Consequences of Loan-to-Value Ratio Policies for Business and Credit Cycles*

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Abstract

Setting maximum Loan-To-Value (LTV) ratios is one of the most widely used macroprudential policies. We examine their implications for the business and credit cycles. This is done using a DSGE model with housing and long-term mortgage debt. Two types of policies are considered: a permanent lowering and activist, "leaning-against-the-wind", policy. The former is found to decrease the proportion of time that the economy is in a recession and the average depth of recessions; these impacts are greater for the credit cycle. Activist LTV ratio policy can also improve the characteristics of business and credit cycles, although care needs to be taken in its design, particularly with respect to which variables the LTV ratio responds to and the aggressiveness of the response.

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1 Introduction

The global financial crisis (GFC) highlighted that monetary policy focused on targeting inflation does not ensure financial stability. This is of particular importance given that the real effects of financial instability are large – the associated recessions are particularly severe (e.g. Reinhart and Rogoff [2009] and Claessens et al. [2012]). Consequently, in many nations there has been increased usage of macroprudential policies, which are a range of policies intended to promote financial stability (see Lim et al. [2011]). There has also been greater emphasis placed on the role of credit in the economy, or more broadly, the financial cycle (e.g. Borio [2012]).

The housing market and residential mortgages, due to their role in the financial crisis and perceived potential future vulnerabilities, have been the focus of many macroprudential policies. Setting maximum Loan-To-Value (LTV) ratios on residential mortgages is a widely used policy (Lim et al. [2011]); examples of nations where it has been introduced include Canada and New Zealand (see Krznar and Morsink [2014] and Wheeler [2013]). The nature of these policies differ; some are permanent (e.g. Canada), whereas other are explicitly temporary (e.g. New Zealand). Activist policy can be used to "lean against the wind" of potential risks and imbalances.

The research question that this paper addresses is what are the consequences of permanent and activist LTV ratio policy for the business and financial cycles? In particular, we examine whether LTV ratio policy lessens the severity of recessions, and/or the frequency with which they occur. As these policies have only recently been implemented or are under consideration in many nations, understanding their potential impacts on these cycle characteristics is of importance to policymakers. We also examine the consequences of LTV ratio policies for expansionary periods of the economy, including whether they are adversely impacted. In assessing the impact of these policies upon the financial cycle we focus on their consequences for the cyclical behavior of credit.

To investigate these questions a model with housing and mortgage debt is required. A natural baseline model therefore has the structure of Iacoviello [2005], which includes mortgage debt and a collateral constraint. Reflecting the focus of the paper on analysing LTV ratio policy, we extend the model to allow for multiple-period mortgage loans, drawing on Kydland et al. [Forthcoming] and Garriga et al. [2013]. This extension is of importance as it will sizably alter the quantitative impact of any LTV ratio policy.

To study how the characteristics of the business and credit cycles are impacted it is necessary to identify these cycles. We use the approach of Burns and Mitchell [1946], which isolates the expansionary and contractionary periods, and was formulated into an algorithm by Bry and Boschan [1971]. This approach has been extensively applied; see, for example, Albuquerue et al. [2015], Blanchard et al. [2015], Stock and Watson [2003], Claessens et al. [2012] and King and Plosser [1994]. In this paper we use a variant of the algorithm developed by Harding and Pagan [2002].

We analyse LTV ratio policies that are either permanent or activist in nature. To capture the latter we study a reaction function, similar to the Taylor rule, which allows the LTV ratio to be set to "lean against the wind" of either house price developments or the credit-to-GDP ratio.

To preview our main findings, a permanent tightening of the LTV ratio reduces the depth of recessions on average, and most notably it extends expansions. Primarily as a consequence of extending expansions, the proportion of time that the economy is in a recession falls. These effects occur for both real and financial cycles, although they are more sizable for the financial cycle. Permanent LTV ratio policy reduces the amplification of demand shocks arising from the credit constraint and the volatility of output growth. It is a policy which in the long-run primarily reduces household indebtedness.

Countercyclical LTV ratio rules potentially can also improve the characteristics of the business and financial cycles, but great care needs to be taken in their implementation. In particular, the indicator variable for the policy rule needs to be chosen carefully to ensure the policy responds in a timely way. In our model, rules based on house prices deliver better cyclical outcomes than those based on the credit-to-GDP ratio. We demonstrate that this reflects that the stock of long-term mortgages responds only slowly to shocks, in comparison to output. As a consequence, when the credit-to-GDP ratio is used to guide LTV policy it is is likely to result in the borrowing constraint being loosened or tightened at the wrong time, leading to worse economic outcomes.

A second factor complicating the conduct of countercyclical LTV ratio rules is that the strength of the response of the LTV ratio that is desirable from the perspective of its impact on the business and credit cycles depends on the mix of shocks hitting the economy. We show that a relatively more aggressive response to house price developments is desirable in economies where housing demand, rather than housing supply, shocks play a larger role. The intuition is that when house prices fall as a result of a positive housing supply shock, a countercyclical LTV ratio policy set with respect to house prices will loosen the LTV ratio, reinforcing the positive impact of the housing supply shock on output. It is also apparent that the range parameter values in the LTV ratio rule responding to house prices that improve the business cycle characteristics is greater than those for the credit cycle. In all, these results suggest that some caution is appropriate when using countercyclical LTV ratio policy.

The literature on evaluating macroprudential policy in DSGE models has been growing fast. So far, most of studies conclude that there is a scope for macroprudential policy to complement monetary policy; early examples include Borio and Shim [2007], N'Diaye [2009] and Angelini et al. [2012].

Our paper is more closely related to the literature studying loan-to-value ratio policy in DSGE models. Lambertini et al. [2013] investigate optimal rules settings of monetary policy and macroprudential policy in news-shock-driven cycles. They find that an optimized LTV ratio policy rule that responds to the credit growth is welfare-improving compared to the use of a constant LTV restriction. Gelain et al. [2013] consider an economy with irrational expectations and show that a LTV ratio rule based on wage income is most effective in dampening macroeconomic volatility compared to a permanent LTV tightening and an interest rate rule responding to financial variables.

Rubio and Carrasco-Gallego [2014] study the optimal policy combination of monetary policy and LTV ratio rules. They highlight the trade-off between the welfare of savers and borrowers, which are affected by different policy objectives. In particular, while savers care more about price stability, borrowers who are subject to collateral constraint prefer more stable financial conditions in the economy. This trade-off gives rise to a scope of coordination between monetary policy and macroprudential policy. Quint and Rabanal [2014] also study the optimal mix of monetary and macroprudential policies, but in an estimated two-country model of the euro area. Alternatively, Alpanda and Zubairy [2014], using a model similar to that in this paper, study the effectiveness of monetary policy, housing-related fiscal policy and a permanent reduction in the LTV ratio in reducing household indebtedness.

Our analysis has a narrower focus in the sense that we take the conduct of monetary policy, as captured by the estimated Taylor rule, as given. However, this paper adds to the existing literature in several ways. First, in contrast to the existing literature on activist LTV ratio policies, we use a model with long-term debt, which has important consequences for the quantitative impact of the policy. Second, we analyse directly the implications of these policies for the business and credit cycles. We believe this approach provides new insights into the likely effects of adopting such LTV ratio policies, such as whether they lessen the the severity of recessions or their frequency. Third, we show that the presence of housing supply shocks contributes to an important trade-off being present that needs to be taken into consideration when designing the LTV ratio rules.

