Countercyclical capital rules for small open economies

This paper demonstrates that economies without flexible interest or exchange rates can benefit from countercyclical capital regulation.

Daragh Clancy
European Stability Mechanism
Rossana Merola
International Labour Organisation

European Stability Mechanism

Countercyclical capital rules for small open economies *

Daragh Clancy[1] European Stability Mechanism
Rossana Merola[2] International Labour Organisation

Abstract

The growing literature on macroprudential regulation focuses on how a combination monetary and macroprudential policies can boost financial stability. We contribute to this literature by developing a DSGE model that assesses the effectiveness of countercyclical capital regulation in small open economies, in monetary unions or with exchange rate pegs, where policymakers do not have full control over traditional stabilisation instruments such as nominal interest and exchange rates. Our model shows that, in such economies, macroprudential policy must play an outsized role in mitigating the adverse effects of macro-financial feedback loops. To validate the model's ability to replicate the stylised facts of financial crises, we calibrate using data for the Irish economy the recent housing crash. Our results demonstrate that the pro-active use of countercyclical capital regulation can indeed help ensure financial stability. In terms of policy advice, we find that bestowing even greater flexibility on regulators to act against the credit cycle has positive benefits. We also find that more aggressive action during the release phase can bolster the economy's ability to absorb a negative shock.

Key words: small open economy, macroprudential policy, macro-financial linkages
JEL codes: E44, E51, G10, G28

*The views contained here are those of the authors and not necessarily those of their respective institutions. This is an updated version of an earlier paper circulated as "The effect of macroprudential policy on endogenous credit cycles".

1 European Stability Mechanism, 6a Circuit de la Foire Internationale, L-1347 Luxembourg; Email: d.clancy@esm.europa.eu; Tel: +352 260 962 816.
2 International Labour Organisation, 4 Route des Morillons, CH-1211 Geneve 22, Switzerland; Email: merola@ilo.org; Tel: +41 22 799 73 12.

ISSN 2443-5503
ISBN 978-92-95085-10-7

doi:10.2852/091929
EU catalog number DW-AB-15-008-EN-N

1 Introduction

The recent financial crisis demonstrated that a mixture of microprudential and macroeconomic policies proved insufficient to ensure financial stability. With macro-financial feedback loops playing a key role in both triggering and propagating the crisis, macroprudential policies addressing systemic risk were widely introduced in its aftermath. Following the seminal contribution by Bernanke, Gertler and Gilchrist (1999), the most recent literature has added the banking sector in DSGE models to further account for these macro-financial linkages. This literature has mainly focused on how a combination of macroprudential and monetary policy can be used to ensure financial stability.[1] However, little attention has focused on the large cohort of countries which do not have conventional macroeconomic stabilisation tools at their disposal. Small open economies (SOEs) in monetary unions, for example, may have such little weight in area-wide aggregates that nominal interest and exchange rates are effectively exogenous. Smaller countries who peg their exchange rate to the currency of a much larger economy are also constrained in their use of these macroeconomic instruments. Given the diminished alternative options, macroprudential policy must play an exaggerated role in maintaining financial stability in these economies.

We fill this gap in the literature by developing a DSGE model to analyse macroprudential policy in such economies, with the banking sector based on the framework proposed by Beneš, Kumhof and Laxton (2014a, 2014b) (hereafter BKL). A key feature of this framework is that banks do not act simply as intermediaries, lending out deposits placed by savers. Instead, banks create new monetary purchasing power by providing loans without the need for pre-existing deposits.[2] This assumption resembles what happens in the real world, where "the banking system does not simply transfer real resources, more or less efficiently, from one sector to another; it generates (nominal) purchasing power. Deposits are not endowments that precede loan formation; it is loans that create deposits".[3] The BKL framework also contains several features which are crucial for the analysis of regulatory policies: an endogenous default mechanism; non-diversifiable risk; incentive-based capital regulation under uncertainty; and a non-price bank lending channel.

We extend the BKL framework in a number of ways. First, while BKL consider a generic open economy with an independent Taylor rule, we consider the case of a SOE in a monetary union. Therefore, in our model monetary policy is exogenous and cannot be used to stabilise the economy in response to shocks.[4] This adds to the importance of

[1]Most of the existing literature analyses macroprudential policy in closed economy DSGE models (*e.g.* Agénor *et al.*, 2013; Angeloni and Faia, 2013; Angelini *et al.*, 2014; Beau *et al.*, 2012; Beneš and Kumhof, 2015; Bailliu *et al.*, 2012; Collard *et al.*, 2012; Carrasco-Gallego and Rubio, 2014; Christensen *et al.*, 2011; Darraq-Pariès *et al.*, 2011; De Paoli and Paustian, 2013; Gelain *et al.*, 2013; Kannan *et al.*, 2012; Lambertini *et al.*, 2013a; Suh, 2012 and 2014) or in two-countries DSGE models designed for large countries which still have some room for using traditional monetary policy tools (*e.g.* Aspachs-Bracons and Rabanal, 2010 and 2011; Quint and Rabanal, 2014) or for small open economies which are not part of a monetary union and hence have independent monetary policy (*e.g.* Brzoza-Brzezina *et al.*, 2013; Medina and Roldos, 2014; Ozkan and Unsal, 2013; Unsal, 2013).

[2]We refer to Jakab and Kumhof (2015) for an exhaustive review of statements by central banks and policy-making authorities supporting the approach that the key role of banks is creating liquidity instead of acting as intermediaries. For a detailed discussion on this mechanism of money creation in the banking system, see also Disyatat (2011) and the Bank of England (2014).

[3]Borio (2012), p. 11.

[4]Fornari and Stracca (2012), amongst others, show that monetary policy is an effective tool for sta-

assessing the usefulness of macroprudential policy as an instrument to smooth fluctuations in the economy when monetary policy is not independent. Second, we introduce a housing asset that now becomes the focus of interactions between the real economy and the financial sector. A bank's willingness to extend loans (*i.e.* mortgages) depends on their expectations for future house prices, which are provided by households as collateral. As the existing housing assets of potential customers is offered as collateral, such expectations impact on lending spreads charged by the banks to cover the risk of the loans defaulting. A greater (lower) perceived risk of house price decreases can influence household demand for loans by raising (reducing) credit standards. Finally, in most of the literature loan defaults are entirely related to the value of the collateralising asset. However, a key determinant of mortgage performance is the borrowers' ability to pay (McCarthy, 2014). Even in regions in which there are non-recourse loans, which have come to be associated with behaviour consistent with "strategic default" of mortgage loans, survey evidence suggests that the vast majority of borrowers regard not paying debts when one can afford to do so as morally wrong (Honohan, 2013). Therefore, while the existence of negative equity greatly increases the probability of default in non-recourse jurisdictions, it does not in those with full recourse (Ghent and Kudlyak, 2011). The incorporation of disposable income into the cut-off point for loan defaults therefore brings the model closer to reality.

Following the recent financial crisis, the European Central Bank (ECB) was assigned a macroprudential supervisory mandate as a shared competency with individual member states' national central banks. One instrument enacted to help fufill this mandate is a countercyclical capital buffer (CCB). Previously, the minimum regulatory capital requirement was fixed at 8%, in line with the Basel II agreement. However, euro area central banks now have the power to require banks to set aside additional capital during periods of strong credit growth. The accumulated capital buffer is designed to protect banks from crippling losses that can impair the supply of credit during recessions, which exacerbated past downturns. With the introduction of this instrument across the euro area at the beginning of 2016, we use our model to examine its ability to promote financial stability. To validate the model's ability to replicate the stylised facts from financial crises, and therefore its suitability for policy analysis, we calibrate using data from the Irish economy during the recent housing crash.[5] Ireland is a member of the euro area whose interest rates are set by ECB. Given the small weight of Ireland in the monetary union (approximately 1%), domestic developments are too small to affect area-wide macroeconomic aggregates. Therefore, nominal interest and exchange rates cannot be used by Irish policymakers to stabilise the economy following shocks, adding to the importance of macroprudential policy.[6]

We first demonstrate the macro-financial feedback loops present in the model by

bilising the economy following financial shocks.

[5]See Appendix A for a brief overview of the stylised facts our model replicates. See also Central Bank of Ireland (2014) for a comprehensive discussion of the Central Bank of Ireland's macroprudential policy aims and powers.

[6]This assertion is consistent with empirical evidence from Honohan and Leddin (2006), who found that nominal interest rates in Ireland were substantially lower than those implied by a standard Taylor rule, with responses insufficiently small to be stabilising. Honohan and Leddin (2006) also note that interest rates were not appropriate for local Irish conditions prior to creation of the euro, which they attribute to agency costs arising from exchange rate pegs during the ERM period. Moreover, numerous other studies suggest that house prices in Ireland were elevated by overly accommodative monetary policy. See Moons and Hellinckx (2015) for an up-to-date discussion of this literature.

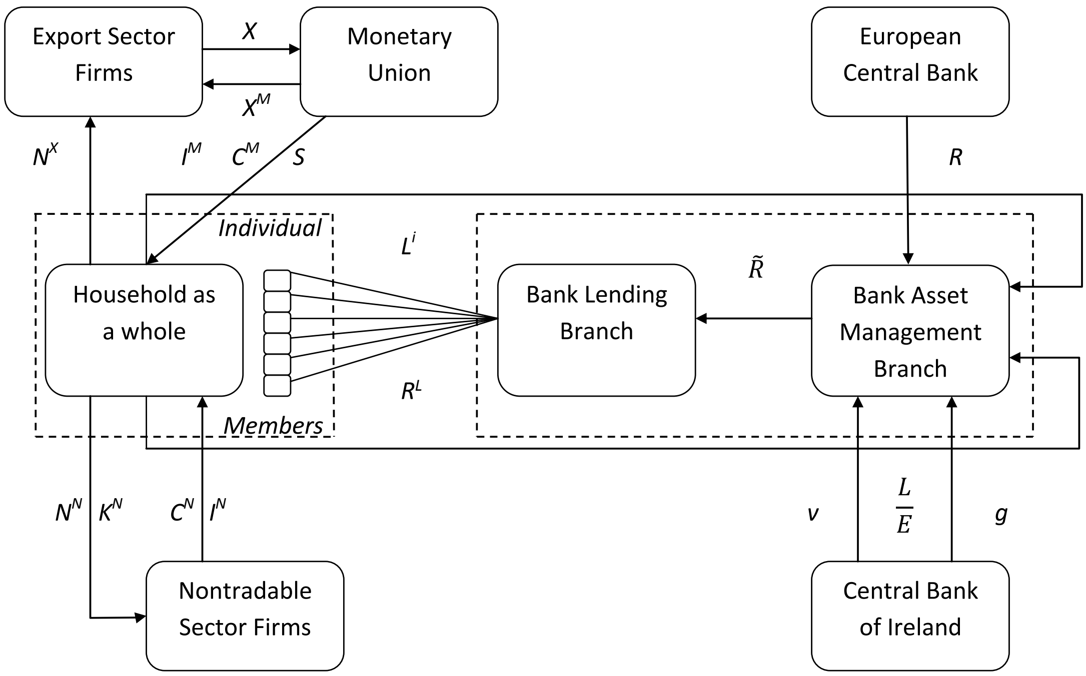
simulating a shock to agents' expectations of housing demand (*i.e.* preferences). We find that positive expectations for future house prices play a role in the accumulation of credit risk. The negative effects of this over-extension of credit materialise when these expectations prove to be over-optimistic. We then compare our results to the empirical literature, and find that our model matches the empirical evidence on the macroeconomic impact of housing shocks in Ireland. Having established that the model is useful for policy analysis, we then assess the impact that countercyclical capital regulation can play in mitigating the build-up of these risks during "bad booms", driven by euphoria and over-optimistic expectations. We find that forcing banks to build up their capital buffers during a period of credit growth can help smooth the economy's resilience to negative shocks. Our simulations further suggest that giving regulators more flexibility to move against the credit cycle has positive benefits.

The paper is structured as follows. The model's equations are provided in Section 2, while the calibration of the model is discussed in Section 3. The results from our simulations are described in Section 4, while the final section summarises and concludes. Finally, in the Appendix we present some robustness checks: we assess whether the same channels are relevant when the shock originates in the financial sector; we examine the effects of different degrees of importance of the countercyclical capital rules and the non-price lending channel. In addition, we detail the stylised facts that our model replicates.

2 The model

We consider a two-sector SOE within a monetary union. Agents in the economy are households, banks, firms producing non-tradable goods and exports, and retailers who import goods from abroad for sale on the domestic market. In the following description of the model, variables not indexed by time denote steady-state values. Variables not internalised (*i.e.* taken as given) by optimising agents, such as external habit formation in consumption, are marked with an overline. A flow-chart of the model economy is depicted in Figure 1.

FIGURE 1. **Model economy flow chart**



2.1 Households

Households gain utility from consumption C_t, housing services H_t, deposits demanded for saving reasons D_t^S and disutility from labour N_t.[7] They maximise their lifetime utility according to:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\chi)\log(C_t - \chi\overline{C}_{t-1}) + \theta \log H_t - \frac{1}{1+\eta} N_t^{1+\eta} + \zeta \frac{1}{1-\iota} \left(\frac{D_t^S}{P_t^D} \right)^{1-\iota} \right] \quad (1)$$

where χ is the degree of habit persistence in consumption, $(1-\chi)$ is a scale factor which guarantees that the marginal utility of consumption in the steady state is independent from the habit parameter, β is the household discount factor, η is the labour supply elasticity and the parameters θ and ζ measure the households' preference for housing and deposits respectively. We introduce a composite price index $P_t^D = (P_t)^{1-\omega^D}(P_t^H)^{\omega^D}$, where P_t^H is the house price and P_t is the CPI price level. This composite price index allows the model to reproduce the strong co-movement between house prices and consumption identified in the empirical literature.[8] Another share of deposits D_t^T are

[7] We assume that the housing stock is fixed, and so $H_t = 1$. Therefore, we focus on the demand rather than the supply side of the housing market.

[8] Empirical evidence indicates that there is strong co-movement between house prices and consumption, with Warren (2007) and Mian and Sufi (2014) highlighting this as one of the key drivers of U.S.

demanded for transactions, that is for purchasing consumption goods C_t at price P_t, investment goods I_t at price P_t^I and housing H_t at price P_t^H, so that:

$$D_t^T = \gamma^C \left(P_t C_t + P_t^I I_t \right) + \gamma^H P_t^H H_t \tag{2}$$

where γ^C and γ^H are the shares of deposits motivated by the need for consumption and investment and housing transactions respectively. Total deposits D_t are the sum of deposits held for saving D_t^S and deposits held to facilitate transactions D_t^T :

$$D_t = D_t^S + D_t^T. \tag{3}$$

This disaggregation means that, in addition to generating interest income, deposits also provide a liquidity service to the household (In't Veld *et al.*, 2011). This additional feature allows us to replicate a precautionary motive for saving.[9] Households maximise their utility subject to two types of constraints. The first is a budget constraint:[10]

$$\begin{aligned} P_t C_t + P_t^I I_t \left[1 - \frac{1}{2} \xi^I \left(\Omega_t^I \right)^2 \right] + P_t^H H_t + E_t - L_t + D_t^S \left[1 - \frac{1}{2} \xi^D \left(\Omega_t^D \right)^2 \right] \\ = W_t N_t \left[1 - \frac{1}{2} \xi^W \left(\Omega_t^W \right)^2 \right] + R_t^K K_{t-1} + P_t^H H_{t-1} + R_t^E E_{t-1} - R_t^L L_{t-1} + R_t D_{t-1}^S \\ + P_t^N Y_t^N \left[\frac{1}{2} \xi^N \left(\Omega_t^N \right)^2 \right] + P_t^M M_t \left[\frac{1}{2} \xi^M \left(\Omega_t^M \right)^2 \right] + P_t^X X_t \left[\frac{1}{2} \xi^X \left(\Omega_t^X \right)^2 \right] + E_t \left[\frac{1}{2} \xi^E \left(\Omega_t^E \right)^2 \right] + \Pi_t - T_t \end{aligned} \tag{4}$$

where $P_t^H H_t$ is the value of household's housing wealth, W_t is the wage rate, K_t denotes claims on physical capital, R_t^K is the return on physical capital, and I_t are investment goods purchased at price P_t^I.[11] L_t denotes the amount borrowed in bank loans, on which households pay the gross interest rate R_t^L, while receiving the risk-free interest rate R_t on deposits D_t. Households transfer equity E_t to banks on which they receive a return of R_t^E.[12] The term $\Omega_t^D = \log \frac{D_t^S}{D_{t-1}^S}$ denotes deposit adjustment costs, implying that households do not like sudden changes in their deposits.[13] The budget constraint also contains net pay-offs received from firms and banks Π_t, discussed in

consumption growth during the early-2000s housing boom. This complementarity is particularly strong between house purchases and durable consumption in Ireland (Clancy *et al.*, 2014). DSGE models often fail to capture this important relationship however, with consumption often moving inversely to housing purchases.

[9] Mody *et al.* (2012) provide empirical evidence of the importance of this effect during the recent financial crisis for a panel of advanced economies, including Ireland.

[10] We point out that in this framework households simultaneously lend and borrow and we do not assume agent heterogeneity (*i.e.* savers and borrowers). This is an implication of the assumption that banks are not intermediaries and hence, to extend loans to borrowers, they do not need pre-existing deposits provided by savers.

[11] In the model we differentiate between physical capital, owned by households and rented by firms for productive purposes, and bank capital, owned and used by banks to support their lending activities. Further details on the latter are provided in the description of the banking sector.

[12] We assume that households delegate banking activity to banks. Banks then give households net transfers of equity, which households take as given. This choice is derived from the banks optimisation problem in Equation (41), with the f.o.c. for equity given in Equation (43).

