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POLICY PAPER

Macroprudential Policy and the Irish Crisis

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Abstract: The interaction between the banking and property sectors has been the source of considerable volatility in the case of Ireland. The Central Bank of Ireland has recently introduced macroprudential instruments that aim to enhance banks' balance sheet resilience and mitigate the build-up of system risk. We use a new model of the Irish banking and property sectors to examine how both borrower- and lender-based instruments of macroprudential policy may have been effective in countering the extreme macrofinancial dynamics of the boom-bust period. Our simulation results suggest that, while instruments that work through the intermediary may help insulate banks against liquidity risk and portfolio losses, those that target credit demand are significantly more effective in dampening the Irish financial cycle.

I INTRODUCTION

Ireland represents the prototypical example of how distortions in the banking and property sectors can lead to substantial macrofinancial volatility in both the expansionary and contractionary phases of the credit cycle. While the impact of these distortions may have been amplified by Ireland's exposure to international financial conditions, the underlying systemic vulnerabilities that manifested with the onset of the financial crisis in 2008 were mainly generated domestically (Honohan, 2010).

The crisis highlighted, in particular, the need to design a regulatory framework that ensures the stability of the financial system as a whole by absorbing rather than

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propagating real and financial shocks. In response, the Basel III accord recommends a set of prudential tools that aim to manage and curtail systemic risk.[1] In this context the Central Bank of Ireland, as the domestic macroprudential authority, has introduced a set of borrower- and lender-based instruments that target these objectives. Given the relative novelty of these instruments in the Irish case, however, little is known about their potential impact, their transmission channels, and whether they are sufficient to safeguard financial stability.

In this paper, we use the model of the Irish banking and property sectors outlined in McInerney (2019) to explore how several instruments of macro-prudential policy may have performed in dampening the extreme dynamics in these sectors. We present alternative paths for property prices, credit, interest rates and indicators of financial distress since the early 2000s through counterfactual simulations. In this respect, our motivation in this paper is loosely related to that of Aikman *et al.* (2018), who examine similar scenarios for the United States. In contrast to our approach, which uses a specifically developed model of macroprudential policy to simulate the scenarios, they try to quantify the impact of different instruments using estimates from the literature. They argue that the impact of the crisis on the real economy was mainly due to financial sector fragility and the indebtedness of households.

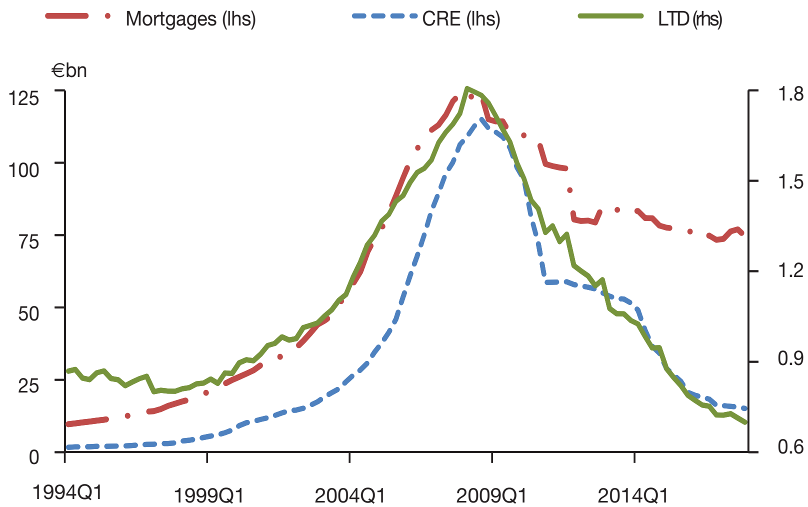
Our analysis can similarly be conceptualised in terms of asking how effective the current macroprudential toolkit would be in dealing with a re-run of the factors that led to the Irish financial crisis. To address how macroprudential policy could have been used to mitigate the severity of the Irish crisis, we focus on several of the systemic drivers that were identified by the Honohan (2010) and Regling and Watson (2010) reports. These include the rapid build-up of household indebtedness via a relaxation of income and collateral constraints, banks' vulnerability to liquidity shocks through overreliance on (short-term) cross-border wholesale funding, and insufficient levels of capital relative to the risks that were accruing on banks' lending portfolios.

Figure 1 illustrates the striking increase in mortgage and commercial real estate (CRE) lending from the early 2000s. From 2002 Q1 to 2008 Q4, the total stock of mortgages held on the balance sheets of Irish banks rose by approximately €90 billion, while the stock of CRE loans rose by almost €100 billion. Figure 1 also shows that this new lending coincided with a changing composition of banks' liabilities. The loan-to-deposit (LTD) ratio increased markedly after 2002 as banks, at the margin, substituted away from relatively "sticky" sources of funding such as retail deposits towards short-term wholesale funding. Membership of the euro with the concomitant absence of exchange rate risk, growth in money markets and deeper financial integration allowed domestic banks to expand their balance sheets with relatively cheap sources of non-deposit funding (Regling and Watson, 2010; Coates and Everett, 2013).

[1] See Grace *et al.* (2015) for an overview of these tools.

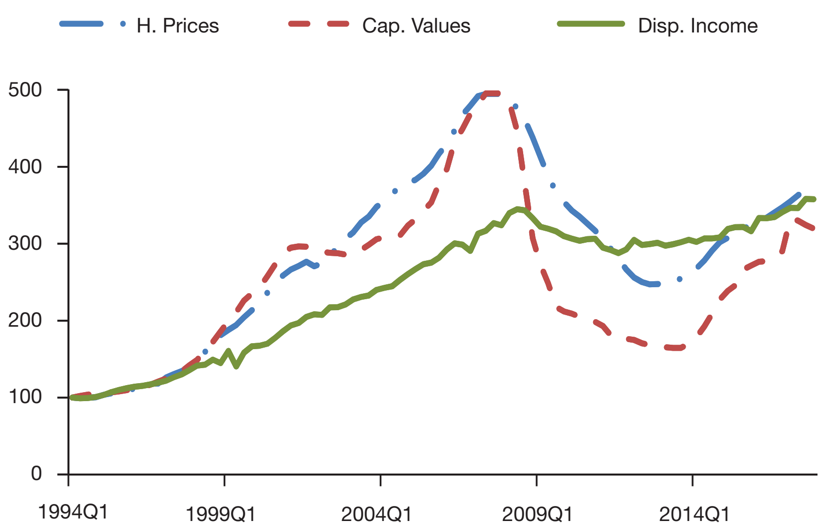
Figures 1 and 2 together show how the rapid increase in bank lending fuelled a boom in property prices. Both residential and commercial property prices grew by over 50 per cent in the 2002-2007 period. Considering the more modest growth in personal disposable income over the same period, it suggests that a relaxation of

Figure 1: Mortgages, CRE Loans and the Loan-to-Deposit Ratio



Source: Central Bank of Ireland.

Figure 2: House Prices, Capital Values and Disposable Income



Source: CSO and Central Bank of Ireland.

credit conditions played an important role in driving the growth rates of credit and property prices prior to the crisis. This is supported by the findings of McCarthy and McQuinn (2017) and Kelly *et al.* (2018) who use microdata to document the significant increase in loan-to-income (LTI) and loan-to-value (LTV) ratios over this period. For example, McCarthy and McQuinn (2017) show that the median LTV ratio on mortgages extended to Irish households increased from 59 per cent in 2001 to 80 per cent prior to the financial crisis. These elevated levels of leverage and income-gearing rendered households and banks increasingly vulnerable to both real and financial shocks.

The property boom was followed by an almost symmetric bust.[2] The latter was characterised by a sharp fall in property prices, a spike in mortgage arrears and corporate insolvencies, and a protracted period of deleveraging by the private sector. The "credit crunch" likely generated accelerator effects whereby the fall in property prices and collateral values affected the ability of firms to rollover existing credit which in turn exacerbated the initial decline in property prices. The distortions that characterised these macrofinancial linkages produced adverse feedback that amplified the decline in house prices by initiating a contraction in credit availability. The ensuing episode of substantial deleveraging by households led to a further reduction in domestic demand.

The scenarios in this paper are designed and calibrated to highlight the extent to which these distortions contributed to the extreme macrofinancial volatility of both the pre- and post-crisis periods and, importantly, how macroprudential policy could have been used to counter these risks. A structural model is apposite for this analysis as it allows us to disentangle demand and supply factors and therefore to trace the transmission mechanism of different shocks. We use the model of the Irish property and banking sectors in McInerney (2019) to test whether these negative feedback loops could have been avoided if particular macroprudential instruments had been part of the policymaker's toolkit.[3] We also aim to identify how changes in credit conditions and in the liability side of banks' balance sheets contributed to the boom-bust dynamics that Ireland experienced.

Our simulations suggest that macroprudential instruments that target credit demand directly are effective in dampening the financial cycle, at least in the Irish case. Those that are designed to work through the intermediary by enhancing resilience to liquidity shocks and loan losses have a relatively small real impact. Therefore, our results indicate that both borrower- and lender-based instruments are essential to provide the macroprudential authority with the necessary toolkit to manage the build-up of systemic risk.