The rest of the paper is structured as follows. In Section 2 we lay out the structure of the model and Section 3 discusses its estimation. Subsequently, in Section 4 we review the approach used to identifying the business and credit cycles. Section 5 presents the consequences of permanent LTV ratio policy for the business and credit cycles, and Section 6 likewise analyses the implications of several rules for setting the LTV ratio. Finally, Section 7 concludes.

2 Model

To investigate the cyclical implications of LTV policy we use a model with collateral constraints based on housing assets. The design of the model follows Kiyotaki and Moore [1997], and was first implemented in an estimated model by Iacoviello [2005]. In brief, the economy is composed of two types of households, borrowers and savers, which differ by their discount factor and access to credit. Borrowers are relatively impatient and therefore exhibit a higher propensity to consume, and, as a result, they borrow from savers in equilibrium. The borrowing, however, is subject to a collateral constraint, which depends on the borrower's housing equity. These features form the basis of many models used to investigate LTV policies.

The inclusion of collateral constraints, as discussed in Kiyotaki and Moore [1997] and Iacoviello [2005], introduces a mechanism that amplifies the effects of shocks. For example, a negative demand shock, which lowers house prices will also decrease the value of collateral and therefore the amount of credit available, which may result in borrowers further reducing their consumption.

In addition to the heterogeneity amongst households, we introduce long-term debt to the model. The motivation for doing so is that it will alter the effectiveness of LTV ratio policy. This occurs as it changes the collateral constraint, the structure of which follows Garriga et al. [2013], and was also used in Alpanda and Zubairy [2014].

In this section, we provide a description of the problems faced by each agent and an overview of the key optimality conditions which arise. For a complete set of equations of the model please see Appendix B.

2.1 Savers

The economy is populated by a unit measure of infinitely-lived savers indexed by j, who maximise the present discounted value of utility, described by the following expected utility function defined over consumption c, housing stock h and labour supply n:

$$E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \omega_{c,t+\tau} \left[\log\left(C_{t+\tau}(j) - \varsigma_c C_{t+\tau-1}\right) + \omega_{h,t+\tau} \log H_{t+\tau}(j) - \frac{\left(N_{t+\tau}(j)\right)^{1+\phi_n}}{1+\phi_n} \right]. \tag{1}$$

ς_c is the external habit parameter for consumption and ϕ_n is the inverse of the Frisch elasticity of labour. Importantly, the savers' discount factor, β, is assumed to be higher than that of borrowers, i.e. they place a relatively smaller weight on current consumption in their consumption choice. ω_c is a preference shock that effectively increases the discount factor of savers, and ω_h is a housing demand shock which stimulates the intratemporal substitution of consumption for housing services.

The savers' period budget constraint, with the laws of motion governing the housing and business capital stock substituted in, is given by

$$\begin{aligned} & C_t(j) + q_{h,t}\left[H_t(j) - (1-\delta_h)H_{t-1}(j)\right] + \frac{B_t(j)}{R_t P_t} + q_{k,t}\left[K_t(j) - (1-\delta_k)K_{t-1}(j)\right] + (1+\Upsilon_t)\frac{L_t(j)}{P_t} \\ \leq\; & r_{k,t} u_t(j) K_{t-1}(j) - a(u_t(j))K_{t-1}(j) + \left(\frac{W_t(j)}{P_t} - \Psi_{w,t}(j)\right) N_t(j) + \frac{\left(R_{L,t-1} - 1 + \tau\right) D_{t-1}(j)}{P_t} + \\ & \frac{B_{t-1}(j)}{P_t} + \Omega_{f,t} + ac_t \end{aligned} \tag{2}$$

ac_t is the sum of adjustment costs on housing stocks and capital stocks, which is equal to

$$ac_t = \frac{\kappa_E K_{t-1} g_t}{2}\left[\frac{K_t(j)}{K_{t-1} g_t} - 1\right]^2 + \frac{\kappa_{HP} H_{t-1} g_t}{2}\left[\frac{H_t(j)}{H_{t-1} g_t} - 1\right]^2 \tag{3}$$

Savers purchase housing services h from the final housing service producers at the CPI-deflated price q_h. δ_h is the depreciation rate of the housing stock. Similarly, savers purchase capital goods K from the final capital goods producers (see subsection 2.3.2) at the relative price q_k and rent them at the real rental rate of r_k to intermediate goods firms. Savers also choose the rate of capacity utilisation, u_t, and incur adjustment costs governed by $a(u_t)$.[1] There are two financial assets available to savers. The first is a risk-free nominal government bond B that generates a gross nominal return R, and the second is to extend consumer loans to borrowers. Savers incur monitoring costs Υ_t on these loans.[2] These monitoring costs are an exogenous financial shock that influences the spread between the interest rate received for new lending and the policy rate. $\Omega_{f,t}$ captures profits due to savers' ownership of the firms.

Mortgages in the model are long-term loans, and consequently it is necessary to distinguish between the flow of new mortgages, L_t, and the stock of outstanding nominal debt, D_t. The latter follows the law of motion:

$$D_t(j) = [1 - \tau] D_{t-1}(j) + L_t(j), \tag{4}$$

where τ denotes the average amortization rate.[3] The introduction of long-term debt is of considerable importance when examining the implications for the business and financial cycles of LTV ratio policy. This is as the policy will only impact on the flow of new loans, rather than the stock of outstanding debt. Alternatively, in models with only one-period mortgages LTV policies would impact on the entire stock of debt, and therefore their impact is likely to be overstated.

The interest rate on these long-run mortgages is assumed to be fixed.[4] Following Garriga et al. [2013], the gross effective return on the outstanding loans, $R_{L,t}$, is determined by

$$R_{L,t} = \left[1 - \frac{L_t(j)}{D_t(j)}\right] R_{L,t-1} + \frac{L_t(j)}{D_t(j)} R_{F,t}, \tag{5}$$

where $R_{F,t}$ is the fixed mortgage rate at period t. At equilibrium, the fixed rate is determined by the arbitrage condition, taking into account that it is fixed over the entire maturity of the loan. This is discussed further below.

Finally, we introduce stickiness in nominal wages. Following Erceg et al. [2000], we assume that each household is a monopolistic supplier of specialised labour $n(j)$ at the nominal wage rate $W(j)$. Perfectly competitive 'employment agencies' aggregate the specialised labour-varieties from the households into a homogeneous labour input (n) using a constant elasticity of substitution

[1] Following Smets and Wouters [2007], we assume that $a(1) = 0$, $a'(1) = r_k$ and $a''(1) = \frac{\psi}{1-\psi}$, where r_k is the steady-state level of the real return to capital and ψ is a parameter governing how costly it is to change the rate of capacity utilisation.

[2] The steady-state of the monitoring costs is Υ_1.

[3] In Garriga et al. [2013] τ was allowed to be time-varying. Preliminary analysis found a higher marginal likelihood was obtained when τ is fixed; this was also used by Alpanda and Zubairy [2014].

[4] On average, over the period 1982-2006, fixed rate mortgages accounted for 70% of mortgage originations in the United States. Source: Federal Housing Finance Agency, Monthly Interest Rate Survey, Table 10.

