Macroprudential policies and credit creation*

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Abstract

We study the effects of macroprudential policy rules in a small-open economy model in which banks effectively create credit. Banks in the model can generate new finance in the process of extending loans rather than just intermediating funds between savers and borrowers; this has been argued to more accurately capture the dynamics of credit (Jakab and Kumhof 2014). We find that borrower-based macroprudential policies that affect the demand for housing and credit are particularly effective in reducing fluctuations in credit, house prices and defaults, and in improving welfare. They outperform financial institution-based policies that primarily affect the supply of credit.

Keywords: Macroprudential policy, credit creation, loan-to-value ratio, capital requirements

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1 Introduction

The conduct of macroeconomic policy was dramatically altered by the financial crisis of 2007–2008. Macroprudential policies – namely policies with the explicit aim of preserving

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the stability of the financial system as a whole – have been employed considerably more frequently to mitigate systemic risks (Akinci and Olmstead-Rumsey 2017). The adoption of these policies was motivated by the significant costs to the real economy stemming from the financial crisis and a recognition that the existing policy framework was insufficient to prevent its re-occurrence. This paper studies the implications for welfare and stability of systematically implemented macroprudential policy.

The efficacy of macroprudential polices can be studied using structural models.[1] Typically, these model the financial sector as an intermediary of funds between savers and borrowers (the 'loanable-funds' framework). This has been criticised as not being a realistic description of the behaviour of financial institutions; an alternative view is that financial institutions actually create new purchasing power, or credit, in the process of extending loans (see Jakab and Kumhof 2014; McLeay, Radia, and Thomas 2014; Borio and Disyatat 2009). This is known as the 'credit-creation' view. According to this view, when a loan is extended to a borrower, an equivalent deposit is placed in that borrower's saving account; the financial institution therefore creates both a new asset (loan) and a new liability (deposit) simultaneously. The balance sheet is in balance despite no intermediation having taken place. Effectively the financial institution controls both its assets and liabilities, with loans and deposits created to the extent that they are expected to be profitable (subject to the regulatory environment and the possibility of default). The dynamics of credit in the credit-creation approach are considerably different to the dynamics in the loanable-funds framework and have been argued to be more realistic (Jakab and Kumhof 2014). These different dynamics sizably alter the transmission mechanism of macroprudential policies.

The contribution of this paper is to assess the effectiveness of macroprudential policies in an environment where financial institutions can create credit. A small literature exists studying macroprudential policies with such financial institutions, including Benes, Kumhof, and Laxton (2014b), Fukač, Greig, and Snethlage (2018) and Benes, Laxton, and Mongardini (2016). These studies examine the macroeconomic effects of a specific policy change in a particular economic scenario. Our focus is different: we study the implications for welfare and economic volatility of macroprudential policies implemented systematically using rules akin to the Taylor rule for monetary policy. We consider two dimensions, namely which macroprudential instrument should be used and what it should respond to. In doing so, this paper provides policymakers with guidance on how best to implement macroprudential policies in this environment.

A wide variety of potential macroprudential policy instruments exists (see Lim et al. 2011). A useful classification is to separate these instruments into those that focus on *demand*, namely those that primarily impact on borrowers, and *supply*, which impact on financial institutions (Cerutti, Claessens, and Laeven 2015). This paper studies the effectiveness of the systematic setting of leading examples of these categories of macroprudential policies – namely Loan-to-Value Ratio (LVR) policies for residential mortgages (demand) and time-varying capital requirements (supply) – which have been the most frequently used types of policies within each category (Akinci and Olmstead-Rumsey 2017).

[1]Examples of papers that use structural models to assess the ability of macroprudential policies to improve stability and welfare include Kannan, Rabanal, and Scott (2012), Suh (2012), Angeloni and Faia (2013), Lambertini, Mendicino, and Punzi (2013), Ghilardi and Peiris (2014), Mendicino and Punzi (2014), Rubio and Carrasco-Gallego (2014), Benes and Kumhof (2015), Bailliu, Meh, and Zhang (2015), Karmakar (2016), Liu (2016), Rubio (2016), Tavman (2016), Tayler and Zilberman (2016), and Collard et al. (2017).

We examine the effectiveness of these policies in a small-open economy setting. This is motivated by the recent use of macroprudential policies in many small-open economies, in response to both the financial crisis and more recent episodes of strong growth in mortgage credit and house prices.[2] The framework used allows us to consider the impact of macroprudential policies on capital flows when assessing the implications for welfare.

We show that supply-side macroprudential policies do not facilitate greater stability or deliver welfare improvements in a small-open economy where financial institutions create credit. These policies primarily shift the supply of credit, which largely influences the lending rate (as the demand for credit is relatively inelastic and the supply of credit is relatively elastic) rather than the quantity of credit or house prices. Consequently they do not enhance financial or macroeconomic stability. Furthermore, in a small-open economy setting, the changes in lending rates produce capital flows that induce a welfare cost. This is in sharp contrast to the existing literature using the loanable-funds or similar frameworks, where countercyclical capital requirements are frequently found to facilitate greater stability and improve welfare (e.g. Angeloni and Faia 2013; Benes and Kumhof 2015; Karmakar 2016; Tayler and Zilberman 2016; Collard et al. 2017). They have even been found to be more effective than demand-side policies (e.g. Suh 2012 and Tavman 2016).

We show that demand-side macroprudential policies deliver the best stability and welfare outcomes when financial institutions can create credit. These policies shift the demand for credit and housing, which has a large effect on the volume of credit and on house prices. Consequently, systematically varying the policies countercyclically with house prices or credit can considerably reduce their volatility – as well as the frequency of sharp increases in the default rate – leading to an improvement in welfare.

The finding that supply-side policies have little impact on housing prices and credit, and that demand-side policies do, is consistent with a growing body of empirical evidence. Using cross-country dynamic panel regressions, Claessens, Ghosh, and Mihet (2013), Zhang and Zoli (2014), Cerutti, Claessens, and Laeven (2015), Kuttner and Shim (2016) and Akinci and Olmstead-Rumsey (2017) all find that there is insufficient evidence to reject a hypothesis that capital requirements policies (or supply-side policies more generally) have no impact on either household or housing credit, bank assets, or house price growth. They also all find that borrower-based policies (or similar categorisations) do have an impact on a measure of credit growth, though evidence regarding their impact on house price growth is mixed.[3]

In summary, this paper contributes to the literature on evaluating macroprudential policies by studying the relative effectiveness of leading examples of demand and supply-side macroprudential instruments in a setting of considerable relevance to many policymakers, namely a small-open economy where financial institutions can create credit. The paper demonstrates that demand-side policies deliver superior welfare outcomes than their supply-side alternatives.

Briefly, this article is structured as follows. We describe the model in Section 2, and Section 3 details its calibration. Section 4 analyses the effects of policies, first in a broad sense and then more specifically on the stability of housing and financial market variables, and on

[2] Additionally, the models of Fukač, Greig, and Snethlage (2018) and Benes, Kumhof, and Laxton (2014a) that our analysis draws upon are of small-open economies.

[3] Akinci and Olmstead-Rumsey (2017) finds that there are large, statistically significant effects, whereas Cerutti, Claessens, and Laeven (2015) and Kuttner and Shim (2016) do not.

welfare. Section 5 contains a sensitivity analysis, and Section 6 concludes.

2 The model

The model is based on Fukač, Greig, and Snethlage (2018); a related paper is Benes, Laxton, and Mongardini (2016). These build on the IMF's macroprudential policy model, MAPMOD (Benes, Kumhof, and Laxton 2014a). The model has many features that are standard of large-scale New-Keynesian models used at policy institutions; consequently this section focuses on the nonstandard aspects of the model. A complete description can be found in Section A of the online appendix.

A key feature of the model is a banking sector that controls both its assets and liabilities. On the assets side, the bank extends mortgage loans, with the expected default rate on these increasing non-linearly in the loan amount. On the liabilities side, it can access deposits of both domestic and foreign households. With access to foreign deposits – that are effectively in perfectly elastic supply – a bank's demand for deposits determines the volume of deposits that they hold; this is a fundamental difference from frameworks in which the bank is purely an intermediary (in which case deposits may be determined by the preferences of households and the behaviour of the central bank, for instance). Consequently, banks can effectively create new purchasing power in the domestic economy by raising foreign deposits and extending mortgage loans, and do so up to the point where the return on loans equals the cost of deposits plus the expected costs associated with defaults.

Banks lend to individuals, who use finance to purchase housing, consumption and investment goods, and put up their stock of housing as collateral. To maintain the tractability of the representative agent framework, each household is comprised of many individuals and therefore is not affected in aggregate if one defaults.

To capture the linkages between the financial sector and the real economy – which allows for an evaluation of the economic impacts of macroprudential policies – these features are embedded into a relatively standard New-Keynesian framework, including typical production sectors and a monetary authority. The model also includes a small-open economy dimension.

We conduct policy analysis using second-order approximations to the policy function. This is necessary to capture key nonlinear relationships in the credit market. These nonlinearities see events that have significant implications for bank balance sheets have distinctly nonlinear effects both in the financial sector and in the real economy (Benes, Kumhof, and Laxton 2014b). As discussed in Section 4, supply-side macroprudential policies have significant implications for bank balance sheets, and the nonlinear effects of these policies have consequences for welfare.

We now outline the model.

2.1 Banks

A profit-maximising representative bank – of which a proportion, $1-\nu$, is owned by foreign households – obtains deposits, extends loans, and manages its stock of equity.

2.1.1 Deposits

Banks obtain deposits (d_t) from both domestic households (D_t) and foreign households (F_t). Deposits of foreign households can be denominated in either the domestic or foreign currency. The bank pays the (policy) deposit rate R_t on both deposits of domestic households and domestic currency deposits of foreign households. Deposits denominated in the foreign currency are paid the foreign deposit rate R_t^W in the foreign currency, but as discussed later in Section 2.3.3, a forward exchange rate market is used to hedge foreign currency risk.[4]

2.1.2 Loans

Each household is comprised of a large number of individuals, indexed by i, and the representative bank extends a one-period loan L_t^i to individual i at the interest rate $R_{L,t}^i$. The individual posts the value of their housing, $P_{H,t}H_t^i$, as collateral, where $P_{H,t}$ denotes the price of housing and H_t^i the quantity. If the individual defaults on the loan, the bank is only able to recover $(1-\lambda)R_{L,t}^i L_t^i$.