[13] Similarly, De Walque *et al.* (2010) also impose a target on deposits through a quadratic disutility term, as households do not like deposits differing from their long-run optimal level.

later sections. Finally, households pay lump-sum taxes T_t to the government.

The budget constraint requires that households' deposit holdings, transfers of bank capital and purchase of consumption and investment goods, physical capital and additional housing must be covered by labour and capital income, bank loans (net of interest payments) and dividends from firms, net of lump-sum taxes T_t. Households' resources in the budget constraint are net of transfers of bank capital and adjustment costs, which are assumed to be private losses. Adjustment costs, not internalised by households but instead rebated in lump-sum form, arise from deviations in non-tradable goods price inflation $\Omega_t^N = \log \frac{\pi_t^N}{\pi_{t-1}^N}$, import sector price inflation $\Omega_t^M = \log \frac{\pi_t^{P^M}}{\pi_{t-1}^{P^M}}$ and quantity adjustment in the export sector $\Omega_t^X = \log \frac{X_t}{X_{t-1}}$. The term $\Omega_t^E = \log \frac{E_t}{E_{t-1}}$ denotes bank capital adjustment costs, which are borne by households, as banks are assumed to be fully owned by domestic households. In addition, households face adjustment costs in investment $\Omega_t^I = \log \frac{I_t}{I_{t-1}}$ and in wage inflation $\Omega_t^W = \log \frac{\pi_t^W}{\pi_{t-1}^W}$. In all cases, the size of these costs are controlled by adjustment cost parameters ξ^D, ξ^E, ξ^I, ξ^M, ξ^N, ξ^W and ξ^X.

The second constraint is a law of motion for capital. This states that the capital stock available at the beginning of period *t*, K_t, is equal to the capital stock available at the end of period *t-1*, net of capital stock depreciation δK_{t-1}, where $0 < \delta < 1$ is the capital depreciation rate, plus the amount of capital accumulated during period *t*, which is determined by the investment made during period *t*, I_t. The capital accumulation equation is:

$$K_t = (1-\delta)K_{t-1} + I_t. \tag{5}$$

The first order conditions for C_t, H_t, D_t^S, I_t, L_t and K_t respectively are:

$$\frac{1-\chi}{C_t - \chi C_{t-1}} = \Lambda_t P_t \tag{6}$$

$$P_t^H = U_t^H \left[\frac{1}{\Lambda_t} \left(\frac{1}{H_t} + \beta \mathbb{E}_t \Lambda_{t+1} P_{t+1}^H \right) \right] \tag{7}$$

$$\frac{\zeta}{\Lambda_t} \left(D_t^S\right)^{-\iota} \left(P_t^D\right)^{\iota - 1} \approx 1 - \left(\beta \mathbb{E}_t R_t \frac{\Lambda_{t+1}}{\Lambda_t} \right) + \xi^D \Omega_t^D \tag{8}$$

$$P_t^I \approx P_t^K \left[\left(1 - \frac{1}{2} \xi^I (\Omega_t^I)^2 \right) - \xi^I \Omega_t^I \right] + \beta \mathbb{E}_t \left[P_{t+1}^K \xi^I \Omega_{t+1}^I \left(\frac{I_{t+1}}{I_t} \right)^2 \right] \tag{9}$$

$$\Lambda_t = \beta \mathbb{E}_t \Lambda_{t+1} R_t^L \tag{10}$$

$$P_t^K = \beta \mathbb{E}_t \frac{\Lambda_{t+1}}{\Lambda_t} (R_{t+1}^K + (1-\delta) P_{t+1}^K) \tag{11}$$

where Λ_t is the multiplier associated with the budget constraint, the $\approx$ sign indicates the omission of second- or higher-order terms from the equation and U_t^H is an autoregressive exogenous housing demand shock process:

$$\log U_t^H = \rho^{U^H} \log U_{t-1}^H + \epsilon_t^{U^H}. \tag{12}$$

Moreover, households use their monopoly power to set its wages so as to maximise the intertemporal objective function subject to both the budget constraint and a downward-sloping demand curve:

$$N_t = \frac{W_t}{\overline{W}_t}^{-\frac{\theta^W}{\theta^W - 1}} \overline{N}_t, \tag{13}$$

where ϵ^W is the elasticity of demand and $\mu^W = \frac{\epsilon^W}{\epsilon^W - 1}$ is a markup over the marginal cost of labour. Households therefore choose their optimal wage according to:

$$\frac{\mu N_t^{\eta}}{W_t \Lambda_t} \approx 1 + (\mu^W - 1)\xi^W \Omega_t^W - (\mu^W - 1)\xi^N \beta \mathbb{E}_t \Omega_{t+1}^W. \tag{14}$$

2.2 Firms

There are three types of firms. While one locally produces non-tradable goods, another produces export goods for sale on the international market. A final type imports foreign goods for sale on the domestic market. Firms producing domestic goods and firms importing foreign goods are assumed to face a small direct cost of adjusting their prices, modelled *à la* Rotemberg (1982).[14] Firms producing export goods face quadratic adjustment costs if they want to change the level of their output. As a result, firms will only adjust prices gradually in response to a shock to demand or marginal cost (Devereux *et al.*, 2005).

2.2.1 Non-tradable goods producers

Local producers combine domestic capital, K_{t-1}^N, and labour, N_t^N, using a Cobb-Douglas production function to assemble a non-tradable good:

$$Y_t^N = A_t^N \left(K_{t-1}^N\right)^{1-\gamma^N} \left(N_t^N\right)^{\gamma^N} \tag{15}$$

where γ^N measures labour share in the non-tradable sector and A_t^N is an exogenous technology term which follows an autoregressive process:

$$\log A_t^N = \rho^A \log A_{t-1}^N + \epsilon_t^A \tag{16}$$

with ρ^A the persistence of the process and ϵ_t^A a shock to non-tradable sector productivity. This shock is sector specific and is identical across all firms in the sector. The local producer optimises the present value of payoffs:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[P_t^N Y_t^N \left[1 - \frac{1}{2}\xi^N \left(\Omega_t^N\right)^2 \right] - W_t N_t^N - R_t^K K_{t-1}^N \right] \tag{17}$$

where ξ_t^N is an adjustment cost parameter associated with deviations in non-tradable goods price inflation $\Omega_t^N = \log \frac{\pi_t^N}{\pi_{t-1}^N}$ and W_t and R_t^K are the cost of factor inputs. The optimal choice of labour and capital is:

$$\gamma^N MC_t^N Y_t^N = W_t N_t^N \tag{18}$$

[14] Adjustment costs for exporters are related to their output levels, as they are price takers.

$$(1-\gamma^N)MC_t^N Y_t^N = R_t^K K_{t-1}^N \tag{19}$$

where MC_t^N is the marginal cost of production in the non-tradable sector. Local firms face a downward-sloping demand curve for their output:

$$Y_t^N = \left(\frac{P_t^N}{\overline{P}_t^N}\right)^{-\frac{\theta^N}{\theta^N-1}} \overline{Y}_t \tag{20}$$

where θ^N is the elasticity of demand for non-tradable goods. Local firms can use their degree of monopoly power to charge a markup over their marginal cost. The optimal price is set according to:

$$(\mu_t^N - 1)\xi^N \Omega_t^N \approx (\mu_t^N - 1)\xi^N \beta \mathbb{E}_t \Omega_{t+1}^N + \left(\frac{\mu_t^N MC_t^N}{P_t^N} - 1\right) \tag{21}$$

where $\mu_t^N = \frac{\theta^N}{\theta^N-1}$ measures the monopolistic markup in this sector, which follows an autoregressive process:

$$\mu_t^N = (1-\rho^N)\mu^N + \rho^N \mu_{t-1}^N + \epsilon_t^N \tag{22}$$

where ρ^N is the persistence of the process and ϵ_t^N is a shock to the non-tradable price markup.

2.2.2 Importers

The import sector consists of firms that buy a homogeneous good in the world market, and use a branding technology to convert the imported goods into differentiated products, which are then sold to local households. It is assumed a set of monopolistic domestic importers purchase the foreign good at its marginal cost (expressed in domestic currency), $MC_t^M = P_t^{M\star} S_t$, where $P_t^{M\star}$ is the world import price expressed in foreign currency and S_t is the nominal exchange rate. For a small open economy, $P_t^{M\star}$ is taken as given. Import firms then use their market power, represented by a downward-sloping demand curve for imports:

$$M_t = \left(\frac{P_t^M}{\overline{P}_t^M}\right)^{-\frac{\theta^M}{\theta^M-1}} \overline{M}_t \tag{23}$$

to charge a markup $\mu^M = \frac{\theta^M}{\theta^M-1}$ over this price, with θ^M representing the elasticity of demand for imported goods. The monopolistic markup in this sector follows an autoregressive process:

$$\mu_t^M = (1-\rho^M)\mu^M + \rho^M \mu_{t-1}^M + \epsilon_t^M \tag{24}$$

where μ^M is the steady state of the markup in the import sector, ρ^M is the persistence of the process and ϵ_t^M is a shock to the import price markup. Assuming $P_t^M = \overline{P}_t^M$ in symmetric equilibrium, these goods are then sold on the domestic market at price P_t^M:

$$\left(\frac{\mu_t^M MC_t^M}{P_t^M}\right) \approx 1 + (\mu_t^M - 1)\xi^M \Omega_t^M - (\mu_t^M - 1)\xi^M \beta \mathbb{E}_t \Omega_{t+1}^M \tag{25}$$

with this price setting mechanism following the same rationale to that described previously for the non-tradable good sector. Local currency price stickiness allows for an incomplete exchange rate pass-through, and thus there is some delay between movements in the terms of trade and the adjustment of imported goods prices.

2.2.3 Tradable goods producers

Competitive local exporters combine domestic labour and fixed capital $\overline{K}_{t-1}^X$ using a Cobb-Douglas technology:[15]

$$Z_t = A_t^X \left(\overline{K}_{t-1}^X\right)^{1-\gamma^X} \left(N_t^X\right)^{\gamma^X} \tag{26}$$

where γ^X measures labour intensity in the export sector and A_t^X is a sector-specific exogenous technology term which follows an autoregressive process:

$$\log A_t^X = \rho^X \log A_{t-1}^X + \epsilon_t^X \tag{27}$$

with ρ^X the persistence of the process and ϵ_t^X a shock to export sector productivity. Re-exports X_t^M, which are goods purchased from abroad but not intended for sale in the domestic market, are combined with locally-produced tradable goods Z_t to produce final export goods using a Leontief production function:

$$X_t = \min\left\{\frac{Z_t}{(1-\alpha)}, \frac{X_t^M}{\alpha}\right\}. \tag{28}$$

The large size of foreign direct investment in many SOEs makes this import content of exports channel very relevant for policy analysis.[16] By considering the international fragmentation of the tradable good production process, this features can account for the reliance of exports in Ireland on imported components. For any given level of output, the inputs in final export goods X_t are combined in proportions fixed by the parameter α:

$$Z_t = (1-\alpha)X_t \tag{29}$$

$$X_t^M = \alpha X_t. \tag{30}$$

The assumption of a fixed proportion is justified by the fact that changes in relative prices should not overly influence the use of imported intermediate goods in the pro-

[15] The capital input decisions of tradable sector firms are not necessarily made domestically in SOEs with a large amount of Foreign Direct Investment (FDI) (for a detailed discussion, see Bradley and Fitzgerald, 1988 and 1990). Consistent with this, here export firms concentrate solely on the minimisation of labour costs and capital follows an autoregressive process $\log K_t^X = \rho^K \log K_{t-1}^X + \epsilon_t^K$, where ρ^K is the persistence of the process and ϵ_t^K is a shock to the export sector's capital stock. This shock could be considered as an influx of capital to the domestic tradable sector by the parent branch of a multinational corporation, for example.

[16] See Hummels *et al.* (2001) for an estimate of the importance of this channel in a panel of OECD and emerging market countries.

duction of the final export good. In SOEs the imported component is often not produced within the country, and so is irreplaceable from domestic sources. With capital fixed, domestic firms producing tradable goods Z_t minimise their costs:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[P_t^X X_t - W_t N_t^X - R_t^K \overline{K}_{t-1}^X \right]. \tag{31}$$

This optimisation choice only considers the domestic component, as the imported component is set to a fixed proportion of the final export good. The optimal choice of labour in this sector is derived from:

$$\gamma^X MC_t^Z Z_t = W_t N_t^X. \tag{32}$$

The exporters' marginal cost of production is:

$$MC_t^X = (1-\alpha) MC_t^Z + \alpha P_t^M \tag{33}$$

where MC_t^Z is the marginal cost of locally-produced export goods used in the final export goods production process, while P_t^M is the price of imported goods defined previously. After substituting the total production cost into the exporters' pay-offs, we can derive the following first-order condition for the optimal level of exports:

$$\frac{P_t^X}{MC_t^X} \approx 1 + \xi^X \Omega_t^X - \beta \mathbb{E}_t \Omega_{t+1}^X. \tag{34}$$

2.3 The banking sector

Banks' assets consist of loans, which are financed through banks' liabilities, namely deposits and capital (*i.e.* equity). Banks choose loans, deposits and capital to maximise the pay-off to shareholders. For simplicity, the model distinguishes between two branches of banks and treats them separately. The lending branch of banks offer loan contracts to households. Banks can incur losses on non-performing loans (NPLs) when the value of a collateralising asset (supplied by households to secure a loan) and disposable income drops significantly. The asset-liability management (ALM) branch of banks decide how much capital is needed to support a portfolio of loans, given certain risk characteristics. The presence of the ALM branch in the model allows for an assessment of the effect of macroprudential policy. Capital regulation limits the bank's optimal choice of capital, by requiring that the ex-post value of bank capital is a certain proportion of the ex-post value of the bank's loan portfolio. If the bank falls short of regulatory capital, it pays a penalty, which is proportional to its ex-post value of assets (*i.e.* performing loans).

The rationale for imposing minimum capital adequacy regulations on banks stems from banks' incentive to take on large amounts of lending risk, and to minimise their own equity base. This moral hazard problem exposes depositors to a significant risk of capital losses. There are several alternatives for maintaining discipline in the banking system. A first solution would be to create deposit contracts which reflect that risk. However, this solution requires depositors to engage in costly monitoring, and also may trigger bank runs when adverse information about individual banks is revealed. A second solution is to create some form of deposit insurance. However, as deposit insurance schemes cannot insure against systemic crises, they have to be accompanied by further macroprudential measures. A third solution is to impose direct capital adequacy regulations that penalise banks for maintaining an insufficient capital buffer. We focus on the latter policy option.

2.3.1 A definition of credit risk

Banks make one-period loans to a large number of households.[17] To access credit, each *i-th* household provides their housing wealth and wage income as collateral.[18] A generic *i-th* household repays this loan if the actual value of their composite wealth $F_{i,t}$ (composed of their housing wealth and wage income) accepted as collateral is above a cut-off value:

$$\psi\left[\phi H_{i,t-1}P_{i,t}^{H}+\left(1-\phi\right)W_{t}N_{i,t}\right]>R_{i,t}^{L}L_{i,t} \tag{35}$$

where $L_{i,t}$ is the individual exposure on which the *i-th* household pays the non-contingent lending rate $R_{i,t}^{L}$, which will be defined later.[19] The parameter ψ is the share of composite wealth accepted as collateral. The loan-to-value ratio on housing wealth for the *i-th* household is defined as $LTV_{i,t}=\frac{L_{i,t}}{H_{i,t-1}P_{i,t}^{H}}$, with the loan-to-income ratio $LTI_{i,t}=\frac{L_{i,t}}{W_{i,t-1}N_{i,t}}$. We define the minimum value of a household's composite wealth needed to repay the loan, *i.e.* the default cut-off value, as:

$$\tilde{F_{i,t}}=\frac{R_{i,t}^{L}L_{i,t}}{\psi}. \tag{36}$$

Three components determine an individual's expected composite wealth:

$$F_{i,t+1}=\mathbb{E}_{t}\left(F_{t+1}\right)\exp\left(u_{i,t+1}^{a}\right)\exp\left(u_{t+1}^{b}\right) \tag{37}$$

where $\mathbb{E}_{t}\left(F_{t+1}\right)$ is the expected aggregate average market price of composite wealth, $\exp\left(u_{i,t+1}^{a}\right)$ is the idiosyncratic risk related to the *i-th* loan and $\exp(u_{t+1}^{b})$ is the systemic risk component. Equation (37) states that uncertainty over house prices includes both an idiosyncratic (microeconomic) and a systemic (macroeconomic) component.[20] At time *t+1*, if the value of composite housing and income wealth $F_{i,t+1}$ used as collateral for the *i-th* loan drops substantially below the threshold $\tilde{F_{i,t}}$, banks cannot recover the full amount of the loan (*i.e.* it becomes non-performing). Therefore, to evaluate the individual probability of default, we introduce a Bernoulli random variable J_{t+1}^{i} describing the performance of the *i-th* individual loan:

$$J_{t+1}^{i}=\begin{cases}0 & \text{loan performs, if } \left(F_{i,t+1}\right)>\tilde{F_{i,t}},\\ 1 & \text{loan defaults, if } \left(F_{i,t+1}\right)<\tilde{F_{i,t}}.\end{cases} \tag{38}$$

[17]We assume that the number of loans is large enough that banks are able to fully diversify away the idiosyncratic risk.

[18]We further assume that all households own some housing stock, and therefore abstract from the issue of first-time buyers.

[19]Non-contingent means that the lending rate is fixed at time t and thus will not change in response to outcomes observed at time $t+1$.