(CES) technology with $\nu > 1$ determining the elasticity of substitution between labour varieties. The labour aggregate is then sold to the intermediate goods firms as an input for production. Adjustment costs in changing wages are introduced following Rotemberg [1982], with $\Psi_w(\cdot)$ denoting the convex cost function which governs the degree of wage stickiness

$$\Psi_{w,t}(j) = \frac{\kappa_w}{2}\frac{W_t}{P_t}\left(\frac{W_t(j)}{W_{t-1}(j)\left(\frac{W_{t-1}}{W_{t-2}}\right)^{\iota_w}\bar{\pi}_w^{1-\iota_w}} - 1\right)^2. \tag{6}$$

2.1.1 Optimality conditions

Savers maximize the discounted lifetime utility function (1), subject to the budget constraint (2), the law of motions (4) and (5). The first order conditions with respect to $C_t(j)$, $H_t(j)$, $K_t(j)$, $B_t(j)$, $L_t(j)$, $D_t(j)$, $R_{L,t}$ and $u_t(j)$ can be summarized as follows:

$$\lambda_t = \omega_{c,t}\left(C_t - \varsigma_c C_{t-1}\right)^{-1} \tag{7}$$

$$\lambda_t = E_t\left[\beta\lambda_{t+1}\frac{R_t}{\Pi_{t+1}}\right] \tag{8}$$

$$\lambda_t\left[q_{h,t} + \kappa_{HP}\left[\frac{H_t}{H_{t-1}g_t} - 1\right]\right] = \frac{\xi_h\omega_{c,t}\omega_{h,t}}{H_t} + E_t\left[\beta\lambda_{t+1}(1-\delta_h)q_{h,t+1}\right] \tag{9}$$

$$\lambda_t\left[q_{k,t} + \kappa_E\left[\frac{K_t}{K_{t-1}g_t} - 1\right]\right] = E_t\left[\beta\lambda_{t+1}\left(r_{k,t+1} + (1-\delta_k)q_{k,t+1}\right)\right] \tag{10}$$

$$\begin{aligned}\lambda_t\left(1+\Upsilon_t\right) &= \beta E_t\left[\lambda_{t+1}\frac{R_{F,t}}{\Pi_{t+1}}\right] \\ &+ (1-\tau)\beta E_t\left[\lambda_{t+1}\frac{\Upsilon_{t+1}}{\Pi_{t+1}}\right] \\ &- (1-\tau)\beta E_t\left[\lambda_{t+1}\frac{\Omega_{t+1}\left(R_{F,t+1}-R_{F,t}\right)}{\Pi_{t+1}}\right]\end{aligned} \tag{11}$$

$$r_{k,t} = a'(u_t(j)), \tag{12}$$

where λ_t is the marginal utility of real income defined by Equation (7). Ω_t is the Lagrange multiplier on the law of motion of the fixed interest rate (5). $\Pi_t \equiv P_t/P_{t-1}$ denotes the gross rate of CPI inflation.

Equation (8) relates intertemporal changes in the marginal utility of income to the *ex-ante* real interest rate, and combined with Equation (7), it yields the standard Euler equation for consumption. Equation (9) determines the demand for housing. At the optimum, the marginal cost of acquiring housing services is balanced by the marginal utility derived from using the housing stock $\left(\frac{\xi_h\omega_{c,t}\omega_{h,t}}{H_t}\right)$ and the discounted expected value of the undepreciated housing stock in the subsequent period. Similarly, an Euler condition for capital can be obtained using Equation (10). It equates for the marginal cost of acquiring business capital to the discounted expected marginal benefit of rental income and the price of the undepreciated capital stock in the next period.

Equation (11) is an intertemporal condition on fixed-rate mortgage loans. From the saver's perspective, granting an additional unit of loan results in a marginal utility loss stemming from the reduction of one unit of current consumption plus the real resource loss on loan monitoring costs. The marginal utility loss is balanced by the expected marginal gain of the fixed interest loan. The latter has three components: 1) The real interest payment $\frac{R_{F,t}}{\Pi_{t+1}}$; 2) In the case of the loan not being amortized, the marginal gain also comes from future saving on loan monitoring, Υ_{t+1}; 3) Because of the fixed interest rate, the marginal utility gain is dampened by the difference between the fixed interest rate in the next period and the current fixed rate $\left(\frac{\Omega_{r,t+1}(R_{F,t+1}-R_{F,t})}{\Pi_{t+1}}\right)$. Savers forgo the gain from interest payments when future interest rate is higher than the current fixed interest rate. Note that Equation (8) and (11) determine the spread between policy rate R_t and the fixed mortgage rate $R_{F,t}$, intuitively, the spread is affected by monitoring costs (Υ_t), tightness of the fixed mortgage rate constraint (Ω_t), and the difference between the fixed mortgage rates in two adjacent periods ($R_{F,t+1} - R_{F,t}$).

2.2 Borrowers

The economy is populated by a unit measure of infinitely lived borrowers indexed by j, who maximise the present discounted value of utility. Their utility function is identical to that of the saver, but is differentiated by a lower discount factor, β'.

$$E_t \sum_{\tau=0}^{\infty} \left(\beta'\right)^{\tau} \omega_{c,t+\tau} \left[\log\left(C'_{t+\tau}(j) - \varsigma_c C'_{t+\tau-1}\right) + \omega_{h,t+\tau} \log H'_{t+\tau}(j) - \frac{\left(N'_{t+\tau}(j)\right)^{1+\phi_n}}{1+\phi_n}\right] \tag{13}$$

The borrowers' variables are denoted with an $'$. They use their labour income and new borrowing to consume, buy housing services and to repay existing loans. The borrowers do not own business capital. Their period budget constraint, with the law of motion for their housing stock substituted in, is

$$\begin{aligned} & C'_t(j) + q_{h,t}\left[H'_t(j) - (1-\delta_h)H'_{t-1}(j)\right] + \frac{\left[R_{L,t-1} - 1 + \tau\right] D'_{t-1}(j)}{P_t} \\ \leq \quad & \left(\frac{W'_t(j)}{P_t} - \Psi'_{w,t}(j)\right) N'_t(j) + \frac{L'_t(j)}{P_t} + ac'_t, \end{aligned} \tag{14}$$

Symmetric to the saver, wage-setting is subject to quadratic adjustment costs $\Psi'_{w,t}(j)$. ac'_t is the adjustment costs on housing stocks, which is equal to

$$ac'_t = \frac{\kappa_{HI} H'_{t-1} g_t}{2} \left[\frac{H'_t(j)}{H'_{t-1} g_t} - 1\right]^2. \tag{15}$$

2.2.1 Collateral Constraint

As borrowers are relatively impatient, they have a higher propensity to consume and consequently borrow from the savers. Their borrowing is subject to a collateral constraint, which following

Garriga et al. [2013] is of the following form:

$$L'_t(j) \leq m q_{h,t} P_t \left[H'_t(j) - (1-\delta_h) H'_{t-1}(j)\right]. \tag{16}$$

This collateral constraint limits new loans to a fraction of the nominal value of the housing investment purchased in the period. In this expression, m, the loan to value ratio, resembles the down-payment restriction on new mortgage loans. For example, when $m = 0.9$, it means the home buyer needs to pay 10% of new housing value in cash.

There are several consequences of this specification of the collateral constraint which are important to note. First, distinct from that in Iacoviello [2005] and Iacoviello and Neri [2010], this collateral constraint relates new borrowing to new investment in housing, rather than the borrowers' entire holdings of housing. Second, as a result of the constraint applying only to new loans there is a distinction between the marginal LTV ratio, m, and the average LTV ratio on the outstanding loan stock. Relatedly, as in Iacoviello [2005] and Iacoviello and Neri [2010], it is assumed that the collateral constraint always binds, so as to make the model is linear. This, however, is a less extreme assumption with the collateral constraint above as a high LTV ratio is typically observed on new loans.

