Oliver et al, 2013). We approximate this exposure with the share of commercial real estate lending in total lending. On the liability side, capital ratios tend to be higher in banks that are more vulnerable to liquidity or rollover risk (Nier and Baumann, 2006; Francis and Osbourne, 2010). This suggests that banks that rely more on (non-insured) non-deposit funding tend to hold more capital to mitigate investor concerns that liquidity issues may generate insolvency risk. We approximate this "market discipline" effect with the share of deposits in total liabilities, which is expected to have a negative impact on the capital ratio.

We model banks' capital ratio in an error-correction framework with its long-run equilibrium a function of the size of the banking sector, bank profitability, the cyclical position of the economy, exposure to the commercial real estate sector, and market discipline:

$$\begin{aligned} CAP_t = \alpha + \beta_1(Assets_t/GDP_t) + \beta_2 URate_t + \beta_3 BProfits_t \\ + \beta_4(CREL_t/Loans_t) + \beta_5(Deposits_t/Liabilities_t) + \varepsilon_t \end{aligned} \tag{16}$$

where CAP is the ratio of capital to risk-weighted assets, $BProfits$ is the difference between weighted-average lending rates and funding costs adjusted for loan losses, $Loans$ are total loans to the non-financial private sector, and $Deposits$ are total retail deposits. $Assets$ and $Liabilities$ are, respectively, the total assets and liabilities of the banking sector.[31] We allow the short-run behaviour of the capital ratio to be driven by lagged and contemporaneous changes in the variables in (16).

Table 9 presents the estimation results of the bank capital equation. Banks' capital ratio tends to fall as the banking sector expands. As mentioned above, this is likely due to capital adjustment costs being lower in larger banking sectors. The coefficient on the unemployment rate is positive and significant, indicating that in the absence of

[30] The losses are calculated as the product of the probability of default, the loss given default and the exposure at default. The probability of default on household loans is linked to the arrears rate, while that on corporate loans is linked to the corporate insolvency rate. The loss given default is calibrated based on average historical values on each type of loan while the exposure at default is simply assumed to be the outstanding loan amount.

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

countercyclical capital regulation, capital ratios tend to behave procyclically. All else equal, a one percentage point increase in the unemployment rate is associated with a 60 basis points increase in the capital ratio.

We find that capital ratios rise when banks' profitability increases. This illustrates the importance of retained earnings as a source of capitalisation, consistent with the pecking order theory. In our model, this is the primary channel through which banks adjust their capital ratios in response to higher capital requirements. Capital ratios are also driven by potential portfolio and liquidity risks. In terms of the former, we find that banks hold more capital as their exposure to the commercial real estate sector increases. This is likely due to the relatively high volatility of that sector. In terms of liquidity or rollover risks, banks' capital ratios are lower the higher the share of deposits in liabilities. For example, a one percentage point increase in the share of deposits in total liabilities lowers the capital ratio by over 15 basis points.

Table 9 also shows that error-correction of the capital ratio to its long-run equilibrium is relatively slow, although most of the adjustment occurs within two years of a shock. This has potentially important implications for prudential policy and, in particular, the sequencing of higher capital requirements, as it suggests that Irish banks may incur significant adjustment costs if they are required to increase their capital ratios at short notice. Finally, the short-run behaviour of the capital ratio is also driven by changes in bank profitability and the unemployment rate.

The results presented in Table 9 determine how the capital ratio of Irish banks behaves in the short and long run. The long-run relationship between this ratio and its determinants can be interpreted as a target towards which banks adjust. The estimated constant in this relationship is therefore a proxy for minimum regulatory capital requirements, giving the average level of the capital ratio when the variables that determine the size of capital buffers are set to zero. In model scenarios, the target can also be augmented with additional capital requirements such as the CCyB. Accordingly, banks' target capital ratio in the model has the following form:

$$\begin{aligned} CAPT_t = & -1.18 - 2.1^*(Assets_t/GDP_t) + 0.7^*URate_t + 14.2^*BProfits_t \\ & + 1.1^*(CRE_t/Loans_t) - 0.6^*(Deposits_t/Liabilities_t) + CCyB_t \end{aligned} \tag{17}$$

where $CAPT$ is the target capital ratio, $CCyB$ is the countercyclical capital buffer, and the coefficients on each variable are taken from Table 9. A change in capital requirements, whether in the form of a permanent change in minimum regulatory levels or time-varying buffers as in the case of a CCyB, will shift this target up or down depending on the policy that is implemented. When the target changes, the long-run equilibrium towards which the actual capital ratio adjusts also changes, with the speed of error-correction and short-run dynamics given by the coefficients in Table 9.

As discussed above, the primary channel through which banks meet higher capital targets is by increasing retained earnings. In scenarios where capital holdings exceed their target level, the difference is assumed to be distributed to households in the form of dividends. Conversely, when the capital ratio is below target, dividends are suspended until the target is reached.

3 Real-Financial Linkages in a Macro Model

We now outline how the macro-financial relationships estimated in the previous section are embedded in the Central Bank of Ireland's structural macroeconomic model of the

Irish economy, COSMO. Figure 1 illustrates the key linkages we incorporate in the model between the Central Bank, the banking sector and the real economy in terms of the transmission mechanisms of different types of policy shocks, the spillovers between sectors, and important feedback effects.[32] These key linkages are represented by the solid arrows while the dashed arrows represent links between sectors that are not directly relevant to the macro-financial shocks we discuss here.[33]

The Central Bank acts as the macroprudential authority in the model. It has four instruments that it can use to mitigate different dimensions of systemic risk. On the borrower side, it can manage mortgage credit conditions by limiting household leverage and income gearing through restrictions on LTI and LTV ratios. On the lender side, it can raise liquidity requirements for banks by imposing a ceiling on LTD ratios and it can raise minimum regulatory capital ratios or activate the CCyB. The Central Bank as part of the ESCB is also the monetary authority in the model, although the latter is assumed to be exogenous to Irish economic conditions.[34]

Borrower-based macroprudential instruments affect mortgage credit demand directly, while lender-based instruments affect banks' lending spreads. The latter also depend on indicators of credit risk associated with lending to households and firms. Lending spreads together with funding costs determine the interest rate on each type of credit. These funding costs comprise the deposit rate, which follows the long-run government bond rate due to deposit insurance, and euribor, which depends on the policy rate.

Credit demand is assumed to depend on the cost of credit, income and the value of collateral, as approximated by house prices and CRE prices. As mentioned, household mortgage demand will also depend on the prevailing LTI and LTV ratios. In addition to mortgages, households also demand consumer loans. On the corporate side, the model distinguishes between CRE loans and other corporate credit due to the differential elasticity of demand of each loan type with respect to economic growth and CRE prices.

Accordingly, there are two credit channels through which real, financial, and macroprudential shocks are transmitted to property prices. In the first channel, changes in interest rates affect the user cost of capital which, net of expectations of property price appreciation, will affect households' and firms' decisions to purchase housing or CRE. In the second channel, given that interest rates are often a poor indicator of credit availability, changes in the quantity of credit relative to income or GDP are used to approximate variations in credit conditions in each sector.