[20]See Acharya (2009) for a discussion on the distinction between systemic and idiosyncratic risk. In most existing models, if lending risk exists, it is idiosyncratic and thus fully-diversifiable, or introduced through *ad-hoc* exogenous shocks (*e.g.* Carlstrom and Fuerst, 1997).

We assume that all households make the same choice regarding loan quantity and interest rate combination, and so we can drop the i subscript, with the representative portfolio L_t as the sum of individual exposures L_t^i, so that $L_t = \sum_{i=1}^{n} L_t^i$. Therefore, all loans have the same probability of default. We define the ex-ante (*i.e.* unconditional) distribution of the NPLs as a proportion of the banks' portfolio. The cut-off value $\tilde{F}_t$ determines the ex-ante probability of default, which is defined as the c.d.f of a standard normal distribution evaluated at the cut-off household wealth F_t:

$$\mathbb{E}_t(J_{t+1}) = Pr(J_{t+1} = 1) = J_{t+1} = \varkappa + (1-\varkappa)\Phi\left[\frac{\log \tilde{F}_t - \log \mathbb{E}_t(F_{t+1})}{\sigma_a + \sigma_b}\right] \tag{39}$$

where Φ is the c.d.f of a standard normal distribution and σ_a and σ_b denote the uncertainty related to the idiosyncratic and systemic components of the risk factor respectively.[21] We assume that a share of loans, determined by the parameter $\varkappa$, might become non performing even if economic conditions are favourable. This ensures that a positive (*i.e.* non-zero) probability of default exists in every period. The ex-ante probability of default depends on expected households' wealth and both the idiosyncratic and systemic components of risk. The ex-post (*i.e.* conditional) probability of default $\tilde{J}_{t+1}$ depends on realised composite households' wealth and only the systemic risk σ_b, and it can be interpreted as the share of NPLs:

$$\mathbb{E}_t(J_{t+1}|F_{t+1}) = Pr(J_{t+1} = 1|F_{t+1}) = \tilde{J}_{t+1} = \varkappa + (1-\varkappa)\Phi\left[\frac{\log \tilde{F_{t-1}} - \log F_{t+1}}{\sigma_b}\right]. \tag{40}$$

Full risk-sharing amongst households ensures that resources are redistributed such that each household has sufficient composite wealth to be eligible for a loan in the next period. Therefore, in line with the rest of the literature focused on one-period loans, there is no path dependency from an individual household's default.

[21] Equation (39) is derived from the threshold condition, which can be re-written as:

$$\frac{R_{i,t}^L L_{i,t}}{\psi} > \mathbb{E}_t(F_{t+1}) \exp\left(u_{i,t+1}^a\right) \exp\left(u_{t+1}^b\right)$$

where the idiosyncratic and aggregate risks are assumed to be distributed normally and independent of each other $u_{t+1}^a \sim \mathcal{N}(0, \varsigma\sqrt{1-\rho})$ and $u_{i,t+1}^b \sim \mathcal{N}(log\mathbb{E}_t\left[(F_{t+1})\right], \varsigma\sqrt{\rho})$. The standard deviations of the two risk factors $\sigma_a = \varsigma\sqrt{\rho}$ and $\sigma_b = \varsigma\sqrt{1-\rho}$ are treated parametrically, where ς is the variance of the aggregate risk factor and ρ is the coefficient of correlation between idiosyncratic and aggregate risks. The presence of autocorrelation between individual risk factors, $\rho > 0$, implies that at least a portion of risk on banks' balance sheets is not fully diversifiable. As ex-ante households are identical, in a symmetric equilibrium the cut-off value is the same for all loans. Taking the log and rearranging, we obtain:

$$\log\left(\frac{R_t^L L_t}{\psi}\right) - \log \mathbb{E}_t\left(F_{t+1}\right) > u_{t+1}^a + u_{t+1}^b,$$

$$\log \tilde{F}_t - \log \mathbb{E}_t\left(F_{t+1}\right) > u_{t+1}^a + u_{t+1}^b.$$

2.3.2 Bank lending and credit risk management

A banks' portfolio consists of a large number of one-period loans L_t extended to households, each at a lending rate R_t^L. At time t, banks' loans are financed by (domestic and foreign) deposits D_t and equity liabilities E_t (*i.e.* bank capital). Bank loans are risky because, depending on macroeconomic developments, some loans may become non-performing at the time of repayment. Whenever a loan becomes non-performing, the bank is able to recover only a portion $1-\nu$ of the total amount of outstanding loans. To avoid a situation where banks take excessive risk and hold an inadequate amount of equity in reserve, banks are subject to minimum capital requirements. Each bank should therefore hold capital in proportion to its risk exposure.

The ALM branch of the bank chooses the size of its balance sheet, *i.e.* the volume of loans, deposits and the optimal bank capital reserves required to support a portfolio of loans with given risk characteristics, observed ex-post. Banks maximise the expected pay-off to shareholders, net of initial equity investment and corrected to account for both the risk and the expected value of the regulatory penalty:

$$\max \mathbb{E}_t \hat{\beta} \frac{\Lambda_{t+1}}{\Lambda_t} \left[R_t^L (1-\nu \tilde{J}_{t+1}) L_t - R_t D_t - \upsilon \left(\frac{L_t}{E_t} - g_t \right) L_t \right] + \left[E_t - \frac{1}{2} \xi^E \left(\Omega_t^E \right)^2 E_t \right] \quad (41)$$

where $R_t^L(1-\nu\tilde{J}_{t+1})$ is the bank lending rate corrected for non-diversifiable risk and ν can be interpreted as the loss given default (LGD). The term $\upsilon\left(\frac{L_t}{E_t} - g_t\right) L_t$ represents the penalty for deviating from the regulatory minimum capital requirement $g_t = g_{min}$. The penalty function, $\upsilon(\bullet)$, is introduced to prevent the bank from going below the regulatory capital minimum during times of large credit expansion (such as during a boom). It is modelled as an exponential function in the deviation from the minimum regulatory capital g_t. This feature allows for asymmetric reactions as the capital buffer gets drawn down and the bank increases its leverage. It is therefore an essential component of the non-linearities embedded in the model, with bank behaviour adjusting more rapidly in response to greater expected penalties when regulatory requirements are in danger of being breached.

However, banks may want to keep an additional buffer over and above this minimum regulatory capital $g_t = g_{min}$. We set the discount factor for banks lower than the discount factors for households, so that $\hat{\beta} < \beta$. This assumption implies that impatient banks will demand a higher future return to forego using their resources in the current period and they will display a propensity to overlend. They can use this higher return to accumulate a capital buffer in excess of the regulatory minimum. The first order condition for L_t states that:[22]

$$R_t^L (1-\nu \tilde{J}_{t+1}) \approx \tilde{R}_t - \upsilon \left(\frac{L_t}{E_t} - g_t \right) = R_t \quad (42)$$

where $\tilde{R}_t$ is the minimum return banks must make to avoid breaching their minimum capital requirement, with the spread over the risk-free deposit rate R_t determined by

[22]Following BKL, we ignore higher order stochastic interactions between the household's shadow value of wealth Λ_{t+1} and the banks' portfolio default ratio $\tilde{J}_{t+1}$.

the banks' expected penalties for any such breaches. The spread $\tilde{R}_t - R_t$ (the regulatory spread) compensates the bank for their greater risk of breaching the minimum capital requirement at higher leverage levels. Once the ALM branch determines $\tilde{R}_t$, it gives the lending branch instructions to offer each household a supply curve defined by all possible combinations of R_t^L and L_t that is consistent with $\tilde{R}_t$. This further spread, $R_t^L - \tilde{R}_t$ (the default spread), accounts for the credit risk (*i.e.* the possibility of NPLs). The f.o.c. for equity E_t, after some algebra, is given by:[23]

$$\mathbb{E}_t \hat{\beta} \frac{\Lambda_{t+1}}{\Lambda_t} R_t^E \approx 1 + \xi^E \Omega_t^E \tag{43}$$

and so banks increase their capital up to the point that the return on equity:

$$R_t^E = R_{t-1} + (R_{t-1}^L [1 - \nu \tilde{J}_t] - R_{t-1}) \frac{L_{t-1}}{E_{t-1}}. \tag{44}$$

equals their discount factor $\hat{\beta}$, corrected for adjustment costs. The return on equity is determined by the lending spread charged on (performing) loans over their cost of funding.

To adjust the loan-to-equity ratio following a negative shock, banks face two options: (i) cut back lending, either by increasing interest rates (through higher lending spreads) or by reducing the quantity of credit or (ii) issue new equity. We focus on the first option. By requiring banks to pay a penalty if they violate the capital requirement, this framework closely resembles the current Basel regime. In other words, banks' choice of capital is modelled as an incentive-based mechanism which changes their behaviour. Hence, while in most of the existing models capital requirements are an ever-binding constraint (*e.g.* Angeloni and Faia, 2013; van den Heuvel, 2008), in this framework capital buffers change over the time in response to financial cycles. Incentives to create capital buffers arise because equity from households is costly and not always available, and hence banks decide to maintain a cushion to avoid capital shortfall.

Banks often use instruments other than interest rates to manage credit risk (Strahan 1999). This is particularly true when non-diversifiable risk exists on a banks' loan portfolio (Arnold *et al.*, 2014). As a result, the observed lending rates do not fully reflect the availability of credit, a commonly used definition of credit rationing (Jaffee and Russell, 1976). We follow BKL and account for this non-price lending channel by constraining the banks' ability to fully enact desired changes in their lending rates as follows:

$$R_t^C - R_t = \tau \left(R_t^L - R_t \right) + (1 - \tau)(R^L - R) \tag{45}$$

where R_t^C is the lending rate that banks can charge, given that they are unable to pass on the full amount of their desired changes to the spread. The coefficient τ determines to what extent credit tightening is implemented via increased lending rates and $1 - \tau$ is the degree of credit rationing needed with the spread fixed at its steady state level.[24] This feature replicates the presence of tracker mortgages on Irish banks' loan portfo-

[23]See Appendix A.3 in BKL for a detailed derivation of this equation.

[24]Similarly to the BKL modelling framework, this feature is not derived from strict first principles, and is instead modelled as an *ad-hoc* mechanism designed to mimic the dynamic reaction of the economy to credit rationing. There is, however, a large literature which considers the optimality of credit rationing (see, for example, Jaffee and Modigliani, 1969; Stiglitz and Weiss, 1981).

lios.[25] The difference $R_t^L - R_t$ represents the lending spread, with their steady-state counterparts represented by R^L and R. The non-price bank lending channel is a useful feature in that it restricts banks' ability to recapitalise. If the feature is disabled, banks can increase their lending spreads more rapidly, and use their much higher profits to rebuild their retained earnings and capital.[26] The presence of a high proportion of inelastic tracker mortgages on banks' loan portfolios, coupled with political pressure following the nationalisation of the banks, meant that this strategy was very curtailed. It is thus a necessary feature to accurately capture the Irish reality.

2.4 Policy authorities

As Ireland is part of the euro area, monetary policy is assumed to be exogenous, consistent with the empirical evidence cited earlier. Therefore, instead of a Taylor rule, we assume that a fixed exchange rate is maintained (*i.e.* the nominal exchange rate equals one). The fiscal authority is stylised. Government spending consists entirely of domestically produced non-tradable goods, and is specified as a constant proportion of nominal steady-state output Y:

$$G_t = gY. \tag{46}$$

A balanced budget is ensured in every period by a lump-sum tax (transfer) T_t that offsets any fiscal deficit (surplus):

$$P_t^N G_t = T_t. \tag{47}$$

In a SOE which is part of a monetary union, the constraints placed on traditional monetary policy make macroprudential policy all the more important. We focus our attention on the countercylical capital requirement, which is expected to both increase the resilience of banks to negative shocks, and attenuate any credit contraction experienced during a downturn (Drehmann and Gambacorta, 2012). In the past the minimum capital requirement was set as a constant $g_t = g_{min}$, in line with the Basel II recommendations. However, new legislation empowers the Central Bank of Ireland to set the minimum capital requirement as a time-varying target g_t. This should allow the regulatory target to respond asymmetrically to market conditions, thereby mirroring the financial cycle. In this latter case, macroprudential policies are pro-active and the capital requirement becomes:[27]

$$g_t = \min\left[g_{max}, \max\left[g_{min}, \phi_{g1} g_{t-1} + (1-\phi_{g1})\phi_{g2}\left(\log\frac{L_t}{Y_t} - \log\frac{L}{Y}\right)\right]\right] \tag{48}$$

where $\frac{L_t}{Y_t}$ is the loans-to-GDP ratio. The deviation from the steady-state level, $\frac{L}{Y}$, rep-

[25]These variable rate mortgages have a fixed margin above the ECB base rate. Therefore, movements in the lending rate of these mortgages are outside of the banks control. Given the exogenity of euro area nominal interest rate movements to the Irish economy, banks are therefore limited in their ability to use lending rates to respond to economic developments.

[26]We conducted simulations in which the importance of the non-price bank lending channel varied. As expected, when it is turned off banks recapitalised much faster following a larger increase in lending spreads. When banks cannot adjust at all, banks recapitalise much more slowly. The results are detailed in Appendix C.

[27]When the minimum capital requirement is set as a time-varying target, Equation (48) replaces $g_t = g_{min}$ in the banks' maximisation problem in Equation (41) and corresponding first order conditions.

resents a measure of credit expansion (see Angelini *et al.*, 2014). The two parameters driving the dynamic response of this rule are ϕ_{g1}, which mimics the strength of policy inertia, and ϕ_{g2}, which measures the weight of the response to a credit expansion. Therefore, setting ϕ_{g1} to a higher value will emphasise caution in changing the regulatory capital requirement. Meanwhile, setting ϕ_{g2} to a higher value will allow for a more aggressive policy response to credit expansions and contractions. Banks may want to keep an additional buffer over and above this minimum regulatory capital g_{min}, without going beyond g_{max}, which is the capital required after the full legislated countercyclical capital buffer available to financial regulators has been utilised. Macroprudential policy can discipline bankers and penalise banks for maintaining an insufficient equity buffer, either by setting a lower reference level for the loan-to-equity ratio or by increasing the penalty in the case of deviations from the regulatory level.

2.5 Rest of the world and closing conditions

The domestic interest rate R_t is assumed to be tied to the euro area interest rate, $R_t^\star$, through an uncovered interest parity (UIP) condition:

$$R_t = R_t^\star \frac{\mathbb{E}_t S_{t+1}}{S_t} + \theta^B \left(\log \frac{B_t}{P_t} - \log \frac{B}{P} \right). \tag{49}$$

where the term $\theta^B(\bullet)$ is a debt elastic risk premium used to close the model, as in Schmitt-Grohe and Uribe (2003), and θ^B is a parameter governing how quickly debt returns to its steady-state level $\frac{B}{P}$. Furthermore, $R_t^\star$ can be subject to exogenous shocks U_t^F, described by the following autoregressive process:

$$\log U_t^F = \rho^{U^F} \log U_{t-1}^F + \epsilon_t^{U^F}. \tag{50}$$

We do not formally differentiate between domestic and foreign deposits. In the steady state, the domestic and foreign deposit (*i.e.* policy) rates are equal. As these interest rates represent the banks' cost of (deposit) liabilities, banks have no preference between them. However, if there is a shock to interest rates, the presence of a debt elastic risk premia can cause a gap between the domestic and foreign cost of liabilities to develop. This will alter banks' preferences; they will adjust the composition of their balance sheets accordingly.[28] The balance of payments equation for the country as a whole is obtained by combining the households' budget constraint with the definition of banks' and firms' profits:

$$B_t = B_{t-1} - R_{t-1} - (P_t^X X_t - P_t^M M_t) + \left(R_{t-1}^C\right) L_{t-1} \nu \tilde{J}_t \tag{51}$$

where the term $\left(R_{t-1}^C\right) L_{t-1} \nu \tilde{J}_t$ measures the total cost of loan defaults, at the lending rate banks can feasibly charge, with defaults assumed to be social losses.[29] The final consumption goods C_t and investment goods I_t are an aggregate of locally-produced

[28] See Appendix B for a simulation assessing this transmission channel.

[29] Alternatively, the cost of bank losses could be borne by the government or some other agent. Future extensions of the model will explore these other channels.

non-tradables and imports, bundled in fixed proportions:[30]

$$C_t = \omega^C C_t^M + \left(1 - \omega^C\right) C_t^N \tag{52}$$

$$I_t = \omega^I I_t^M + \left(1 - \omega^I\right) I_t^N \tag{53}$$

where ω^C and ω^I are the share of imports in final consumption and investment goods respectively. Real prices of the consumption and investment goods are derived by imposing the following conditions:

$$P_t C_t = P_t^N C_t^N + P_t^M C_t^M \tag{54}$$

$$P_t^I I_t = P_t^N I_t^N + P_t^M I_t^M. \tag{55}$$

In equilibrium, the final goods markets clear when demand from households and the foreign economy is matched by the production of final goods firms. The bond market is in equilibrium when the positions of the export and importing firms equals the households' choice of bond holdings (*i.e.* a trade surplus is necessary to pay down borrowings from abroad). The following equations represent the clearing conditions for the final non-tradable good, import, labour and capital markets respectively:

$$Y_t^N = C_t^N + I_t^N + G_t \tag{56}$$

$$M_t = C_t^M + I_t^M + X_t^M \tag{57}$$

$$N_t = N_t^N + N_t^X \tag{58}$$

$$K_t = K_t^N + \overline{K_t^X} \tag{59}$$

where capital in the export sector is fixed. Given that all households choose identical allocations in equilibrium, the aggregate quantity is expressed in domestic per-capita terms. The economy's aggregate resource constraint is therefore:

$$Y_t = P_t C_t + P_t^I I_t + P_t^N G_t + P_t^X X_t - \left(P_t^M C_t^M + P_t^M I_t^M + P_t^{M\star} S_t X_t^M\right). \tag{60}$$

3 Calibration

The model is calibrated to match the underlying structure of the Irish economy, with the values of steady-state ratios and parameters provided in Tables 1-2. We assume that the economy starts out in a steady state with zero consumption growth. Thus, the interest rate must equal the rate of time preference. As the calibration of the real economy follows that described in Clancy and Merola (2016), we focus instead on the calibration of the banking sector.