Our results contribute to the burgeoning literature on the impact of macrofinancial shocks and macroprudential policy on credit and property markets.

[2] See Duffy *et al.* (2016) for a discussion of this episode.

[3] As the model we use focuses on interactions and spillover effects between the banking and property sectors, it necessarily abstracts from feedback effects from the wider economy.

Most international studies have used calibrated DSGE models to analyse these issues, typically focusing on the impact of a single macroprudential instrument on borrower or bank leverage, and on welfare.[4] In contrast to DSGE models, the incorporation of macroprudential and macrofinancial transmission channels in structural econometric models is at a relatively nascent stage. One early example is Davis and Liadze (2012), who embed a banking sector for several countries in the NiGEM model in which capital-based prudential policy affects the supply of credit. Davis *et al.* (2019) subsequently augment this model with a LTV ratio that affects both house prices and the demand for mortgage credit. Their scenario results highlight how fluctuations in the LTV ratio mainly affect the economy through the housing market, while regulatory changes to banks' capital ratios have a more broad-based impact.

From the perspective of single-country models, Berben *et al.* (2018) outline a structural econometric model of the Netherlands in which macroprudential policy mainly operates by changing the gap between banks' actual and target capital ratios. As in the NiGEM model, changes to regulatory instruments such as the countercyclical capital buffer (CCyB) will affect target ratios and thus lead to higher lending rates on all types of credit.

There are relatively few studies that examine these issues in an Irish context using a structural model. In terms of DSGE models, Clancy and Merola (2017) and Lozej *et al.* (2018) use a small open economy New Keynesian model that is calibrated for Ireland to show how countercyclical capital regulation can be used to dampen macrofinancial volatility when it is driven by over-optimistic expectations. Lozej *et al.* (2018) demonstrate how welfare can be improved if these regulations target a house price rather than a credit gap. Lozej and O'Brien (2018) further highlight the importance of early activation of the CCyB in order to build bank resilience and minimise the economic cost of these regulations. Lozej and Rannenberg (2018) also use this model to examine the impact of restrictions on mortgage LTI and LTV ratios on the Irish economy. They find that, while these restrictions do raise welfare in the long run by lowering borrower default, they can also lead to a fall in economic activity in the short run.

In terms of structural econometric models, Duffy *et al.* (2016) use a five-equation model of the Irish economy to illustrate the mechanism through which restrictions on LTI and LTV ratios can reduce new mortgage lending and house prices. Given the model's relatively small scale, it necessarily omits the spillovers of these restrictions to other credit and property markets, and the spillbacks to banks' balance sheets. Bergin *et al.* (2017) incorporate an earlier, more parsimonious version of the model of the Irish banking and property sectors outlined in McInerney (2019) into a macroeconomic model of the Irish economy, COSMO,

[4] See ESRB (2017) and Araujo *et al.* (2020) for an overview of the international evidence on the impact of macroprudential policy.

although the scenarios considered in the paper do not illustrate the macrofinancial mechanisms in the model or the impact of macroprudential policy on the economy. Finally, Duffy *et al.* (2017) use the Bergin *et al.* (2017) model to examine the impact of an increase in the fundamental demand for housing on both the banking and property sectors. Their scenario results highlight how housing demand that is driven by demographic and household formation trends can have important implications for banks' balance sheets over the medium to long term.

Our results on the quantitative impact of macroprudential policy are complementary to those from existing DSGE and structural econometric models of the Irish economy. However, the central analytical objective of our paper differs from other studies in that we seek to address how the Irish property and banking sectors might have evolved if an aggressive macroprudential policy regime had been in place prior to the onset of the credit boom. This also allows us to illustrate the relative importance of the systemic risk factors, which the policy levers target, to Ireland's boom-bust dynamics. Moreover, the model we use incorporates a more detailed set of linkages between these sectors and a wider range of macroprudential instruments, than the models used in these studies.

The remainder of the paper is organised as follows. Section II presents an overview of the structural model. Section III simulates alternative scenarios for the LTI and LTV ratios. Section IV examines the potential impact of restrictions on the LTD ratio. Section V shows how a CCyB might have operated. Section VI concludes.

II MODEL OF THE BANKING AND PROPERTY SECTORS

We now provide a brief outline of the structural model of the Irish banking and property sectors that we use to generate our scenarios.[5] The model's equations are presented in Appendix A1, while the variables are defined in Appendix A2. The model highlights the key mechanisms through which real and financial shocks are transmitted within both sectors. It has several novel features. First, it quantifies the direct and indirect dynamic impact of borrower- and lender-based macroprudential instruments on both sectors. Second, it provides a direct link between bank lending and the two main asset classes that are used as collateral, which are housing and commercial property. Finally, it models bank capital holdings explicitly, thereby allowing banks to adjust to shocks in the real economy.

The model includes four types of credit: mortgages, consumer loans, commercial real estate loans, and other non-property commercial loans. The demand for credit depends on the cost of each type of credit, income levels, and the value of collateral. The separation of the CRE and non-CRE components of

[5] See McInerney (2019) for details on the specification and estimation of the model.

corporate credit is important due to their differential cyclical behaviour and sensitivity to fluctuations in collateral values. For example, all else equal, a one per cent increase in the value of commercial property increases the stock of CRE loans by 0.83 per cent in the long run, but only increases the stock of other types of corporate loans by 0.35 per cent.

The demand for new mortgages is also determined by credit conditions. The latter are captured by fluctuations in LTI and LTV ratios, which are adjusted to remove the influence of demand-side factors. Macroprudential policy can thus affect credit demand through the imposition of restrictions on these ratios. The estimated coefficients suggest that a one per cent increase in the adjusted LTV ratio raises the volume of new mortgages by over 2.5 per cent in the long run. The coefficient on the adjusted LTI ratio suggests that a one percentage point increase in that variable raises the volume of new mortgages by over 1.5 per cent. The quantitative impact of the LTI and LTV on mortgage credit is consistent with international estimates in Carreras *et al.* (2018) and Davis *et al.* (2019).

There are three lending rates in the model, one for each category of household credit, and an aggregate rate for all corporate loans. The lending rates are a variable markup or spread over funding costs. The latter comprise a combination of the deposit rate and the three-month Euribor rate. Lending spreads are a function of macroeconomic and sector-specific risks, internal capital management or regulatory requirements, and the composition of banks' liabilities. Macroeconomic risk is mainly reflected by the unemployment rate, household risk by household equity and income-gearing, and corporate risk by the corporate insolvency rate.

The lender-based macroprudential instruments affect the economy through their impact on banks' lending spreads. Accordingly, banks' capital ratio, calculated as the ratio of capital to risk-weighted assets, is included to allow banks to pass through higher capital requirements to lending rates. As the coefficients on this variable are different in each of the lending rate equations, they illustrate the relative strength of each margin along which banks adjust to higher capital requirements. In this context, a one percentage point increase in capital requirements due for example to the activation of the CCyB, will in the long run raise the consumer, mortgage, and corporate rates by eleven, nine and seven basis points, respectively. These estimates are consistent with the international literature on the relationship between lending rates and higher capital requirements. See BCBS (2010) for a discussion of this literature.

Similarly, the LTD ratio is included in each lending rate equation to reflect the impact of changes to liquidity requirements. As deposit rates have historically been higher than the cost of wholesale funding, any restriction on the LTD ratio will raise the average cost of funding for banks, which is assumed to be passed through to higher lending rates. As in the case of banks' capital ratios, the estimated coefficients suggest that the pass-through of changes in liquidity regulations is quite heterogeneous and is much larger for the consumer rate relative to the other lending rates.

House prices are modelled as a standard inverted demand function for housing in which real house prices depend on household income, the housing stock relative to the number of 25- to 39-year-olds in the population, and the user cost of housing. The coefficient on income indicates an almost unitary elasticity of housing demand, which is consistent with the empirical literature.[6] The user cost of capital is calculated as the difference between the mortgage rate and expected house price appreciation. The formation of house price expectations is assumed to be extrapolative and are based on a moving average of annual house price changes over the previous eight quarters.

The house price equation is further augmented by a measure of credit conditions given by the ratio of the mortgage stock to personal income. Therefore, the model incorporates two credit channels: the traditional user cost channel and an additional channel via credit conditions. The coefficient on the mortgage stock-to-income ratio implies that a one percentage point increase in this variable would raise (real) house prices by over 1.3 per cent in the long run, all else equal.

Commercial property capital values are modelled analogously and are related to real GDP, the user cost of capital, the stock of commercial property relative to the number of employees, and the ratio of corporate credit to GDP.[7] The latter is used to capture credit conditions facing firms in the CRE sector. The coefficient on this variable suggests that a one percentage point increase in the corporate credit-to-GDP ratio raises capital values by two per cent in the long run.

On the supply side, the completion of new housing units depends on the profitability of construction, demographic trends, uncertainty, and the cost and availability of credit to construction firms.[8] The profitability of building houses is approximated by the ratio of house prices to building costs, with a one per cent increase in this ratio leading to a 1.5 per cent increase in completions in the long run. The housing stock is generated by accumulating the newly completed units on the depreciated housing stock from the previous period via the perpetual inventory method. The model assumes an annual rate of depreciation of close to 0.8 per cent, in line with the rate used by the CSO.