The response of house prices to shocks affects household consumption and the demand for consumer loans through the housing wealth effect. It also affects residential investment by changing the profitability of housing development. As both consumption and investment are components of non-traded output, employment and wages in that sector will rise or fall depending on the shock. The impact on household mortgage arrears is contingent on the relative strength of the response of housing equity, the mortgage rate and the stock of mortgage debt.

[32] Note that some of the spillover and feedback channels are omitted from Figure 1 for expository reasons.

[33] See Bergin et al (2017) and Conefrey et al (2018) for details on different aspects of COSMO.

[34] To simulate changes in the ECB policy stance, the model can be used in conjunction with NIESR's NIGEM model of the global economy.

The channels through which shocks in the banking system are transmitted to the corporate sector are similar to those in the household sector. The corporate lending rate is particularly important as it is the key component of the user cost of capital, which in turn affects the demand for CRE and non-CRE credit as well as commercial property prices. The latter have a dual role in the propagation of shocks in this sector. First, they determine the profitability of CRE investment and affect the demand for CRE credit. Second, they act as collateral and an approximate indicator of firms' balance sheet strength, which influences banks' willingness to rollover existing loans and extend credit for working capital. Both CRE and non-CRE corporate investment are key drivers of the long-run productive capacity of the traded- and non-traded sectors in the model as they determine the capital stock in each sector. Similar to mortgage arrears, the impact of macro-financial shocks on the corporate insolvency rate will depend on the responses of the corporate lending rate, CRE prices, and firms' income gearing.

Finally, Figure 1 shows how macro-financial shocks can spillover to the government and international sectors. The impact on the government sector is indirect and occurs through automatic stabilisers as government revenue and expenditure responds passively to economic growth. The response of consumption and investment to these shocks also affects the economy's external position. The current account evolves according to the impact of changes in the level of economic activity on the demand for imports and on wage dynamics, which determine competitiveness and thus exports.

4 Scenarios

We now illustrate the usefulness of our model for both macroprudential policy and financial stability analysis. We first assess the macro-financial impact of a change to LTI and LTV ratios. These ratios affect credit demand directly and therefore have a potentially important role in dampening the financial cycle. We then consider the stabilising properties of one of the lender-based macroprudential instruments, the CCyB, and show that releasing this buffer in a cyclical downturn can mitigate the decline in credit provision. Finally, we simulate a scenario in which there is an exogenous permanent fall in CRE prices and highlight the strength of the linkages between this sector, the banking system, and the wider economy.

Borrower-based Instruments

The sharp relaxation of Irish mortgage credit conditions over the 2003-2007 period was mainly evident in higher LTI and LTV ratios on new mortgage lending to households (McCarthy and McQuinn, 2017). The increase in these ratios was also associated with higher subsequent levels of borrower default (Hallissey et al, 2014). As restrictions on these ratios are a key component of the Central Bank of Ireland's macroprudential toolkit, it is important to elucidate and quantify the channels through which changes in these ratios are transmitted to the economy.

LTV Ratio

We first simulate an exogenous five percentage point fall in the mortgage LTV ratio over the period Q1 2020 to Q4 2032.[35] The results of this scenario are shown in Figure 2. The LTV ratio, together with the LTI ratio, are incorporated in the equation for new mortgage lending to reflect the change in credit conditions related to constraints on household leverage. A five percentage point fall in the LTV ratio reduces new mortgage lending by over 20 percent in the long run relative to a baseline scenario in which the LTV ratio remains constant. The reduction in new mortgage lending leads to a mortgage stock, which net of redemptions, is 12 percent lower by the end of the simulation period.

The tightening of credit conditions leads to lower house prices, which fall by eight percent in the medium term and six percent in the long term. The rise in house prices back towards baseline in the long run is mainly due to lower housing supply. One of the key drivers of housing demand in the model is the ratio of the housing stock to the population of 25 to 39 year olds. The latter is exogenous in the model so the decline in the housing stock due to the reduction in residential investment causes this ratio, and consequently housing demand, to increase. The housing stock is almost one percent lower relative to baseline after ten years.

The fall in residential investment leads to lower demand for construction related CRE loans, which fall by over six percent in the long run. As construction firms are assumed to operate in both the residential and CRE sectors, the fall in house prices diverts resources from the former to the latter with CRE prices falling as a result. Deposits are assumed to grow in line with the economy so that banks are utilising less wholesale funding at the margin due to the decline in credit demand from the residential sector. This lowers the LTD ratio by four percentage points. The credit gap, given by the difference between the credit-to-GDP ratio and its trend, falls by a similar amount.

The rate of mortgage arrears initially rises above baseline due to lower household equity and higher unemployment. However, as the mortgage stock falls relative to baseline, average household equity converges towards the prevailing LTV ratio and the income gearing of households falls. This leads to a reduction in mortgage delinquency with the arrears rate 0.4 percentage points lower than its baseline value by the end of the simulation period. Banks' profitability deteriorates mainly due to lower lending volumes but eventually tapers due to the reduction in mortgage arrears.

For households, the decline in house prices generates a negative housing wealth effect, which has a strong impact on consumption. The latter falls by close to one percent after five years. As the fall in income is small relative to the reduction in consumption, the savings rate adjusts and is 60 basis points higher when the deviation of consumption from baseline is at its peak.

Overall, the medium-run impact of a five percentage point reduction in the LTV ratio is a fall in GDP of 0.25 percent and an increase in the unemployment rate of 15 basis points, before these variables gradually return to baseline. The reduction in domestic demand and increase in the savings rate lead to an improvement in the current account balance, which is approximately 35 basis points higher in the medium term. Finally, the general government budget balance deteriorates by 10 basis points over the same period

[35] Note that the LTV and LTI scenarios that we simulate reflect the impact of a generalised exogenous change in these ratios. Accordingly, they abstract from how "binding" constraints on these ratios are at a particular point in time. See Kelly et al (2018) and Kelly and Mazza (2019) for details on how the bindingness of these constraints can be derived using loan-level data.

due to automatic stabilisers, before rising back to baseline in line with the aggregate economy.

LTI Ratio

We next consider the impact of an exogenous fall in the mortgage LTI ratio of 0.25 times income. As the transmission channels and dynamics are similar to those for a shock to the LTV ratio, we focus here on the magnitude of the impact on each variable. Figure 3 shows the response of each selected variable to this shock. The LTI ratio is incorporated in the equation for new mortgage lending to capture exogenous changes in credit conditions related to the relaxation of constraints on household income gearing. A shock to the LTI ratio of this size reduces new mortgage lending by approximately 15 percent, leading to a mortgage stock that is eight percent lower by the end of the scenario horizon.

More restrictive credit conditions reduce housing demand and generate a decline in house prices of close to eight percent in the medium term. Lower house prices reduce the profitability of residential investment which lowers the housing stock by over one percent relative to baseline by the end of the simulation period. The decline in residential investment leads to lower demand for credit by construction firms, with the stock of CRE loans ultimately falling by four percent. The reduction in housing demand diverts resources away from the residential sector and towards the CRE sector. This lowers CRE prices by over 1.5 percent in the medium term before they return to baseline.