Let the event of a default by individual i on a time t loan in $t+1$ be denoted by θ_{t+1}^i. The probability of default is modelled as depending on two independent components:

$$\Pr(\theta_{t+1}^i = 1) = \Pr\big(u_{t+1}^i + p_{d,t+1} \leq \vartheta_t\big),$$

where ϑ_t is a function of time t variables. The first component, u_{t+1}^i, is a random variable that differs across individuals, and can be thought of as capturing the idiosyncratic factors that cause an individual to default. It is assumed to be normally distributed: $u_{t+1}^i \sim N\big(0, \sigma_1\big)$. This distribution is known, and does not change over time.

For the second component we assume:

$$p_{d,t+1} \sim N\left(\mathbb{E}_t\left[\log\left(\frac{P_{H,t+1}}{P_{H,t}}\right)\right], \sigma_2\right),$$

where σ_2 is the standard deviation of $\log\big(\frac{P_{H,t+1}}{P_{H,t}}\big)$. It is a normal approximation to $\log\big(\frac{P_{H,t+1}}{P_{H,t}}\big)$.[5] The final term, ϑ_t, is defined as $\vartheta_t \equiv \log\left(\frac{R_{L,t}^i LVR_t^i}{\kappa}\right)$, where the loan-to-value ratio (LVR)

[4] Effectively foreign deposits cost the bank the domestic policy rate R_t in the domestic currency, as shown in Section A.1.2 of the online appendix.

[5] In a first-order approximation to the model they are equal. Consequently, $p_{d,t+1}$ is treated as known when conditioning upon $\log\big(\frac{P_{H,t+1}}{P_{H,t}}\big)$.

is defined as $LVR^i_t \equiv \frac{L^i_t}{P_{H,t}H^i_t}$.

The motivation for these definitions is that an individual is assumed to default on their loan if the value of their housing falls beneath a proportion of the value of the loan to be repaid:

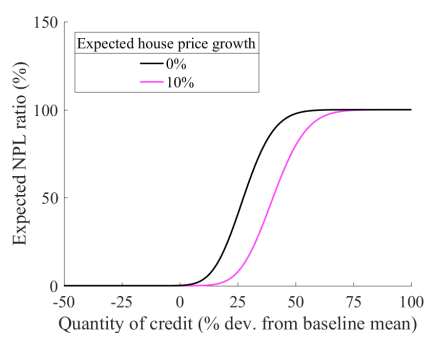
$$P_{H,t+1}H^i_t < \frac{1}{\kappa \mathrm{e}^{u^i_{t+1}}} R^i_{L,t} L^i_t.$$

This assumption carries three important implications.

1. When banks extend credit, they can diversify away risk stemming from the unknown idiosyncratic risk factors that affect defaults (u^i_{t+1}), but cannot diversify away risk stemming from the unknown evolution of house prices ($p_{d,t+1}$). If house prices fall by more than expected, the proportion of loans that are in default – which we call the non-performing loan (NPL) ratio, denoted θ_{t+1} – will be higher than expected. The risk that this generates remains on the bank's balance sheet.[6] This sees banks' optimally choose to hold more capital than is required, with the size of the buffer varying over time, consistent with that observed in the data.

2. The expected NPL ratio is non-linearly increasing in the amount that banks lend (given current and expected future levels of house prices; Figure 1). Banks take this into account when determining the optimal amount of credit to extend.

Figure 1: Lending and defaults



Notes: Parameters are as described in Table 1, with variables at their unconditional mean.

3. Over the relevant domain, the expected NPL ratio is increasing in the variance of house price growth σ_2.[7] Policies that reduce σ_2 will therefore reduce the expected default rate on a given loan amount.

[6] This reflects the fact that the terms of the loan contract (L^i_t and $R^i_{L,t}$) are determined at the time the loan is made, while defaults on those loans are a function of house prices at the time of repayment. This is a difference from the framework of Bernanke, Gertler, and Gilchrist (1999), where the lending rate is conditional on the realisation of variables at the time of repayment, so that risk is not present on the lender's balance sheet.

[7] The expected NPL ratio is increasing in the variance of house price growth σ_2 when the expected NPL ratio is below 50 per cent, which is always the case in calibrations of the model considered here.

2.1.3 Equity (and capital requirements)

The representative bank manages a stock of equity, E_t. Equity is raised from – and dividends returned to – domestic and foreign households in proportion to their ownership share. The bank pays adjustment costs if it deviates from a fixed dividend policy where it pays out the steady-state return on equity and retains any profits in excess of this. Including equity adjustment costs in this form sees bank equity exhibit similar dynamics to that observed in the data, and ensures a well-behaved steady state (see Benes, Kumhof, and Laxton 2014a).

A regulator requires that the equity-to-loan ratio remains above some minimum, φ_t. Requirements are imposed on the *ex-post* value of loans (LL_{t+1}) and equity (EE_{t+1}), defined as the value after default losses and interest payments are taken into account:

$$LL_{t+1} = R_{L,t} L_t (1 - \lambda \theta_{t+1})$$
$$EE_{t+1} = LL_{t+1} - R_t d_t.$$

If $\frac{EE_{t+1}}{LL_{t+1}} < \varphi_t$, the bank pays a penalty υL_t. This is not a social cost as the regulator returns it to the banking sector (though this is not internalised by the representative bank).

The minimum capital requirement, φ_t, is held constant in the baseline analysis. In Section 4, it will be the first of two macroprudential policy tools available to the policymaker.

2.1.4 The representative bank's behaviour

The representative bank chooses all the components of its balance sheet – L_t, d_t and E_t – to maximise the discounted sum of expected future profits, subject to the balance sheet constraint ($L_t = d_t + E_t$).

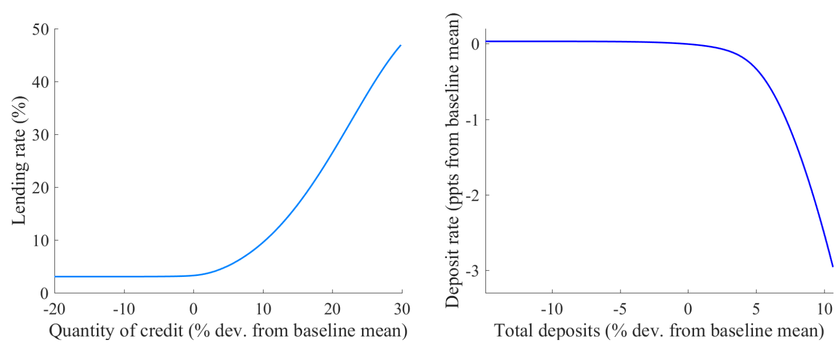
This sees the bank choose L_t such that the return on an extra unit of loans ($R_{L,t}$) equals the sum of the cost of an extra unit of deposits (R_t), the additional expected default costs ($R_{L,t} \lambda \mathbb{E}_t \theta_{t+1}$) and the increased expected cost of paying the penalty; see Equation (A.6) in Section A.1.4 of the on-line appendix for the mathematical expression. This is an upward-sloping supply curve for credit (Figure 2a); the counterpart (through the balance sheet constraint) is a downward-sloping demand curve for deposits (Figure 2b). Notice that the curve is nearly perfectly elastic over part of the domain, but then becomes increasingly inelastic; this reflects the relationship between loans and expected defaults shown in Figure 1.

The bank's lending policy to individuals is to offer them any combination of interest rate and loan amount that gives the expected rate of return implied by the bank's optimal choice of aggregate loans. This is referred to as the bank lending supply curve for individuals.

Also, banks raise equity until the discounted return on equity (given the bank's discount factor $\hat{\beta}$) equals equity adjustment costs.

Figure 2: Bank optimisation

(a) Credit or loan (L_t) supply curve (b) Deposit (d_t) demand curve



Note: Plotted at the unconditional mean under the baseline calibration.

2.2 Households and individuals

A utility-maximising representative household consists of a large number of individuals, indexed by i. There is a continuum of households, $q \in [0,1]$, each consisting of individuals $i \in q$. Households are assumed to be monopolistically-competitive suppliers of labour, in the spirit of Erceg, Henderson, and Levin (2000).

Decisions are split between those made at the household level, and those made by individuals. Individuals choose how much to borrow $L_t^i(q)$, their interest rate $R_{L,t}^i(q)$, and their stock of housing $H_t^i(q)$.[8] Each household chooses the amount of hours to work $N_t(q)$ and the wage rate $W_t(q)$, as well as consumption $C_t(q)$, investment $I_t(q)$, capital $K_t(q)$, and the amount to save in bank deposits $D_t(q)$.

The household and its members seek to maximise the expected lifetime utility of the household, V_t:

$$V_t \equiv \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_{P,t} \left[(1-\chi)\log(C_t(q) - \chi C_{t-1}) + \varepsilon_{H,t} \log H_t(q) - \frac{N_t(q)^{1+\eta}}{1+\eta} \right]$$

where β is the household's discount factor, $\varepsilon_{P,t}$ is a preference shock to the period utility function, $\varepsilon_{H,t}$ is a housing-specific preference shock and $H_t(q)$ is the aggregate stock of housing owned by the household.