The model includes two indicators of financial stress: the rate of mortgage arrears and the rate of corporate insolvency. The equation for mortgage arrears follows the "double-trigger" theory in which mortgage delinquency depends on both equity and repayment capacity factors (Bajari *et al.*, 2008; Gerardi *et al.*, 2010). The latter are captured in the equation by the unemployment rate, the mortgage rate, and households' debt-to-income ratio. The estimated coefficients suggest that

[6] See Duca *et al.* (2011) and Duffy *et al.* (2016) for an overview of this literature.

[7] The user cost of capital in the CRE sector is given by the difference between the corporate rate and expectations of future capital appreciation. Expectations formation in CRE sector is assumed to be similar to that in the residential sector and is therefore based on a moving average of annual changes in capital values over the previous eight quarters.

[8] The supply of commercial real estate is exogenous in the model.

a one per cent increase in home equity reduces the rate of mortgage arrears by 12 basis points in the long run, while a similar increase in the debt-to-income ratio raises the arrears rate by approximately 18 basis points.

The equation for the corporate insolvency rate also models firm survival as a function of real and financial factors (Vlieghe, 2001). Real factors reflect fluctuations in corporate profitability due to the macroeconomic environment and are captured by the unemployment rate. On the financial side, changes to firms' repayments burden are captured by the ratio of corporate credit to GDP, which proxies firm indebtedness, and by the interest rate on corporate credit. For example, a one percentage point increase in firm indebtedness in the model would raise the long-run insolvency rate by three basis points, ceteris paribus. The equation also includes the ratio of nominal stock of CRE to corporate credit to incorporate the impact of changes in firms' net worth on their ability to obtain credit or working capital, through the mechanism outlined in Kiyotaki and Moore (1997). The coefficient on this variable indicates that this channel may be quite weak in the Irish context with a one per cent fall in this approximate measure of firms' net worth raising the corporate insolvency rate by less than one basis point.

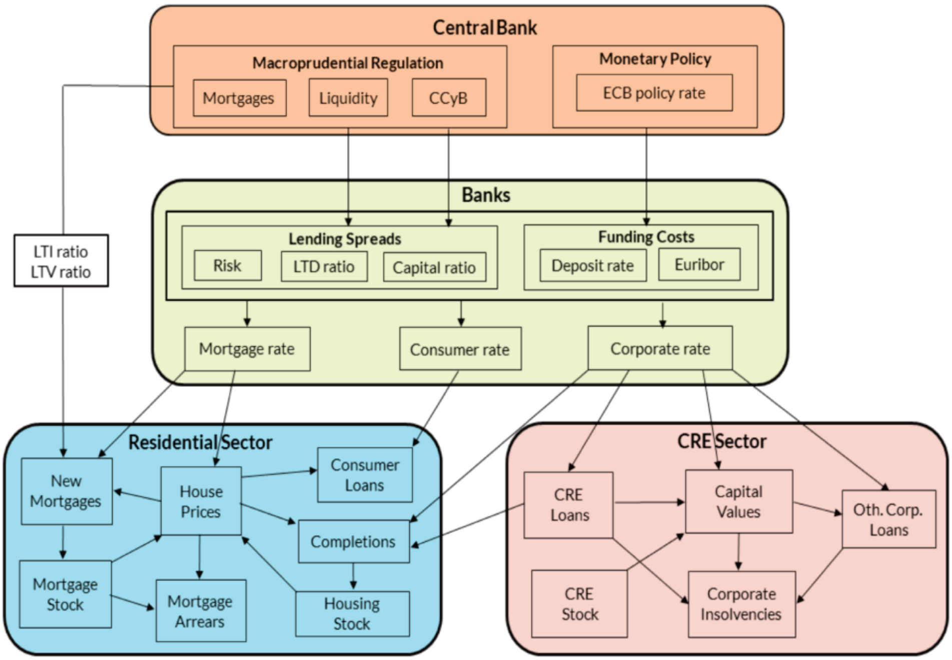
Finally, the model allows banks' capital ratios to adjust endogenously to shocks in both the real and financial sectors of the economy. The equation shows that banks' capital ratios fall as the banking sector expands, as capital adjustment costs tend to be lower in larger banking systems (Gropp and Heider, 2010). Capital ratios rise procyclically with the unemployment rate, with a one percentage point increase in the unemployment rate raising capital ratios by approximately 50 basis points. Capital ratios increase with bank profitability, illustrating the importance of retained earnings as a source of capitalisation. Finally, capital ratios are also driven by potential portfolio and liquidity risks. In terms of the former, banks hold more capital as their exposure to the commercial real estate sector rises due to the high volatility of that sector (Martin-Oliver *et al.*, 2013). In terms of liquidity risks, banks hold higher levels of capital the lower the share of deposits in liabilities due to a market disciplining effect (Francis and Osbourne, 2010). The coefficient suggests that a one percentage point fall in the liability share of deposits raises banks' capital ratios by around 16 basis points.

Figure 3 provides a schematic representation of how different sectors interact in the model. In particular, it illustrates how both monetary and macroprudential policy shocks are transmitted to the real economy.[9] Given the aim of this paper, we focus on the transmission of macroprudential policy.[10]

[9] Note that for expository reasons, the diagram omits the spillovers and spillbacks in the model from these shocks. It also excludes variables such as the unemployment rate and demographics which are exogenous to the model.

[10] As mentioned above, monetary policy shocks determine banks' funding costs in the model and it is assumed that the ECB refinancing rate is exogenous to Irish economic conditions.

Figure 3: Policy Shocks, Banking and the Property Sector



Source: Author's representation of model in Appendix A1.

As the domestic macroprudential authority in the model, the Central Bank has four instruments it can use to manage different aspects of systemic risk. On the borrower side, it can influence mortgage credit conditions by restricting household leverage and income gearing through the LTI and LTV ratios. On the lender side, it can raise liquidity requirements by imposing ceilings on LTD ratios or, through the CCyB, it can require banks to hold higher levels of capital relative to the phase of the economic cycle.

Borrower-based macroprudential measures directly limit the volume of new mortgage lending, while lender-based instruments affect banks' lending spreads. The latter are also affected by macroeconomic and sector-specific risk factors, with banks raising spreads if, for example, the unemployment rate or the corporate insolvency rate is increasing. Lending spreads together with deposit and wholesale funding costs determine the interest rate that banks charge on each type of loan.

Accordingly, macroprudential policy affects households directly through restrictions on mortgage LTI and LTV ratios, and indirectly though the impact liquidity and capital requirements have on the cost of both mortgage and consumer credit. House prices respond to the mortgage market through the user cost and credit conditions channels, and the resulting change in house prices leads to an adjustment in the volume of new mortgages demanded. The level of mortgage arrears is affected by these house price and credit dynamics due to their impact on households' equity position and repayment burden.

House prices are a key determinant of the profitability of residential construction in the model. Therefore housing completions, and ultimately the housing stock, will also respond to changes in the former. The profitability of house building is also affected by the impact of macroprudential policy on the corporate lending rate, as this is assumed to approximate the cost of credit for construction firms.

For firms in the CRE sector, macroprudential policy affects the cost of CRE loans and other types of corporate borrowing, such as that for working capital needs. Analogous to the mechanism in the housing market, changes in the cost and volume of CRE loans affect commercial property capital values through the user cost and credit conditions variables. Fluctuations in capital values further affect the demand for each type of corporate credit through the collateral channel. Finally, the cumulative change in collateral values, the cost of credit, and firm indebtedness determine the impact of the macroprudential measures on the corporate insolvency rate.

We now use the model to simulate a number of counterfactual scenarios which are chosen to highlight how macroprudential policy could have been used to mitigate the build-up of macrofinancial risks prior to the financial crisis.

III BORROWER-BASED INSTRUMENTS

One of the central objectives in analysing the recent Irish boom and bust experience is identifying the key drivers of the rapid expansion in credit and subsequent protracted episode of deleveraging. Isolating and quantifying these originating factors is clearly crucial from a macroprudential and financial regulation perspective. There is considerable evidence to suggest that changes in credit conditions were particularly important. For example, McCarthy and McQuinn (2017) use loan level data from Irish banks to show that the change in non-interest related credit conditions in terms of the LTI and LTV ratios explains much of the growth in credit. In this context, the Central Bank of Ireland recently introduced a set of measures that impose restrictions on LTI and LTV ratios (Cassidy and Hallissey, 2016).

One of the primary benefits of our structural model is that it can be used to elucidate and quantify how macroprudential policy, by imposing restrictions on LTI and LTV ratios, is transmitted not only to mortgage lending but also to house prices, housing supply, CRE lending, interest rates and mortgage arrears. Importantly, it illustrates the dynamic nature of the impact of macroprudential policy and highlights the feedback between the banking and property sectors.