The fall in the LTI ratio reduces the credit gap and LTD ratio by approximately 2.5 percentage points. Bank profitability also falls due to the contraction of banks' balance sheets but tapers in the long run as mortgage arrears fall. As in the case of the shock to the LTV ratio, arrears rise in the short- to medium-term due to a combination of lower housing equity and a higher unemployment rate, but fall in the longer term because of the reduction in household indebtedness. However, the net impact of the LTI shock on the arrears rate is quantitatively small at 20 basis points.

Consumption responds relatively strongly to the shock, falling by 0.6 percent in the medium term. This is mainly due to the negative housing wealth effect from lower house prices, which raises household saving. The aggregate savings rate rises by 40 basis points as a result of the shock.

Overall, the macroeconomic impact of a shock to the LTI ratio of this magnitude is relatively small. GDP falls by over 0.15 percent in the medium term, while the unemployment rate rises by 10 basis points. Lower consumption and higher saving lead to a 20 basis point increase in the current account balance relative to baseline. The general government balance deteriorates slightly due to lower tax receipts from the reduction in economic activity and higher transfer payments due to greater unemployment. However, the macroeconomic impact of the shock dissipates substantially over the longer term as these variables converge towards their baseline values.

Countercyclical Capital Buffer

The Central Bank of Ireland, in its capacity as the national macroprudential authority, activated a CCyB for Irish banks in 2018. The aim of the CCyB is to enhance the loss-absorbing capacity of the banking system so that it "buffers" rather than amplifies the impact of cyclical shocks on banks' balance sheets.[36]. This mitigates the tendency of banks to boost their capital ratios by contracting credit provision in a downturn, which generally exacerbates financial stress among households and firms, leads to further deterioration of banks' balance sheets, and impedes recovery in the real economy.[37]

This raises an important question from a macroprudential perspective in terms of the extent to which the "release" of the CCyB can support the supply of credit in the contractionary phase of the cycle. To address this issue, we implement the CCyB in our model by incorporating a trend for the credit-to-GDP ratio, which is estimated using the linear projection method outlined in Hamilton (2018). The CCyB is calibrated in proportion to the credit gap, given by the deviation of the credit-to-GDP ratio from its trend. It is activated once the credit gap exceeds two percentage points. The buffer then increases linearly from zero to 2.5 percentage points until the credit gap exceeds 10 percentage points, above which the 2.5 percentage point maximum is applied.[38]

To demonstrate the potentially stabilising impact of the CCyB, we simulate a scenario in which it is initially set to the maximum value before the economy experiences a sudden permanent real and financial shock that is sufficient to lower the credit gap from 10 percentage points to below zero within one year.[39] In response to the shock, the central bank sets the CCyB to zero so that banks can reduce their capital buffers by 2.5 percentage points.[40] The shock absorptive role of the CCyB is illustrated by comparing the behaviour of each variable in this scenario to a baseline scenario in which the target capital ratio of the banking sector does not fall in response to the shock.

Figure 4 shows the deviation of selected variables from their baseline values. As the target capital ratio falls, banks are required to hold less retained earnings and so reduce lending rates. The mortgage, corporate and consumer rates fall by 30, 25, and 45 basis points, respectively. Lower lending rates boost demand for credit relative to the baseline. New mortgage lending is three percent higher in the long run, which leads to a mortgage stock which is almost 1.2 percent higher. The large fall in the consumer rate means that the demand for consumer loans rises by 1.6 percent relative to baseline.

In terms of corporate lending, the demand for CRE loans rises more than for other types of corporate credit due mainly to the higher interest sensitivity of demand for

[36]While the aim of the CCyB is not explicitly to dampen fluctuations in the financial cycle, it can potentially complement more direct tools such as restrictions on LTI and LTV ratios (Donnery, 2018).

[37]While higher levels of bank capital may reduce the probability of a financial crisis occurring, they may also generate macroeconomic costs due to the associated increase in lending rates. See McInerney et al (2020) for an analysis of the net benefits of higher capital requirements for Ireland.

[38]Note that the actual implementation of the CCyB is much more multi-faceted than a simplistic implementation based on the gap between the credit-to-GDP ratio and its underlying trend (O'Brien and Ryan, 2017). Moreover, Lozej et al (2018) find that it may be more optimal from a welfare perspective to target a house price gap rather than a credit gap.

[39]This is calibrated as a three percent fall in world demand and a two percentage point increase in banks' funding costs.

[40]We assume that banks' capital ratios are at their target levels inclusive of the CCyB prior to the shock. As Lozej and O'Brien (2018) show, the presence or loss of additional buffers may affect the timing of the CCyB release and may also affect the behaviour of banks as they adjust their non-CCyB buffers.

this type of loan. CRE lending is 1.5 percent higher relative to baseline in the long run, while other corporate lending is over one percent higher.[41] Lower lending rates and higher credit volumes lead to higher property prices and investment. House prices rise by 1.2 percent above baseline after 10 years. This increases the profitability of residential investment, which also rises due to lower borrowing costs. Similarly, CRE values increase by 0.5 percent over the same period, which raises CRE investment by 0.8 percent.

The increase in economic activity due to higher investment raises the demand for labour which puts upward pressure on wages. In the medium run household income is 0.1 percent higher than the baseline, which together with higher house prices leads to higher consumption. The overall macroeconomic impact of the release of the CCyB is to raise GDP and employment by approximately 0.12 percent above baseline. The fall in interest rates induced by lower capital requirements also has a long-run effect on the supply potential of the economy by raising the aggregate productive capital stock through higher levels of investment.

Our results suggest that the CCyB can attenuate the decline in bank lending and output in response to an adverse shock but that its impact may be weak. The credit gap is 80 basis points higher than baseline at the end of the scenario horizon. By contrast, the moderate changes to borrower-based instruments in the scenarios above generated increases in the credit gap of between 2.5 and four percentage points. The differential effects on credit of borrower- and lender-based instruments are mainly due to the relatively low interest elasticity of credit demand that we estimate in the model and the mechanism through which borrower-based instruments affect credit demand directly. While some components of GDP such as consumption and real estate investment respond strongly either directly or indirectly (through wealth effects) to the fall in interest rates, the overall impact on GDP indicates that other components exhibit much lower interest-sensitivity.

Commercial Real Estate Prices

Finally, we illustrate how our model can be used to generate stress scenarios that are central to the assessment of macro-financial risks. One of the novel features of our model is the incorporation of the CRE sector. CRE prices fell by more than 60 percent in the aftermath of the financial crisis, while the rate of non-performing CRE loans rose to over 70 percent (ESRB, 2015; McCann and McGeever, 2018). While the CRE share of bank lending has diminished significantly since the crisis, the volatility of the commercial property sector along with its linkages to the rest of the economy imply that it remains a potential source and propagator of real and financial risks.[42]

To illustrate how shocks to the CRE sector in our model have both macroeconomic and financial effects, we consider a scenario in which there is an exogenous and permanent 10 percent fall in CRE prices. As with the other scenarios, the shock is implemented in Q1 2020 and the model is simulated until Q4 2032. Figure 5 presents the response of selected variables to this shock.