2.2.2 Optimality conditions

Borrowers maximize the discounted lifetime utility function (13), subject to the budget constraint (14), the law of motions (4), (5) and the collateral constraint (16). The first order conditions with respect to $C'_t(j)$, $H'_t(j), L'_t(j)$, $D'_t(j)$ and $R_{L,t}$ can be summarized as follows:

$$\lambda'_t = \omega_{c,t}\left(C'_t - \varsigma_c C'_{t-1}\right)^{-1} \tag{17}$$

$$\begin{aligned} \lambda'_t\left[q_{h,t} + \kappa_{HI}\left[\frac{H'_t}{H'_{t-1}g_t} - 1\right]\right] &= \frac{\xi'_h \omega'_{c,t}\omega'_{h,t}}{H'_t} + \lambda'_t\gamma_t m q_{h,t} + (1-\delta_h)\beta' E_t\left[\lambda'_{t+1}q_{h,t+1}\right] \\ &- (1-\delta_h)\beta' E_t\left[\lambda'_{t+1}\gamma_{t+1} m q_{h,t+1}\right] \end{aligned} \tag{18}$$

$$\begin{aligned} \lambda'_t(1-\gamma_t) &= \beta' E_t\left[\lambda'_{t+1}\frac{R_{F,t}}{\Pi_{t+1}}\right] - (1-\tau)\beta' E_t\left[\lambda'_{t+1}\frac{\gamma_{t+1}}{\Pi_{t+1}}\right] \\ &- (1-\tau)\beta_I E_t\left[\lambda'_{t+1}\frac{\Omega'_{t+1}(R_{F,t+1} - R_{F,t})}{\Pi_{t+1}}\right] \end{aligned} \tag{19}$$

where λ'_t is the marginal utility of real income of borrowers, defined by Equation (17). Ω'_t and γ_t are the Lagrange multipliers on the law of motion of the fixed interest rate (Equation (5)) and the collateral constraint (Equation (16)) respectively.

Equation (18) is an intertemporal condition on housing demand, akin to that for savers, Equation (9). An important difference, however, is that due to the presence of the collateral constraint, it includes terms relating to the marginal utility gain of relaxing the borrowing constraint from the purchase of an additional unit of housing this period, $\left(\lambda_t' \gamma_t m q_{h,t}\right)$. However, as this investment has the effect of increasing the housing stock in the next period, it reduces the need to invest in housing then. As a consequence, Equation (18) includes an additional term to capture the forgone marginal utility gain of relaxing the borrowing constraint through further investment in the future.

The Euler condition from mortgage debt for borrowers is given by Equation (19). From the borrower's perspective, the marginal utility of additional borrowing arises as the loan is used to increase current consumption, but, by doing so, she forgoes the marginal gain from relaxing the collateral constraint through accumulating more housing. This marginal benefit has to be balanced by the expected marginal loss stemming from the loan. The future loss of utility comes from three sources: 1) The interest payment $R_{F,t}$ in the next period; 2) The loan reduces the future need of borrowing, and therefore relaxes the future collateral constraint $\left(\frac{\gamma_{t+1}}{\Pi_{t+1}}\right)$; 3) As mortgages are fixed rate loans, the utility loss is also affected by the difference between the fixed interest rate on new loans in the next period and the current fixed rate $\left(\frac{\Omega'_{t+1}(R_{F,t+1}-R_{F,t})}{\Pi_{t+1}}\right)$. When the future interest rate is higher, the fixed rate nature of the loan means borrowers save on interest payments, lessening their marginal utility loss.

2.3 Production

The structure of the supply-side of economy draws on the Bank of Canada's macroprudential policy model, Alpanda et al. [2014], and is also in some respects similar to Christiano et al. [2005]. In brief, intermediate goods are produced by firms with pricing power, which gives rise to a New Keynesian Phillips curve. These goods are sold to a final goods producer, which essentially is an aggregator. Capital and housing producers combine these final goods with the existing capital and housing stocks.

2.3.1 Intermediate goods firms

There is a continuum of monopolistically competitive firms indexed by $j \in [0, 1]$ specialising in the production of a unique intermediate good variety $Y(j)$ using the following technology

$$Y_t(j) = (u_t K_{t-1}(j))^{\alpha_k} \left[Z_t N_t(j)^{\alpha_n} N_t'(j)^{1-\alpha_n}\right]^{1-\alpha_k}, \ \alpha_k, \ \alpha_n \in [0, 1] \tag{20}$$

where N and N' are the labour bundles from the savers and borrower households respectively, aggregated by the employment agencies and sold to the intermediate goods firm. As in Iacoviello [2005], the labour share of savers, α_n, effectively governs their size relative to that of borrowers in the model. k represents the capital stock rented from the patient households and α_k is the share of capital in production. Finally, labour augmenting technology, Z, follows a random walk process with drift, with its growth rate denoted by g.

The intermediate goods firms sell their output to a final goods producer who uses a continuum of these goods in production. We impose quadratic price adjustment costs *a la* Rotemberg [1982] in the price-setting problem of the intermediate goods firm. Analogous to the treatment of wages previously, prices are partially indexed to lagged inflation, the extent of which is determined by the parameter ι_p, and to steady-state inflation $(1-\iota_p)$.

2.3.2 Business and housing capital producers

Business capital producers are perfectly competitive. These firms purchase the undepreciated physical capital from patient households at a relative price of q_k and the new capital investment goods from aggregator firms and produce the capital stock to be carried over to the next period. This production is subject to adjustment costs in investment, and follows the following law of motion

$$K_t = \omega_{ik,t} IK_t \left[1 - \frac{\kappa_{ik}}{2}\left(\frac{IK_t}{IK_{t-1}} - g\right)^2\right] + (1-\delta_k)K_{t-1},\ \delta_k \in [0,1]\,,\ \kappa_{ik} > 0 \qquad (21)$$

where ω_{ik} is the investment-specific technology shock affecting business capital. After capital production, the end-of-period installed capital stock is sold back to savers at the consumption-based price of q_k.

Housing capital producers are modelled analogously to business capital producers. They transform housing investment goods IH into housing services H by using the following technology

$$H_t = \omega_{ih,t} IH_t \left[1 - \frac{\kappa_{ih}}{2}\left(\frac{IH_t}{IH_{t-1}} - g\right)^2\right] + (1-\delta_h)H_{t-1},\ \delta_h \in [0,1]\,,\ \kappa_{ih} > 0 \qquad (22)$$

where ω_{ih} is the investment-specific technology shock affecting housing.

2.4 Monetary policy

Monetary policy is set according to a Taylor rule. The nominal interest rate therefore reacts to the current CPI inflation rate, output normalized by technology, y_t, and output growth. We also allow for interest rate smoothing. The Taylor rule is

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{r_r} \left[\left(\frac{\pi_{c,t}}{\bar{\pi}_c}\right)^{r_\pi} (y_t)^{r_y} \left(\frac{y_t}{y_{t-1}}\right)^{r_{\Delta y}}\right]^{1-r_r} \exp \omega_{r,t}. \qquad (23)$$

r_r captures the inertia in the policy rate, r_π, r_y and $r_{\Delta y}$ the response to deviations of inflation from target $(\bar{\pi}_c)$, output and output growth. ω_r is the monetary policy shock.

Government expenditure is assumed to be exogenous, akin to Smets and Wouters [2007].

2.5 Stochastic shocks

The stochastic shocks in the model are allowed to follow first-order autoregressive processes, with the exception of the non-stationary labour augmenting technology shock.

3 Parameterisation

To parameterise the model we adopt a mixture of calibration, fixing parameters based on previous studies, and estimation. The parameters that enter the steady-state of the model are either fixed or calibrated, whereas those only entering the dynamics of the model are estimated using Bayesian methods (see An and Schorfheide [2007] for an overview).