To examine how borrower-based macroprudential instruments might have altered the paths of variables in these sectors over the Irish boom and bust period, we simulate a counterfactual scenario in which the LTI and LTV ratios are held constant at their 2002 Q1 values over the 2002 to 2015 period.[11]

Figure 4 shows the percentage (%d) or percentage point (ppd) deviation of each variable from a baseline of no change in credit conditions, under three scenarios: (1) holding the LTI ratio at its 2002 Q1 level, (2) holding the LTV ratio at its 2002 Q1 level, and (3) holding both ratios at their 2002 Q1 levels.[12] It is striking how changes in the LTI ratio have had the greatest impact on mortgage lending over the simulation period. New mortgage lending would have been almost 50 per cent lower and the mortgage stock 30 per cent lower by 2008 if the LTI ratio had remained at its 2002 level. If we hold both the LTI and the LTV ratios constant at their 2002 levels, new mortgage lending and the mortgage stock would have been 60 per cent and 40 per cent lower, respectively. While mortgage lending increased rapidly in the pre-crisis period, there was a sharp contraction in the subsequent period due mainly to falling LTI ratios. For example, the 'excess' mortgage stock, or the difference between the actual stock and that which would have prevailed had credit conditions remained constant, falls from 40 per cent at the onset of the crisis to 20 per cent by the end of the simulation period.

Changes in credit conditions consequently had a significant impact on the housing market. The increase in the LTI ratio raised house prices by almost 15 per cent at the onset of the financial crisis relative to what their level would have been if this ratio had remained constant at its 2002 level. The increase in the LTV ratio raised house prices by an additional 5 per cent.[13] On the supply side, higher house prices raised quarterly housing completions by almost 25 per cent at the onset of the financial crisis relative to a scenario in which the LTI ratio remained at its 2002 level. The increase in the LTV ratio raised completions by an additional 8 per cent. In terms of stocks, the combined impact of both ratios was to increase the total volume of housing units by approximately 5 per cent. This competition for resources within the construction sector resulted in commercial capital values that were over 10 per cent higher than would have prevailed in 2008 if credit conditions had remained unchanged. The counterfactual post-crisis higher levels of mortgage lending primarily explain why house prices and housing completions would have been almost 15 and 20 per cent higher, respectively, by 2015 if the LTI and LTV ratios had remained at their 2002 levels.

[11] Gerlach-Kristen and McInerney (2014) find that the unconditional statistical relationship between mortgage credit and house prices becomes statistically explosive after 2002.

[12] Note that all other exogenous variables in the model are set to their historical values in each counterfactual simulation.

[13] The median fall in the LTV ratio over this period is five percentage points. Accordingly, our results are consistent with those from the single-equation model in Lyons (2018), who finds that a ten percentage point fall in the LTV ratio raises Irish house prices by close to 9 per cent.

The lower level of housing supply relative to the baseline in the pre-crisis period would have generated lower derived demand for CRE loans to finance construction. Figure 4 shows that the volume of these loans would have been more than 20 per cent lower if the credit conditions-driven increase in house prices and commercial capital values had not occurred. In the post-crisis period, the higher level of housing supply would also have required a higher volume of construction and real estate lending to the extent that the 'excess' housing stock generated by the relatively high LTI and LTV ratios in the pre-crisis period would have been essentially eliminated.

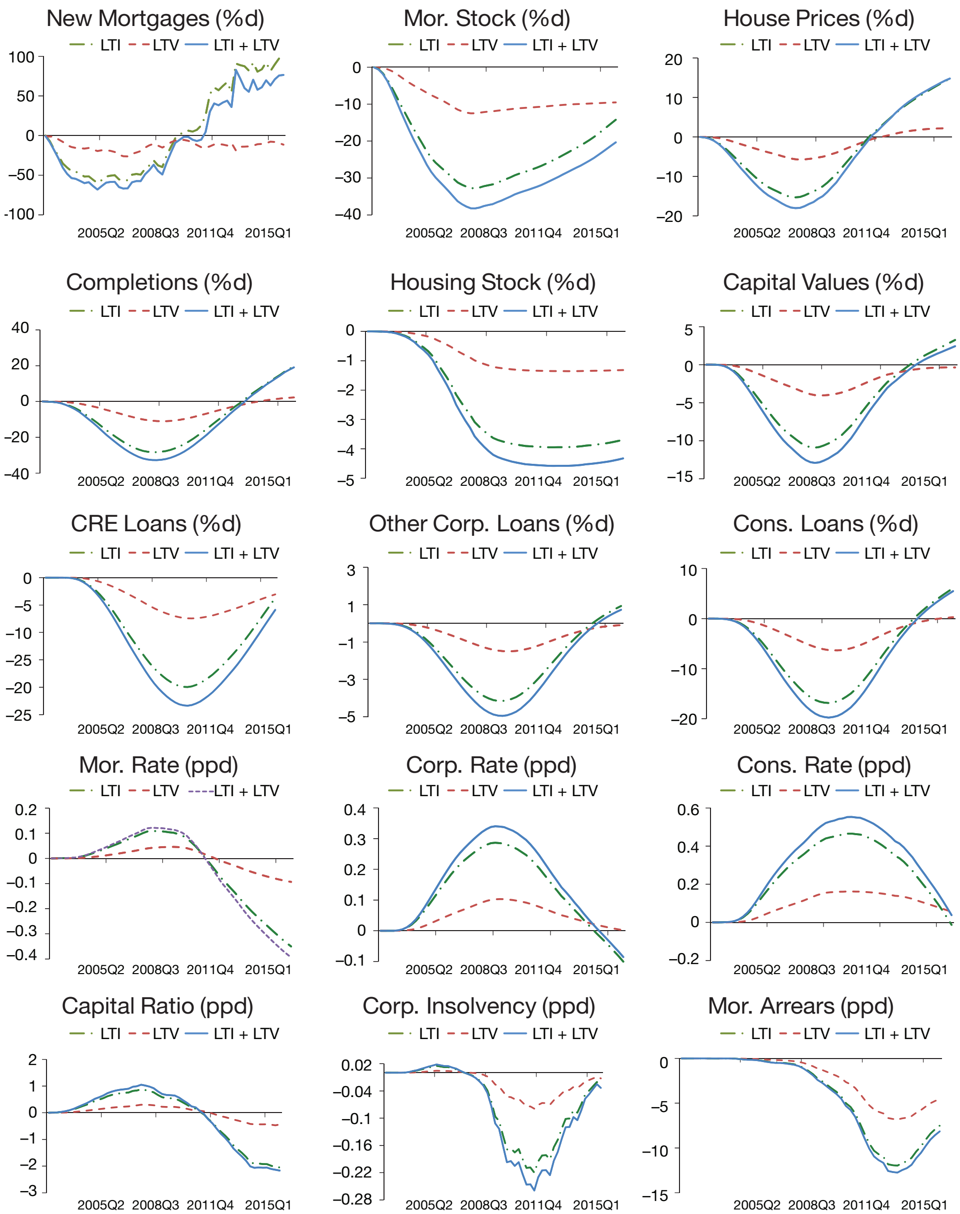
Figure 4 also illustrates how sensitive consumer loans are to changes in net housing wealth via changes in house prices and mortgage credit. These unsecured household loans would also have been approximately 20 per cent lower under constant credit conditions by 2008 but would have been five per cent higher by 2015.

In terms of interest rates, the effects tend to be relatively weaker. The counterfactual levels of mortgage rates relative to the baseline are mainly driven by the dynamics of household equity, with for example, lower counterfactual levels of equity in the pre-crisis period generating higher rates. Corporate and consumer lending rates in these scenarios mainly respond to the LTD ratio, with a lower ratio relative to the baseline in the period up to 2008 implying a higher average cost of funding, and a subsequently higher ratio implying declining average costs.

Finally, Figure 4 shows the impact of the assumption of constant credit conditions on the indicators of financial stability in the model. The capital ratio is one percentage point higher relative to the baseline prior to the onset of the financial crisis but 2.5 percentage points lower relative to the baseline by the end of the simulation period. This is mainly due to the dynamics of house prices which are used to capture fluctuations in collateral values in the model's equation for the capital ratio of the banking sector. As several Irish banks were recapitalised mainly by the Irish State following the crisis, our results are suggestive of the potential savings if the LTI and LTV ratios had remained constant.

Lower levels of capital holdings relative to baseline in the post-crisis period reflect lower levels of financial distress in the real economy. For example, the corporate insolvency rate falls by 28 basis points (bps) by 2011 due to the lower counterfactual levels of corporate debt. From a financial stability perspective, perhaps the most interesting finding from these simulations, however, relates to household mortgage arrears. The scenario suggests that the latter would have been almost 13 percentage points lower at their post-crisis peak if both the LTI and LTV ratios had remained constant. This is due to the lower levels of income gearing and leverage that are generated by the relatively lower stock of mortgages and higher levels of house prices. These results highlight the potential effectiveness of these ratios in their role as instruments of macroprudential policy. In the Irish context at least, our simulations indicate that restrictions on these ratios could have yielded greater stability in housing and credit markets.