The minimum capital adequacy ratio is fixed at 8%, in line with the proposals in

[30] Kee *et al.* (2008) provide empirical evidence on the relatively low degree of substitution between imported and domestically produced goods in Ireland.

Basel III. As detailed in the previous section, banks optimally choose to hold an additional buffer on top of this. For instance, if the minimum capital requirement g_{min} is a constant and it is set equal to 8%, then banks can set their optimal amount of capital g_{max} up to 10.5%, and the capital buffer is 2.5%. In the baseline scenario, we assume that the macroprudential authority fixes a minimum capital requirement which does not respond to a credit expansion (*i.e.* $\phi_{g1} = \phi_{g2} = 0$). However, in the simulation exercises we also consider the implications of a pro-active macroprudential rule (*i.e.* $\phi_{g1} = 0.8$ and $\phi_{g2} = 1.2$) imposing a countercyclical minimum capital requirement.[31] A fixed proportion of loans $\varkappa$ default in each period, irrespective of developments in the real economy. This share is calibrated to be 0.5%. The LGD, ν, is set at 0.5 (*i.e.* only 50% of the value of a defaulted loan can be recovered by the bank).

[31] Given the importance of these parameters to our analysis, we conduct a sensitivity analysis to assess the effect of both a more cautious and more aggressive approach to changing the minimum capital requirement. These results are reported in Appendix C.

TABLE 1. Calibrated parameters (quarterly frequency)

Households		
Discount Factor	β	0.98
Frisch elasticity of labour supply	η	0.50
Consumption habit persistence	χ	0.65
Wage markup	μ^W	0.10
Weight on housing in P^D	ω^D	0.20
Weight on consumption and investment goods in deposits for transactions	γ^C	0.20
Weight on housing in deposits for transactions	γ^H	0.05
Degree of debt convergence to the steady state	θ^B	0.10
Elasticity of deposits	ι	5
Preference on housing	θ	0.5
Preference on deposits	ζ	0.007
Depreciation rate	δ	0.025
Firms		
Export sector share of labour	γ^X	0.40
Non-tradable sector share of labour	γ^N	0.70
Import content of exports	α	0.50
Bias towards imported consumption goods	ω^C	0.29
Bias towards imported investment goods	ω^I	0.48
Non-tradable goods price markup	μ^N	0.10
Imported goods price markup	μ^M	0.10
Banks		
Discount factor	$\hat{\beta}$	0.92
Loss given default	ν	0.50
Idiosyncratic uncertainty	σ_a	0.05
Aggregate uncertainty	σ_b	0.30
Degree of credit rationing	$1-\tau$	0.50
Loan-to-value ratio	LTV	0.74
Loan-to-income ratio	LTV	2.75
Weight on housing wealth in the default	ϕ	0.20
Minimum capital adequacy ratio	$\overline{g}_{min}$	0.08
Maximum capital adequacy ratio	$\overline{g}_{max}$	0.105
"Fixed" rate of default	$\varkappa$	0.005
Adjustment costs		
Imports	ξ^M	20
Investment	ξ^I	10
Non-tradables	ξ^N	50
Wages	ξ^W	50
Exports	ξ^X	3
Equity	ξ^E	0
Deposits	ξ^D	0.5

TABLE 2. Steady-state ratios, in nominal terms and as share of GDP (if not differently specified)

Domestic Demand	
Private Consumption	75%
Private Investment	11%
Public Expenditure	13%
Trade Balance	1%
Trade	
Exports (total)	65%
Imports (total)	64%
Imports of intermediate goods	32%
Imports of consumption goods	26%
Imports of investment goods	6%
Production	
Tradables	64%
Non-tradables	36%
Labour share	54%
Non-tradable sector labour input (as share of total labour)	76%
Tradable sector labour input (as share of total labour)	24%
Financial (annual)	
Housing stock	200%
Loans	147%
Deposits	87%
Net foreign liabilities	46%

Idiosyncratic and systemic risks are treated parametrically and are set equal to 0.05 and 0.10 respectively. The loan-to-value ratio is determined endogenously and it is equal to 74%. This value is consistent with the increasing proportion of loan-to-value ratios on mortgage loans in Ireland between 2004 and 2008 (see Honohan, 2009; Kennedy and McIndoe Calder, 2011). The loan-to-income ratio is 2.75 in steady state. If a negative shock erodes banks' capital, they must recapitalise to meet the minimum regulatory requirements. In order to do so, banks are faced with the choice of either increasing the lending spread or restricting the supply of new loans. The degree to which banks can pass on desired changes in the lending spread, $1-\tau$, is treated as a parameter and set at 0.5 (*i.e.* banks can pass on 50% of their desired lending spread increases). Using detailed loan-level data gathered by the Central Bank of Ireland as part of the 2011 bank stress tests, Kennedy and McIndoe-Calder (2011) find that 54% of the oustanding mortgage balance is made up of loans subject to tracker interest rates. Therefore our calibration is consistent with the current loan portfolio of Irish banks, and accurately represents the constrained ability of these banks to raise lending rates by the desired amount.

In order to provide values for parameters for which there is no empirical evidence, we calibrate them consistently with the steady-state ratios and the interest rate margins observed in Irish data. While the balance sheet ratios can be calculated from official statistics, the interest margins are purely illustrative. They should therefore not be taken as an attempt to calibrate the average lending rate spread charged by Irish banks. The interest rate on deposits, which is equal to the policy rate, is set at 3%. We calibrate the markup on the deposit rate, designed to compensate the banks' high leverage risk, at 2%. Therefore, the marginal cost of lending $\tilde{R}_t$, which indicates the minimum return on loans necessary to ensure capital requirements are met, is set at 5%. The retail lending rate, which consumers internalise in their loan demand decisions, is calibrated to be 8%. All interest rates are quoted in annual terms. The weights of housing and deposits in the utility function, θ and ζ, are calculated using the annual ratio of housing stock-to-GDP (200%) and deposits-to-GDP (87%) respectively. These figures are based on Quarterly Financial Accounts data from 2003 - 2012. The banks discount factor is set to be consistent with an equity-to-loans ratio of $e = 10\%$. This is the inverse of the $\frac{L_t}{E_t}$ term in the banks' maximisation problem.

4 Simulation exercises

We next present the results from various simulations, designed to highlight the macro-financial feedback loops and policy analysis capabilities of the model.[32] In most DSGE models with financial/banking sectors, recessions are the result of large financial shocks, that either push up the cost of loans or decrease the demand for credit (*e.g.* Gerali *et al.*, 2010). These adverse financial-type shocks might be amplified and propagated by financial frictions (*e.g.* Gertler and Karadi, 2011; Jermann and Quadrini, 2012). On the contrary, in the modelling framework adopted here, credit crunches are not necessarily triggered by financial-type shocks.[33] We simulate the transmission of a shock to housing demand (via preferences) and assess the channels through which this impulse spreads through the banking sector and the real economy. The importance of housing preference shocks has been verified by studies for the United States (Iacoviello and Neri, 2010), the euro area (Darracq-Paries and Notarpietro, 2008) and Spain (Aspachs-Bracons and Rabanal, 2010). Using a DSGE model with a housing sector, Gareis and Mayer (2013) find that housing preference shocks explain the vast majority of the recent Irish house price boom. De Bandt *et al.* (2010) provide empirical evidence that fundamentals do not explain Irish house price movements, and therefore demand rather than supply factors are more relevant. McCarthy and McQuinn (2013) provide empirical evidence (from a combination of regulatory and survey micro-data) that house price expectations played an important role in the Irish housing boom and bust. Kennedy and McQuinn (2012) show that expectations for house price decreases matter during a downturn in Ireland. Kenny (1998) shows that house price expectations were an important channel in Ireland even before the introduction of the euro. We therefore feel that our choice of shock is appropriate.

[32] All simulations are deterministic, and performed using the IRIS toolbox add-on to Matlab (http://iristoolbox.codeplex.com/).

[33] In this respect, several works have pointed out that shocks other than financial shocks may be responsible for financial distress. For instance, Boissay *et al.* (2013) show that credit booms driven by a sequence of positive supply shocks are the primary cause of systemic banking crises. Mendicino and Punzi (2014) show that external shocks are an important driver in the current account deficits associated with sharp increases in house prices and household debt. Although our model supports the idea that credit crunches are not necessarily triggered by financial-type shocks, we also assess the transmission channels of financial shocks by simulating the impact of a reduction in the cost of banks' foreign liabilities (*i.e.* capital inflows). The results are detailed in Appendix B.

The literature distinguishes between two phases of house price bubbles. During the boom, a large and increasing fraction of households receive positive signals about future fundamentals and believe that it is a good time to buy a house. During the bust, agents receive increasingly negative signals and change their expectations (*i.e.* Piazzesi and Schneider, 2009; Burnside *et al.*, 2015). Therefore, we also explicitly consider the role that expectations for future house prices play in the endogenous accumulation of credit risk.[34] Lambertini *et al.* (2013b) provide empirical evidence for the importance of expectations over house prices for explaining the path of macroeconomic variables during house price booms. By setting a shock that agents in the model expect to occur in the future, we can analyse the response of these agents in anticipation of these future changes. We can also assess the reaction of agents when the anticipated shock fails to materialise (*i.e.* the expectations were over-optimistic). By doing so, we distinguish between "good booms", based on solid economic fundamentals, and "bad booms" driven by irrational expectations or unsustainable changes in the economy.[35]

We then compare the dynamic reaction of our model to this shock to those found in the theoretical and empirical literature. The benchmarking of our results against the empirical evidence is a particularly important component in assessing the model's suitability for policy analysis. Finally, we consider the role that countercyclical macro-prudential policy can play in mitigating the build-up of credit risk in periods of "bad booms". We compare the performance of a time-varying minimum capital requirement to the baseline case where this target is constant, and assess whether it can limit the impact of negative shocks to the financial system and the real economy. We also assess whether allowing the regulatory authority greater scope to increase capital requirements is of further benefit.

4.1 Real economy shock: housing preferences

We set a positive 5% shock to housing preferences U_t^H, expected to occur after three years (*i.e.* at $t = 13$). This shock is expected to be temporary but persistent. We consider two scenarios: one in which the increase in demand occurs as expected; the other in which these expectations are unfulfilled, and when the shock was supposed to occur housing preferences remain unchanged. The results of these simulations are reported in Figure 2.

We initially focus on the period in which the expectations are still valid (*i.e.* they are still assumed by agents to be correct). This is represented by the shaded area of the plot. There is an immediate rise in house prices, as consumers want to purchase these assets before the expected increase in demand. With the supply of housing fixed by assumption, demand side pressure leads to a large increase in house prices. As the threshold for non-performing loans is based partly on house prices, banks respond by

[34] There is a large literature suggesting that changes in expectations may play an important role in driving economic fluctuations. For example, Beaudry and Portier (2006) provide empirical evidence of the importance of this channel. Angeletos and La'O (2013) use a unique-equilibrium, rational-expectations macroeconomic model to demonstrate that the business cycle may be driven by shifts in expectations, without shifts in underlying preferences and technologies. Jaimovich and Rebelo (2008) show that news is also important for the business cycles of open economies. Based on survey data, Leduc and Sill (2013) find that in the United States changes in expected future economic activity is an important driver of economic fluctuations. The pure perception that good times are ahead leads to a significant rise in economic activity.

[35] See Dell'Ariccia *et al.* (2012) for a comprehensive discussion.

decreasing their lending spreads to cover the (erroneously) expected lower default risk. The perceived decrease in default risk also manifests itself in an increase in lending, with the supply of loans increasing to keep pace with demand. The increased leverage on the banks' balance sheet means that they are now eroding some of their capital buffer. As they are now closer to the regulatory minimum capital adequacy ratio, banks increase the regulatory spread to cover the expected marginal costs of breaching this requirement. However, this increase is minimal in comparison to the decrease in the default risk spread, and thus overall lending rates decrease.

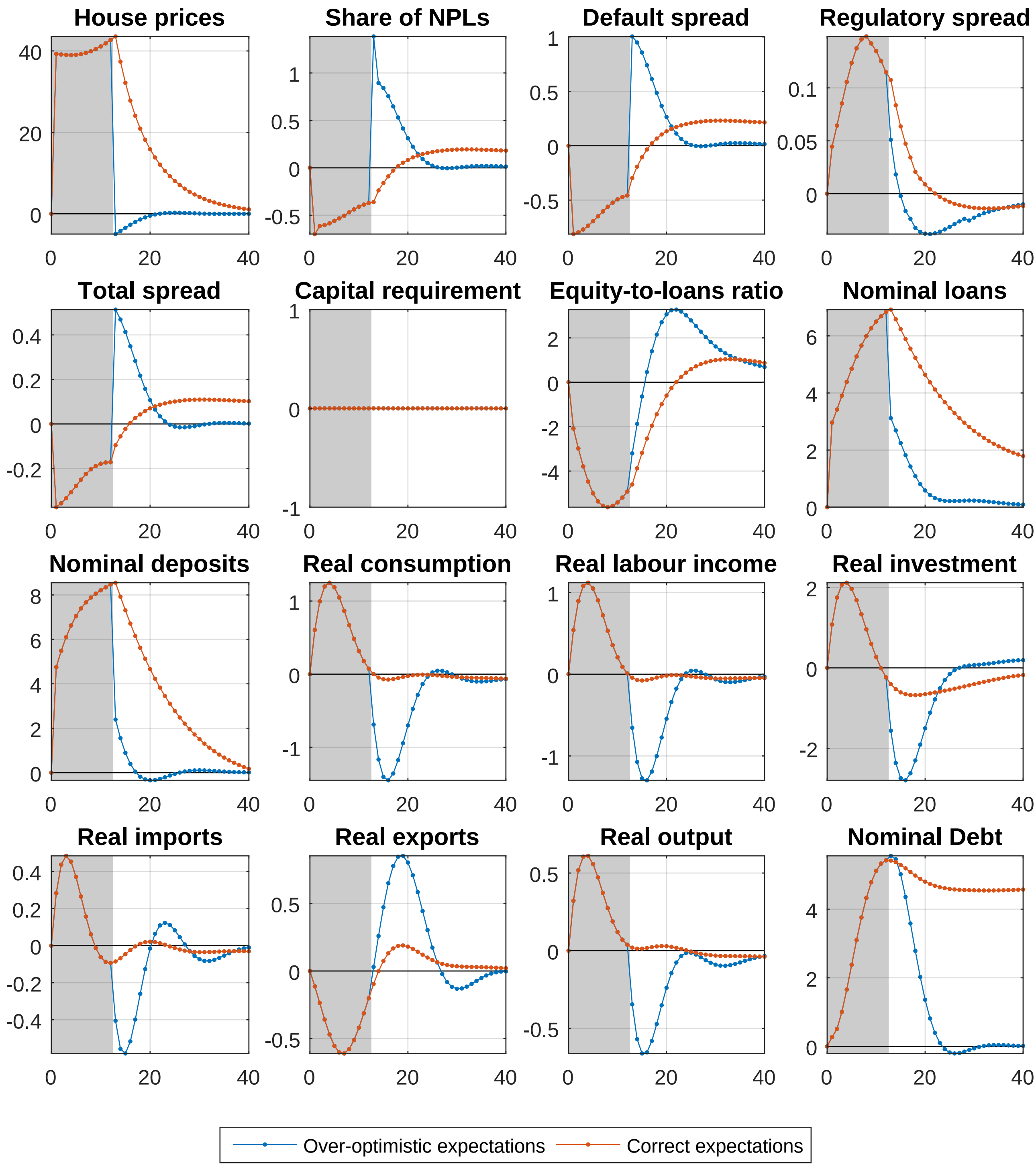
Higher asset (house) prices and cheaper lending rates combine to loosen household's budget constraints, with debt levels increasing after taking on a greater amount of loans. There is a consequent increase in domestic demand, with output expanding to meet this demand. The higher demand for labour leads to an increase in both the wage rate and in hours worked. This increase in labour income further increases the default threshold, making loans even more likely to be repaid in full. Thus, there is an endogenous build-up of credit with strong feedback loops between the financial sector and the real economy. Finally, exports decrease as external competitiveness is affected by the increase in factor input prices, driven by higher demand for these resources from the non-tradable sector.

We next focus on the period after the shock has materialised. We first describe what happens when the expectations for housing demand have proven to be correct (orange line scenario). House prices follow a smooth adjustment path back to their steady-state level. The share of NPLs and the spread covering the default risk converge to a permanently higher level than the initial steady state. This is because the higher level of loans provided by the banks requires a permanently higher spread to cover the increased possibility of default. As the banks have reduced their capital buffer to extend these loans, the spread covering the risk of failing to meet the regulatory capital requirements remains elevated. The continued easing of credit conditions means that consumption, output and imports can smoothly return to their steady-state levels. However, investment remains below its steady state for a prolonged period as households continue to bring forward consumption in light of favourable economic conditions. Due to the large accumulation of debt levels, exports need to remain above their steady-state level in order to cover the increased foreign debt repayments.

Conversely, when the expectations concerning housing prove to be over-optimistic (blue line scenario), house prices are over-valued and fall accordingly. This lowers the threshold for non-performance of loans and causes banks to increase their spread covering default risk. The resulting increase in lending rates reduces demand for loans, with domestic demand also suffering as households begin to deleverage the large amount of debt accumulated during the boom period. Therefore, the transmission mechanism from the financial sector to the real sector is via two channels. On the one side, households start deleveraging and reallocating their savings. On the other side, banks tighten credit standards and start recapitalising.