Household optimisation occurs subject to five constraints. The first is a standard budget constraint restricting outflows of funds to be less than inflows of funds in every period. The second is a financing constraint that requires households to hold sufficient deposits at the

[8]Variables indexed by both i and q pertain to individual i in household q. Household aggregates are defined as follows. For loans, $L_t(q) \equiv \sum_{i \in q} L_t^i(q)$. For housing, $H_t(q) = \sum_{i \in q} H_t^i(q)$. The household lending rate can be defined as $R_{L,t}(q) \equiv \sum_{i \in q} R_{L,t}^i(q) L_t^i(q) L_t(q)^{-1}$, though we can invoke the symmetric equilibrium condition that all individuals choose the same interest rate to define the household lending rate as $R_{L,t}(q) \equiv R_{L,t}^i(q)$ for all $i \in q$.

beginning of each period – defined as deposits carried over from last period plus new loans, less loan repayments – to cover some proportion of expenditure on domestic output (ϕ_C) and housing (ϕ_H) for the period; this induces the household to hold deposits. The third is the bank lending supply curve for individuals, described in Section 2.1.4. The fourth is a downward-sloping labour demand curve that stems from the optimal choice of the labour aggregator (noted in Section 2.3). The fifth is the law of motion of capital.[9]

Households are subject to a macroprudential policy that provides a disincentive to borrow at higher LVRs by charging them a premium that increases with the LVR. Specifically, households pay $(1+\Upsilon_{H,t})R_{L,t}L_t$ on loans, with $R_{L,t}L_t$ paid to the lender and a premium of $\Upsilon_{H,t}R_{L,t}L_t$ paid to the regulator. $\Upsilon_{H,t}$ is defined as:

$$\Upsilon_{H,t} = \Upsilon_1(LVR_t - \Upsilon_{c,t})$$

where $\Upsilon_1 \geq 0$. The variable $\Upsilon_{c,t}$ is referred to as the level of the policy; if the aggregate LVR is greater than the level of the policy, then a premium is paid. As demonstrated in Figure 3, a tightening of the LVR policy (a lower $\Upsilon_{c,t}$) increases the regulatory premium at any LVR.[10] In Section 4, allowing $\Upsilon_{c,t}$ to be time-varying will be the second of the two macroprudential policy tools that is available to the policymaker.

The parameter Υ_1 is the slope of the premium function. We use it to compare policy frameworks without borrower-based macroprudential policies (where Υ_1 is set to 0) to policy frameworks with borrower-based macroprudential policies (where Υ_1 is set to a fixed value that is greater than 0).

To more closely align investment and wage dynamics to the data, investment and wage adjustment costs are included (as in Benes, Kumhof, and Laxton 2014a). An investment technology shock also appears in the model.

While the solution to the problems of the household and the individual leads to a mostly standard set of first-order conditions, two non-standard elements are of consequence. The first is that the demand curve for loans is downward sloping and increasingly inelastic in loans (due to the bank lending supply curve constraint; Figure 4). The second is that the presence of foreign trade allows there to be a flow of funds from the representative household to the representative partially foreign-owned bank in every period; for instance, if the bank is entirely foreign owned, this flow of funds equals inflows to the bank from the household ($D_t + R_{L,t-1}L_{t-1}$) less the flows from the bank to the domestic household ($R_{t-1}D_{t-1} + L_t$).

[9] See the online appendix for detailed descriptions of the constraints.

[10] As shown in Section 4, tightening the LVR policy and increasing the premium will shift the demand for loans lower. Other functional forms for $\Upsilon_{H,t}$, such as step functions – akin to an LVR cap implemented at some level – also see a policy tightening shift the demand curve lower. However, this only occurs over part of the domain. In an environment where individuals are *ex-ante* identical, a policy with a step function premium only has an effect if the step is below the equilibrium LVR. Using the linear premium function abstracts from the issue of the level of the policy.

Figure 3: The premium function

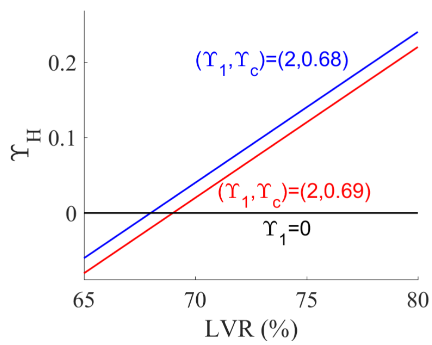
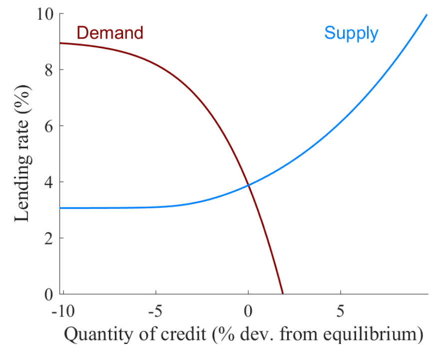


Figure 4: Credit (or loan) market



Note: Plotted at the unconditional mean under the baseline calibration

2.3 Further model features

2.3.1 Production sectors

Reflecting its small-open economy nature, the model involves the production of essentially two types of goods: intermediate goods used domestically and exports. Perfectly competitive, profit-maximising local producers and exporters both create output using Cobb-Douglas technology, and face a sector-specific technology shock. There are three inputs: domestic labour, imported inputs and capital.[11] In addition, to more closely match export dynamics to the data, we follow Benes, Kumhof, and Laxton (2014a) in assuming that exporters face a cost when adjusting output.

Nominal rigidities are introduced for the domestic goods, and to facilitate this a monopolistically competitive wholesale sector and a perfectly competitive retail sector who aggregate the differentiated goods are also included. These nominal rigidities are introduced using adjustment costs in prices, akin to Rotemberg (1982).

The model also includes perfectly competitive labour aggregators, in order to aggregate the differentiated labour supplied by households.

For simplicity, it is assumed that the supply of housing is fixed. Specifically, $H_t = 1$.

2.3.2 Monetary policy

Monetary policy is set using a Taylor rule:

$$\log(R_t) = \kappa_1 \log(R_{t-1}) + (1-\kappa_1)\left[\log\left(\frac{1}{\beta_W}\right) + \kappa_2 \log\left(\frac{\pi_t}{\pi^*}\right) + \kappa_3 \log\left(\frac{RGDP_t}{RGDP_{SS}}\right)\right] + \varepsilon_{MP,t}$$

[11]It is assumed that exporters use labour and imports only as inputs into the production process.

where $\pi_t \equiv \frac{P_{2,t}}{P_{2,t-1}}$, π^* is the inflation target, β_W is the foreign household's discount factor, the subscript SS denotes the steady-state level of a variable, and $\varepsilon_{MP,t}$ is the monetary policy shock. $RGDP_t$ denotes real GDP, which is a steady-state share-weighted geometric mean of the output of domestic goods, exports and imports. Other monetary policy regimes are considered in Section 5.3.

2.3.3 The exchange rate

It is the banks' choice between foreign deposits denominated in domestic currency (paid R_t) and those denominated in the foreign currency (paid R_t^W in the foreign currency) that determines the nominal exchange rate in this model.

There is a one-period forward market for the exchange rate in which the bank can trade. Defining the nominal exchange rate S_t so that a rise is a depreciation, we assume that the forward rate $\hat{S}_{t+1}$ is determined according to $\hat{S}_{t+1} = \mathbb{E}_t\left[S_{t+1}\right]U_t$, where U_t is a forward exchange rate shock capturing the empirical fact that the forward rate is an imperfect predictor of the future spot rate. A regulation is assumed to exist which prohibits banks from being exposed to foreign exchange risk.[12]

The bank optimally substitutes between foreign deposits denominated in the domestic and foreign currencies until they are indifferent between the two, yielding the following covered interest parity condition:

$$R_t = R_t^W \frac{\mathbb{E}_t\left[S_{t+1}\right]U_t}{S_t}$$

which implies that foreign denominated deposits effectively cost the bank R_t in the domestic currency (with foreign households receiving a return of $R_{W,t}$ in the foreign currency).[13]

2.3.4 Foreign sector and exogenous variables

The foreign sector consists of three variables: inflation, an interest rate, and the terms of trade (defined as the ratio of export to import prices). Foreign inflation, the foreign interest rate, the terms of trade, technology processes for the production of domestic goods and exports, and shocks to wholesalers' market power, the forward exchange rate, preferences and housing-specific preferences are determined exogenously, and evolve according to log AR(1) processes.[14] Investment and monetary policy shocks are assumed to be white noise.

[12] As discussed in Benes, Kumhof, and Laxton (2014a), imposing this regulation sees banks in the model behave in a manner that closely corresponds to observed behaviour (in regards to foreign exchange exposures).

[13] See Section A.1.2 of the online appendix for further details.

[14] Constant terms for the foreign interest rate, the shock to wholesalers market power, and household specific preferences are specified such that their steady-state values are $\frac{1}{\beta^W}$, $\mu_{2,SS}$ and β_H, respectively.

2.3.5 Symmetric equilibrium and market clearing conditions

In a symmetric equilibrium, all individuals i make identical decisions. That is, individuals choose the same loan amount, stock of housing and lending rate in each time period; it follows that the latter also equals the aggregate household loan rate, and that the LVR is the same for all individuals (and equal to the aggregate for a household, and across all households). Similarly, all households make identical decisions, as do all wholesalers.

The intermediate goods, final goods, labour, housing and credit markets must all clear in each time period t.

3 Calibration

The parameter settings are intended to represent a small open economy at an annual frequency.[15] The baseline policy settings – to which we will compare alternative policies – represent the policy framework prevalent throughout most of the 1990s and 2000s: monetary policy is focused on maintaining price stability, while the preservation of macrofinancial stability is left to a fixed capital requirement. We calibrate the model using data for New Zealand from 1991 (shortly after the introduction of inflation targeting) to 2007 (prior to the introduction of Basel II). This section primarily details the calibration of the parameters pertaining to the finance sector, household sector, and policy, all of which are shown in Table 1; details on the calibration of the parameters pertaining to the relatively standard aspects of the model (including the production and trade sectors, and the exogenous variables) are contained in Section B of the online appendix.

Banking sector parameters are calibrated as follows. One standard deviation of the default threshold distribution across individuals (σ_1) is set to 0.08, to match the variance of the log NPL ratio to the data. The domestic ownership share of banks (ν) is set to 0, reflecting that the banking sector in New Zealand is largely comprised of foreign-owned banks. The loss-given-default (LGD) parameter λ is 0.35, based on the average adjusted LGD rates used in Brooks and Cubero (2009), which are a little above the minimum LGDs for residential mortgage loans set by the Reserve Bank of New Zealand recently (Reserve Bank of New Zealand 2015). The bank penalty υ is set to 1 to match features of the bank's capital buffer to the data.[16] We set the bank's discount factor $\hat{\beta}$ to 0.955 in line with Benes, Kumhof, and Laxton (2014b).