Figure 4: Counterfactual Scenarios Holding LTI and LTV Ratios Constant



Source: Author's analysis based on model in Appendix A1.
Notes: The counterfactual path of each variable is shown in per cent (%d) or percentage point (ppd) deviation from the historical baseline for three scenarios: (1) LTI ratio is fixed at 2002 Q1 value, (2) LTV ratio is fixed at 2002 Q1 value, and (3) both LTI and LTV ratios are fixed at 2002 Q1 values.

IV LIQUIDITY RESTRICTIONS

Another important dimension of the Basel III framework for macroprudential policy is the focus on reducing liquidity risk in the financial system. Figure 1 shows how the explosion in bank lending coincided with a fall in the proportion of lending that was financed by retail deposits.[14] In particular, the LTD ratio sharply increased from 2002 until the onset of the crisis. As mentioned, the reliance of Irish banks on short-term wholesale funding meant that they experienced a severe liquidity shortage during the crisis, which ultimately required recourse to finance from the European Central Bank (Honohan, 2010).

Although new liquidity regulations such as the Net Stable Funding Ratio (NSFR) and the Liquidity Coverage Ratio (LCR) are being introduced across countries, the Central Bank of Ireland implemented a similar type of liquidity restriction following the recapitalisation of Irish banks. As part of the Financial Measures Programme (2011) that was introduced in 2011, Irish banks were required to lower their LTD ratios to below 122 per cent. As Figure 1 illustrates, banks' current LTD ratios are significantly below this ceiling.

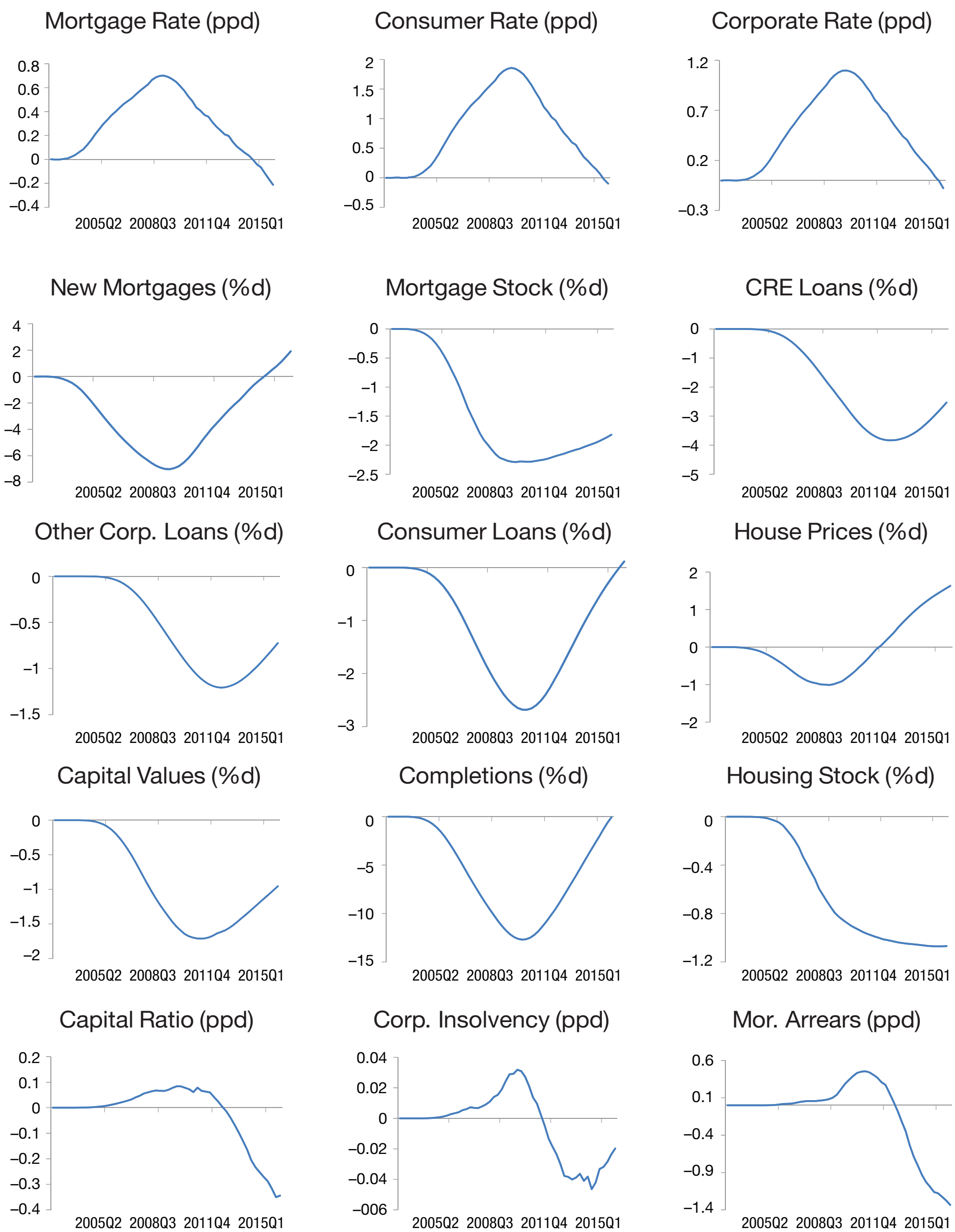
In the framework presented in McInerney (2019), the LTD ratio is included as a liquidity restriction that can be imposed on the banking sector so that it is required to fund additional lending from deposits when this ratio is above a particular value. During the housing boom period, deposit interest rates were higher than those on wholesale funding. Accordingly, the requirement to fund proportionately more of their lending from deposits would have raised banks' cost of funding. In McInerney (2019), this increase in funding costs is then transmitted to higher interest rates on consumer, corporate and mortgage lending.

We now analyse how the evolution of the property and banking sectors might have been different if Irish banks had not been able to access relatively cheap wholesale funding on such a scale as actually occurred. Figure 5 presents the results of a counterfactual scenario in which the LTD ratio is kept constant at its 2002 Q1 level of unity from that period onwards.

As mentioned, the primary channel through which lower LTD ratios affect banks is by increasing their cost of funding at the margin, which is subsequently passed-through to higher lending rates. The impact of the liquidity restriction has quite heterogeneous effects on each lending rate. While the mortgage rate would have been approximately 80bps higher at the onset of the financial crisis, the corporate rate would have been more than one percentage point and the consumer rate two percentage points higher than their historical baseline values. These results thus provide insight into the differential rates of pass-through to interest rates of changes in funding conditions. We also see convergence back to baseline soon after the crisis as wholesale funding markets effectively froze and the LTD ratio fell.

[14] See Duffy *et al.* (2016) for a discussion of the factors that drove the changes in banks' funding environment.

Figure 5: Counterfactual Scenario Holding the LTD Ratio Constant



Source: Author's analysis based on model in Appendix A1.
Notes: The counterfactual path of each variable is shown in per cent (%d) or percentage point (ppd) deviation from the historical baseline for a scenario in which the loan-to-deposit (LTD) ratio is fixed at its 2002 Q1 value.

The increase in lending rates due to the restriction on the LTD ratio is transmitted to the real economy as an increase in the cost of credit. Figure 5 shows that the latter would have reduced the stock of mortgages, commercial real estate loans, and consumer credit by between two and four per cent. The modest decline in credit relative to baseline would have generated an even smaller difference in property prices relative to their historical baseline values. House prices and commercial property capital values would have been between 1 and 1.5 per cent lower by 2008.

By the end of the simulation period, house prices are above their baseline value. This is due to a combination of factors. As population is exogenous in this scenario, the lower counterfactual level of completions and the housing stock up to 2008 imply a lower per capita housing stock. This generates an increase in the demand for housing which drives house prices back towards their baseline values. In addition, as the restriction on the LTD ratio no longer binds in the post-crisis period, the mortgage rate falls back to its baseline value, which leads to the demand for mortgages to also return to its baseline value.

In terms of financial stress, our results suggest that the impact on household mortgage arrears would have been significantly less with liquidity restrictions than with restrictions on borrower-based instruments. By the end of the simulation period, arrears are 1.5 percentage points below their historical baseline, compared to 13 percentage points in the composite LTI and LTV ratio scenario from the previous section. Similarly, in terms of magnitude, the impact of the imposed ceiling on the LTD ratio on the corporate insolvency rate is almost negligible, while the latter is 20bps lower in 2008 in the LTI ratio scenario, alone.

Our results illustrate that the real impact of liquidity regulations is small relative to those that target credit demand explicitly, such as restrictions on LTI and LTV ratios. However, it is important to emphasise that liquidity regulations are intended to mitigate bank's vulnerability to short-term changes in market funding conditions and are therefore targeted towards the composition of banks' balance sheets rather than dampening macrofinancial volatility.