[41] The increase in corporate lending is also partly driven by the appreciation in CRE prices, which raises the value of firms' collateral.

[42] The share of CRE in the stock of credit extended to Irish non-financial corporations has fallen from a peak of 66 percent in Q2 2009 to its current level of 31 percent.

The decline in CRE prices reduces the incentive to invest in CRE, with CRE investment falling by five percent over the long term relative to the baseline scenario. The demand for CRE loans falls by eight percent due to the decline in the profitability of CRE investment. The fall in the value of collateral also adversely affects firms' ability to rollover existing credit lines and obtain working capital, thereby constraining the demand for non-CRE corporate credit. The latter is approximately four percent lower over the medium to long term. As CRE investment is now less profitable relative to residential investment, real estate and construction firms shift resources to the housing sector. As residential investment increases, the supply of housing relative to the population of 25 to 39 year olds rises, so that house prices fall relative to baseline in the medium term.

The deterioration in credit conditions lead to some firms becoming insolvent as seen by the 15 basis points increase in the corporate insolvency rate after five years. Banks respond to this indicator of economic stress by increasing the risk premium component of the corporate lending rate, although the effect is relatively small. Higher lending rates raise the user cost of capital, further depressing investment and lowering the demand for credit. This mechanism is similar to the financial accelerator outlined in Bernanke et al (1999), whereby a negative shock to firms' asset values leads to a credit crunch which reduces investment and exacerbates the initial decline in firms' net worth. The fall in corporate lending reduces bank profits, the LTD ratio and the credit gap. The latter is more than two percentage points lower by the end of the scenario horizon.

The macroeconomic impact of the shock to CRE prices is relatively large.[43] GDP falls by 0.4 percent in the medium term, mainly driven by lower consumption and investment, while the unemployment rate rises by 15 basis points. Corporate profits decline initially due to the fall in output in the non-traded sector. The recovery in profits in the long run is driven by the traded sector as exports increase due to the improvement in cost competitiveness relative to trading partners, with the current account balance rising by 30 basis points after five years. This more than offsets the continued decline in the profitability of firms in the non-traded sector. Potential output declines in the long run mainly due to lower levels of CRE investment, which reduces the economy's productive capital stock relative to baseline. Finally, automatic stabilisers reduce the government balance although the effect is again quantitatively small.

Our results highlight the macro-financial risks that can be generated by fluctuations in CRE prices. They illustrate the role of the latter in determining the profitability of real estate investment and the value of collateral used to obtain other types of corporate credit. They also show that these fluctuations have a direct and indirect impact on lending rates, banks' balance sheets, and on firm survival.

5 Conclusion

We specify and estimate a system of macro-financial linkages for the Irish economy, incorporating transmission channels for both borrower- and lender-based macroprudential instruments. We then embed these linkages in a semi-structural model of the Irish economy. We highlight the dynamic direct and indirect nature of the interactions between the banking sector and the real economy, as well as the role of sectoral spillovers and spillbacks. Importantly from a financial stability perspective, we

[43] To put the macroeconomic (real GDP) impact of this shock in comparative terms, it is equivalent to a 10 percentage point fall in the LTV ratio.

show that aggregate indicators of household and corporate stress such as mortgage arrears and insolvency rates have both real and financial triggers, which subsequently feed back into banks' loan pricing decisions.

We simulate four scenarios to illustrate the usefulness of the model for macroprudential policy and financial stability analysis. The first two scenarios consider how changes to borrower-based instruments can affect macro-financial volatility. We then consider the shock-absorbing capacity of the CCyB in the event of an adverse shock to the economy. Finally, we illustrate the usefulness of the model for simulating stress-test scenarios by examining the impact on the Irish economy of an exogenous fall in CRE prices.

We find that borrower-based macroprudential instruments have a strong impact on credit demand. This emphasises the important role that these instruments can play in mitigating macro-financial risks and dampening fluctuations in the Irish financial cycle. In terms of lender-based instruments, we find that although the CCyB does attenuate the contraction in credit provision and output in response to an adverse shock, its stabilising role may need to be complemented with other instruments in the event of a particularly severe shock. We also show that fluctuations in CRE prices can generate substantial real and financial volatility. This is primarily due to the different role CRE prices play for different firms in terms of determining the profitability of investment, reflecting collateral values, and as an indicator of balance sheet strength. It should be noted however, that our model is essentially linear, whereas the impact of macroprudential policy or macro-financial shocks may be highly non-linear.

An interesting extension of our framework would be to incorporate reaction functions for each macroprudential instrument, which apart from the CCyB are exogenous in the model. This would require constructing an indicator of systemic risk which could include, similar to Davis et al (2018), a measure of house price misalignment, capital adequacy, excess credit growth, and imbalances in the current account. Different calibrations of the response function for each instrument could inform priors about the relative effectiveness and stabilising properties of different instruments and importantly, the dynamic interactive behaviour of these instruments within a given set of policy measures. Moreover, as the systemic risk indicator would respond to changes in bank capital, the model could incorporate the benefits of higher capital requirements in terms of mitigating systemic risk.

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Figure 1. Macro-Financial Linkages in COSMO