The median of the default threshold distribution (κ), as well as the weight on housing services in household preferences (β_H), and the proportion of finance needed for purchases of housing (ϕ_H) and consumption and investment (ϕ_C), all have a large effect on the size of the bank's balance sheet. These were chosen jointly to match the steady-state loan- and

[15]To work with the stationary moments of variables, we normalise domestic nominal and price variables with respect to the price level; foreign price variables are normalised with respect to import prices. The normalised nominal exchange rate is the real exchange rate.

[16]Banks in New Zealand maintained equity to loan ratios that were typically well above minimum capital requirements (averaging around $2\frac{1}{2}$ per cent), ranging from a little under 1 per cent to 4 per cent. Setting the bank penalty υ to 1 sees the bank in the model exhibit similar behaviour: the buffer averages around 1.7 per cent, and in simulations of 1000 observations it ranges from just above 0 to 4 per cent.

deposit-to-GDP ratios. We set $\{\kappa, \beta_H, \phi_H, \phi_C\}$ to $\{0.87, 0.07, 0.4, 0.07\}$.

With regard to other household parameters, steady-state foreign and domestic interest rates – determined by the foreign household's discount factor β^W – are set to 3 per cent, which are towards the lower end of the estimates of the neutral real rate in New Zealand (for instance, see Chetwin and Wood 2013). The steady-state return to capital – determined by the domestic household's discount factor – is set to 9.3 per cent, to match the steady-state capital to output ratio to the data. In line with values commonly used in models representing a similar economy and time period, the inverse Frisch elasticity of labour supply η is 1, and the consumption habit parameter χ is 0.5 (similar to Kamber et al. 2015).

Table 1: Baseline parameter settings

Parameter	**Description**	**Value**
Banking sector		
$\hat{\beta}$	Bank's discount parameter	0.955
κ	Median of default threshold distribution	0.87
λ	Loss given default	0.35
ν	Domestic ownership share of banks	0
σ_1	Std. dev. of default threshold distribution	0.079
σ_2	Std. dev. of log house price growth	0.03
υ	Bank penalty	1
Household sector		
β	Discount rate	0.915
β_H	Weight on housing services in household preferences	0.07
β_W	Foreign household's discount rate	0.971
χ	External consumption habits	0.5
η	Inverse elasticity of labor supply	1
ϕ_C	Financing of consumption and investment	0.07
ϕ_H	Financing of housing investment	0.4
Policy		
κ_1	Monetary policy smoothing	0.7
κ_2	Monetary policy reaction to inflation	3.7
κ_3	Monetary policy reaction to output	0
φ	Minimum capital adequacy ratio	0.04
Υ_1	Slope of LVR premium	0

We calibrate the monetary policy parameters using estimates from a small three-variable SVAR.[17] The coefficients on the lagged interest rate and inflation, κ_1 and $(1-\kappa_1)\kappa_2$, are 0.7 and 1.1, while the coefficient on the output gap is estimated to be small and statistically insignificant, and is therefore set to 0, which is standard for New Zealand (see, for example, Benes, Binning, et al. 2009 and Jacob and Munro 2016).

[17] The SVAR contains the OECD measure of the output gap, inflation and the cash rate, identified recursively.

Macroprudential policy in the baseline represents the policies implemented under Basel I. In short, banks are required to hold capital worth 4 per cent of residential mortgage loans.[18] No LVR premium is paid under the baseline; Υ_1 is 0. When we allow the regulator to use the LVR policy in Section 4, Υ_1 is assumed to be 2.[19]

Remaining parameters are detailed in Appendix B. In brief, production parameters are calibrated to match the input and expenditure shares of GDP to the data. Adjustment costs – which are embedded in exports, prices, wages, investment and equity – are set to match the first-order autocorrelations of exports, inflation, wages, investment and equity to the data. Similarly, coefficients and shock variances of the 11 AR processes are calibrated to match the first-order autocorrelations and variances of the corresponding variables to the data (subject to the model variances of inflation and GDP being less than or equal to that observed in the data).

Tables 2 and 3 compare selected moments in the model with those observed in the data. The model appears to match a number of features of the data that are key to both the motivation for and the transmission mechanism of macroprudential policies. For instance: the variance and persistence of the variables on the bank's balance sheet in the model are close to that observed in the data; the model captures the very high correlation between house prices and (housing and personal) credit; and, the model replicates the negative relationship between these variables and both the equity-to-loan ratio and default rates.

The model also captures a transmission from housing market fluctuations to domestic demand. To illustrate this, Figure 5 shows responses to a housing preference shock that boosts house prices by around 5 per cent. Higher house prices raise both credit demand and supply, so that the quantity of credit is around 3 per cent higher. This – along with higher wages, mentioned below – lifts households' demand for consumption and investment goods, putting upward pressure on prices; an associated rise in domestic-good producers' demand for inputs (imports, capital and labour) drives up the quantity of these, and the supply of the domestic good. Higher supply and demand sees the quantity of the domestic good (i.e., domestic demand) around $\frac{1}{2}$ per cent larger – with consumption and investment approximately 0.4 and 0.8 per cent larger – and inflation around 0.2 per cent higher. However, the impact on aggregate GDP is mitigated by the fact that monetary policy is tighter than would otherwise be the case, inducing an appreciation that – with increased input costs – reduces exports by more than 1 per cent.[20] The reduction in exporters demand for labour offsets much of the increase from domestic-good producers; with lower labour supply, wages are around $\frac{1}{2}$ per cent higher and there is little change in employment. Thus, a boost to housing demand that drives up house prices by 5 per cent also leads to an increase in domestic demand of $\frac{1}{2}$ per cent that is facilitated by a 3 per cent rise in credit and a $\frac{1}{2}$ per cent increase in wages.

In the model, the largest drivers of real activity are productivity and terms of trade shocks, while inflation is more driven by interest rate, forward exchange rate and terms of trade shocks. The shock to the period utility function plays an important role in driving move-

[18]Under Basel I, banks were required to hold Tier 1 and 2 capital worth 8 per cent of risk-weighted assets. Residential mortgages received a risk weight of 50 per cent, meaning effective capital requirements on these loans was 4 per cent. Since all loans in this model are backed by housing, we set capital requirements to 4 per cent.

[19]Results are not sensitive to the choice of Υ_1.

[20]Allowing the supply of housing to vary may affect the magnitude of the response of output to fluctuations in the housing market. We leave a consideration of this to future work.

ments in bank buffers and the LVR, while house prices, credit and defaults are relatively more heavily driven by the housing preference shock. For further details, see the variance decompositions and impulse responses in Sections B and D of the online appendix.

Table 2: Selected statistics

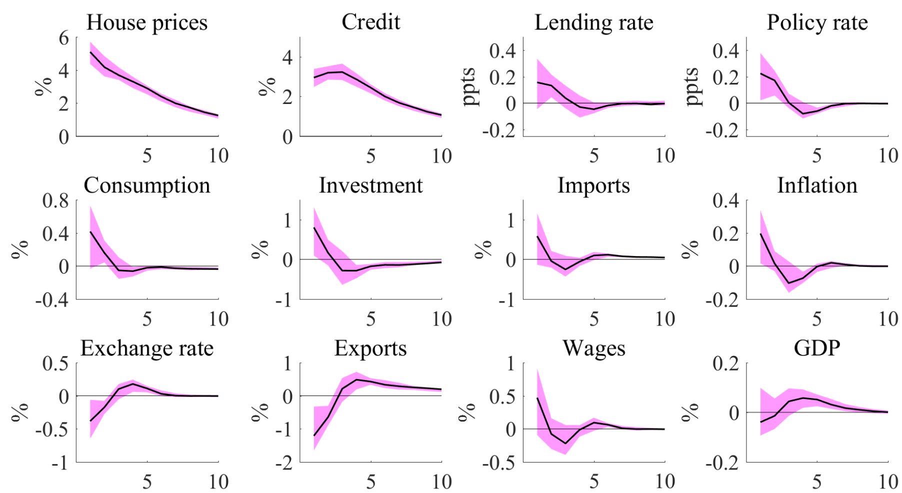
	Mean (per cent of GDP)		**Standard deviation (percentage points)**		**First-order autocorrelation**	
	Data	**Model**	**Data**	**Model**	**Data**	**Model**
Financial variables						
Policy interest rate	–	–	1.4	1.6	0.7	0.8
Credit	**56**	**56**	4.6	4.1	0.8	0.8
Household deposits	**40**	**41**	3.7	4.5	0.6	0.6
Equity	8.3	3	11.2	9.2	**0.7**	**0.6**
House prices	–	–	**9.2**	**5**	**0.8**	**0.8**
NPL ratio	0.2[b]	0.2[b]	**1.3**	**1.3**	0.8	0.2
Buffer	**2.7**[b]	**1.7**[b]	0.2	0.5	0.4	0.7
Domestic activity and price variables						
GDP	–	–	**2.2**	**2.2**	**0.8**	**0.7**
Consumption[a]	84	84	2.7	2.2	0.8	0.8
Capital investment	**15**	**15**	8.7	7.3	0.8	0.8
Exports	30	30	2	2.5	0.4	0.4
Imports	29	29	0.5	4.2	0.6	0.7
Capital	**154**	**154**	–	–	–	–
Inflation	–	–	**0.9**	**0.9**	**0.5**	**0.5**
Wages	–	–	1.1	2.8	**0.6**	**0.6**
Foreign variables						
Terms of trade	–	–	**5.2**	**2.6**	**0.8**	**0.8**
Foreign interest rate	–	–	**1.5**	**1.5**	**0.7**	**0.8**
Import price growth	–	–	**0.6**	**0.6**	**0.4**	**0.4**
Exchange rate	–	–	**11.2**	**3.8**	**0.5**	**0.6**

Notes: Bold font indicates that the statistic was used in calibration.
a Including residential investment b Per cent of loans

Table 3: Correlations

	Credit		**House prices**		**Equity-to-loan ratio**	
	Model	**Data**	**Model**	**Data**	**Model**	**Data**
House prices	0.9	0.9	–	–	-0.4	-0.3
Household deposits	0.7	0.7	0.9	0.8	-0.4	-0.1
Equity to loan ratio	-0.6	-0.6	-0.4	-0.3	–	–
NPL ratio	-0.4	-0.5	-0.5	-0.3	0.0	0.2
GDP	0.2	0.5	0.3	0.5	-0.1	0.3

Figure 5: Responses to a housing preference shock



Notes: Figures depict the range of responses from 200 simulations, and the response that is closest to the median. See Section D in the online appendix for further details.