3.1 Steady-state parameters

An annual inflation target of 2 per cent is assumed. The trend growth rate of labour productivity, $\bar{g}$, is set to the average growth rate of GDP per capita over the sample 1984:Q1 - 2007:Q4, 1.0048. Given these, the discount factor of patient households is calibrated so as the annualised nominal risk-free rate is the sample average, 5.31 per cent, yielding $\beta_p = 0.9966$. The discount factor for impatient households then is set to be lower than for patient households, namely 0.993. The inverse of the Frisch elasticity of labour supply is assumed to be 2, based on Smets and Wouters [2007]. ς_c, the habits parameter, is set to be 0.85, which is similar to the posterior mean estimate of 0.88 obtained by Alpanda and Zubairy [2014]. A wide range of values for the share of patient households' share of labour income, e.g. Iacoviello and Neri [2010] obtain a posterior mean estimate of 0.79, whereas Alpanda and Zubairy [2014] use 0.38. We assume a value of 0.4.

The depreciation rates of housing and business capital 0.01 and 0.025, all of which are taken from Iacoviello and Neri [2010]. Similarly, the elasticity of substitution is between types of intermediate goods is set so as the steady-state mark up is 15 per cent, also following Iacoviello and Neri [2010]. We assume the elasticity of substitution between types of labour is the same.

The steady-state LTV ratio, m, is chosen to be 0.9, which is higher than used by Iacoviello and Neri [2010], 0.85, which they describe as "conservative". The amortization rate, τ, is set to be 0.0144, the steady-state value used by Garriga et al. [2013]. We then set $\Upsilon_1 = 0.2742$, yielding a steady-state spread between the lending and Federal Funds rate of 3.036 per cent, the data average.

Finally, the Government's share of output is set to be 0.191, the data average. The implications of this parameterisation for steady-state expenditure ratios are shown in Table 1. The implied residential investment share of output is slightly greater than evident in the data, and consequently the consumption share is smaller, but overall the model matches the data quite well.

Table 1: Steady-state Expenditure Ratios (%)

Ratio	*Data*	*Model*
$\frac{C}{Y}$	63.68	61.93
$\frac{X}{Y}$	4.68	6.57
$\frac{I}{Y}$	12.53	12.40
$\frac{G}{Y}$	19.10	19.10
Memo items:		
$\frac{c}{c+c'}$	–	0.38
$\frac{h}{h+h'}$	–	0.45

Note: Average over 1984:Q1 - 2007:4.

3.2 Parameters only entering the dynamics

The priors selected for the remaining parameters are standard and are presented in Tables 2 to 3. We set the mean of the prior for the Rotemberg adjustment cost parameters for both prices and wages, κ_p and κ_w, given the elasticities of substitution assumed above, to correspond approximately to a Calvo parameter of 0.7 and an indexation parameter of 0.5, following Smets and Wouters [2007]. The mean of the prior for the investment adjustment costs, κ_k, is set to 5, based on the posterior estimates from Smets and Wouters [2007]. We use the same prior for the housing adjustment cost parameter. For the Taylor rule parameters the values for the priors selected allow for a high degree of interest rate smoothing and for a more aggressive response to inflation relative to both output and output growth. Finally, loose priors are used for the shock processes.

3.3 Data

To estimate these parameters 9 data series are used, namely: per capita output, consumption, business and residential investment growth, the Federal Funds rate, inflation, real house price and credit growth, and the spread between the lending and the Federal Funds rate. Consequently the number of observed variables used in estimation is the same as the number of shocks in the model. The precise data definitions are given in the appendix. The data were de-meaned prior to estimation.[5] The sample is 1984:Q1 – 2007:Q4.

[5] The consequence of de-meaning the observed data is that we do not impose the implication of the model that many of the observed data, such as consumption and investment, should have a common linear trend.

Table 2: Parameter Estimates

Parameter	Description	Prior	Posterior		
			Mean	90 % HPD Interval	
κ_w	Adjustment costs - wages	$N(130, 20^2)$	167.970	138.053	197.100
ι_w	Indexation - wages	$B(0.3, 0.1)$	0.093	0.032	0.153
κ_{ph}	Adjustment costs - goods	$N(130, 20^2)$	127.162	96.865	158.642
ι_{ph}	Indexation - goods	$B(0.3, 0.1)$	0.204	0.065	0.339
κ_h	Residential investment producers	$G(5, 3)$	0.954	0.648	1.247
κ_k	Capital good producers	$G(5, 3)$	7.868	3.075	12.274
κ_{hp}	Adjustment costs - housing (savers)	$G(5, 3)$	0.098	0.032	0.162
κ_{hi}	Adjustment costs - housing (borrowers)	$G(5, 3)$	23.166	17.852	28.438
κ_{ke}	Adjustment costs - capital	$G(5, 3)$	2.082	1.876	3.237
r_r	Monetary policy - smoothing	$B(0.8, 0.1)$	0.803	0.767	0.839
r_π	Monetary policy - inflation	$G(1.5, 0.25)$	2.203	1.876	2.534
r_y	Monetary policy - output	$B(0.25, 0.1)$	0.087	0.050	0.123
$r_{\Delta y}$	Monetary policy - output growth	$B(0.25, 0.1)$	0.362	0.220	0.502
ψ	Capacity utilisation	$B(0.5, 0.15)$	0.628	0.497	0.761

Note: $B(a, b)$ and $G(a, b)$ denote Beta and Gamma distributions with mean a and standard deviation b. HPD denotes the Highest Probability Density interval.

3.4 Estimates

Estimates of the posterior were obtained using the random-walk Metropolis Hastings algorithm. Two chains of 600,000 observations long were used, with the first half dropped as burn-in.[6]

The posterior estimates for the Phillips curves for wages and goods prices are similar, with only a small role found for the backward-looking component. The mean of the posterior of the adjustment costs in the supply of capital goods is greater than that for housing capital. Turning to the consumers' adjustment costs, for savers these are both smaller than the mean of the prior, whereas they are larger for borrowers' holdings of housing. As expected, the estimated Taylor rule displays considerable interest rate smoothing, and there is a strong response to inflation. The shock processes are generally found to be quite persistent, with the exceptions of the monetary policy and wage mark-up shocks.

4 Identifying the Business and Credit Cycles

To identify the business and credit cycles we use the approach of Bry and Boschan [1971], as implemented by Harding and Pagan [2002]. This approach focuses on fluctuations in the level of

[6] This was implemented in the Dynare Matlab pre-processor, version 4.4.3.