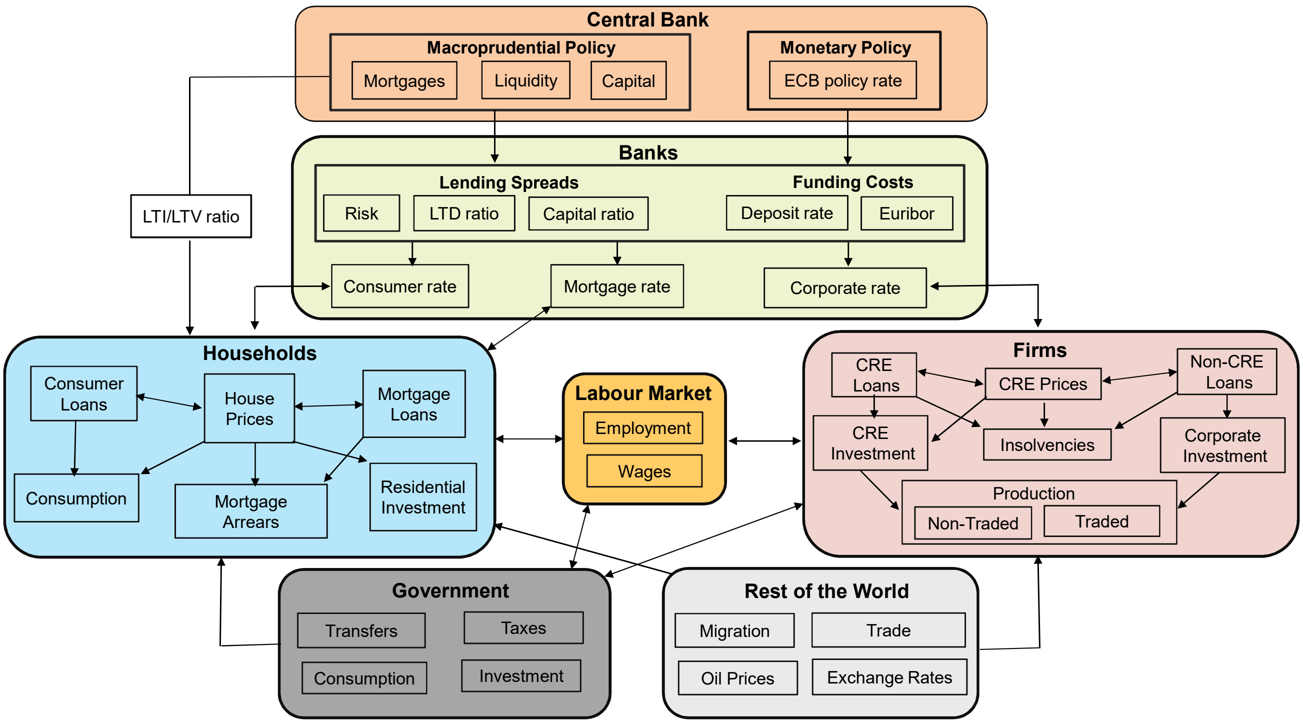
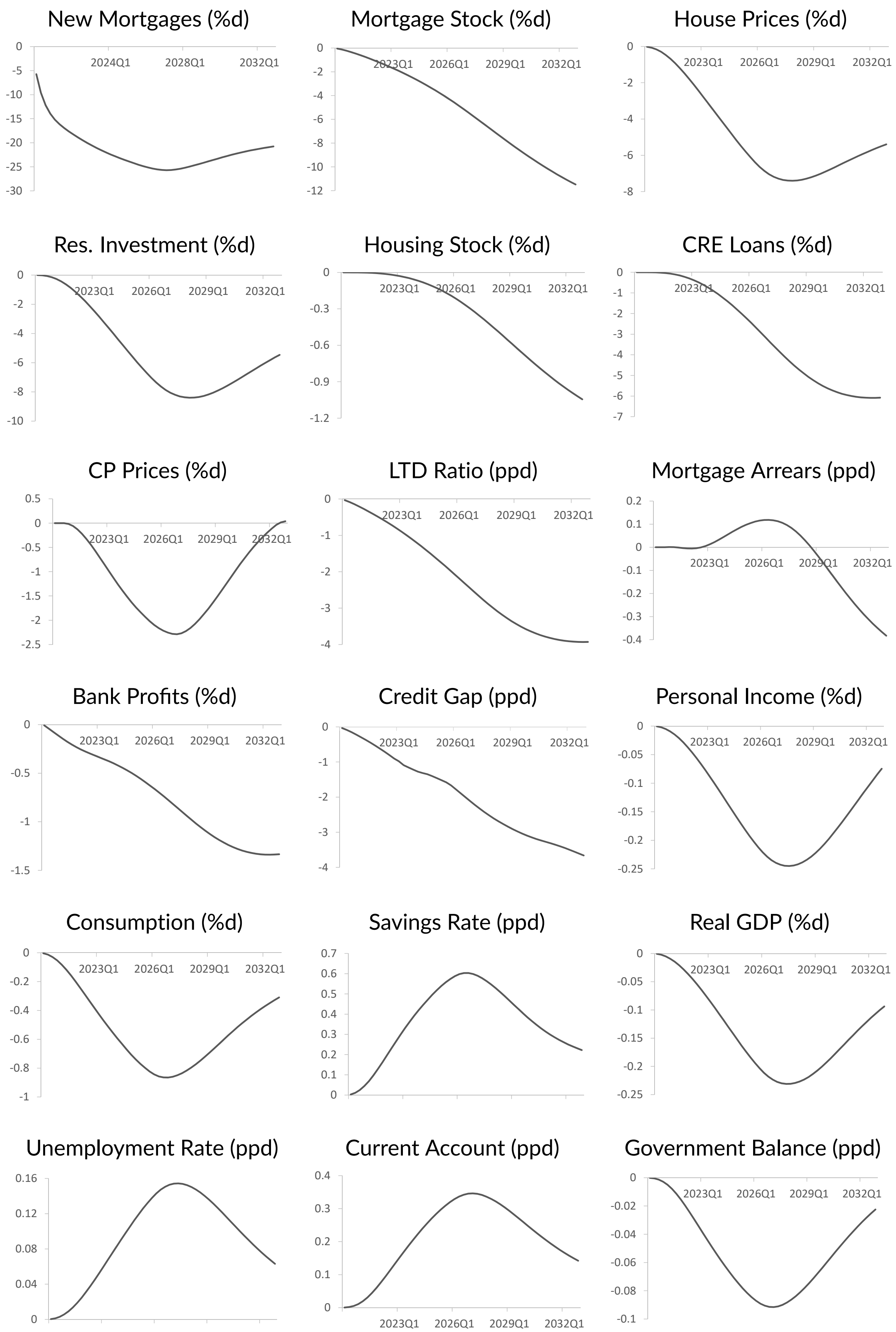
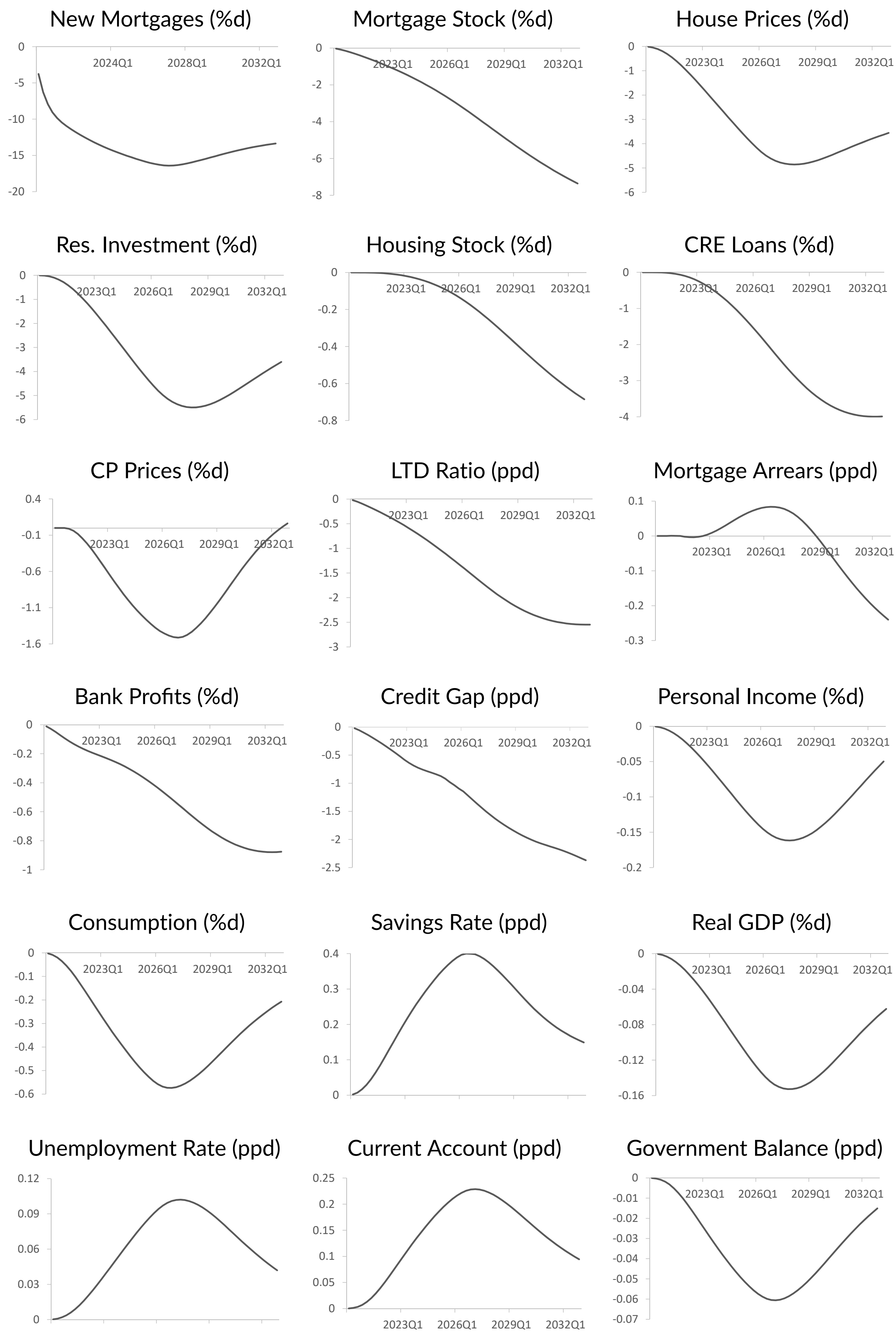