The decrease in output lowers the demand for labour, which reduces the wage income and puts further pressure on non-performing loans. This feedback loop between the real economy and the financial sector reinforces the bank's decision to increase lending rates and results in a persistent downturn. The reduction in wages, however, boosts the external competitiveness of export sector firms. Accordingly, these firms increase their output and the resulting trade surplus enables the paying down of foreign debt.

FIGURE 2. **Housing preference shock**



Notes: Impulse responses to a 5 percent increase in housing preferences, expected at time $t = 13$. Under the first scenario (orange line), the expectations are correct and the shock materialises. Under the second scenario (blue line), expectations turn out to be over-optimistic and the shock never materialises. All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

4.2 Comparison with literature

Our results resemble the balance sheet and lending channels discussed in Brunnermeier (2009).[36] In the balance sheet channel, a drop in asset prices erodes the capital of financial institutions, which respond by tightening lending standards and lending margins. In the lending channel, banks are concerned about their future access to capital markets and hence decide to hoard funds, although the creditworthiness of borrowers might not have changed. Our simulations show that macroprudential policies which require banks to hold a fixed minimum capital adequacy ratio can exacerbate this hoarding, because banks build up new equity only when forced during recession periods.[37] In this respect, therefore, our model reproduces the countercyclical equity observed in the model of Adrian and Boyarchenko (2012). This matches the empirical evidence provided by Kelly *et al.* (2011) of the statistical significance of the relationship between credit and output growth in Ireland. These patterns contrast with the assumptions in Brunnermeier and Sannikov (2014) and He and Krishnamurthy (2012, 2013), which feature procyclical equity.

The negative association between higher economic activity and external competitiveness is a common feature of empirical studies of the Irish economy (see, for example, Bergin *et al.*, 2013; Bermingham and Conefrey, 2014). In fact, Podstawski (2014) provides empirical evidence that this price competitiveness channel is the most important driver of Irish current account deficits.[38] The model dynamics, both in terms of direction and magnitude, are in accordance with the empirical literature. Hubrich *et al.* (2013), using data up to and including part of the current crisis (their last data observation is the final quarter of 2010), find that a negative house price shock of approximately 30% persistently lowers Irish GDP by over 1%. Duffy *et al.* (2005) find that a positive house price shock of approximately 10% boosts output (measured by GNP) by 0.5% and the average real wage by 0.4%. Finally, Bergin *et al.* (2013) find that a 10% fall in house prices leads to a reduction in output, consumption and investment by 0.5%, 1.3% and 4.3% respectively, and an increase in the current account of 0.6%. The relative magnitudes of our impulse responses correspond to the empirical literature, and therefore we consider our model well tailored for the Irish economy and useful for counterfactual policy experiments.

4.3 Countercyclical capital rules

Due to the nature of their operations, banks often impose tighter financial conditions precisely at the time when the real economy would benefit from a more countercyclical lending policy (Borio, 2012). The principle of countercyclical lending implemented through a time-varying capital target is to address the so-called procyclicality of the financial system and the real economy, which can cause financial instability. More countercyclical macroprudential policies could limit procyclicality by encouraging the accumulation of buffers and restraining the build-up of credit during an expansionary

[36] Our representative bank framework means that we abstract from the other two channels discussed in Brunnermeier (2009): runs on financial institutions and network effects.

[37] In the next sub-section, we assess if countercyclical capital requirements can reduce banks' incentives to hoard funds when it is most damaging to the economy.

[38] Honohan and Leddin (2006) also document the loss of competitiveness during the economic boom. They show that, without positive migratory flows, this problem would have had a much more counteracting effect on economic growth.

phase. These buffers could then be drawn down, although still adhering to the minimum regulatory requirement, as harder times materialise and financial strains threaten to emerge.

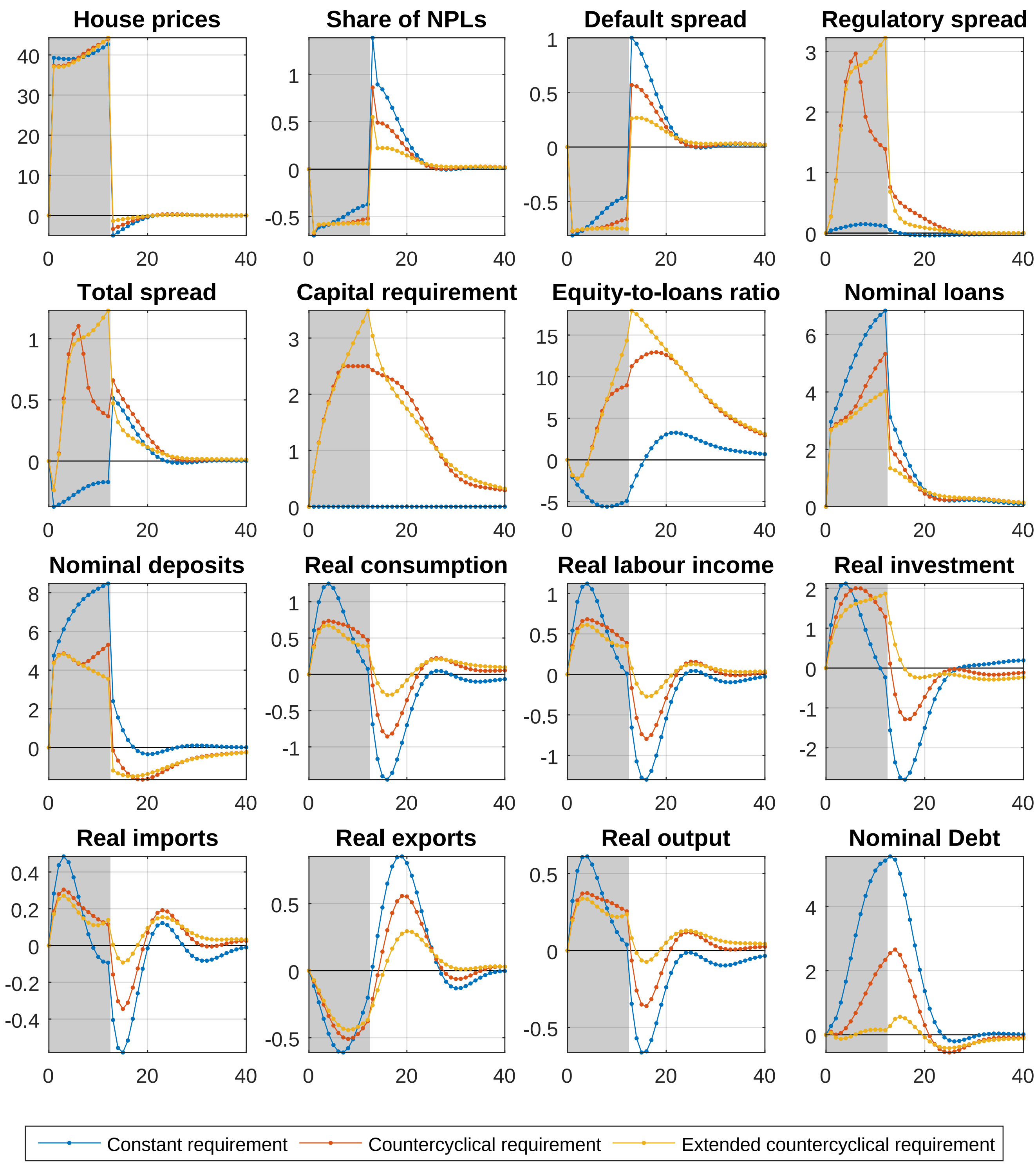
Unfortunately, distinguishing between "good booms" and "bad booms" is extremely challenging. Policy-makers are often faced with a difficult trade-off between containing tail risk in the financial system and facilitating the financial sector's contribution to economic growth.[39] Macroprudential tools therefore need to be flexible, and permit both action and caution. We analyse the effect of a countercyclical capital requirement and compare the impact it has to that of the baseline simulation in which the capital requirement was constant. To implement this aspect of the model we allow the capital requirement to be time-varying (*i.e.* g_t rather than g_{min}), as described in Equation 48. The results are detailed in Figure 3.

Up to now, we have assumed that the minimum capital requirement has been fixed (8%) and that banks keep a buffer over and above this to prevent against any regulatory capital breach (and ensuing penalty). Recently introduced legislation in the euro area allows the regulatory authorities in individual member states to increase the minimum capital requirement by up to 2.5%. This extra capital is used to develop what is described as a "conservation buffer". With a pro-active macroprudential rule, we now discuss the effects of increasing the minimum capital requirement. This scenario is represented by the red line in Figure 3. We see that pro-active capital regulation reacts to the house price boom by raising the capital requirement. The increased possibility of breaching this more stringent target forces banks to increase the spread used to cover this over-lending risk, $\tilde{R}_t - R_t$, to a much higher level than in the case of constant capital requirement. Higher lending rates reduce the demand for loans relative to the scenario assuming a constant capital requirement, and thus help to limit the accumulation of debt and the boom in domestic demand and output. Higher lending rates also make lending more profitable, and allow banks to build up their capital buffers. Therefore, when the expectations over housing demand prove to be over-optimistic, the financial sector is much better placed to handle the shock.

Although non-performing loans – and thus credit risk – increase, they do so by less than in the simulation assuming a constant capital requirement. This is because a lower amount of loans – which are now riskier as lower house prices and reduced wage income make default more likely – were extended during the boom phase. Banks do not need to recapitalise, as the extra spread charged to cover the increase costs of regulation have allowed them to develop a large buffer. As a result, the persistence of the crisis is much lower when countercyclical capital regulation is used, as banks balance sheets are much healthier and can therefore help support the recovery. We therefore confirm the findings of Martin and Philippon (2014) that macroprudential policy is helpful in Ireland. Interestingly, our results now replicate the phenomena of procyclical equity observed in Brunnermeier and Sannikov (2014) and He and Krishnamurthy (2012, 2013) and therefore differ from those observed under the assumption of a fixed minimum capital requirement. This procyclicality occurs as banks build up capital buffers during booms, rather than being forced by stress tests (for example) to issue new equity during recessions. This suggests that countercyclical capital rules have the desired properties of encouraging banks to build buffers during booms, while being flexible enough to allow banks to support economic activity during a downturn.

[39]See Popov and Smets (2011), and the references therein, for a discussion.

FIGURE 3. **Countercyclical capital regulation**



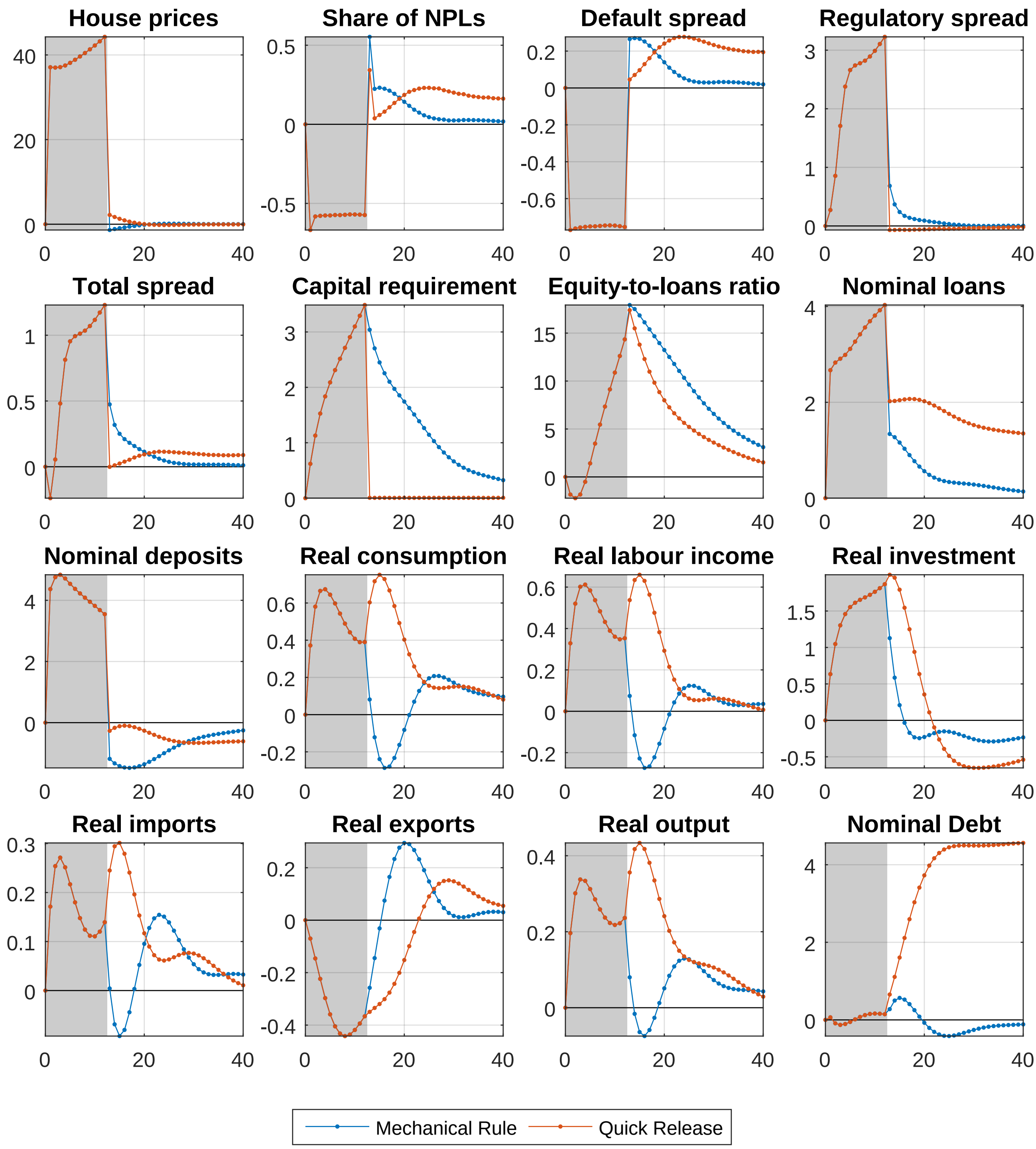
Notes: Impulse responses to a 5 percent increase in housing preferences, expected at time $t = 13$, which however never materialises. Under the first scenario (blue line), regulatory capital is fixed at 8%. Under the second scenario (red line), the macroprudential policy is allowed to respond countercyclically to the credit cycle ($\phi_{g1} = 0.8$ and $\phi_{g2} = 1.2$) with an upper limit $\overline{g}_{max} = 10.5\%$. Under the third scenario (orange line), macroprudential policies are pro-active ($\phi_{g1} = 0.8$ and $\phi_{g2} = 1.2$) and the minimum capital requirement can be raised to $\overline{g}_{max} = 12\%$. All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

Although it is possible in principle to extend minimum capital requirements beyond this amount, the fact that macroprudential policy is a shared competency between euro area national central banks and the ECB means the need for external approval may discourage its potential use. At a very minimum, it takes the decision out of the full control of domestic authorities. In the previous simulation, represented by the red line in Figure 3, the upper bound of the minimum capital requirement is reached very quickly, after which the regulatory authority has no ability to act further in this regard. We next assess whether the use of a larger range for the countercyclical capital requirement (with the lower bound always fixed by Basel III) is of value in terms of minimising the output loss from boom and bust cycles. In this simulation, the results of which are described by the orange line in Figure 3, we allow the minimum capital requirement to be increased by up to 4% (*i.e.* the minimum capital requirement can vary between 8% and 12% instead of being capped at 10.5% as in the other scenario represented by the green line).

We can see that allowing the minimum capital requirement to be raised even further during the boom phase allows bank to build up extra buffers and helps the economy to recover faster during the subsequent downturn. In response to rapidly increasing house prices and credit growth, the regulatory authority raises the minimum capital requirement above the one permitted by current legislation. This additional capital requirement forces banks to raise the regulatory spread even higher, and for a more extended period, than in a case where the countercyclical capital requirements are limited to a 2.5% increase. The higher profits earned on loans allow the bank to build up a larger capital buffer. The increased price on these loans also limits the increase in demand for loans, and so diminishes the boom in the real economy. During the downturn, the share of non-performing loans is even lower than in the baseline. The reduced amount of losses on the banks' loan portfolio allows them to smooth the reduction in credit to the real economy. As a result, the impact of the house price crash is much less damaging, with the downturn also being far less persistent in this scenario.

A notable feature of our results is the gradual reduction in capital requirements following the onset of the economic downturn (*i.e.* the release phase). This is due to the mechanical nature of the countercyclical rule. Drehmann *et al.* (2011) show that although the credit gap is the best indicator of the need to accumulate additional capital, it is not as effective during the release phase. This may dampen the overall effectiveness of the policy rule. We therefore examine the effect of immediately reducing the minimum capital requirement when a crisis emerges. We do so by implementing a negative shock to g_{max} in order to reduce it to the regulatory minimum g_{min} in tandem with the shock to expectations that causes the economic downturn. We compare this to the case where capital regulation moves in accordance with the rule. The results are presented in Figure 4.