Table 3: Shock Processes Parameter Estimates

Parameter	Description	Prior	Posterior		
			Mean	90 % HPD Interval	
Autoregressive parameters					
ρ_m	Monetary policy	$B(0.5, 0.15)$	0.344	0.237	0.448
ρ_{ph}	Price mark-up	$B(0.5, 0.15)$	0.756	0.597	0.906
ρ_c	Consumption	$B(0.5, 0.15)$	0.740	0.634	0.851
ρ_{hd}	Housing demand	$B(0.5, 0.15)$	0.914	0.881	0.949
ρ_{ah}	Housing technology	$B(0.5, 0.15)$	0.982	0.971	0.992
ρ_{ak}	Capital technology	$B(0.5, 0.15)$	0.699	0.615	0.786
ρ_{up}	Monitoring	$B(0.5, 0.15)$	0.961	0.938	0.987
ρ_g	Government	$B(0.5, 0.15)$	0.949	0.927	0.972
ρ_w	Wage mark-up	$B(0.5, 0.15)$	0.422	0.271	0.572
Standard deviations					
σ_{ah}	Housing technology	$IG(0.1, 0.02)$	0.013	0.011	0.015
σ_m	Monetary policy	$IG(0.001, 0.005)$	0.001	0.001	0.001
σ_{hd}	Housing demand	$IG(0.1, 0.02)$	0.106	0.083	0.130
σ_z	Technology	$IG(0.1, 0.02)$	0.006	0.005	0.007
σ_c	Consumption	$IG(0.1, 0.02)$	0.037	0.032	0.042
σ_{ak}	Capital technology	$IG(0.1, 0.02)$	0.090	0.042	0.134
σ_{ph}	Price mark-up	$IG(0.1, 0.02)$	0.023	0.018	0.029
σ_{up}	Monitoring	$IG(0.1, 0.02)$	0.127	0.111	0.143
σ_g	Government	$IG(0.1, 0.02)$	0.022	0.019	0.024
σ_w	Wage	$IG(0.1, 0.02)$	0.195	0.139	0.248

Note: $B(a, b)$, $G(a, b)$ and $IG(a, b)$denote the Beta, Gamma and Inverse Gamma distributions with mean a and standard deviation b. HPD denotes the Highest Probability Density interval.

activity, and is also known as the classical cycle. It closely replicates the decisions made by the National Bureau of Economic Research (NBER) Business Cycle Dating Committee.

This algorithm identifies turning points in a series. A peak, $\wedge$, and a trough, $\vee$, occur in y_t when

$$\begin{aligned} \wedge_t &= 1(\Delta y_t > 0,\ \Delta_2 y_t > 0,\ \Delta y_{t+1} < 0,\ \Delta_2 y_{t+2} < 0) \\ \vee_t &= 1(\Delta y_t < 0,\ \Delta_2 y_t < 0,\ \Delta y_{t+1} > 0,\ \Delta_2 y_{t+2} > 0), \end{aligned}$$

where Δ is the first difference operator and Δ_2 denotes six-monthly growth (see Harding and Pagan [Forthcoming]). These are also subject to additional criteria, such as a minimum length of a phase (expansions and recessions) in the cycle. Using these turning points the characteristics of expansions (trough to peak) and contractions (peak to trough) can then be calculated. Note that characteristics of the cycle are determined by the growth rate of y_t - its volatility and autocorrelation - and it is not necessary to extract the low frequency components.

To analyse the implications of LTV ratio policy for the business and credit cycles we simulate long series of the level of output and credit by repeatedly drawing shocks from their estimated multivariate distribution and passing them through the model.[7] The algorithm is then applied to these data. We use long series of data so as to focus on the population characteristics of the cycles.[8] Varying the LTV ratio policy and repeating these simulations allows us to examine how the policy changes the cycle characteristics. This approach is related to examining how the impulse response functions of output and credit change, although as the Pagan and Robinson [2014] discuss, these cycle characteristics effectively combine the individual impulse responses to all of the shocks together in an economically meaningful way.

5 Permanent LTV Policy

According to Bank for International Settlements (BIS) [2010], an objective of macroprudential policy is to strengthen the resilience of the financial system. To achieve that goal, in some countries, such as Canada, one of the macroprudential policies that has been implemented is to permanently reduce the maximum LTV permitted on mortgages.[9]

What might we expect the effects of such a policy be in this model? Lowering the LTV ratio should lessen the amplification mechanism introduced by the collateral constraint. More precisely, as discussed in Iacoviello [2005], adverse shocks which reduce the price of housing decrease the value of collateral, and therefore the amount of credit available. Borrowers may subsequently reduce their consumption, for example, which increases the real impact of these shocks. Consequently, negative

[7] We fix the parameters at the posterior mean.

[8] In this paper we use 100,000 observations.

[9] An overview of macroprudential policies that have been implemented in Canada is provided by Krznar and Morsink [2014].

demand shocks are amplified, whereas supply shocks, which drive output and prices in opposite directions, are not.

To study the consequences of the policy for the business cycle, Table 4 presents several of the characteristics of recessions - namely their average duration and amplitude, together with the proportion of time the economy is in recession - and how they vary as the steady-state LTV ratio is permanently lowered. It also similarly presents the characteristics of expansions. This is examining how the business cycle of the economy would perform, on average, under macroprudential policy, rather than the dynamics of the adjustment to the new policy, which others have focused upon (e.g. Alpanda et al. [2014]).

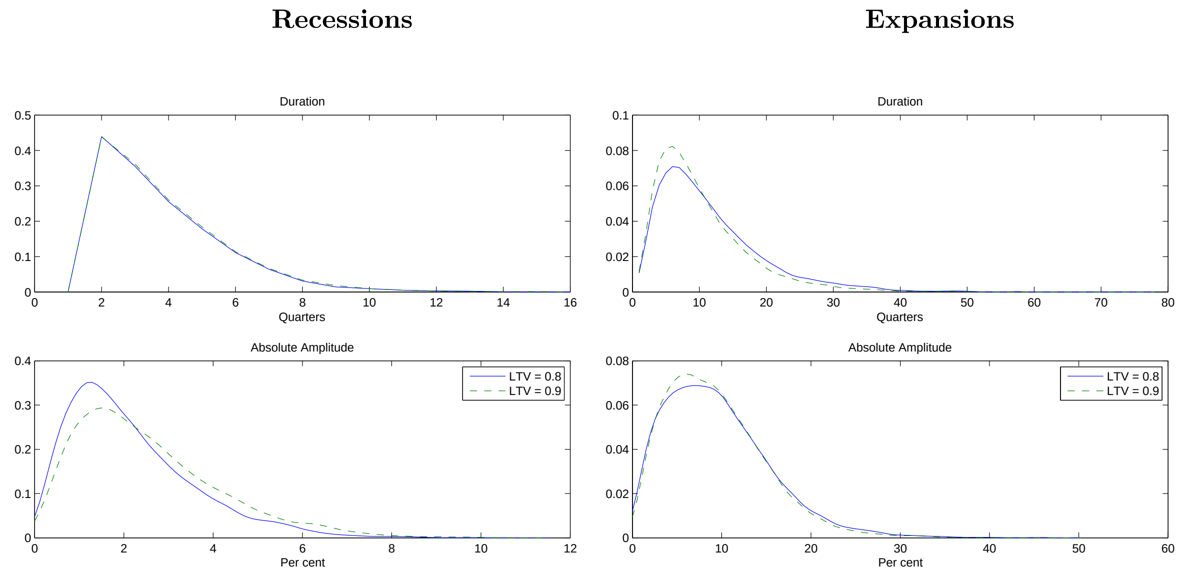
Table 4: Business Cycle Consequences of Permanent LTV Ratio Policy

	Recessions			**Expansions**	
LTV	Duration (qtrs)	Amplitude (%)	Proportion of time in recession (%)	Duration (qtrs)	Amplitude (%)
0.9	3.84	-2.53	27.11	10.32	9.31
0.8	3.80	-2.15	24.41	11.66	9.55
0.7	3.78	-1.97	23.20	12.50	9.77

Focusing initially on the characteristics of recessions, the impact on their average duration is small. Alternatively, the average amplitude of recessions is sizeably reduced by permanently lowering the LTV ratio. However, the largest impact is on the proportion of time that the economy is in a recession. Consequently, it appears that permanently lowering the LTV ratio is a policy which primarily prevents recessions from occurring. This is also reflected in the characteristics of expansions, whose average duration increases considerably. One might have expected permanently tighter credit policy to result in a trade-off with respect to the characteristics of expansions, such as a reduction in their average amplitude, but this is not the case; in fact it increases modestly. Recall that the amplitude of an expansion is measured from the trough in economic activity to its peak, so an increase in the average duration of expansions will tend to be accompanied by a larger amplitude. Looking at the entire distributions of these business cycle characteristics, rather than just the averages, delivers qualitatively similar messages (Figure 1). Interestingly, while the tighter LTV ratio policy does increase the probability of recessions having a small amplitude, a non-trivial probability of relatively severe recessions (e.g. with an amplitude greater than 4 per cent) persists. The distributions of the characteristics of both recessions and expansions are highly skewed to the right.