4 Policy effects

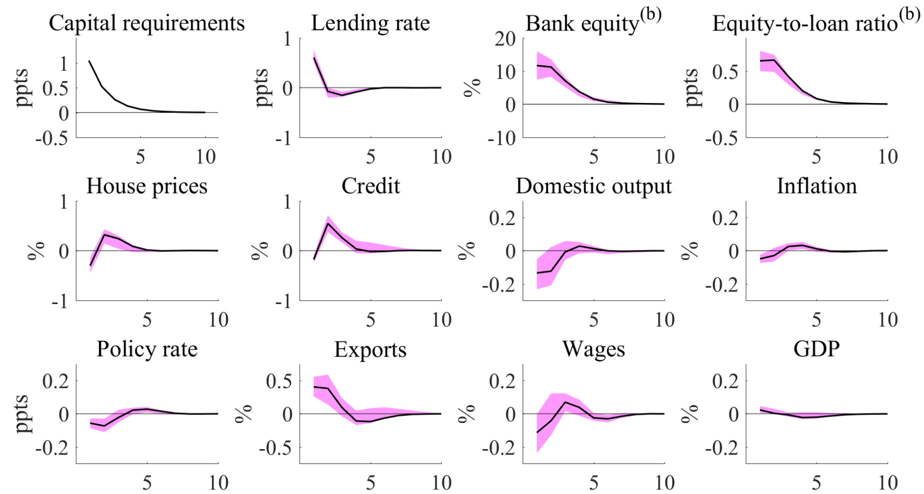
We allow the policymaker to operate two macroprudential policy instruments in the model in addition to monetary policy. They can operate a lender-based capital requirements policy by altering φ_t, a borrower-based LVR policy by altering $\Upsilon_{c,t}$, and monetary policy by altering the deposit rate R_t. To gauge the effects of these policies, this section examines the responses to shocks to the policy tools, assesses the ability of policy rules to reduce the variances of key variables, and evaluates the welfare implications of the policy rules.

4.1 Impact of exogenous policy changes

The capital requirements policy predominantly affects the lending rate. Through this, it affects the interest spread – i.e., the lending rate minus the deposit rate – and bank profitability. An exogenous 100 basis point tightening of capital requirements drives up the interest spread by an average of 0.7 percentage points, whereas a one standard deviation movement under the baseline is just 0.2 percentage points (Figure 6). This raises bank profits, and therefore increases the stock of equity and the equity-to-loan ratio. However, there is very little impact on credit and house prices: these are reduced by less than $\frac{1}{3}$ percentage point, whereas the coefficients of variation (CVs) – one standard deviation movements as a percentage of the mean – are 4 and 5 per cent respectively under the baseline calibration.

The effects of the LVR policy in the credit and housing markets are vastly different to the

Figure 6: Response to 100 basis point tightening of capital requirements$^{(a)}$



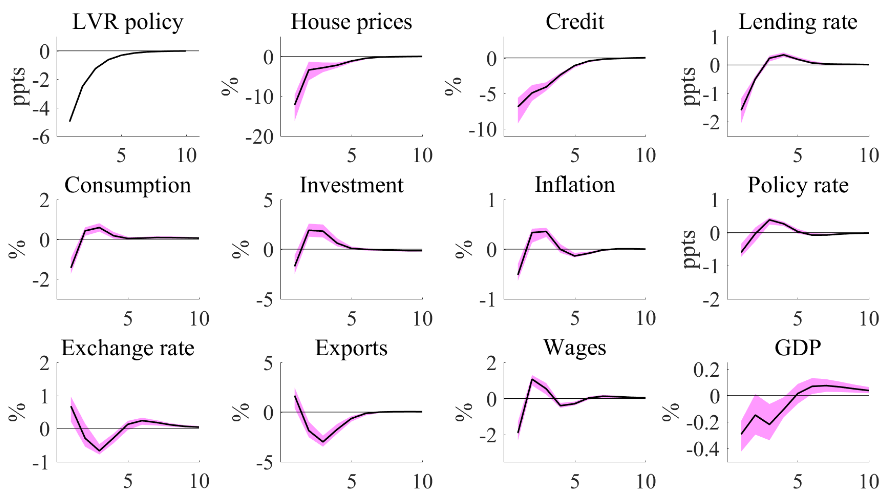
Notes: a) See notes to Figure 5. The persistence of the capital requirements shock is set to 0.5. b) Ex-post values, advanced one period.

effects of the capital requirements policy. It has relatively larger effects on credit and house prices, and relatively smaller – and negative – effects on lending rates and interest spreads. An exogenous tightening of the LVR policy by 5 percentage points reduces credit and house prices by 6 per cent and 12 per cent respectively, while the interest spread is around 1 percentage point lower (Figure 7). So, a tightening of the LVR policy that reduces credit by 5 per cent would lead to a 0.9 percentage point reduction in the lending spread, whereas a tightening of capital requirements that reduces credit by 5 per cent would raise the lending spread by 19 percentage points.

Differences in the effects of the macroprudential policies occur because tightening capital requirements primarily reduces the supply of credit, whereas tightening the LVR policy primarily reduces the demand for credit. The contemporaneous effect of a tightening in capital requirements policy on housing and credit markets can be seen in Figure 8, which shows the markets for credit and housing before and after a shock to capital requirements. The main effect is a reduction in the supply of credit; this has a relatively small effect on the quantity of credit and a relatively large effect on the lending rate, due to the inelasticity of the demand curve and the elasticity of the supply curve around the equilibrium. The contemporaneous effect of a tightening in LVR policy is largely to reduce the demand for credit and housing, which has a larger effect on credit and a smaller effect on the lending rate (Figure 9).

Despite their different impacts in credit and housing markets, the macroprudential policies have similar effects in goods and labour markets. Tightening either policy reduces households' demand for consumption and investment goods, leading to lower output prices and

Figure 7: Response to 5 percentage point tightening of LVR policy

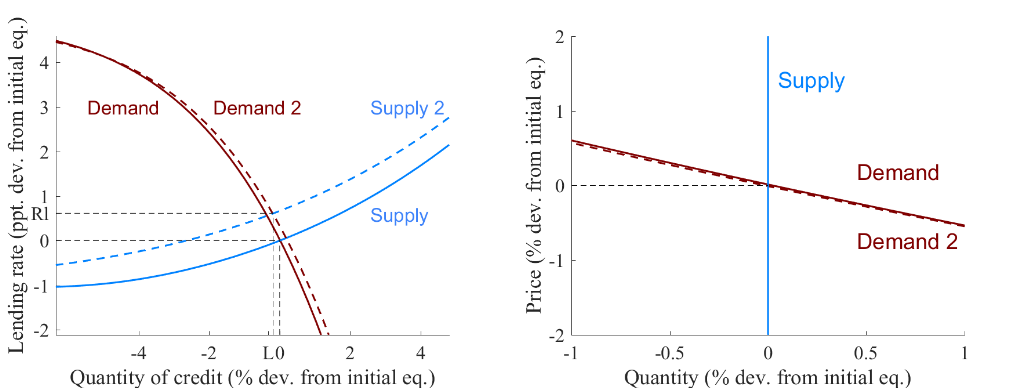


See notes to Figure 5. The persistence of the LVR policy shock is set to 0.5.

Figure 8: The effect of a 1 percentage point increase in capital requirements

(a) Credit market

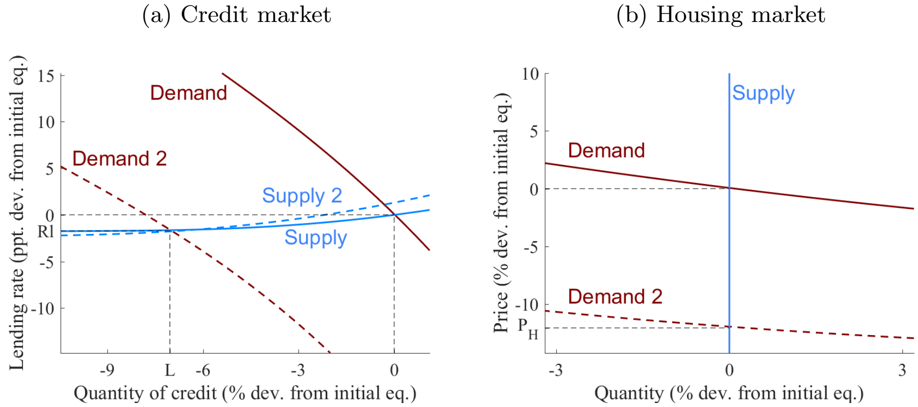
(b) Housing market



Notes: The curves labelled Supply and Demand are the supply and demand of housing and credit prior to a capital requirements shock. Supply 2 and Demand 2 are the curves in the period of the shock. Parameters are as described in Table 1, with all variables initially at their means.

inflation. The associated reduction in domestic-good producers' demand for imports, capital and labour sees the quantity of these inputs – and the supply of the domestic good – lowered. Wages are also reduced. The size of these effects is not negligible: a tightening of the LVR policy that lowers credit by 5 per cent also reduces domestic demand (i.e., consumption and

Figure 9: The effect of a 5 percentage point tightening of LVR policy



See Notes to Figure 8.

investment) and wages by close to 1 per cent, and inflation by $\frac{1}{3}$ per cent.[21] However, effects on aggregate GDP and employment are mitigated by the fact that the monetary authority eases policy, inducing a depreciation that – with the decline in wages – boosts exports.