FIGURE 4. **Rules versus discretion**



Notes: Impulse responses to a 5 percent increase in housing preferences, expected at time $t = 13$, which however never materialises. Under the first scenario (blue line), the minimum capital requirement is reduced mechanically in line with equation 48. Under the second scenario (orange line), the policy authorities use their discretion to pursue a more aggressive reduction in the minimum capital requirement during the release phase. All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

We find that this more aggressive policy stance during the release phase prevents the economy from entering a recessionary period. The buffers accumulated by banks during the boom period facilitate the continued extension of loans to the real economy. As banks are well capitalised, they also do not need to charge higher lending spreads, and so these loans are affordable for consumers. This allows domestic demand to remain high and prevent a contraction in output. This comes at the cost of a higher debt level, with exports increasing to pay down the economy's net foreign liabilities. Of course, in reality policy-makers may not be able to move so aggressively during the release phase, and therefore this simulation represents a best case scenario. However, even if the buffer was not released for a quarter or two, the decisive action to fully release it provides real benefits to the economy.

5 Conclusions

The Great Recession demonstrated that a mixture of microprudential and macroeconomic policies proved insufficient to ensure financial stability. In the aftermath, many international institutions such as the BIS, the IMF and the ECB have espoused the potential of macroprudential policies to help in this regard. Macroprudential policies are seen as a complement to more traditional stabilisation instruments, such as nominal interest and exchange rates. However, there are a large cohort of SOEs for which such policy tools are not available. This may be due to their membership of a monetary union, or because they peg their exchange rate to a larger economy. In such a case, diminishing alternative policy options have the effect of placing an even greater burden on macroprudential policy to ensure financial stability.

We develop a DSGE model to analyse macroprudential policy in such economies, focusing on the usefulness of countercyclical capital buffers. With the introduction of this instrument across the euro area at the beginning of 2016, we use our model to examine its ability to promote financial stability. We demonstrate how expectations of future favourable events, such as a long-lasting increase in house prices, may accelerate credit growth and potentially result in a more vulnerable economy susceptible to downward revisions to the original expectations. The model is therefore able to replicate the stylised facts of a classic financial crisis, the recent Irish housing bust. As such, it is a suitable tool for policy analysis. We then assess the ability of a pro-active macroprudential rule, responding to credit growth, to help smoothe economic fluctuations. We find that forcing banks to build capital buffers during an economic upswing helps limit the damage from any ensuing downturn. In terms of additional policy advice, we find that bestowing even greater flexibility on regulators to move against the credit cycle has positive benefits. We also find that more aggressive action during the release phase can greater boost the economy's ability to absorb a negative shock.

Although already suitable for policy analysis, there is still room for further extensions and improvements to our model. When analysing the effects of macroprudential tools in mitigating credit and output volatility, we focus exclusively on capital target instruments (*i.e.* countercyclical macroprudential rules and capital buffers). Therefore, the next step will be to also analyse the effects of borrowing target instruments (*i.e.* caps on loan-to-value and loan-to-income ratios). Another step forward would imply the analysis of the legacy costs of a credit boom and bust. Banks' balance sheets may have a large portfolio of non-performing loans for many years following lax lending standards during an economic upturn. However, at present, all loans are modelled as lasting only one-period. This enables banks to clean up their balance sheet much more quickly after a crash, and thus help support a recovery. However, computational limitations imply that this problem is wide-spread in the literature, and not unique to our study. Utility-based welfare analysis could also be undertaken to assess which policies produce the best outcomes from a societal perspective. Lastly, further research should address the implications of banks' losses on public finances, and the interaction between fiscal and macroprudential policy.

6 Acknowledgements

We acknowledge the significant contribution of Jaromír Beneš (IMF) to this work. We also thank Larry Christiano, Marco Del Negro, Aitor Erce, Gabriel Fagan, Refet Gürkaynak, Alejandro Justiniano, Luisa Lambertini, Matija Lozej, Luca Onorante, Gerard O'Reilly and Ansgar Rannenberg for valuable comments and discussion, as well as participants at two IMF Economic Modelling Unit Workshops on Modelling Macrofinancial Stability and Macroprudential Policy in Washington D.C., the Annual Conference of the Irish Economic Association 2014, the IFABS 2014 Conference in Lisbon, the Conference on Advances in Applied Macro-Finance and Forecasting in Istanbul, the 2^{nd} Macro Banking and Finance Workshop at the University of Rome Tor Vergata, the 8^{th} International Risk Management Conference in Luxembourg, the 11^{th} Dynare Conference in Brussels, the CFE-CMStatistics Conference in London and seminar attendees at the Central Bank of Ireland and the European Stability Mechanism. However, all errors remain our own.

References

Acharya, V., 2009. A Theory of Systemic Risk and Design of Prudential Bank Regulation. Journal of Financial Stability 5, 224-255.

Adrian, T., Boyarchenko, N., 2012. Intermediary Leverage Cycles and Financial Stability. FRBNY Staff Report 567.

Agénor, P.-R., Alper, K., Pereira da Silva, L., 2013. Capital Regulation, Monetary Policy, and Financial Stability. International Journal of Central Banking 9, 19-238.

Angeletos, G-M., La'O., J., 2013. Sentiments. Econometrica 81, 739-779.

Angelini, P., Neri, S., Panetta, F., 2014. The Interaction Between Capital Requirements and Monetary Policy. Journal of Money, Credit and Banking 46, 1073-1112.

Angeloni, I., Faia, E., 2013. Capital Regulation and Monetary Policy with Fragile Banks. Journal of Monetary Economics 60, 311-324.

Arestis, P., Gonzalez, A.R., 2013. Modeling the housing market in OECD countries. Levy Economics Institute Working Paper 764.

Arnold, L.G., Reeder, J., Trepl, S., 2014. Single-Name Credit Risk, Portfolio Risk, and Credit Rationing. Economica 81, 311-328.

Aspachs-Bracons, O., Rabanal, P., 2010. The Drivers of Housing Cycles in Spain. SERIEs 1, 101-130.

Aspachs-Bracons, O., Rabanal, P., 2011. The Effects of Housing Prices and Monetary Policy in a Currency Union. International Journal of Central Banking 7, 225-274.

Bailliu, J., Meh, C., Zhang, Y., 2012. Macroprudential Rules and Monetary Policy when Financial Frictions Matter. Bank of Canada Working Paper 2012-6.

Bank of England., 2014. Money Creation in The Modern Economy. Quarterly Bulletin 2014/Q1.

Beau, D., Clerc, L., Mojon, B., 2012. Macro-Prudential Policy and the Conduct of Monetary Policy. Banque de France Working Paper 390.

Beaudry, P., Portier, F., 2006. Stock Prices, News, and Economic Fluctuations. American Economic Review 96, 1293-1307.

Beneš, J., Kumhof, M., 2011. Risky Bank Lending and Countercyclical Capital Buffers. Journal of Economic Dynamics and Control 58, 58-80.

Beneš, J., Kumhof, M., Laxton, D., 2014a. Financial Crises in DSGE Models: Selected Applications of MAPMOD. IMF Working Paper WP/14/56.

Beneš, J., Kumhof, M., Laxton, D., 2014b. Financial Crises in DSGE Models: A Prototype Model. IMF Working Paper WP/14/57.

Bergin, A., Conefrey, T., FitzGerald, J., Kearney, I., Žnuderl, N., 2013. The HERMES-13 Macroeconomic Model of the Irish Economy. ESRI Working Paper 460.

Bermingham, C., Conefrey, T., 2014. The Irish Macroeconomic Response to an External Shock with an Application to Stress Testing. Journal of Policy Modeling 36, 454-470.

Bernanke, B., Gertler, M., Gilchrist, S., 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics 1, 1341-1393.

Boissay, F., Collard, F., Smets, F., 2013. Booms and Systemic Banking Crises. ECB Working Paper 1514.

Bordo, M.D., Cavallo, A. F., Meissner, C., 2010. Sudden stops: Determinants and Output Effects in the First Era of Globalization, 1880-1913. Journal of Development Economics 91, 227-241.

Borio, C., 2012. The Financial Cycle and Macroeconomics: What Have We Learnt?. BIS Working Paper 395.

Bradley, J., Fitzgerald, J., 1988. Industrial Output and Factor Input Determination in an Econometric Model of a Small Open Economy. European Economic Review 32, 1227-1241.

Bradley, J., Fitzgerald, J., 1990. Production Structures in a Small Open Economy with Mobile and Indigenous Investment. European Economic Review 34, 364-374.

Bruno, V., Shin, H.S., 2013. Capital Flows, Cross-Border Banking and Global Liquidity. NBER Working Papers 19038.

Brunnermeier, M. K., 2009. Deciphering the Liquidity and Credit Crunch 2007-2008. Journal of Economic Perspectives 23, 77-100.

Brunnermeier, M. K., Sannikov, Y., 2014. A Macroeconomic Model with a Financial Sector. American Economic Review 104, 379-421.

Brzoza-Brzezina, M., Kolasa, M., Makarski, K., 2013. Macroprudential Policies and Imbalances in the Euro Area. National Bank of Poland Working Paper 138.

Burnside, C., Eichenbaum, M., Rebelo, S., 2015. Understanding Booms and Busts in Housing Market. Journal of Political Economy, forthcoming.

Calvo, G.A., Izquierdo, A., Mejia, L.F., 2004. On the Empirics of Sudden Stops: The Relevance of Balance-Sheet Effects. NBER Working Paper 10520.

Carlstrom, C., Fuerst, T., 1997. Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. American Economic Review 87, 893-910.

Carrasco-Gallego, J. A., Rubio, M., 2014. Macroprudential and Monetary Policies: Implications for Financial Stability and Welfare. Journal of Banking and Finance 49, 326-336.

Central Bank of Ireland., 2013. Macro-Financial Review 1.

Central Bank of Ireland., 2014. A Macro-Prudential Policy Framework for Ireland.

Christensen, I., Meh, C., Moran, K., 2011. Bank Leverage Regulation and Macroeconomic Dynamics. Bank of Canada Working Paper 2011-32.

Ciccarelli, M., Ortega, E., Valderrama, M., 2012. Heterogeneity and Cross-Country Spillovers in Macroeconomic-Financial Linkages. ECB Working Paper 1498.

Clancy, D., Merola, R., 2016. Eire Mod: A DSGE Model for Ireland. The Economic and Social Review, Vol. 47, No. 1, pp. 1-31.

Clancy, D., Cussen, M., Lydon, R., 2014. Housing Market Activity and Consumption: Macro and Micro Evidence. Central Bank of Ireland Research Technical Paper 13/RT/14.

Coates, D., Everett, M., 2013. Profiling the Cross-Border Funding of the Irish Banking System. Central Bank of Ireland Economic Letter 2013-2014.

Collard, F., Dellas, H., Diba, B., Loisel, O., 2012. Optimal Monetary and Prudential Policies. CREST Working Paper No. 2012-34, Banque de France Working Paper 413.

Conefrey, T., FitzGerald, J., 2010. Managing Housing Bubbles In Regional Economies Under EMU: Ireland And Spain. National Institute Economic Review 211, 91-108.

Darracq-Paries, M., Notarpietro, A., 2008. Monetary Policy and Housing Prices in an Estimated DSGE Model for the US and the Euro Area. ECB Working Paper 972.

Darracq-Pariès, M., Kok Sørensen, C., Rodriguez-Palenzuela, D., 2011. Macroeconomic Propagation under Different Regulatory Regimes: Evidence from an Estimated DSGE Model for the Euro Area. International Journal of Central Banking 7, 49-113.

Dell'Ariccia, G., Igan, D., Laeven, L., Tong, H., 2012. Policies for Macrofinancial Stability: Options to Deal with Credit Booms. IMF Staff Discussion Note SDN/12/06.

De Bandt, O., Barhoumi, K., Bruneau, C., 2010. The International Transmission of House Price Shocks. Banque de France Working Paper 274.

De Paoli, B., Paustian, M., 2013. Coordinating Monetary and Macroprudential Policies. FRBNY Staff Report 653.

De Walque, G., Pierrard, O., Rouabah, A., 2010. Financial (In)Stability, Supervision and Liquidity Injections: A Dynamic General Equilibrium Approach. Economic Journal 120, 1234-1261.

Disyatat, P., 2011. The Bank Lending Channel Revisited. Journal of Money, Credit and Banking 43, 711-734.

Drehmann, M., Borio, C., Tsatsaronis, K., 2011. Anchoring Counter-Cyclical Capital Buffers: The Role of Credit Aggregates. International Journal of Central Banking 7, 189-240.

Drehmann, M., Gambacorta, L., 2012. The Effects of Counter-Cyclical Capital Buffers on Bank Lending. Applied Economics Letters 19, 603-608.

Duffy, D., FitzGerald, J., Kearney, I., 2005. Rising House Prices in an Open Labour Market. ESRI Working Paper 166.

Fagan, G., Gaspar, V., 2007. Adjusting to The Euro, ECB Working Paper 716.

Fornari, F., Stracca, L., 2012. What Does a Financial Shock Do? First International Evidence. Economic Policy 27, 407-445.

Gareis, J., Mayer, E., 2013, What Drives Ireland's Housing Market? A Bayesian DSGE Approach. Open Economies Review 24, 919-961.

Gelain, P., Lansing, K. J., Mendicino, C., 2013. House Prices, Credit Growth, and Excess Volatility: Implications for Monetary and Macroprudential Policy. International Journal of Central Banking 9, 219-276.

Gerali, A., Neri, S. , Sessa, L., Signoretti, F., 2010. Credit and Banking in a DSGE Model of the Euro Area. Journal of Money, Credit and Banking 42, 1107-1141.

Gertler, M., Karadi, P., 2011. A Model of Unconventional Monetary Policy. Journal of Monetary Economics 58, 17-34.

Ghent, A.C., Kudlyak, M., 2011. Recourse and Residential Mortgage Default: Theory and Evidence from U.S. States. Review of Financial Studies 24, 3139-3186.

He, Z., Krishnamurthy, A., 2012. A Model of Capital and Crises. Review of Economic Studies 79, 735–777.

He, Z., Krishnamurthy, A., 2013. Intermediary Asset Pricing. American Economic Review 103, 732–770.

Honohan, P., Leddin, A., 2006. Ireland in EMU? More Shocks, Less Insulation? Economic and Social Review 37, 263-294.

Honohan, P., 2009. Resolving Ireland's Banking Crises. Manuscript Prepared for the UCD-Dublin Economic Workshop Conference: "Responding to the crisis".

Honohan, P., 2013. Adverse Selection and Moral Hazard in Forecasting and Limiting Arrears and Loan Losses on Mortgages. Speech to the Society of Actuaries in Ireland.

Hristov, N., Hulsewig, O., Wollmershauser, T., 2012. Loan Supply Shocks During the Financial Crisis: Evidence for the Euro Area. Journal of International Money and Finance 31, 569-592.

Hubrich, K., D'Agostino, A., Červená, M., Ciccarelli, M., Endrész, M., Guarda, P., Haavio, M., Jeanfils, P., Mendicino, C., Ortega, E., Valderrama, M., 2013. Financial Shocks and the Macroeconomy: Heterogeneity and Non-Linearities. ECB Occasional Paper 143.

Hummels, D., Ishii, J., Yi, K-M., 2001. The Nature and Growth of Vertical Specialization in World Trade. Journal of International Economics 54, 75-96.

Iacoviello, M., Neri, S., 2010. Housing Market Spillovers: Evidence from an Estimated DSGE Model. American Economic Journal: Macroeconomics 2, 125-164.

In't Veld, J., Raciborski, R., Ratto, M., Roeger, W., 2011. The Recent Boom-Bust Cycle: The Relative Contribution of Capital Flows, Credit Supply and Asset Bubbles. European Economic Review 55, 386-406.

Jaffee, D.M., Modigliani, F., 1969. A Theory and Test of Credit Rationing. American Economic Review 59, 850-872.

Jaffee, D.M., Russell, T., 1976. Imperfect Information, Uncertainty, and Credit Rationing. Quarterly Journal of Economics 90, 651-666.

Jaimovich, N., Rebelo, S., 2008. News and Business Cycle in Open Economies. Journal of Money, Credit and Banking 40, 1699-1711.

Jakob, Z., Kumhof, M., 2015. Banks Are Not Intermediaries of Loanable Funds – and Why This Matters. Bank of England Working Papers 529.

Jermann, U., Quadrini, V., 2012. Macroeconomic Effects of Financial Shocks. American Economic Review 102, 238-271.

Justiniano, A., Primiceri, G., Tambarlotti, A., 2013. The Effects of the Saving and Banking Glut on the U.S. Economy. Working Paper Series WP-2013-17, Federal Reserve Bank of Chicago.

Kannan, P., Rabanal, P., Scott, A.M., 2012. Monetary and Macroprudential Policy Rules in a Model with House Price Booms. B.E. Journal of Macroeconomics 12, Article 16.

Kee, H.L., Nicita, A., Olarreaga, M., 2008. Import Demand Elasticities and Trade Distortions. Review of Economics and Statistics 90(4), 666-682.

Kelly, R., McQuinn, K., Stuart, R., 2011. Exploring the Steady-State Relationship Between Credit and GDP for a Small Open Economy - The Case of Ireland. Economic and Social Review 42, 455-477.

Kennedy, G., McIndoe-Calder, T., 2011. The Irish Mortgage Market: Stylised Facts, Negative Equity and Arrears. Central Bank of Ireland Research Technical Paper 12/RT/11.

Kennedy, G., McQuinn, K., 2012. Why Are Irish House Prices Still Falling? Central Bank of Ireland Economic Letter 2012-5.

Kenny, G., 1998. The Housing Market and The Macroeconomy: Evidence From Ireland. Central Bank of Ireland Research Technical Paper 1/RT/98.

Lambertini, L., Mendicino, C., Punzi M.T., 2013a. Leaning Against Boom-Bust Cycles in Credit and Housing Prices, Journal of Economic Dynamics and Control, 37, 1500-1522.

Lambertini, L., Mendicino, C., Punzi, M.T., 2013b. Expectations Driven Cycles in the Housing Market: Evidence from Survey Data. Journal of Financial Stability 9, 518-529.