Figure 2. Impact of a 5 percentage point fall in the LTV ratio



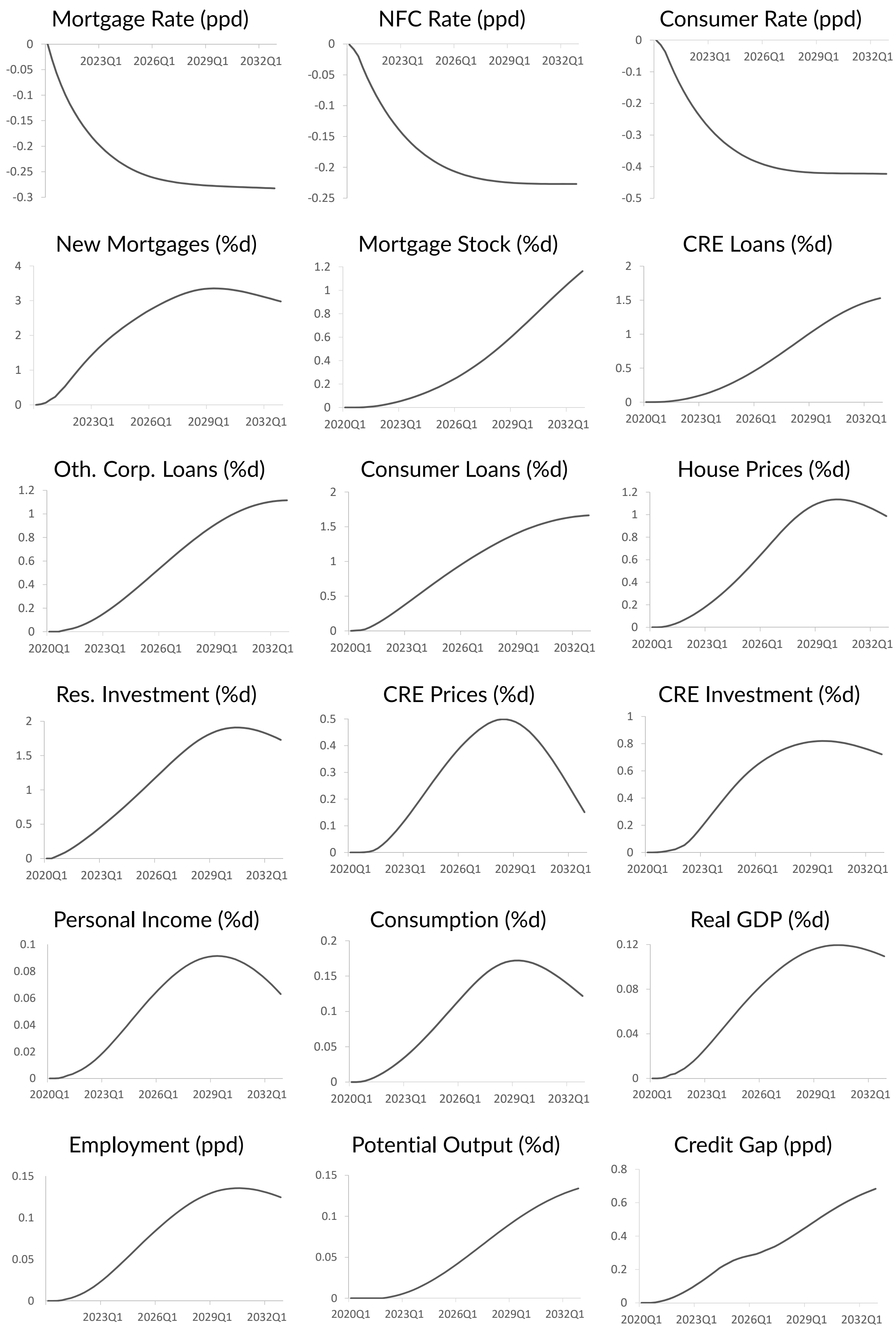
Note: Figure 2 shows the percent (%d) or percentage point (ppd) deviation of each variable from baseline.