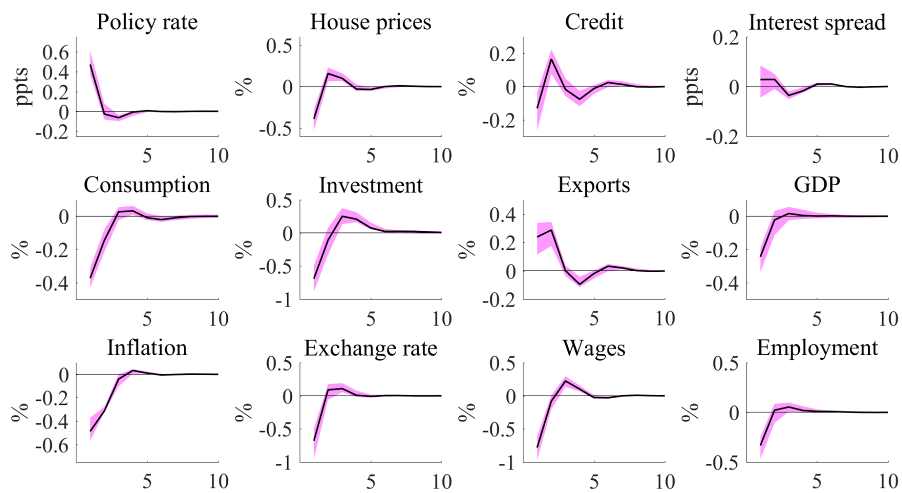
Monetary policy has larger effects on the goods market – relative to its impact on the credit market – than the macroprudential policies. A one standard deviation monetary policy shock reduces inflation by $\frac{1}{2}$ per cent, consumption by 0.4 per cent and GDP by $\frac{1}{4}$ per cent (Figure 10); these estimates are of a broadly comparable magnitude to Liu (2016). House prices and credit are only reduced by 0.4 per cent and 0.1 per cent though. A substantial tightening of monetary policy would therefore be required to reduce credit by 5 per cent; this would lower inflation by around 8 per cent, domestic good output by 10 per cent, and GDP by 7 per cent. Macroprudential policy can have the same effect on credit with one-tenth of the effect on activity and prices.

One other feature of consequence is that the capital requirements policy has asymmetric effects on the lending rate. In particular, a tightening of policy has a greater impact than an equivalent easing. For instance, while a 100 basis point tightening drives the lending rate up by an average of around 60 basis points on impact, a 100 basis point easing sees the lending rate fall by around 45 basis points.

The asymmetry stems from the nonlinearity in the NPL ratio, and the fact that banks hold capital buffers. All else equal, changing the minimum capital requirement affects the NPL ratio needed to cause the bank to violate requirements, and through this affects the probability that the bank incurs a penalty, and the supply of credit. The NPL ratio needed to cause banks to incur the penalty is typically very high, and the probability of this occurring very low, as banks optimally choose to hold sizable capital buffers. Reducing the requirement raises the level the NPL ratio needs to reach to cause the bank to violate the requirement, and tightening the requirement reduces it by the same amount. However, the increase in the probability of exceeding the lower NPL ratio is greater than the decrease in

[21] A tightening of the capital requirements policy that reduces credit by 5 per cent lowers domestic good output and wages by around 4 per cent, and inflation by $1\frac{3}{4}$ per cent.

Figure 10: Response to a one standard deviation monetary policy shock



See notes to Figure 6.

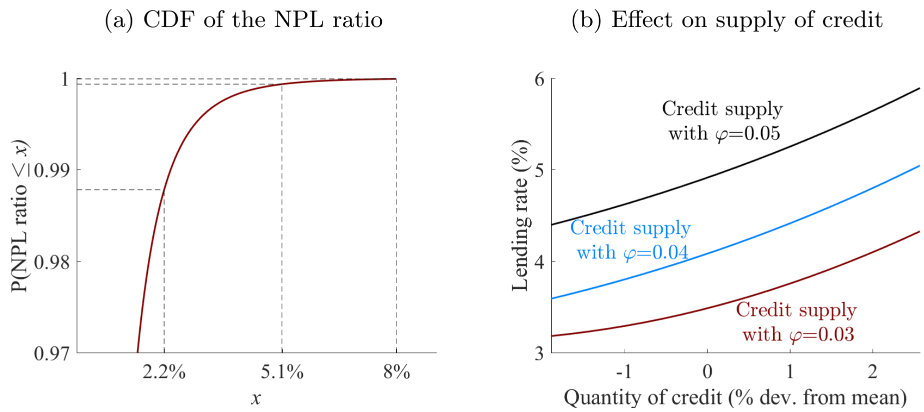
the probability of exceeding the higher NPL ratio. This reflects the fact that house price growth (and the NPL ratio) are normally distributed (and not uniformly distributed). The consequence is that a tightening has a larger impact on the expected penalty and the supply of credit than an easing.

A numerical example serves to illustrate this. Let all variables be at their means under the baseline calibration of the model. For banks to violate minimum capital requirements – given their substantial capital buffers – house prices must fall to such an extent that the NPL ratio rises above 5.1 per cent (from 0.2 per cent); the probability of this is 0.08 per cent (Figure 11a). If the capital requirement was 1 percentage point lower, all else equal, the NPL ratio would need to spike up above 8 per cent; the probability that this occurs is less than 0.01 per cent. If the capital requirement were 1 percentage point higher, the NPL ratio would only need to rise above 2.2 per cent; the probability of this is 1.2 per cent. So easing the policy reduces the probability of incurring the penalty by 0.07 percentage points, while tightening the policy increases it by 1.12 percentage points. Hence, tightening capital requirements has a larger effect on the probability of paying the penalty – and consequently on the credit supply curve – than an easing (Figure 11b).

4.2 Policy rules and stability

In this section, we study the implications for stability of the prudential regulator following simple rules for the minimum capital requirement (φ_t) and the level of the LVR policy

Figure 11: The asymmetric effects of capital requirements



Notes: All variables other than capital requirements are at their mean under the baseline calibration.

($\Upsilon_{c,t}$). These rules take the form:

$$\varphi_t = (1 - \varphi_2)\varphi_0 + \varphi_1 \Sigma_t + \varphi_2 \varphi_{t-1} \tag{1}$$
$$\Upsilon_{c,t} = (1 - \upsilon_2)\upsilon_0 + \upsilon_1 \Sigma_t + \upsilon_2 \Upsilon_{c,t-1} \tag{2}$$

where Σ_t denotes a variable (or a vector of variables).[22] The inclusion of the lag of the respective policy instruments is motivated by interest rate smoothing often being found to be considerable in estimated Taylor rules for monetary policy.

The aim is to assess how these policies can best be used to lower the volatility of variables thought to be key for financial stability, namely credit, house prices and the NPL ratio, and whether they also affect the variances of activity and price variables. We therefore examine the effect of varying $\varphi_1, \varphi_2, \upsilon_1$ and υ_2 on the variances of variables.[23]

We allow Σ_t to be house prices in deviation from mean. In Section 5, we look at the sensitivity of the results to the choice of Σ_t, alternatively considering credit, other financial variables (such as the lending spread), price and activity variables, and variables in growth terms; we also look at the effect of allowing monetary policy to respond to credit and house prices in that section.

We now consider the effect on stability of each macroprudential policy.

[22] Allowing capital requirements to vary linearly with variables means that capital requirements might occasionally be negative; however, under all parameters considered here, equity to loan ratios remain well above zero.

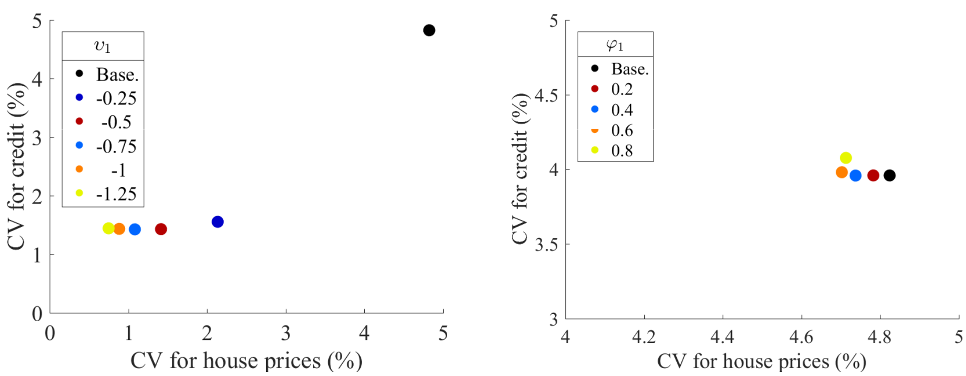
[23] The constant terms υ_0 and φ_0 are treated as given: φ_0 is set in line with the baseline calibration (0.04), while υ_0 is set to the baseline steady-state LVR ratio (69.65%).

4.2.1 LVR policy

Allowing the LVR policy to vary with the deviation of house prices from their mean is particularly effective in creating more stable financial conditions. Under more aggressive LVR policy – i.e., with higher absolute values of υ_1 and υ_2 – the variances of both house prices and credit are lower. Specifically, the CVs for credit and house prices are $1\frac{1}{2}$ and $\frac{1}{2}$ per cent under aggressive LVR policy, compared with 4 and 5 per cent under the baseline policy settings (Figure 12a). The variance of house price growth is also considerably lower under the LVR policy; this is a point which we return to in Section 4.3.

Figure 12: Effect of policies on the variance of loans and house prices

(a) LVR policy (b) Capital requirements policy



Notes: In Figure a), the parameter υ_2 is set to 0.75. In Figure b), the parameter φ_2 is set to 0.1.

The LVR policy is effective in mitigating the impact of many shocks on house prices and credit. This is illustrated in Figure 13, which shows responses of house prices to selected shocks under various policy settings.[24] The effect on house prices (and credit) of housing preference shocks, domestic and foreign monetary policy shocks, and productivity shocks, in particular, are reduced substantially under the LVR policy.

By reducing the volatility of house prices, the LVR policy fosters increased financial stability, with fewer spikes in the amount of defaults. In large simulations with identical draws of shocks, only 4 per cent of NPL ratio observations are above 1 per cent when time-varying LVR policy settings are used, compared with 7 per cent of observations under the baseline.