How can permanent LTV ratio policy decrease the frequency with which recessions occur? A key aspect of the model which influences these business cycle characteristics is the volatility of

Figure 1: Distributions of Business Cycle Characteristics



output growth. In a more volatile economy, all else equal, the chance of a negative growth rate occurring, and hence a recession, is greater. A permanent lowering in the LTV ratio dampens the amplification mechanism, and hence the volatility of output growth. An example is that reducing the LTV ratio from 0.9 to 0.8 results in a fall in the the standard deviation of output growth of around 0.13 percentage points. The implications for how output responds to unanticipated shocks tend to be small; for example, for a negative housing demand shock there is a much larger impact on credit growth (Figure 2).

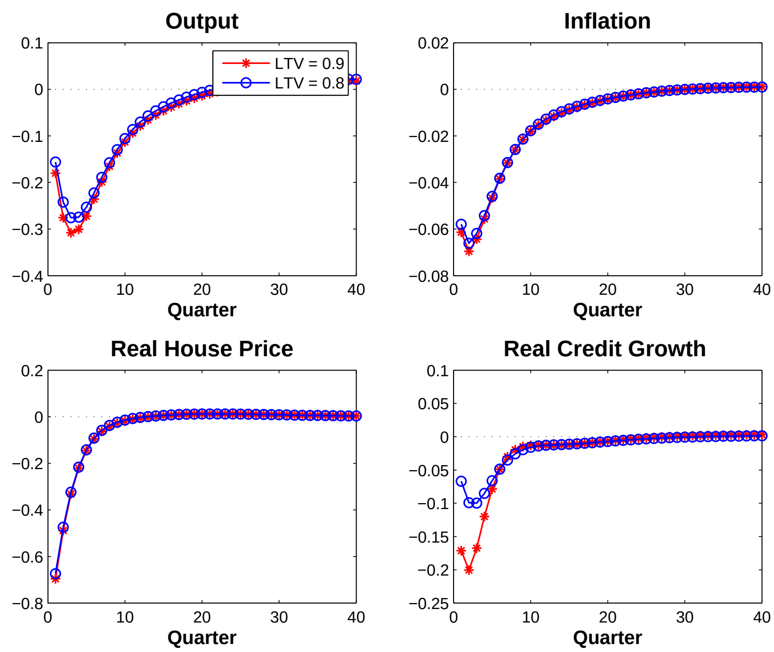
The small degree of amplification, such as that evident in Figure 2, is in contrast with the larger effects found by Iacoviello [2005]. This divergence is in part a reflection of the presence of long-term debt and the related structure of the collateral constraint, which means it is related to the flow of new debt, rather than the debt stock.[10]

As this is a linear model the impulse responses to a negative shock are symmetric to those from a positive shock, and therefore it is perhaps surprising that the effects of a permanent tightening in LTV policy on recessions and expansions differ. This is a reflection of our focus on the business cycle and the presence of trend output growth, which means more sizable negative demand shocks are required to generate successive negative output growth rates, and hence a recession, than otherwise. Consequently, the reduction of output growth volatility stemming from a permanent reduction in the LTV ratio makes it more likely that the economy will be in an expansion.

[10] Pagan and Robinson [2014] found that when the LTV ratio was increased in the Iacoviello and Neri [2010] model the economy became very volatile.

Figure 2: Impulse Responses to Housing Demand Shocks

Negative, 1 standard deviation



Another, related, way to interpret these results is that the dampening of the amplification mechanism by permanently lowering the LTV ratio decreases the role of demand shocks for the business cycle as it is these that are amplified, and it is this which increases the average duration and amplitude of expansions. In an extreme case where there are no demand shocks at all (including monitoring costs) the duration of expansions increases by more than 4 percentage points. This is consistent with the findings of Harding and Pagan [Forthcoming], who study the business cycle properties of the Cho and Moreno [2006] small New-Keynesian model and find that when supply shocks are suppressed the duration and amplitude of expansions are greatly reduced.

A permanent reduction in the LTV ratio has a considerable impact on the characteristics of the credit cycle (Table 5). Akin to the business cycle, the proportion of time in a credit recession decreases with tighter policy, as does the amplitude, and the characteristics of expansions improve. The magnitudes of these effects, however, are greater than for the business cycle and are accompanied by a sizable reduction in the average duration of credit recessions. This moderation of the credit cycle also is evident in the impulse response functions, which generally show a smaller response when the tighter policy is imposed, such as is evident for a housing demand shock in Figure 2 above.

The change in behaviour of credit in part reflects that a permanent reduction in the LTV ratio alters the steady state of the economy, in particular, lowering household indebtedness (relative

Table 5: Credit Cycle Consequences of Permanent LTV Policy

	Recessions			Expansions	
LTV	Duration (qtrs)	Amplitude (%)	Proportion of time in recession (%)	Duration (qtrs)	Amplitude (%)
0.9	4.35	-7.98	28.38	10.96	29.89
0.8	3.94	-3.68	17.15	19.02	36.54
0.7	3.53	-2.00	9.07	35.24	57.60

to income). As the borrowing constraint binds in steady state, a given level of the borrower's holdings of housing relative to income will accord with a lower level of new loans, which by the debt accumulation identity results in lower a lower debt-to-income ratio. Interestingly, there is little impact on the steady-state expenditure ratios, and in steady-state level of real house prices is pinned down by the supply-side of the economy.

In summary, the business cycle consequences of a permanently lower LTV ratio primarily are that expansions, on average, last for longer, reducing the proportion of time that the the economy is in recession. The average depth of a recession is also lessened. These effects, however, are considerably smaller than those for the credit cycle. The long-run implications of the policy are mainly that household indebtedness is reduced.

6 Activist LTV Policy

An objective of macroprudential policy, as discussed by Bank for International Settlements (BIS) [2010], is to actively counteract financial cycles, i.e. limit the build-up of financial risks in the credit boom and relieve financial constraints in crises. This kind of macroprudential policy requires the policy instrument to be time-varying.

An intuitive way of modelling activist LTV ratio policy is to use a reaction function akin to the Taylor rule for monetary policy. In particular, we consider rules for the absolute deviation of the LTV from its steady-state, $\hat{m}_t$, of the form:

$$\hat{m}_t = \rho_{LTV}\hat{m}_{t-1} + (1-\rho_{LTV})\eta_{LTV}\tilde{f}_t, \tag{24}$$

where ρ_{LTV} is a smoothing parameter, and η_{LTV} is the parameter governing the reaction of the LTV to the variable $\tilde{f}_t$, where $\tilde{}$ denotes the log deviation from steady state.[11]

[11] One aspect to note is that there is no LTV shock included in the rule. This reflects that it would be difficult to calibrate how large the standard deviation of this shock should be.