V COUNTERCYCLICAL CAPITAL BUFFER

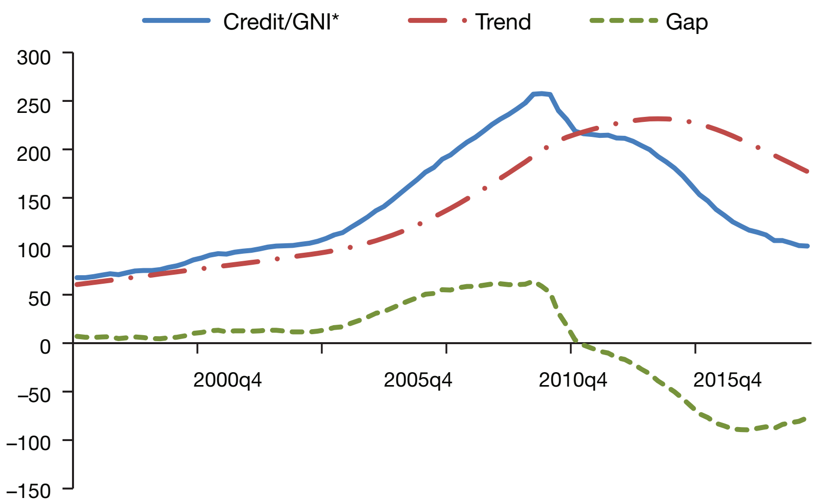
The final macroprudential instrument we consider is the CCyB. Prior to the introduction of the CCyB as part of the Basel III regulatory framework, banks' capital ratios tended to fall as lending expanded and systemic risk started to accumulate. Consequently, when the financial cycle entered its contractionary phase and the rate of non-performing loans increased, banks responded by achieving capital requirements through a combination of deleveraging, higher lending rates and raising equity in a period when it is likely to be the most expensive to do so. The resulting "credit crunch" exacerbated the impact of the downturn on the real economy.

The CCyB aims to dampen this procyclical behaviour by requiring banks to increase capital ratios in the expansionary phase of the cycle so that they have adequate buffers to absorb losses in a downturn. This should obviate the need to severely tighten credit conditions and reduce the supply of credit to firms and households.

Operationally, the CCyB is typically calibrated in proportion to a "credit gap" given by the difference between the ratio of private sector credit to GDP and its long-run trend. Due to the distortions to GDP in the case of Ireland, we follow O'Brien *et al.* (2018) and instead use the ratio of private sector credit to modified Gross National Income, or GNI*.[15] The trend in this ratio is estimated using the Hodrick-Prescott (HP) filter with a smoothing parameter of 400,000. The CCyB is activated once the gap exceeds 2 percentage points and increases linearly from 0 until the credit gap exceeds 10 percentage points, above which the 2.5 percentage point CCyB maximum is applied.

Figure 6 illustrates the historical credit gap for Ireland. The credit-to-GNI* ratio remained close to trend until the late 1990s, after which a substantial gap developed, peaking at approximately 60 percentage points at the onset of the crisis.

Figure 6: Irish Credit Gap



Source: Central Bank of Ireland CCyB dataset.
Notes: Credit/GNI* is the ratio of private non-financial sector credit to modified Gross National Income. The numerator in the ratio is a national specific measure calculated by the Central Bank of Ireland and refers to credit extended by domestic institutions to residents."Trend" is the Hodrick-Prescott filtered trend credit-to-GNI* ratio with a lamda value of 400,000. "Gap" is the difference between the ratio and the trend.

[15] Note also that the credit variable refers only to credit that is extended by domestic institutions to Irish residents. See O'Brien *et al.* (2018) for details.

As discussed above, this was mainly driven by the rapid increase in mortgage and commercial real estate lending. Following the crisis, extensive and protracted deleveraging resulted in the credit gap closing and ultimately becoming negative. This procyclical behaviour of the banking sector is what the CCyB aims to mitigate.

We therefore consider how the CCyB might have affected the evolution of the Irish banking and property sectors. Specifically, we generate a counterfactual scenario in which the ratio of capital to risk-weighted assets increases by 2.5 percentage points from 2000 Q4 to 2010 Q3, the period during which the credit gap exceeded 10 percentage points of GNI*, and then gradually falls back to its baseline value as the credit gap closes and the CCyB returns to zero.[16]

Figure 7 presents the deviation of each variable from its historical baseline path conditional on the activation of the CCyB. The increase in capital requirements is initially transmitted in the model through an increase in lending rates, as the increase in the average cost of banks' liabilities is passed through to borrowers. The increase in lending rates is highest for consumer credit (30bps), followed by mortgages (25bps), and finally by corporate loans (20bps). The impact on lending rates peaks at the onset of the financial crisis and falls back to baseline by 2011 when the CCyB is reset to zero.

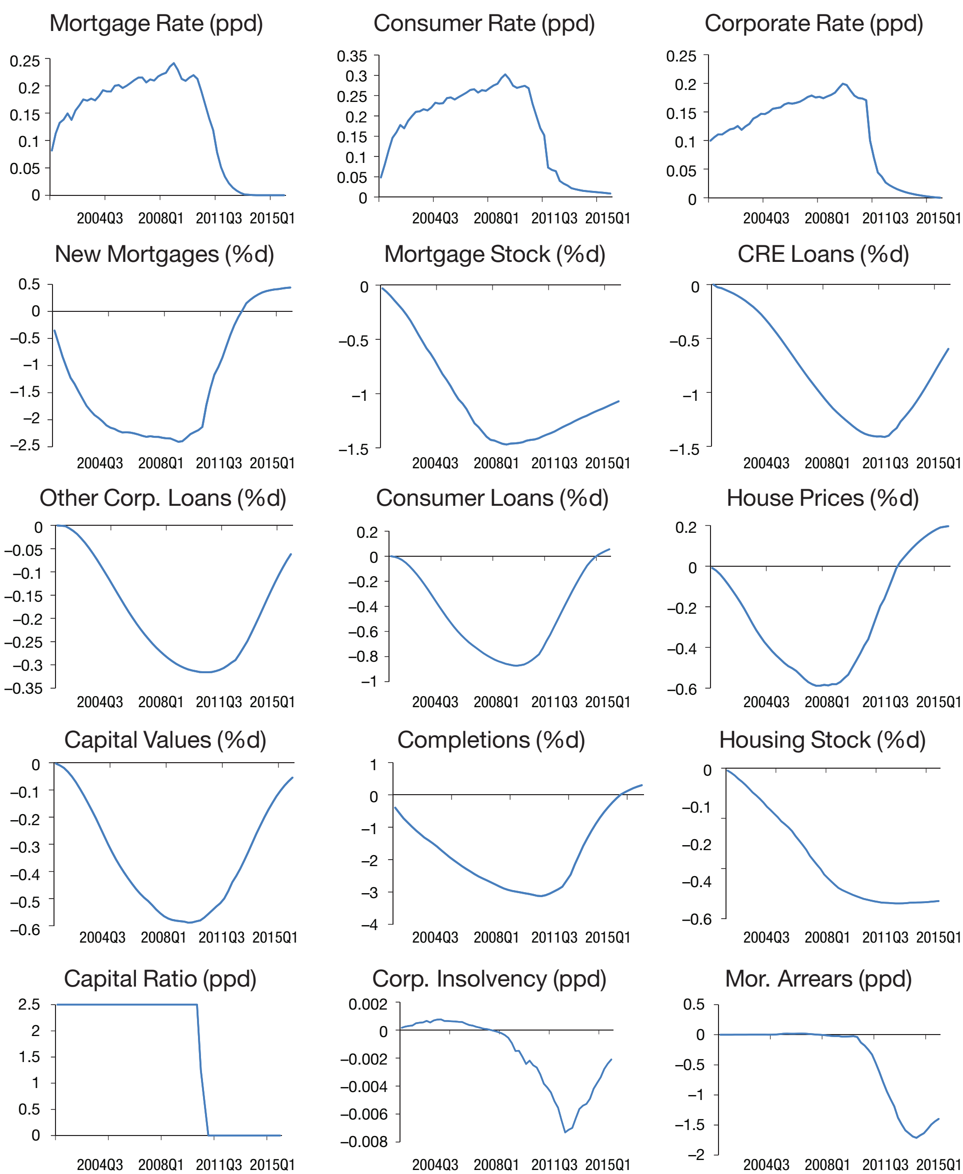
Although the aim of the CCyB is to increase banks' balance sheet resilience, an interesting question is whether the counterfactual increase in interest rates generated by the CCyB would have dampened the financial cycle to the same extent as the other macroprudential scenarios we consider.

Figure 7 shows that the impact of the CCyB on lending and the real economy would have been much weaker than simply keeping the LTI, LTV, and LTD ratios at their 2002 levels. New mortgage lending is on average 2 per cent lower relative to baseline at the credit gap peak, resulting in a mortgage stock that is approximately 1.4 per cent lower.[17] This is mainly due to the relatively low interest elasticity of demand for all types of credit (McInerney, 2019). The impact on the property sector is similarly quite weak, with property prices on average 0.5 per cent lower than their baseline values by 2008. The relatively small decline in house prices means that the difference between the counterfactual and actual levels of housing supply is also relatively small: housing completions and the housing stock are 3 per cent and 0.3 per cent lower, respectively, by 2008. The lower levels of property prices and housing supply lead to a lower demand for commercial real estate credit, which falls by a similar amount to the mortgage stock.