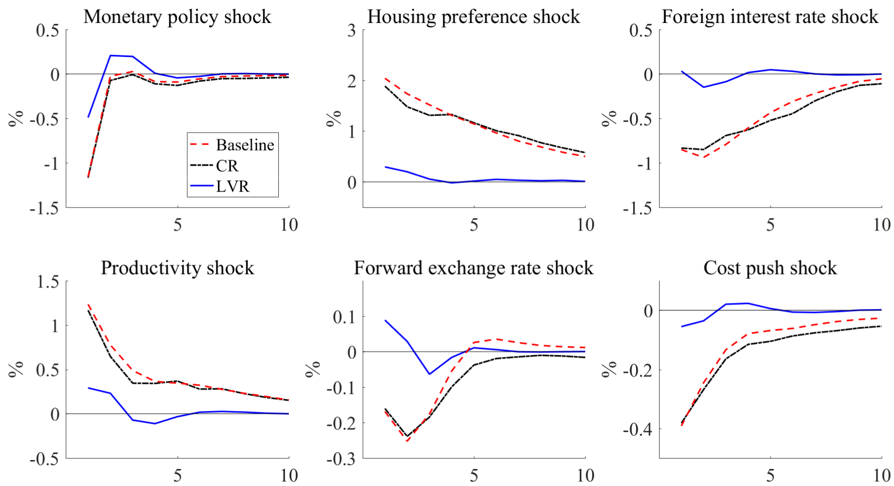
Allowing the LVR policy to vary with the deviation of house prices from their mean has little effect on the variances of inflation, activity and labour market variables.

4.2.2 Capital requirements

Allowing the capital requirements policy to vary with the deviation of house prices from their mean is much less effective in safeguarding stability. The variance of credit changes

[24]See Section D.2 in the online appendix for further responses to the shocks.

Figure 13: Response of house prices to shocks under various policy settings



Notes: Under capital requirements policy (CR), φ_1 is 0.4 and φ_2 is 0. Under LVR policy (LVR), υ_1 is -1.25 and υ_2 is 0.75. Figures depict the response of house prices that is closest to the series representing the median response of house prices in each period to that particular shock.

little as capital requirements policy is used more aggressively (Figure 12b). The frequency of spikes in the NPL ratio is also unaffected. The CV for house prices is around 4.7 per cent under aggressive capital requirements policy, marginally lower than the 5 per cent under baseline policy settings but much more than the $1\frac{1}{2}$ per cent observed under aggressive LVR policy.

With little improvement in financial stability, capital requirements have almost no stabilising effect on the macroeconomy. There is very little change in the variances of price, activity and labour market variables.

Instead, the capital requirements policy affects the volatility of the interest rate spread and equity. The variances of these variables are increasing in the aggressiveness of the policy, φ_1. And the effect is large: the CV of equity increases fivefold as φ_1 is raised from 0 to 0.5.

4.3 Welfare analysis

In this section, we study the welfare implications of the macroprudential regulator following the simple rules for φ_t and $\Upsilon_{c,t}$ defined in (1) and (2). Specifically, we examine the effect of varying φ_1, φ_2, υ_1 and υ_2 on the unconditional expectation of expected lifetime utility (denoted $E[V_t]$, where V_t is expected lifetime utility). Differences between policies are expressed in consumption equivalent units (λ_c), implicitly defined as:

$$\mathbb{E}[V_0^y] = \mathbb{E}\left[\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(\left(1 - \frac{\lambda_c}{100}\right) C_t^x, H_t^x, N_t^x\right)\right]$$

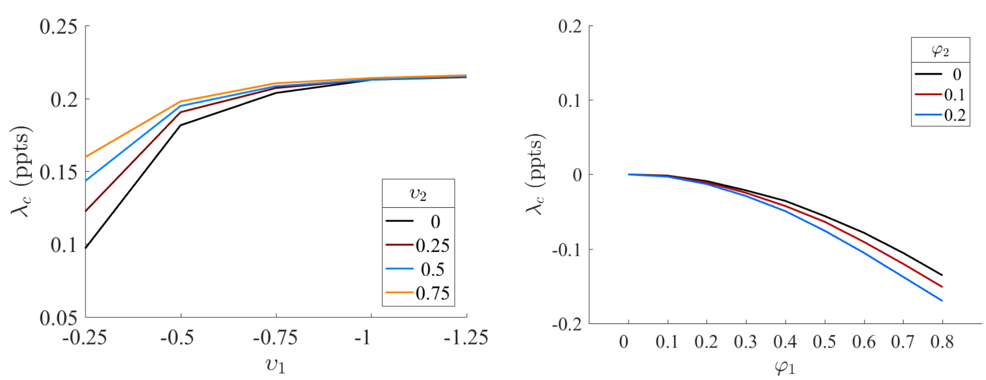
where V_0^y is expected lifetime utility, given some initial condition, under a certain policy regime (that we call Regime YY); C_t^x, H_t^x and N_t^x denote aggregate household consumption, housing and hours worked under an alternate policy regime (Regime XX).[25] That is, in expectation, a household could choose to live under Regime XX and give up λ_c per cent of its consumption and still be as well off as it would be if it chose to live in an economy that has the policy settings of Regime YY (but is otherwise identical).

Allowing the borrower-based LVR policy to vary with the deviation of house prices from their mean can improve welfare. Welfare increases as the policy is used more aggressively – i.e. at lower levels of υ_1 and higher values of υ_2 – though there are decreasing returns to additional aggressiveness (Figure 14a). Welfare is highest when υ_1 is less than -0.75; a household choosing to live in an economy with this aggressive LVR policy could give up around 0.2 per cent of consumption and still expect to be as well off as if they had chosen to live in an economy with the baseline policy regime.

Figure 14: Welfare comparison with policies responding to house prices

(a) LVR policy

(b) Capital requirements policy



Notes: Figure a) depicts welfare when $\upsilon_1 \in \{-0.25, -0.5, -0.75, -1, -1.25\}$ and $\upsilon_2 \in \{0, 0.25, 0.5, 0.75\}$. Figure b) shows welfare with $\varphi_1 \in \{0, 0.1, 0.2, ..., 0.8\}$ and $\varphi_2 \in \{0, 0.1, 0.2\}$. Gains or losses are relative to welfare under the baseline policy settings. Figures depict only a small subset of the parameters examined; however, results are indicative of those observed over wider and finer intervals for the parameters.

In contrast, allowing capital requirements to respond to house prices in deviation from mean reduces welfare (Figure 14b). The welfare loss increases with both φ_1 and φ_2.

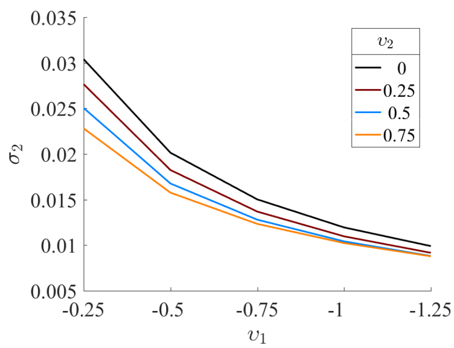
The differences in the welfare outcomes reflects differences in the ways the policies affect the means of variables, particularly those related to flows between the domestic economy and foreign bank.

[25] See Section C of the online appendix for a derivation of the explicit definition of λ_c.

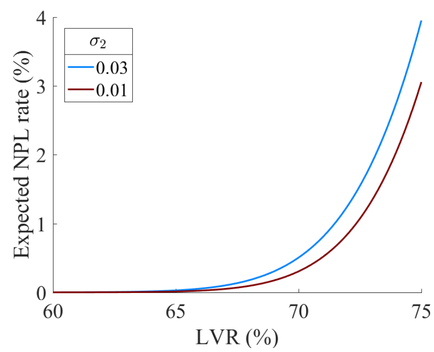
The LVR policy affects the means of variables by creating a fundamentally more stable housing market, which makes individuals less likely to default and banks' more willing to lend. To be more specific, the variance of house price growth – which is the parameter σ_2 – is less than 1 per cent under aggressive LVR policy, compared with 3 per cent under the baseline (Figure 15a). Consequently, the probability that the fall in house prices will be sufficiently large to cause an individual to default is lower under aggressive LVR policy than under the baseline (given expectations of house price growth, the LVR and default threshold; Figure 15b). This reduces the amount of defaults that a bank expects if it lends a given amount, affecting its willingness to lend (and the supply of credit; Figure 15c). As a result, the LVR policy not only affects the variances of variables, but also their steady states and means.

Figure 15: Effect of LVR policy

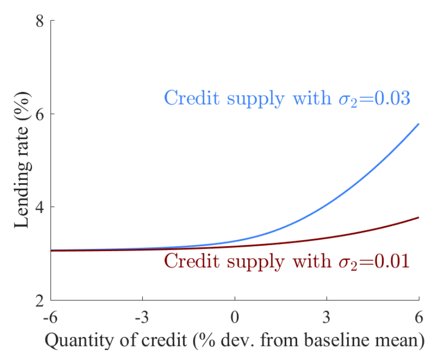
(a) Effect on σ_2



(b) Effect of σ_2 on the NPL ratio



(c) Effect of σ_2 on the supply of credit



Notes: In Figure a), Υ_1 is set to 2. In Figures b) and c), all parameters other than σ_2 are as described in Table 1, and all variables are at their steady-state levels under the baseline.

Comparing the steady-state equilibria under the LVR policy to the baseline provides insights into how these effects lead to welfare gains.[26] In the credit and housing markets, the steady-state demand for credit and housing and the supply of credit are much lower under the LVR

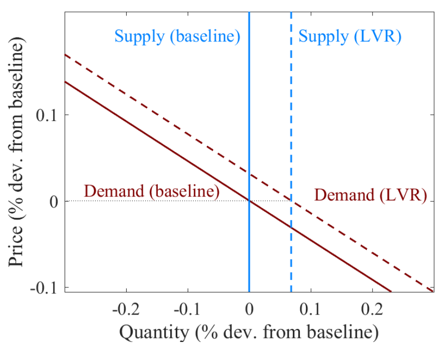
[26]Comparing equilibria at the unconditional mean of variables, or at the equilibrium that the economy tends to in the absence of shocks, presents very similar results.

policy; steady-state loans and house prices are therefore considerably lower, while the lending rate is roughly the same. The lower stock of loans sees a smaller flow of funds from the domestic household to the foreign bank under the LVR policy.