Lane, P.R., 2010. A New Fiscal Framework for Ireland. Journal of the Statistical and Social Inquiry Society of Ireland 34, 144-165.

Lane, P.R., 2014. International Financial Flows and the Irish Crisis. IIIS Discussion Paper 444.

Lane, P.R., 2015. The funding of the Irish domestic banking system during the boom. Journal of the Statistical and Social Inquiry Society of Ireland, forthcoming.

Leduc, S., Sill, K., 2013. Expectations and Economic Fluctuations: An Analysis Using Survey Data. The Review of Economics and Statistics 95, 1352-1367.

Martin, P., Philippon, T., 2014. Inspecting the Mechanism: Leverage and the Great Recession in the Eurozone. NBER Working Paper 20572.

McCarthy, Y., 2014. Dis-Entangling The Mortgage Arrears Crisis: The Role of the Labour Market, Income Volatility and Negative Equity. Journal of the Statistical and Social Inquiry Society of Ireland 43, 71-90.

McCarthy, Y., McQuinn, K., 2013. Price Expectations, Distressed Mortgage Markets and The Housing Wealth Effect. Central Bank of Ireland Research Technical Paper 6/RT/13.

Medina, J. P., Roldos, J., 2014. Monetary and Macroprudential Policies to Manage Capital Flows. IMF Working Paper WP/14/30.

Mendicino, C., Punzi, M.T., 2014. House Prices, Capital Inflows and Macroprudential Policy. Journal of Banking and Finance 49, 337-355.

Mian, A.R., Sufi, A., 2014. House of Debt: How they (and you) caused the Great Recession and how we can prevent it from happening again. The University of Chicago Press.

Mody, A., Ohnsorge, F., Sandri, D., 2012. Precautionary Savings in the Great Recession. IMF Economic Review 61, 114-138.

Moons, C., Hellinckx, K., 2015. Did Monetary Policy Fuel the Housing Bubble in Ireland? KU Leuven Discussion Paper Series DPS15.01.

O'Hanlon, N., 2011. Constructing a national house price index for Ireland. Journal of the Statistical and Social Inquiry Society of Ireland 40, 167-196.

Ozkan, F. G., Unsal, D.F., 2013. On the Use of Monetary and Macroprudential Policies for Financial Stability in Emerging Markets. University of York Discussion Paper in Economics 13/14.

Piazzesi, M., Schneider, M., 2009. Momentum Traders in the Housing Market: Survey Evidence and a Search Model. American Economic Review 99, 406-411.

Podstawski, M., 2014. What Drives EMU Current Accounts? A Time Varying Structural VAR Approach. IAAE Annual Conference, Belfast.

Popov, A., Smets, F., 2011. On the Trade-off Between Growth and Stability: The Role of Financial Markets. VoxEu November 2011.

Quint, D., Rabanal, P., 2014. Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. International Journal of Central Banking 10, 169-236.

Rotemberg, J.J., 1982. Monopolistic Price Adjustment and Aggregate Output. Review of Economic Studies 49, 517-31.

Schmitt-Grohe, S., Uribe, M., 2003. Closing Small Open Economy Models. Journal of International Economics 61, 163-185.

Shin, H.S., 2012. Global Banking Glut and Loan Risk Premium. IMF Economic Review, 60(2), 155-192.

Stiglitz, J., Weiss, A., 1981. Credit Rationing in Markets with Hidden Information. American Economic Review 71, 393-410.

Strahan, P.E., 1999. Borrower Risk and the Price and Non-price Terms of Bank Loans. FRBNY Staff Report 90.

Suh, H., 2012. Macroprudential Policy: Its Effects and Relationship to Monetary Policy. Federal Reserve Bank of Philadelphia Working Paper 12-28.

Suh, H., 2014. Dichotomy between Macroprudential Policy and Monetary Policy on Credit and Inflation. Economics Letters 122, 144-149.

Unsal, D. F., 2013. Capital Flows and Financial Stability: Monetary Policy and Macroprudential Responses. International Journal of Central Banking 9, 233-285.

van den Heuvel, S. J., 2008. The Welfare Cost of Bank Capital Requirements. Journal of Monetary Economics 55, 298-320.

Warren, E., 2007. The Vanishing Middle Class. In: Edwards, J., Crain, M., and Kalleberg, A. (Eds.), Ending Poverty in America, 38-52.

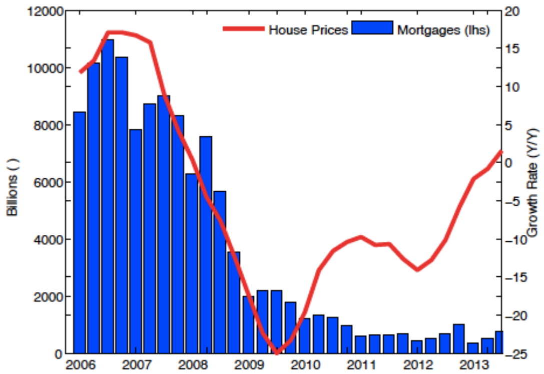
A Stylised facts from the Irish housing crash

The awareness of the need for macroprudential policy measures is particularly acute in Ireland, where the bursting of a housing bubble has resulted in negative feedback loops between the financial sector and the real economy, causing a large recession. Residential property prices increased significantly in the run-up to the financial crisis and dropped dramatically after the crash. In response to the rapid decrease in asset values, particularly housing, Irish banks have become increasingly risk-averse and have reduced lending in order to rebuild their balance sheets and conform to regulatory pressures (Figure 5). Due to both demand and supply factors, many households and firms have undertaken a wide-scale deleveraging (Figure 6) in order to pay-down some of the debt accrued during the bubble period. A side-effect of credit tightening and deleveraging has been a large reduction in consumption and business investment, with the fiscal consolidation undertaken by the government further depressing domestic demand.

The reduction in domestic demand has coincided with higher unemployment and lower wages and disposable income (Figure 7). Lower disposable incomes and a greater risk of unemployment, combined with devalued collateral, have in turn led to an increase in non-performing loans (Figure 8), further damaging bank balance sheets. Due to a combination of higher credit risk and the need to repair their balance sheets, banks have responded by tightening credit standards (Figure 9). Such tightening took the form of both a reduction in lending volume (quantity), and higher interest rate spreads demanded on successful loan applications (price). Therefore, the spread charged on loans have been at an elevated level throughout the post-crisis period (Figure 10). Given this vicious cycle, the health of the banking sector and its ability to support the real economy with credit at sustainable rates has been identified as the largest uncertainty in Ireland's post-crisis adjustment (Central Bank of Ireland, 2013).

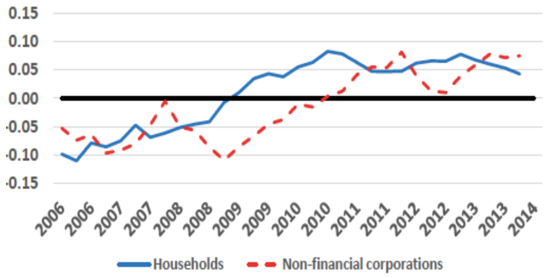
Stylised facts of the Irish boom and bust I

FIGURE 5. **House prices and mortgage credit**



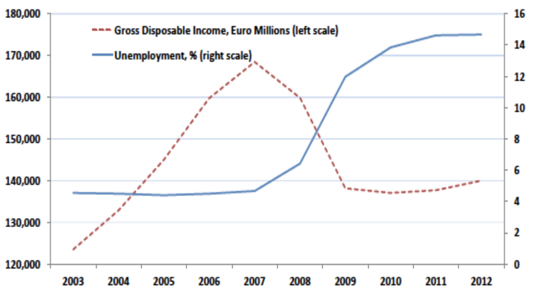
Notes: The house price series is the Central Statistics Office Property Price Index. See O'Hanlon (2011) for details on the construction of the index. Mortgage credit is represented by new mortgage drawdowns as reported by the Irish Banking Federation.

FIGURE 6. **Household and non-financial corporation deleveraging**



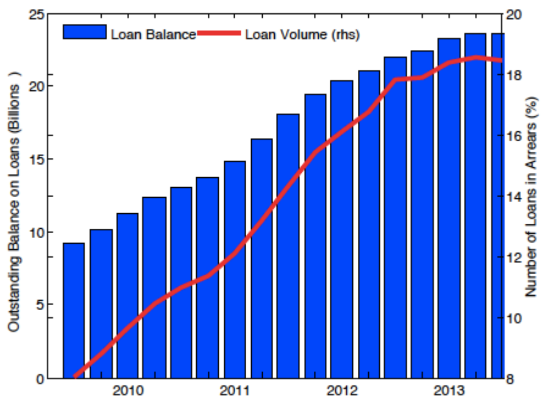
Notes: Sectoral deleveraging is represented by net lending/borrowing from the Central Bank of Ireland's Quarterly Financial Accounts. A positive (negative) number in any given period indicates that the sector in question is reducing (increasing) their liabilities. The figures are stated as a percentage of GDP.

FIGURE 7. **Unemployment and disposable income**



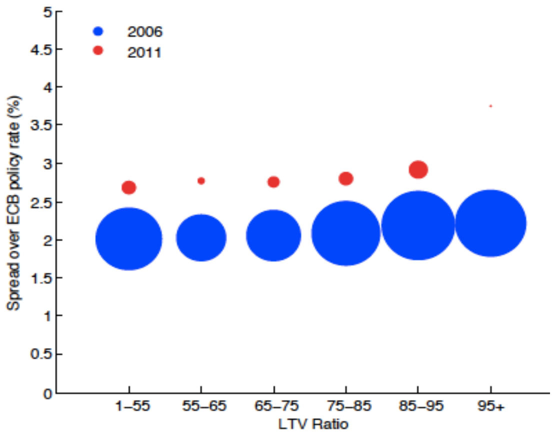
Notes: The unemployment rate is seasonally-adjusted and for both sexes. National gross disposable income is in millions of euros. Source: Central Statistical Office.

FIGURE 8. **Mortgage arrears**



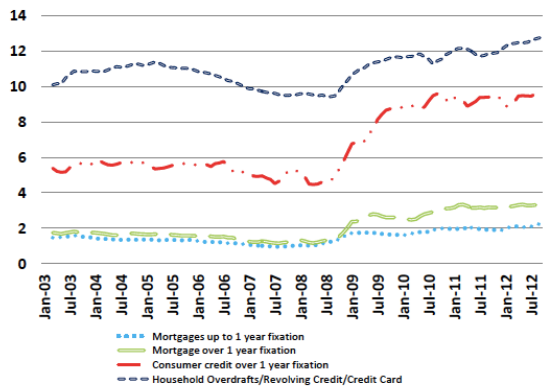
Notes: Loan volume is the percentage of mortgage accounts in arrears for 90 days or more. Loan balance is the outstanding amount owed on these loans, and not the value of arrears themselves. The data are from the Central Bank of Ireland's Residential Mortgage Arrears and Repossessions Statistics.

FIGURE 9. **Loan volume and lending Spreads**



Notes: These data are mortgage spreads and product availability across loan-to-value ratios from the four Irish lenders subject to the Financial Measures Programme. Source: Central Bank of Ireland calculations. See Lydon and O' Brien (2012) for further details.

FIGURE 10. **Lending spreads over policy rate**



Notes: The data are lending spreads over households loans versus vs ECB MRO. Source: Central Bank of Ireland Money and Banking Statistics, all institutions, 3-month moving average. See Lydon and O'Brien (2012) for further details.

B Financial shock: capital flows

Having examined the reaction of the model economy to a real economy shock, it is appropriate to ask whether the same channels are important when the shock originates in the financial sector. Therefore, we consider a shock that decreases the cost of banks' foreign liabilities, a key channel in cross-border capital inflows (Bruno and Shin, 2013).

A large body of literature has investigated the contribution of financial variables to real fluctuations and found that they can be quite heterogeneous. Shin (2012) claims that the "global banking glut" has played an important role in easing financial conditions in the United States during the boom and then has been responsible for the propagation of the crisis during the bust. Hubrich *et al.* (2013) provide empirical evidence that financial shocks play an important role in explaining the movement of key macroeconomic variables such as output, consumption and investment. Fornari and Stracca (2012) find similar results for a panel of countries which includes Ireland. The results in Kelly *et al.* (2011) and Arestis and Gonzalez (2013) further support the importance of credit availability as an explanation for house price growth in Ireland. A further motivation for the inclusion of these shocks is the empirical evidence provided by Ciccarelli *et al.* (2012) that find that both asset price and loan market factors played an important role in the recent Irish downturn.

However, there is a disagreement amongst these studies as to whether the results are context specific, with greater effects in times of financial stress, for example. Moreover, as discussed in Lane (2014), the role that international flows played in driving the rapid growth in the external debt of the banking system during the boom remains unclear. On the one hand, bank-intermediated debt inflows certainly contributed to the amplification of the property boom. Yet, on the other hand, other types of international flows have played a stabilising role and partially offset the effect of bank-intermediated debt. In relation to crisis dynamics, much remains to be worked out in terms of modelling official flows (*i.e.* eurosystem funding of the banks, EU-IMF funding of the sovereign). In relation to the recovery phase, it is crucial to identify the most successful policy tools to re-build confidence among international investors. With free capital mobility and cross-border lending, national regulatory requirements may become a weaker instrument for moderating the credit cycle.

We assess this transmission channel of the model by introducing a negative 1% shock to the cost of banks' foreign liabilities U_t^F, which occurs immediately. The results of these scenarios are reported in Figure 11. The presence of a debt elastic risk premia ensures that foreign deposits become relatively cheaper than those from domestic sources, and so banks adjust their balance sheets to accumulate more of the former.[40] This shock mimics the increase in foreign funding flows that facilitated the Irish credit boom.[41] We assess two alternative paths: one in which this decrease in costs is permanent (represented by the orange line); the other in which the decrease is unexpectedly reversed (represented by the blue line). In this latter scenario, after 3 years (i.e. at $t = 13$) the cost of foreign banks' liabilities increases by 0.5% and stays permanently at this level. The first scenario results in the economy converging to a new steady state. The second scenario replicates the impact of a capital reversal or a sudden stop, with the economy returning back towards the original steady state. We focus first on the period in which the cost of foreign liabilities are reduced. This is represented by the shaded area of the plot and the impulse responses are the same for both scenarios during this period.

With the domestic interest rate, which serves as the deposit rate, tied to the external interest rate, the cost of domestic liabilities also decreases. In response to their reduced costs of liabilities, banks increase their lending as each loan is now more profitable. The expansion in credit fuels higher demand for housing assets and final goods, and requires an expansion in domestic output and imports to fulfill this extra demand. Higher asset prices and wage income levels reduce the amount of non-performing loans. This lower default risk further encourages banks to reduce their lending spreads and reinforce the increased demand for loans. The increase in leverage and reduction in the capital buffer force banks to raise the spread used to ensure the minimum capital adequacy ratio is achieved. On aggregate, however, this is insufficient to offset the decrease in the default spread and so lending rates decrease. In the first scenario, represented by the orange line, the reduction in the cost of liabilities is permanent. In this case, there is a smooth transition to a greater level of lending and debt accumulation in the steady state. However, the permanent increase in the volume of loans results in a greater number of non-performing loans in the steady state. This is because of the accumulation of risk due to the greater amount of lending. Accordingly, banks charge a higher spread to cover this increased default risk. A trade deficit can be financed due

[40] Similarly, Justiniano *et al.* (2013) model capital inflows as a reduction in the spread between the interest rate paid by (mortgage) borrowers and the funding rates of the shadow banking system, which are tied in turn to the interest rate earned by savers. A reduction in spreads is also an outcome of the model of intermediation proposed by Shin (2012) to formalise the effects of the "Global Banking Glut".