[16] See McInerney (2019) for a similar analysis using the ratio of loans extended by Irish banks to real-time GDP as the relevant credit variable. Note also that the CCyB would actually have been activated in the late 1990s when the credit gap exceeded the 2 percentage point threshold. Our simulation period begins in 2000 Q4 due to constraints on the availability of mortgage arrears data.

[17] This compares to a fall in the mortgage stock relative to baseline of over 2 per cent in the LTD ratio scenario, over 10 per cent in the LTI ratio scenario and nearly 30 per cent in the LTV ratio scenario.

Figure 7: Counterfactual Scenario with Countercyclical Capital Buffer



Source: Author's analysis based on model in Appendix A1.

Notes: Results are presented in per cent (%d) or percentage point (ppd) deviation of each variable from its baseline value for the period 2000 Q4 to 2015 Q4. The countercyclical capital buffer is set to its maximum value of 2.5 percentage points from 2000 Q4 to 2010 Q3, falls back to its baseline value of zero over the subsequent three quarters, and remains at zero thereafter.

The buffers accumulated under the CCyB are released in the simulation at the end of 2010. This results in lending rates falling back to their baseline values over the subsequent year, which leads to credit and property prices also converging to their baseline values. By the end of the simulation in 2015 Q4 new mortgage lending and house prices are higher than their baseline values. This is primarily due to the housing stock being below its equilibrium value for a given level of income and demographics, which generates higher house price appreciation and ultimately higher mortgage demand.

Given the modest impact of the CCyB on the real economy, it is not surprising that the counterfactual rates of mortgage arrears and corporate insolvencies under the CCyB are close to their actual historical levels. The decline in the corporate insolvency rate is negligible while arrears are 1.5 percentage points lower by 2015. The latter is similar to the fall under the LTD scenario but much smaller than that under the LTI and LTV ratio scenarios.

In the context of the literature on the real impact of capital requirements, the cost of higher capital requirements in terms of higher lending rates reducing credit demand is broadly similar to that found in studies for other countries.[18] Our results suggest, however, that while the CCyB is designed to build greater resilience and insulate banks' balance sheets from the build-up of systemic risk, it is a relatively ineffective tool in dampening macrofinancial fluctuations. In terms of the latter, our counterfactual scenarios indicate that restrictions on LTI and LTV ratios would likely have prevented the extreme volatility in both credit and property markets.

One caveat to our analysis is that we do not consider the role of competition from foreign banks on the pass-through of higher capital requirements to lending rates. As competition from foreign banks increased significantly over the period of our simulations, it may be that these banks would have undercut domestic rivals if the latter had sought to increase lending rates in response to the activation of the CCyB.[19] Our framework does not include foreign banks and accordingly does not incorporate this strategic complementarity. However, as our results are consistent with the empirical literature on the relationship between lending rates and capital requirements across countries, it is not clear how strong this channel would have been in this Irish case.

VI CONCLUSION

We examine the extent to which macroprudential policy could have mitigated the build-up of systemic risk in the Irish banking sector and dampened the extreme macrofinancial dynamics of the pre- and post-crisis periods. We design and calibrate

[18] See BCBS (2010), Dagher *et al.* (2016) and ESRB (2017) for an overview of the empirical findings of this literature.

[19] See Honohan (2010) and McCarthy and McQuinn (2017) for a discussion of the role of foreign banks in the Irish economy over this period.

several scenarios that highlight the bi-directional feedback mechanisms and spillovers between the property and banking sectors. These scenarios are used to generate counterfactual paths for real and financial variables that are conditional on particular values for the macroprudential instruments and therefore indicate the relative importance of these factors in determining the severity of the Irish crisis.

Our simulation results suggest that higher capital and liquidity requirements could have reduced the growth in mortgage and commercial real estate lending, but their impact in this respect would have been modest. These macroprudential instruments are more suited to building banks' balance sheet resilience rather than curtailing the (unsustainable) build-up of household indebtedness. To address the latter, borrower-based measures that directly affect credit demand are more effective. In particular, we show that holding these ratios at their 2002 levels would have significantly dampened the volatility in mortgage and house price growth rates and ultimately prevented much of the spike in arrears that occurred in the post-crisis period. These results therefore suggest that both borrower- and lender-based instruments are necessary to avoid costly crises.

It is important to note that our analysis only considers the potential impact of a subset of macroprudential instruments and is not an evaluation of the potential impact of macroprudential policy in general. For example, maximum LTV ratio restrictions on commercial real estate credit or higher risk-weights on lending to that sector could potentially have had a similar stabilising effect in the Irish case. However, as our analysis shows, the instruments and restrictions that are currently available to the Irish macroprudential authority, at a minimum, greatly enhance its ability to manage a re-run of the factors that generated the last crisis.

REFERENCES

Aikman, David, Jonathan Bridges, Anil Kashyap and Caspar Siergert, 2018. "Would Macroprudential Regulation Have Prevented The Last Crisis?", Bank of England Working Papers 747, Bank of England.

Araujo, Juliana Dutra, Manasa Patnam, Adina Popescu, Fabian Valencia and Weijia Yao, 2020. "Effects of Macroprudential Policy: Evidence from Over 6,000 Estimates", IMF Working Papers 20/67, International Monetary Fund.

Bajari, Patrick, Chenghuan Sean Chu and Minjung Park, 2008. "An Empirical Model of Subprime Mortgage Default from 2000 to 2007", NBER Working Papers 14625, National Bureau of Economic Research, Inc.

BCBS, 2010. "An assessment of the Long-Term Economic Impact of Stronger Capital and Liquidity Requirements", Technical report, Basel Committee on Banking Supervision, Bank of International Settlements, Basel, Switzerland.

Berben, Robert-Paul, Ide Kearney and Robert Vermeulen, 2018. "DELFI 2.0, DNB's Macroeconomic Policy Model of the Netherlands", DNB Occasional Studies 1605, Netherlands Central Bank, Research Department.

Bergin, Adele, Niall Conroy, Abian Garcia-Rodriguez, Dawn Holland, Niall McInerney, Edgar Morgenroth and Donal Smith, 2017. "COSMO: A new COre Structural MOdel for Ireland", ESRI Working Paper 553, Economic and Social Research Institute.

Carreras, Oriol, E. Philip Davis and Rebecca Piggott, 2018. "Assessing Macroprudential Tools in OECD Countries Within a Cointegration Framework", *Journal of Financial Stability*, Vol. 37, pp. 112–130.

Cassidy, Mark and Niamh Hallissey, 2016. "The Introduction of Macroprudential Measures for the Irish Mortgage Market", *The Economic and Social Review*, Vol. 47, pp. 271-297.

CBI, 2011. "The Financial Measures Programme Report", Technical report, Central Bank of Ireland.

Clancy, Daragh and Rossana Merola, 2017. "Countercyclical Capital Rules for Small Open Economies", *Journal of Macroeconomics*, Vol. 54, pp. 332-351.

Coates, Dermot and Mary Everett, 2013. "Profiling the Cross-Border Funding of the Irish Banking System", Economic Letters 04/EL/13, Central Bank of Ireland.

Dagher, Jihad, Giovanni Dell'Ariccia, Luc Laeven, Lev Ratnovski and Hui Tong, 2016. "Benefits and Costs of Bank Capital", IMF Staff Discussion Notes 16/4, International Monetary Fund.

Davis, Philip E. and Iana Liadze, 2012. "Modelling and simulating the banking sectors of the US, Germany and the UK", NIESR Discussion Papers No. 396, National Institute of Economic and Social Research.

Davis, E. Philip, Iana Liadze and Rebecca Piggott, 2019. "Assessing the Macroeconomic Impact of Alternative Macroprudential Policies", *Economic Modelling*, Vol. 80, pp. 407-428.

Duca, John V., John Muellbauer and Anthony Murphy, 2011. "House Prices and Credit Constraints: Making Sense of the US Experience", *Economic Journal*, Vol. 121, pp. 533-551.

Duffy, David, Niall McInerney and Kieran McQuinn, 2016. "Macroprudential Policy in a Recovering Property Market: Too Much Too Soon?" *International Journal of Housing Policy*, Vol. 16, pp. 491-523.

Duffy, David, Daniel Foley, Niall McInerney and Kieran McQuinn, 2017. "Demographic Change, Future Housing Supply and the Related Challenges for the Irish Banking Sector" in A. Bergin, E. Morgenroth and K. McQuinn (eds.), *Ireland's Economic Outlook: Perspectives and Policy Challenges*: Dublin: The Economic and Social Research Institute.

ESRB, 2017. "Final Report on the Use of Structural Macroprudential Policy Instruments in the EU", Technical report, European Systemic Risk Board.

Francis, William B. and Matthew Osbourne, 2010. "On the Behavior and Determinants of Risk-Based Capital Ratios: Revisiting the Evidence from UK Banking Institutions", *International Review of Finance*, Vol. 10, pp. 485-518.

Gerardi, Kristopher S., Andreas Lehnert, Shane M. Sherlund, Paul Willen and Robert W. Kolb, 2010. *Making Sense of the Subprime Crisis*, pp. 109-117, John Wiley & Sons, Inc.