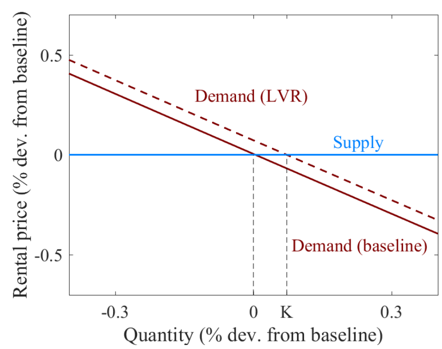
This has consequences for the domestic goods and labour markets. With less expenses on loan repayments in the steady state under the LVR policy, households demand for domestic goods is higher (Figure 16a). This implies that domestic-good producers' demand for capital is also higher; since the supply of capital is perfectly elastic in steady state, there is a larger capital stock and supply of the domestic good (Figure 16b). In the labour market, this leads to higher demand for labour from domestic goods producers, but this is more than offset by lower demand from exporters; combined with a lower labour supply, employment falls while the wage rate is little changed (Figure 16c).

Figure 16: Comparison of steady states under the baseline and LVR policies

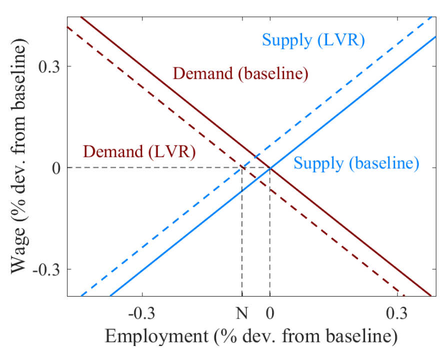
(a) Domestic good market



(b) Market for capital goods



(c) Labour market

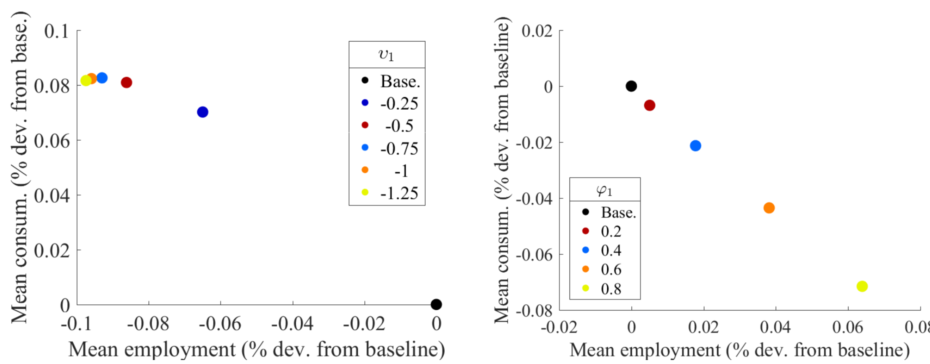


Notes: Curves labelled baseline, depicted with solid lines, are graphed in steady state under the baseline calibration. Those labelled LVR (dashed lines) are the curves in steady state under aggressive LVR policy (i.e. Υ_1, υ_1 and υ_2 are set to 2, -1.25 and 0.75.)

Thus, aggressive LVR policy, in creating a more stable housing market, leads to higher steady-state consumption and lower steady-state employment. Average consumption is higher, while average employment is lower (Figure 17a). This contributes to the welfare improvement associated with the LVR policy.

Figure 17: Effect of macroprudential policies on average consumption and employment

(a) LVR policy (b) Capital requirements policy



With capital requirements policy, however, average hours worked rises relative to the baseline, while average consumption falls. This reflects the asymmetric effects of the policy, which induces a heavy positive skew in the distribution of lending rates and equity.[27] As a result, the *average* level of equity and bank profitability, and hence the flow of funds from domestic households to foreign banks, is higher under capital requirements policy than under the baseline. This has the opposite effect to the LVR policy on the markets for domestic goods and labour: average consumption falls and average employment rises (Figure 17b). This contributes to the welfare reduction caused by the capital requirements policy.

The result that supply-side policies are ineffective in improving stability and welfare, while demand-side LVR policies are effective, contrasts with findings under the loanable-funds framework. As discussed in Section 1, countercyclical capital requirements are frequently found to reduce the volatility of key variables and improve welfare in loanable-funds frameworks. Demand-side LVR policies that respond to house price or credit growth are also found to improve aggregate welfare and stability in this environment (though some households may be worse off; see Kannan, Rabanal, and Scott 2012, Lambertini, Mendicino, and Punzi 2013, Mendicino and Punzi 2014, Rubio and Carrasco-Gallego 2014 and Rubio 2016). When compared though, countercyclical capital requirements policies are found to be more effective than LVR policies under loanable-funds frameworks.

5 Sensitivity analysis

In this section, we look at whether LVR policies still improve welfare – and whether capital requirements policies still cause a deterioration in welfare – when we: a) allow the macroprudential policies to vary jointly; b) allow macroprudential policies to respond to variables other than house prices in deviation from mean; and, c) alter the monetary policy rule.

[27]For instance, in simulated data, the skewness coefficient on equity is between 0 and 1 under the baseline policy settings (and under time-varying LVR policies), but is close to 7 under capital requirements policy with φ_1 and φ_2 set to 0.5.

5.1 Jointly implementing macroprudential policies

Allowing the macroprudential policies to vary simultaneously does not substantially alter the key results. The highest level of welfare gains achieved over the baseline is a little over 0.2 per cent, as occurs under aggressive LVR policy and fixed capital requirements. In fact, the effects of the two policies seem largely independent, with one exception: when combined with aggressive LVR policy, which reduces the variance of credit and house prices, the capital requirements policies considered involve very small changes in minimum capital requirements (φ_t) and therefore have negligible impacts on welfare.

5.2 Allowing macroprudential policies to respond to other variables

Setting Σ_t to the deviation of credit from its mean produces similar results to those reported in Section 4. This is to be expected given the tight relationship between mortgage credit and house prices in both the data and the model.

Allowing the LVR policy to respond to inflation or activity reduces welfare considerably. While the variance of output can be reduced under this policy, the variance of house prices, credit and defaults are much higher; this has the opposite effects to those observed when the LVR policy responds to house prices, and thus welfare is lower.[28] Allowing capital requirements to respond to inflation, activity, or the lending spread has almost no effect on stability or welfare.

A policy regime that sees the LVR policy respond to house price or credit *growth* does not perform as well as one in which the LVR policy responds to these variables in deviation from mean. This can be viewed as reflecting the fact that house price growth is very volatile with little persistence, while the deviation of house prices from their mean displays clear cyclical behaviour; varying policies with house price growth therefore sees the policymaker frequently alter the stance of policy, but not in line with house price cycles. That is, policy is loose when house prices are high but decline, and tight when house prices are low but increase. As a result, when the policy is used with moderate aggressiveness (e.g. $0 > \upsilon_1 > -0.5$ and $0 < \upsilon_2 < 0.5$), there is a large reduction in welfare relative to the baseline, and the variances of credit, house prices, house price growth and the NPL ratio are much higher. Only by using this policy very aggressively (e.g. $\upsilon_1 < -1.75$ and $\upsilon_2 > 0.75$) can a policymaker reduce the variance of house price growth and produce welfare gains.

5.3 Sensitivity to monetary policy rules

The key findings do not appear to be sensitive to the choice of monetary policy rule. We considered six alternative monetary policy settings: i) optimal policy within the class of rules defined in Section 2.3.2, where κ_2 and κ_3 have been chosen to maximise welfare;[29] ii) highly

[28] The CV for real GDP can be reduced by around 1 percentage point when this policy is used aggressively, but the CV for house prices, for instance, increases from 5 to around 8 per cent even under moderately aggressive policy settings. Welfare is lower than under the baseline by more than 0.3 per cent of consumption, even under moderately aggressive policy settings.

[29] Allowing monetary policy to respond to GDP reduces welfare; while the variance of output is lower, the variance of inflation, house prices and credit are higher. Using a grid search over κ_2, we find that the

persistent but moderately aggressive policy, with κ_1 and κ_2 set to (0.9,1.5), which improves welfare outcomes; iii) aggressive policy, with κ_1 and κ_2 set to (0.7,10), which reduces the variance of inflation considerably; iv) a policy setting where interest rates respond to the output gap; v) a policy setting where interest rates respond to the deviation of house prices from their mean; vi) a policy setting where interest rates respond to house price growth.

In all of these cases aggressive borrower-based LVR policies reduce the variances of loans, house prices and defaults, and improve welfare. Also, in all cases time-varying capital requirements policies reduce welfare.

An alternative to macroprudential policies that has been discussed considerably is using monetary policy to "lean against the wind" of asset prices. In this model allowing monetary policy to respond to house prices or credit – either in deviation from mean or in growth terms – has small effects on welfare. When monetary policy responds to these variables in growth terms, the variances of credit, house prices and defaults are a little lower; however, it comes at the cost of a rise in the variance of inflation. When monetary policy responds to house prices or loans in deviation from mean, the variances of inflation, house prices, loans, and the NPL ratio are all higher than under the baseline.

6 Conclusions

A major development in the conduct of macroeconomic policies worldwide in the past decade has been the increased prevalence of macroprudential policies. Unlike monetary policy, macroprudential policy encompasses a wide range of instruments. We have examined the relative effectiveness of systematically implemented demand-side (or borrower-based) and supply-side (or financial institutions-based) macroprudential policies in a framework where banks create credit.

Demand-side LVR policies which respond to either house prices or credit were found to be particularly effective. These policies shift the demand for credit and housing; since the demand for credit is inelastic and the supply of credit is elastic, there is a large effect on credit and house prices. They can therefore be used to reduce the volatility of house prices, credit and defaults, and can improve welfare.

Demand-side macroprudential policies were found to be distinctly different to monetary policy; their effects are relatively concentrated on the behaviour of housing and credit. This makes monetary policy "leaning against the wind" of house prices a poor substitute for these macroprudential policies.

Supply-side capital requirements policies that respond to house prices or credit do not deliver welfare improvements. They primarily affect the supply of credit and hence the lending spread; there is little effect on the quantity of credit, house prices, or defaults, all of which are not materially more stable.

In summary, in an environment where banks engage in credit creation, systematically implemented demand-side macroprudential policies were found to be preferable to supply-side policies.

highest levels of welfare are achieved when κ_2 is just over 1. Also, welfare is increasing in κ_1.

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