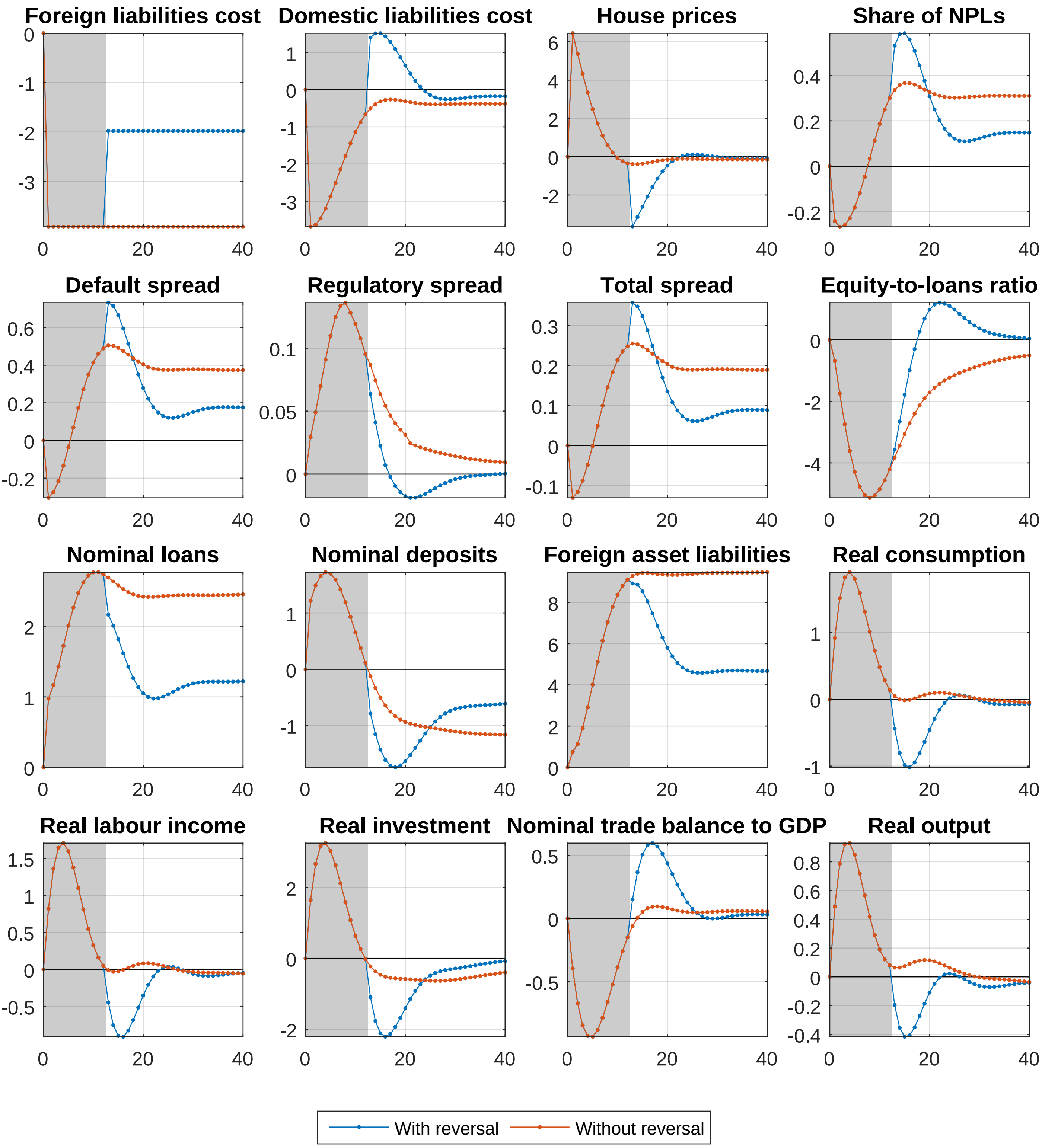
[41] See, for example, Coates and Everett (2013) and Lane (2015) for details.

to the lower cost of servicing the foreign debt, and so domestic demand remains elevated with negative effects for the competitiveness of exporters. Our model replicates the channels in Fagan and Gaspar (2007), through which a significant fall in the costs of international financing can trigger an expenditure boom, current account deficits and an increase in household indebtedness.

In the alternative scenario, represented by the blue line, the reduction in the cost of liabilities is temporary and after 3 years is partially reversed. The convergence of costs back towards their original level encourages banks to reduce their lending. This contraction in credit availability leads to a drop in demand for housing assets (the price of which suffers from a sharp reduction) and final goods, as households begin to deleverage some of the foreign debt accumulated during the boom. The reduction in labour demand as output contracts pushes down wage income (from both lower wages and decreased hours worked). As a result of this, and the large decrease in house prices, the default threshold is lower and the share of non-performing loans increases. This adds to the downward pressure on lending, as banks try to recapitalise. The trade balance increases as lower competition for factor inputs improves the export sectors' external competitiveness.[42] The corresponding trade surplus is essential in paying down the foreign debt accrued during the boom.

[42]Overall, our results are in line with those in Bergin *et al.* (2013), who find that a 1% increase in domestic interest rates reduces output by 0.5%, consumption by 0.4% and investment by 1.5%. Curiously, in Bergin *et al.* (2013) exports decrease as a result of this shock. This may be because the Bergin *et al.* (2013) analysis assumes that multinationals are affected by the rise in domestic interest rates, whereas we follow Clancy and Merola (2016) and assume that the capital decisions of the export sector are made abroad by their parent corporations.

FIGURE 11. **Capital flows shock**



Notes: Impulse responses to a 1 percent decrease in the cost of foreign liabilities, which stimulates capital inflows. Under the first scenario (blue line), the cost of foreign liabilities remains permanently lower and so there is no capital reversal. Under the second scenario (orange line), an unexpected increase in the cost of foreign liabilities occurs at time $t = 13$, leading to a capital reversal. All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

The capital reversal is associated with a recession, as discussed in Calvo *et al.* (2004) and Bordo *et al.* (2010). Our simulations are in accordance with empirical works for Ireland. For instance, Hristov *et al.* (2012) provide empirical evidence of the adverse effect that loan supply shocks have on output and loan volume growth in Ireland. Our simulations are also in line with the mechanism suggested in Shin (2012) and Justiniano *et al.* (2013) for the U.S. financial crisis. They argue that capital inflows played a key role in triggering and propagating the financial crisis in the United States. Spreads are negatively related to the total amount of funds intermediated by the financial system. Lower interest rates stimulate the demand for non-durable consumption, investment and housing by the lenders. The resulting upward pressure on house prices then relaxes the collateral constraint of the borrowers, who can thus also consume more. Then, when the boom turned to bust and capital inflows reversed, the mechanism worked in reverse, contributing to the propagation of the U.S. financial crises around the world.

C Sensitivity Analysis

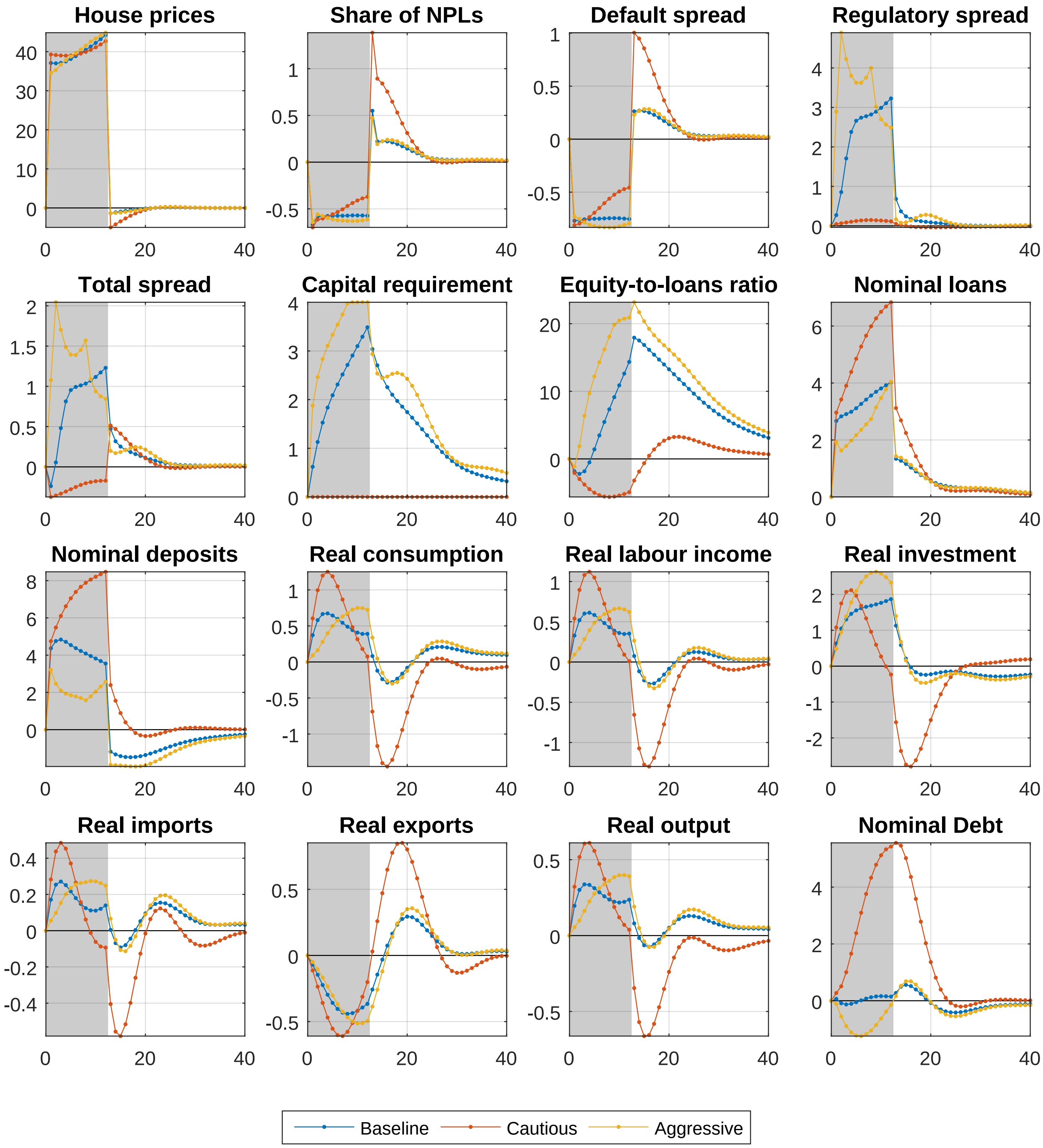
The subject of our analysis is the performance of a countercyclical minimum capital requirement relative to the old benchmark where this level was fixed. We showed that by forcing banks to accumulate a capital buffer during periods of output and credit growth, their resiliance to negative shocks was enhanced. This allowed the model economy to recover much faster from a downturn. We model the countercyclical capital target through a Taylor-type rule that has two key parameters: ϕ_{g1} which mimics the strength of policy inertia, and ϕ_{g2} which measures the weight of the response to a credit expansion. We next examine the effect of alternative values for these parameters and the impact that they have on the models results. We also examine the impact of the non-price bank lending channel in the model. This channel is particularly important in Ireland due to the large proportion of tracker mortgages in the banks' loan portfolios. In all of the sensitivity analyses, we work with the housing preference shock presented in the main text.

C.1 Countercyclical capital rule parameters

In our baseline, we assume that the regulators place a higher weight on credit expansion when deciding on the minimum capital requirement ($\phi_{g1} = 0.8$, $\phi_{g2} = 1.2$). However, we also allow for a strong role for policy inertia. We now compare this baseline to scenarios in which the policy maker is more cautious ($\phi_{g1} = 1$, $\phi_{g2} = 0.5$) and more aggressive ($\phi_{g1} = 0.5$, $\phi_{g2} = 2$). The results of this experiment are detailed in Figure 12.

Our results show that a more aggressive approach to capital regulation is most beneficial to macroeconomic and financial stability. The cautious strategy is by far the worst, with uncurtailed banks facilitating a credit boom that drives domestic demand and output up. The more aggressive strategy delays the positive spillovers in to the real economy, but when they arrive they are more sustainable. During the release phase, banks are well capitalised and do not have to substantially raise lending rates, as is the case in the cautious scenario. These results therefore match the evidence from the main text (see Section 4.3) showing that a more decisive policy response to a negative shock prevents the economy from entering a prolonged downturn.

FIGURE 12. **Countercyclical capital rules parameters**



Notes: Impulse responses to a 5 percent increase in housing preferences, expected at time $t = 13$, which however never materialises. Under the first scenario (red line), the policy authorities pursue a cautious approach to adjusting capital requirements ($\phi_{g1} = 1$ and $\phi_{g2} = 0.5$). Under the second scenario (blue line), the policy authorities have a balanced approach as in our baseline ($\phi_{g1} = 0.8$ and $\phi_{g2} = 1.2$). In the third scenario (orange line) the policy authorities follow an aggressive approach ($\phi_{g1} = 0.5$ and $\phi_{g2} = 2$). All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

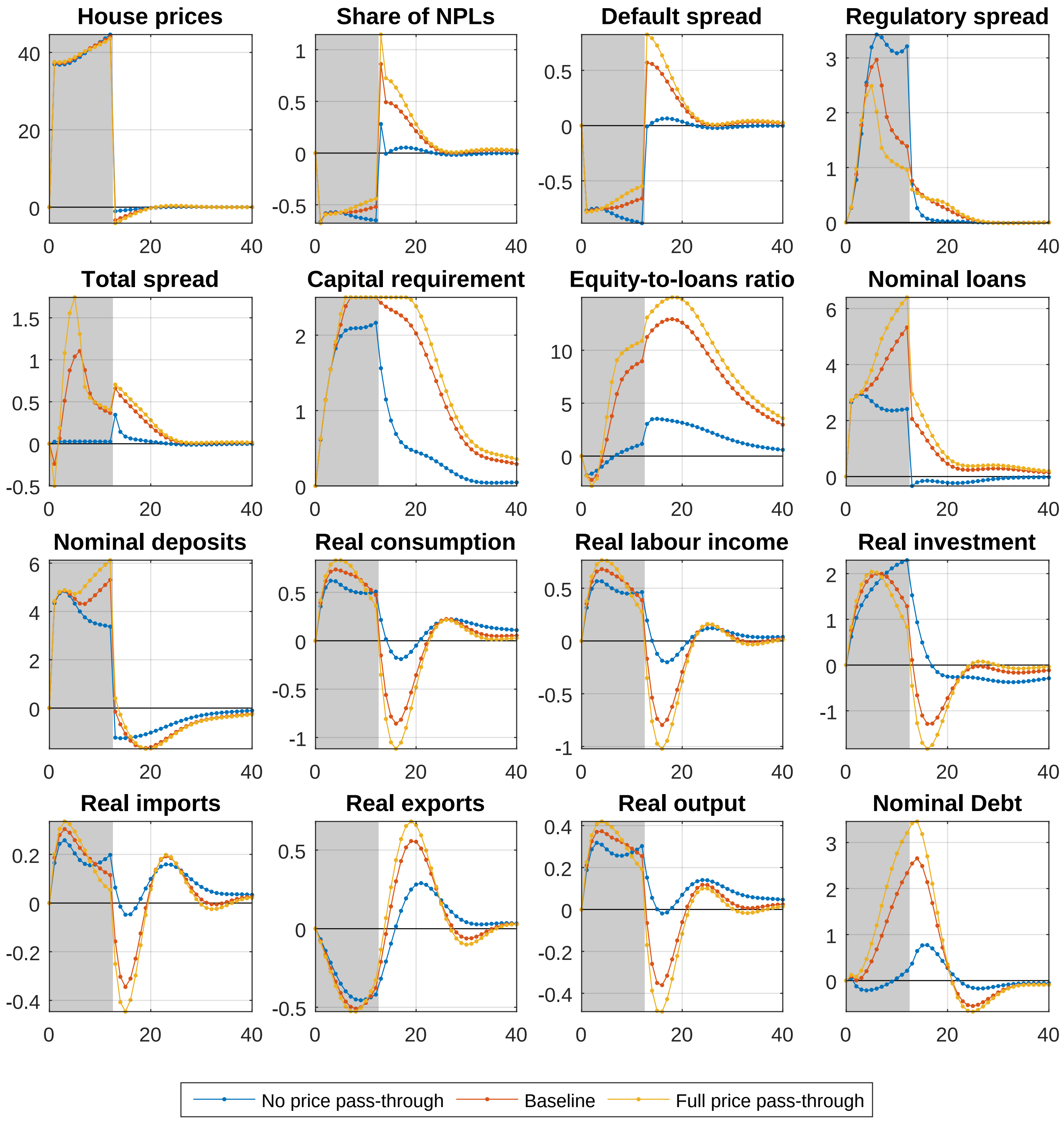
C.2 Non-price bank lending channel

In the baseline scenario, banks can pass-on a large part of the adjustment in the lending spread they need to recapitalise in the face of a negative shock. However, in reality, this may not be the case. This is particularly true for Ireland where banks have a large proportion of tracker mortgages on their loan book. These loans have a set spread over the ECB refinancing rate and therefore cannot be adjusted by banks if the desire to do so should arise. All of the desired adjustment therefore has to come on the quantity, rather than the price, of loans. We analyse the effect that such imperfect lending rate pass-through can have on the propagation channels and persistence of booms and busts. The results are detailed in Figure 13.

All the scenarios reported in Figure 13 assume that capital regulation is counter-cyclical. However, under the first scenario, represented by the orange line, credit tightening is implemented only by increasing lending spread without tightening the amount of extended loans ($\tau = 1$). Under the second scenario, represented by the blue line, the adjustment is implemented through loan quantity rationing ($\tau = 0$). The third scenario, represented by the red line, assumes that the adjustment is implemented by a mix of credit rationing and interest rate tightening ($\tau = 0.5$) according to our baseline calibration.

We focus on the scenario represented by the blue line and assuming that banks are unable to fully pass on the desired lending rate cuts and hence credit conditions are tightened by reducing the amount of extended loans. Despite rising house prices and wage income reducing the probability of default on loans, banks are unable to fully pass on the desired lending rate cuts. This has the effect of limiting the increase in demand for credit. It also impacts on banks profitability, as a lower amount of less risky loans are now extended relative to the baseline simulation. As these excess returns are used to develop capital buffers, protecting the bank from breaches of the minimum capital requirement, the spread covering this risk must also be increased. This further reduces demand for loans. Accordingly, debt levels do not expand as quickly and the real economy does not experience as large a boom. During the downturn, banks' lending prudence in the boom period helps them to avoid large losses in their loan portfolio. The legacy of bad loans from the boom are not as big a problem, and thus the economy can return to normal levels following the downturn at a much faster rate. Also, the need to deleverage debt accumulated during the boom is not as strong, and thus real economic activity is not as adversely affected by the house price crash.

FIGURE 13. **Non-price bank lending channel**



Notes: Impulse responses to a 5 percent increase in housing preferences, expected at time $t = 13$, which however never materialises. All the scenarios assume that capital regulation is countercyclical. In the first scenario (orange line), credit tightening is implemented only by increasing lending rates ($\tau = 1$). In the second scenario (blue line), the adjustment is mainly through restricting lending rather than price changes ($\tau = 0$). The third scenario (red line) assumes that the adjustment is implemented by a mix of lending restrictions and interest rate tightening ($\tau = 0.5$), as in our baseline. All variables are in percentage deviations from the steady state, with the spreads reported in annualised terms.

European Stability Mechanism

6a Circuit de la Foire Internationale
L-1347 Luxembourg

Tel: +352 260 292 0

www.esm.europa.eu

info@esm.europa.eu