Figure 3. Impact of a fall in the LTI ratio of 0.25



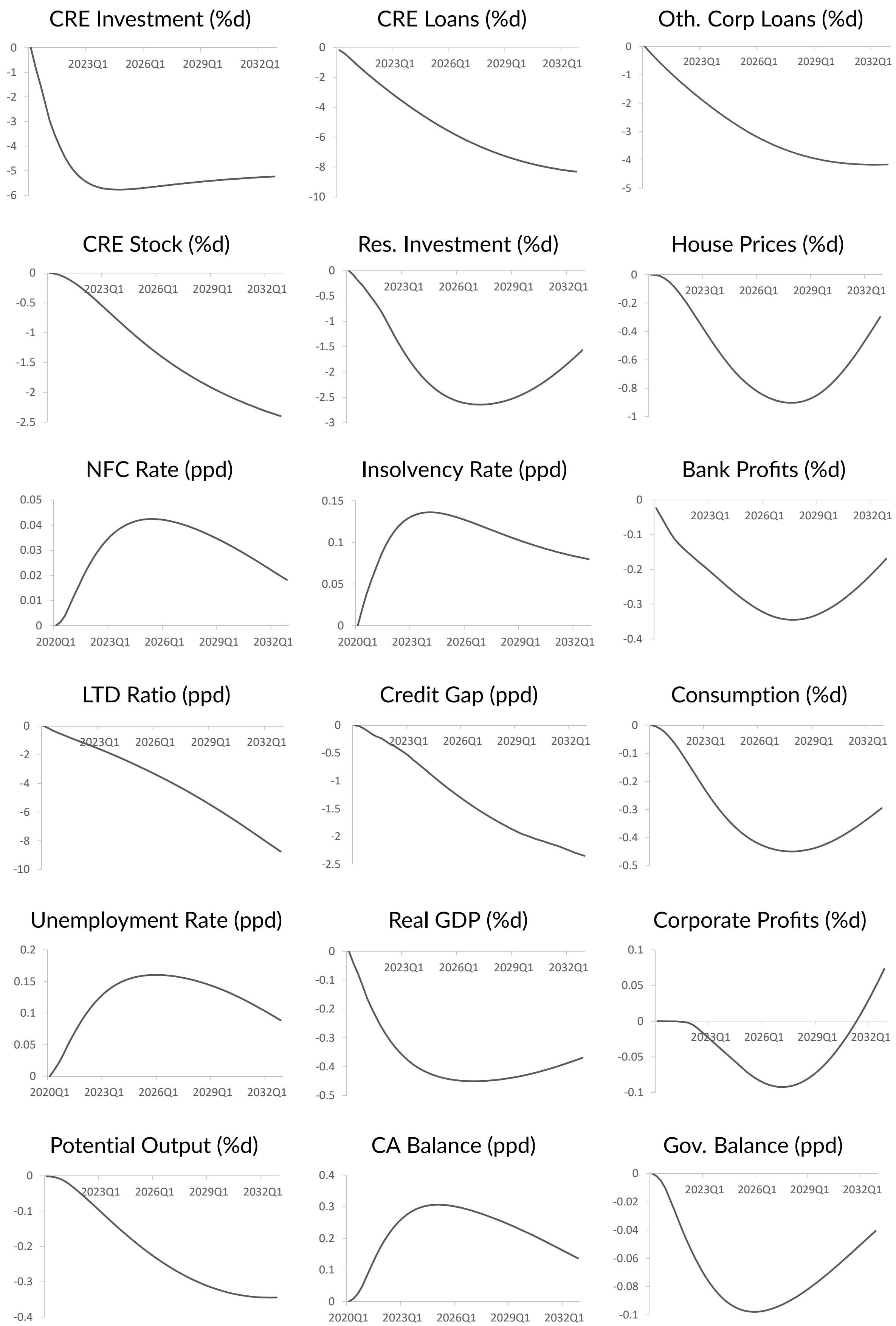
Note: Figure 3 shows the percent (%d) or percentage point (ppd) deviation of each variable from baseline.

Figure 4. Impact of releasing the Countercyclical Capital Buffer



Note: Figure 4 shows the percent (%d) or percentage point (ppd) deviation of each variable from baseline.

Figure 5. Impact of a 10 percent fall in CRE Prices



Note: Figure 5 shows the percent (%d) or percentage point (ppd) deviation of each variable from baseline scenario.

Table 1. Mortgage Demand

	$NewMortgages_t$		$MorStock_t$
Constant	-0.041	$MorStock_{t-1}$	0.988
	(4.2)		(5.9)
$NewMortgages_{t-1}$	0.644	$NewMortgages_t$	1.0
	(7.4)		(n.a)
$RMorRate_t$	-0.025		
	(-2.0)		
LTV_t	0.845		
	(2.2)		
LTI_t	0.319		
	(2.1)		
ΔHP_{t-2}	0.694		
	(3.3)		
$\Delta Income_{t-1}$	0.871		
	(2.3)		
$HCompl_{t-1}$	0.14		
	(1.8)		
Adj. R^2	0.957	Adj R^2	0.997
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 1 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*, *Income*, *HCompl* are real house prices, real personal disposable income, and housing completions, respectively. All variables in the equation for new mortgages, except for interest rates, are in logs. Variables in the mortgage stock equation are in levels. *t*-statistics are in parentheses.

Table 2. Mortgage Supply

	$MorRate_t$
Constant	11.599
	(1.4)
$MMRate_t$	0.741
	(17.3)
$DepRate_t$	0.259
	(n.a)
$HHEquity_t$	-0.792
	(-1.9)
$URate_t$	0.819
	(4.4)
LTD_t	-1.723
	(-3.3)
CAP_t	0.682
	(2.2)
	$\Delta MorRate_t$
ECT_{t-1}	-0.217
	(-2.2)
$\Delta MMRate_t$	0.483
	(8.4)
$\Delta MMRate_t$	0.157
	(3.3)
$CAPT_{t-1}$-CAP_{t-1}	0.011
	(1.9)
Adj R^2	0.751
Sample	1997Q1-2018Q2

Notes: Table 2 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. *CAP* is the ratio of bank capital to risk-weighted assets and *CAPT* is the target capital ratio. 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	-7.663	Constant	3.297
	(-8.1)		(7.2)
$RConsRate_t$	-0.029	$MMRate_t$	0.461
	(-5.3)		(7.1)
$Income_t$	1.245	$DepRate_t$	0.539
	(13.5)		(n.a)
$HHEquity_t$	0.255	$URate_t$	0.903
	(9.9)		(2.1)
NFW_t	-0.408	$ConsCredit_t/Income_t$	2.334
	(6.6)		(2.1)
		CAP_t	0.791
			(2.5)
		LTD_t	-3.312
			(-5.3)
	$\Delta ConsCredit_t$		$\Delta ConsRate_t$
ECT_{t-1}	-0.106	ECT_{t-1}	-0.151
	(-2.3)		(-2.1)
$\Delta ConsCredit_{t-1}$	0.439	$\Delta DepRate_t$	0.273
	(3.4)		(2.1)
$\Delta RConsRate_{t-1}$	-0.007	$\Delta MMRate_{t-1}$	0.377
	(2.4)		(4.8)
$\Delta Income_{t-1}$	0.328	$CAPT_{t-2}$-CAP_{t-2}	0.016
	(2.7)		(3.1)
$\Delta Income_{t-2}$	0.276	$\Delta(ConsC_{t-3}/Income_{t-3})$	1.991
	(2.4)		(3.0)
Adj. R^2	0.512	Adj. R^2	0.647
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 3 shows the estimation results for the consumer credit, *ConsCredit*, and consumer lending rate, *ConsRate*, equations. *RConsRate* is the real consumer lending rate. *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