Gerlach-Kristen, Petra and Niall McInerney, 2014. "The role of credit in the housing market", ESRI Working Paper No. 495. Economic and Social Research Institute.

Grace, Therese, Niamh Hallissey and Maria Woods, 2015. "The Instruments of Macro-Prudential Policy", *Quarterly Bulletin Articles*, pp. 90-105.

Gropp, Reint and Florian Heider, 2010. "The Determinants of Bank Capital Structure", *Review of Finance*, Vol. 14, pp. 587-622.

Honohan, Patrick, 2010. *The Irish Banking Crisis: Regulatory and Financial Stability Policy 2003-2008. A Report to the Minister for Finance from the Governor of the Central Bank*, Dublin: Central Bank of Ireland.

Kelly, Jane, Julia Le Blanc and Reamonn Lydon, 2018. "Pockets of Risk in European Housing Markets: Then and Now", Research Technical Papers 12/RT/18, Central Bank of Ireland.

Kiyotaki, Nobuhiro and John Moore, 1997. "Credit Cycles", *Journal of Political Economy*, Vol. 105, pp. 211-48.

Liadze, Iana and Philip Davis, 2012. "Modelling and Simulating the Banking Sectors of the US, Germany and the UK", NIESR Discussion Papers 396, National Institute of Economic and Social Research.

Lozej, Matija and Martin O'Brien, 2018. "Using the Countercyclical Capital Buffer: Insights from a Structural Model", Economic Letters 7/EL/18, Central Bank of Ireland.

Lozej, Matija, Luca Onorante and Ansgar Rannenberg, 2018. "Countercyclical Capital Regulation in a Small Open Economy DSGE model", Working Paper Series 2144, European Central Bank.

Lozej, Matija and Ansgar Rannenberg, 2018. "The Macroeconomic Effects of the LTV and LTI Ratios in Ireland", *Applied Economics Letters*, Vol. 25, pp. 1507– 1511.

Lyons, Ronan C., 2018. "Credit Conditions and the Housing Price Ratio: Evidence From Irelands Boom and Bust", *Journal of Housing Economics*, Vol. 42, pp. 84-96.

Martin-Oliver, Alfredo, Sonia Ruano and Vicente Salas-Fumas, 2013. "Banks' Equity Capital Frictions, Capital Ratios and Interest Rates: Evidence from Spanish Banks", *International Journal of Central Banking*, Vol. 9, pp. 183-225.

McCarthy, Yvonne and Kieran McQuinn, 2017. "Credit Conditions in a Boom and Bust Property Market: Insights for Macro-Prudential Policy", *The Quarterly Review of Economics and Finance*, Vol. 64, pp. 171-182.

McInerney, Niall, 2019. "Macroprudential Policy, Banking and the Real Estate Sector", MPRA Paper 91777, Germany: University Library of Munich.

O'Brien, Eoin, Martin O'Brien and Sofia Velasco, 2018. "Measuring and Mitigating Cyclical Systemic Risk in Ireland: The Application of the Countercyclical Capital Buffer", Financial Stability Notes 04-18, Central Bank of Ireland.

Regling, Klaus and Max Watson, 2010. *A Preliminary Report on The Sources of Ireland's Banking Crisis*, Dublin: Government Publications.

Vlieghe, Gertjan W., 2001. "Indicators of Fragility in the UK Corporate Sector", Bank of England working papers 146, Bank of England.

APPENDIX

A1. Model Equations

New Mortgages:[20]

$$\log(morn_t/pcd_t) = 2.18 - 0.03 * (rmor_t - pcdx_{t-1}) + 0.75 * \log(ltv_t) \\ +0.48*\log(lti_t) + 1.08 * \Delta(\log(pdr_t)) \\ + 0.64*\Delta(\log(hp_{t-1}/pcd_{t-1})) + 0.71 * \log(morn_t/pcd_t)$$

CRE Credit:

$$\log(cres_t/pcd_t) = 25.98 - 0.019 * (infc_t - pcdx_{t-1}) + 1.72 * \log(rgdp_t) \\ + 0.77 * \log(cps_t/emp_t)$$

Non-CRE Corporate Credit:

$$\log(ocorp_t) = -5.93 - 0.01*(infc_t - pcdx_{t-1}) + 0.35 * \log(cpv_t/pcd_t) \\ +1.36 * \log(rgdp_t) - 0.66 * \log(prof_t/pcd_t)$$

Consumer Credit:

$$\log(conss_t/pcd_t) = -18.34 - 0.01 * (consr_t\text{-}pcdx_{t-1}) + 0.32 * \log(pdr_t) \\ + 0.84 * \log(heq_t) + 0.08 * \log(nfa_t)$$

Mortgage Interest rate:

$$rmor_t = 15.95 - 0.86 * \log(heq_t) + 0.61 * \log(urx_t) + 0.18 * idep_t \\ +0.77*eur_{t-}1.28 * \log(ltd_t) + 0.59 * \log(capr_t) - 4.35 * D92Q4 \\ - 2.99 * D93Q1$$

Corporate Interest rate:

$$infc_t = 0.16 * idep_t + 0.81*eur_{t-}2.12 * \log(ltd_t) + 0.86 * \log(insolr_t) \\ + 0.34 * \log(capr_t) + 0.92 * \log((cres_t + ocorp_t)/ngdp_t) + 2.72 \\ + 2.12 * D93Q1 - 1.29 * D92Q4$$

Consumer Interest rate:

$$consr_t = 15.66 + 0.66 * idep_t + 0.33 * eur_t + 0.69 * \log(capr_t) \\ - 3.43 * \log(ltd_t) + 1.22 * \log(conss_t/pdr_t) + 0.43 * \log(urx_t) \\ + 2.27 * D92Q3 - 1.63 * D93Q1$$

House Prices:

$$\log(hp_t/pcd_t) = 24.1 - 0.008 * user_t^h + 0.69 * \log(pdr_t) \\ + 0.51 * \log(mors_t/pdr_t) - 1.28 * \log(hs_t/p2539_t)$$

[20] Note that we exclude the short-run dynamics from the equations due to space limitations.

Commerical Property Capital Values:

$$\log(cpv_t/pcd_t) = 17.09 - 1.85 * \log(cps_t/emp_t) + 1.05 * \log(rgdp_t) - 0.01 * user_t^c + 0.79 * \log((cres_t + ocorp_t)/ngdp_t)$$

Housing Completions:

$$\log(hc_t) = 0.19 + 0.79 * \log(hc_{t-1}) + 0.35 * \log(hp_t/ccost_t) - 0.02 * (infc_t - pcdx_{t-1}) + 0.51 * \Delta(\log(cres_{t-1})) + 0.46*(gap_t) + 1.5 * \Delta(\log(p2539_t/ptn_t)) - 0.13 * \Delta(insolr_{t-1})$$

Mortgage Arrears rate:

$$\log(arr_t) = 44.18 - 2.45 * \log(heq_t) + 1.26 * \log(rmor_t) + 0.54 * \log(urx_t) + 5.55 * \log(mors_t/pin_t)$$

Corporate Insolvency rate:

$$\log(insolr_t) = -0.075 + 0.011 * (infc_t - pcdx_{t-1}) - 0.33 * \log(cpv_t/(ocorp_t + cres_t)) + 0.41 * \log(urx_t) + 0.66 * \log((ocorp_t + cres_t)/ngdp_t)$$

Bank Capital ratio:

$$\log(capr_t) = 0.14 - 1.41 * \log(assets_t/ngdp_t) + 0.45 * \log(urx_t) + 0.026 * (brev_t - bcost_t) + 0.69 * \log(cres_t/(mors_t + ocorp_t + cres_t + conss_t)) - 0.77 * \log(deps_t/liabs_t)$$

A2. Variable Definitions

Variable	*Description*	*Variable*	*Description*
arr	Mortgage arrears rate	infc	Corporate lending rate
assets	Total assets of banking sector	insolr	Corporate insolvency rate
brev/ bcost	Banks' interest revenues/ costs	liabs	Total liabilities of banking sector
capr	Banks' capital ratio	ltd	Loan-to-deposit ratio
ccost	Construction costs	lti	Loan-to-income ratio
consr	Consumer lending rate	ltv	Loan-to-value ratio
conss	Stock of consumer credit	morn	New mortgage lending
cps	Value commercial property stock	mors	Stock of outstanding mortgages
		nfa	Households' net financial assets
cpv	Commercial capital values	ngdp/rgdp	Nominal/real GDP
cres	Stock of CRE credit	ocorp	Non-property corporate credit
deps	Total retail deposits	p2539	Population 25-39 year olds
emp	Total employment	pcd	Consumer expenditure deflator
eur	3-month Euribor	pcdx	Annual change in pcd
gap	Output Gap	pdr	Personal disposable income (real)
hc	Housing completions	ptn	Total population
heq	Household equity	rmor	Mortgage interest rate
hp	Average house prices	urx	Unemployment rate
hs	Housing stock	$user^h/user^c$	User cost of housing/comm. property
idep	Deposit interest rate		