	$CREL_t$		$OCorpL_t$
Constant	-0.161	Constant	-0.294
	(-0.6)		(-1.2)
$RCorpRate_t$	-0.034	$RCorpRate_t$	-0.052
	(-1.9)		(-2.0)
YNT_t	1.248	YNT_t	1.473
	(6.3)		(2.8)
CP_t	0.811	CP_t	0.444
	(2.0)		(1.9)
HP_t	0.902	$NTProfits_t$	-1.045
	(2.1)		(-2.1)
	$\Delta CREL_t$		$\Delta OCorpL_t$
ECT_{t-1}	-0.039	ECT_{t-1}	-0.041
	(-4.4)		(-3.6)
ΔCP_{t-1}	0.272	ΔYNT_t	0.046
	(3.1)		(2.0)
$\Delta RCorpRate_{t-1}$	-0.001	$\Delta RCorpRate_{t-1}$	-0.005
	(-1.8)		(3.3)
Adj. R^2	0.645	Adj R^2	0.597
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 4 shows the estimation results of the equations for for commercial real estate loans, *CREL*, and for other non-CRE corporate loans, *OCorpL*. *RCorpRate* is the real interest rate on lending to non-financial corporations. *YNT* is the output of the non-traded sector in real terms. *CP* are CRE prices and *NTProfits* are corporate profits in the non-traded sector. 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	4.158
	(3.3)
$MMRate_t$	0.788
	(10.9)
$DepRate_t$	0.176
	(2.0)
$Insolv_t$	1.185
	(4.5)
$CorpL_t/GDP_t$	0.847
	(3.0)
CAP_t	0.422
	(1.9)
LTD_t	-2.105
	(-4.4)
	$\Delta CorpRate_t$
ECT_{t-1}	-0.184
	(-3.1)
$\Delta URate_t$	0.817
	(2.5)
$\Delta MMate_t$	0.602
	(9.4)
$\Delta MMate_{t-1}$	0.141
	(3.6)
$CAPT_{t-2}$-CAP_{t-2}	0.007
	(1.9)
Adj R^2	0.787
Sample	1997Q1-2018Q2

Notes: Table 5 shows the estimation results of the equation for the nominal interest rate on corporate lending, *CorpRate*. *CorpL* is total non-financial corporate credit extended by Irish banks. 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		CP_t
Constant	-5.498	Constant	1.458
	(2.7)		(2.0)
$User^h_t$	-0.009	$User^c_t$	-0.006
	(-6.7)		(-2.1)
$Income_t$	1.219	$RGDP_t$	0.821
	(7.7)		(3.4)
$NewM._t/Income_t$	0.271	$\Delta(CorpL_t/GDP_t)$	0.771
	(5.7)		(5.3)
$HStock_t/Pop2539_t$	-0.963	$CREStock_t/Emp_t$	-0.805
	(-1.9)		(-2.8)
$URate_t$	-0.128	$Insolr_t$	-0.188
	(-3.7)		(-2.3)
	ΔHP_t		ΔCPP_t
ECT_{t-1}	-0.121	ECT_{t-1}	-0.166
	(-2.1)		(-4.7)
$\Delta Income_t$	0.276	$\Delta RGDP_{t-3}$	0.286
	(2.8)		(1.9)
$\Delta URate$	-0.065	$\Delta Insolv_{t-2}$	-0.095
	(-2.1)		(-1.9)
$\Delta(NewM._{t-1}/Income_{t-1})$	0.073	ΔCP_{t-3}	-0.189
	(1.9)		(2.0)
ΔHP_{t-1}	0.625	ΔHP_{t-3}	0.799
	(4.6)		(2.5)
Adj. R^2	0.721	Adj. R^2	0.663
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 6 shows the estimation results of the equations for real house prices, *HP*, and real CRE prices, *CP*. *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. *CREStock* is the stock of commercial property. *Emp* is total employment. All variables, except for the user cost, are in logs. *t*-statistics are in parentheses.

Table 7. Supply of Residential and Commercial Real Estate

Residential Investment		CRE Investment	
	$ResInv_t$		$CREInv_t$
Constant	8.961	Constant	0.509
	(3.68)		(0.8)
HP_t	0.816	CP_t	0.491
	(4.7)		(2.1)
$BCosts_t$	-0.673	$BCosts_t$	-0.513
	(-1.9)		(-1.8)
$RCorpRate_t$	-0.032	$RCorpRate_t$	-0.044
	(-2.0)		(-1.9)
$\Delta(CREL_t/GDP_t)$	1.331	$\Delta(CREL_t/GDP_t)$	1.084
	(5.2)		(2.4)
$URate_t$	-0.574	$RGDP_t/Emp_t$	2.426
	(-16.9)		(7.1)
	$\Delta ResInv$		$\Delta CREInv$
ECT_t	-0.118	ECT_t	-0.156
	(-2.8)		(-2.4)
ΔHP_{t-1}	0.818	$\Delta URate_{t-1}$	-0.299
	(2.8)		(-2.2)
$\Delta RCorpRate_{t-1}$	-0.014	$\Delta RCorpRate_{t-2}$	-0.012
	(-3.6)		(-2.0)
$\Delta ResInv_{t-3}$	0.179	$\Delta CREInv_{t-2}$	0.192
	(2.3)		(1.8)
Adj. R^2	0.751	Adj. R^2	0.694
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 7 shows the estimates of the residential investment, $ResInv$, and CRE investment, $CREInv$, equations. 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	2.547	Constant	-0.231
	(4.5)		(-0.5)
HHEquity_t	-1.184	CEquity_t	-0.096
	(-2.5)		(-1.8)
RMorRate_t	0.054	RCorpRate_t	0.029
	(1.9)		(2.3)
URate_t	0.815	URate_t	0.379
	(2.6)		(4.7)
$\text{MorStock}_t/\text{Income}_t$	0.638	$\text{CorpL}_t/\text{GDP}_t$	0.401
	(2.1)		(5.9)
	$\Delta\text{Arrears}_t$		ΔInsolv_t
ECT_{t-1}	-0.071	ECT_{t-1}	-0.223
	(-2.5)		(-3.1)
ΔURate_{t-3}	0.467	ΔURate_t	0.605
	(2.9)		(2.9)
$\Delta\text{MorRate}_{t-3}$	0.047	ΔRGDP_{t-1}	-0.349
	(3.5)		(-2.9)
$\Delta\text{HHEquity}_{t-3}$	-0.622	ΔRGDP_{t-3}	-0.231
	(-2.9)		(-1.8)
		$\Delta\text{Insolv}_{t-4}$	0.152
			(1.9)
Adj. R^2	0.617	Adj. R^2	0.427
Sample	1997Q1-2018Q2	Sample	1997Q1-2018Q2

Notes: Table 8 shows the estimation results for the households mortgage arrears, *Arrears*, and corporate insolvency, *Insolv*, equations. All variables are in logs except for interest rates. *CEquity* is corporate equity. All other variables are as previously defined. *t*-statistics are in parentheses.

Table 9. Determinants of Banks' Capital Ratio

	CAP_t
Constant	-1.187
	(-3.5)
$Assets_t/GDP_t$	-2.084
	(-8.3)
$URate_t$	0.712
	(10.6)
$BProfits_t$	14.291
	(2.8)
$CREL_t/Loans_t$	1.070
	(11.2)
$Deposits_t/Liabilities_t$	-0.615
	(-2.0)
	ΔCAP_t
ECT_{t-1}	-0.117
	(-2.3)
$\Delta BProfits_{t-1}$	18.593
	(-3.7)
$\Delta URate_{t-2}$	0.089
	(1.8)
Adj. R^2	0.881
Sample	1997Q1-2018Q2

Notes: Table 9 shows the determinants of banks' capital ratio, *CAP*. *Assets* and *Liabilities* are the total assets and liabilities of the banking sector, respectively. *BProfits* are bank profits. *Loans* is total bank lending to the non-financial private sector. All variables are in logs except for the profit variable.

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