There are many possible variables that could be used to guide activist LTV ratio policy. We focus on two: (i) the deviation of real house prices from their steady state, $q_{h,t}$, and, (ii) the credit-to-GDP ratio gap. The house price rule reflects that many of the macroprudential policies recently adopted worldwide have been motivated by concerns about developments in house prices. A rule of this form essentially allows the LTV ratio to be set so as to "lean against the wind" of cycles in house prices. The credit-to-GDP ratio gap is motivated by its role in the Basel III banking regulations. In particular, one component of these regulations is the countercyclical capital buffer, which the BIS recommend that nations set with reference to the credit-to-GDP ratio gap. This reflects the findings of Borio and Drehmann [2009], who argue that the credit-to-GDP ratio gap is a leading indicator of financial stress.

Less empirical evidence exists to guide the parameterisation of these LTV ratio rules than for monetary policy rules. Intuitively, we expect LTV policy to be highly persistent, which is typically found in estimates of Taylor rules for monetary policy, such as Smets and Wouters [2007]. Consequently, we set the smoothing parameter, ρ_{LTV} to be 0.8.[12] So as to accommodate policies which react aggressively, but also to make negative values of the LTV ratio unlikely, we consider a range of values for η_{LTV}, with the maximum selected so that the implied standard deviation of the LTV ratio is approximately 0.3.

6.1 Business Cycle Consequences

Table 6 summarizes the implications of the countercyclical LTV ratio policy rules for business cycles. Focusing initially on the house price based rule, the impacts on the characteristics of the average recession are small. The decrease in the duration is modest; there is a slightly greater decline in the average depth of recessions. The change which is quantitatively more important is an improvement in the duration of expansions, although there is evidence of a slight trade-off, with the amplitude of expansions decreasing marginally. Consequently, the proportion of time that the economy in a recession decreases, even though the average duration of recessions themselves are little changed. This suggests that a LTV ratio rule with house prices is best thought of as a policy primarily for lessening the likelihood of a recession from occurring.

As discussed previously, the volatility of output growth is an important determinant of the business characteristics. As is evident from Table 6, more aggressively responding to house prices decreases the volatility of growth, even though quantitatively the effect is small. The limited consequences of activist LTV policy for the business cycle reflects in part that two important propagation channels of housing shocks that have opposite effects on business cycles, and as aforementioned, the business cycle characteristics are influenced by all of the shocks hitting the economy.[13]

[12]Results where the smoothing parameter is also varied are available upon request, and show that the business cycle characteristics are not particularly sensitive to a range of values.

[13]In the model without countercyclical LTV ratio policy, at the posterior mean and one-quarter-ahead, 4.51 per

Table 6: Business Cycle Consequences of LTV Rules

	LTV Rule with House Prices						LTV Rule with Credit-to-GDP					
	Recessions			Expansions			Recessions			Expansions		
η_{LTV}	0	-3	-5	0	-3	-5	0	-0.5	-1	0	-0.5	-1
Duration (qtr)	3.84	3.81	3.79	10.32	10.43	10.47	3.84	3.85	3.87	10.32	10.24	10.18
Amplitude (%)	-2.53	-2.48	-2.45	9.31	9.29	9.28	-2.53	-2.57	-2.60	9.31	9.31	9.33

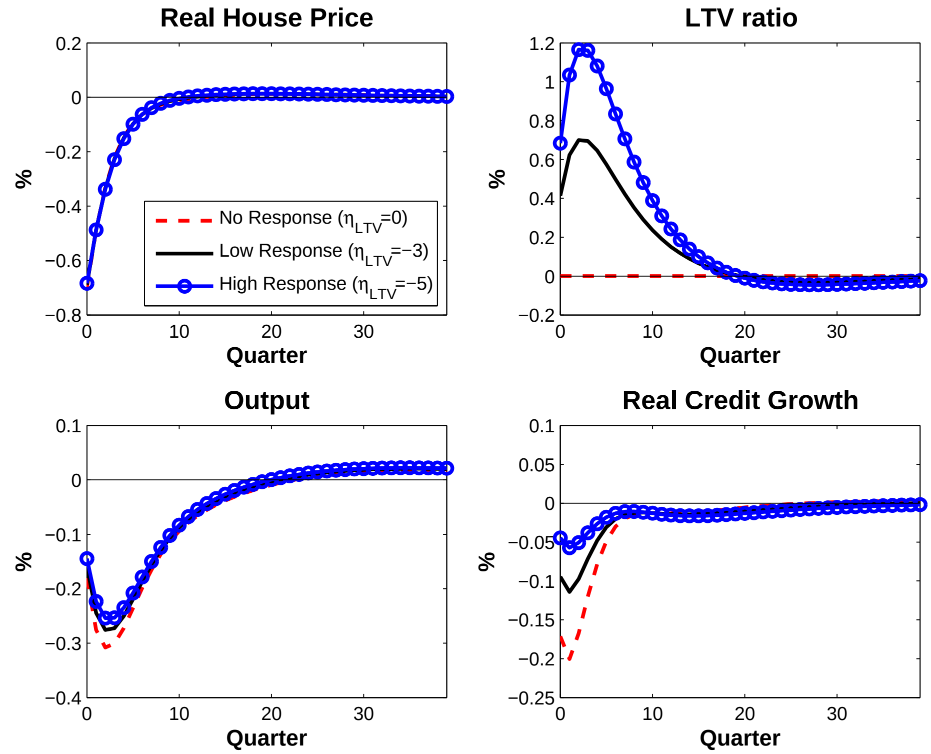
η_{LTV}	0	-3	-5	0	-0.5	-1
Volatility (%)	1.05	1.04	1.03	1.05	1.06	1.07
Proportion of time in recession (%)	27.11	26.71	26.59	27.11	27.32	27.56

Figure 3 plots impulse responses to a housing demand shock under different levels of the response parameter to house prices. An adverse housing demand shock causes house prices to fall, which tightens the borrowing constraint. Without countercyclical LTV ratio policy (shown by the red dash lines), this will trigger a negative feedback loop, with the decreased availability of credit magnifying the loss in output. When countercyclical LTV ratio policy responding to house prices is in place, however, the policymaker responds to the initial fall of house prices by loosening the LTV ratio. As a result, the LTV ratio policy helps to mitigate the negative effects on both the real economy and credit growth. The stronger the response of the reaction function to house prices is, the larger is the stabilization effect, which is illustrated by the blue circled lines and black solid lines in Figure 3.

While a stronger response to house prices in the LTV ratio reaction function reduces the real impact for housing demand shocks, this is not generally true for all of the shocks hitting the economy. Consider, for example, a housing technology shock; the impulse response for a variety of η_{LTV} are shown in Figure 4. In this case, a more aggressive response to house prices boosts credit growth and initially output growth. To understand this, note that in the absence of countercyclical LTV ratio policy (shown in red dash lines) the fall in house prices will result in a tightening of the collateral constraint and a fall in credit growth, dampening the positive real impact of the shock. In contrast, when a countercyclical LTV ratio policy responding to house prices is in effect, the fall in house prices will result in a loosing of the LTV ratio, which lessens the tightening of the collateral constraint and stimulates credit growth. This in turn will reinforce the positive impact of the housing technology shock on output, with borrowers increasing both their consumption and stock of housing, although this is short lived, with the persistence of the increase in output decreasing

cent of the forecast error variance of output growth is accounted for by housing demand shocks, and only 0.24 per cent by housing supply shocks. Housing demand shocks are important for residential investment growth (42.76 versus 3.64 per cent), whereas housing technology shocks are relatively more important for real house price growth (23.12 versus 54.68 per cent).

Figure 3: Impulse responses to a negative housing demand shock under a reaction rule on house prices

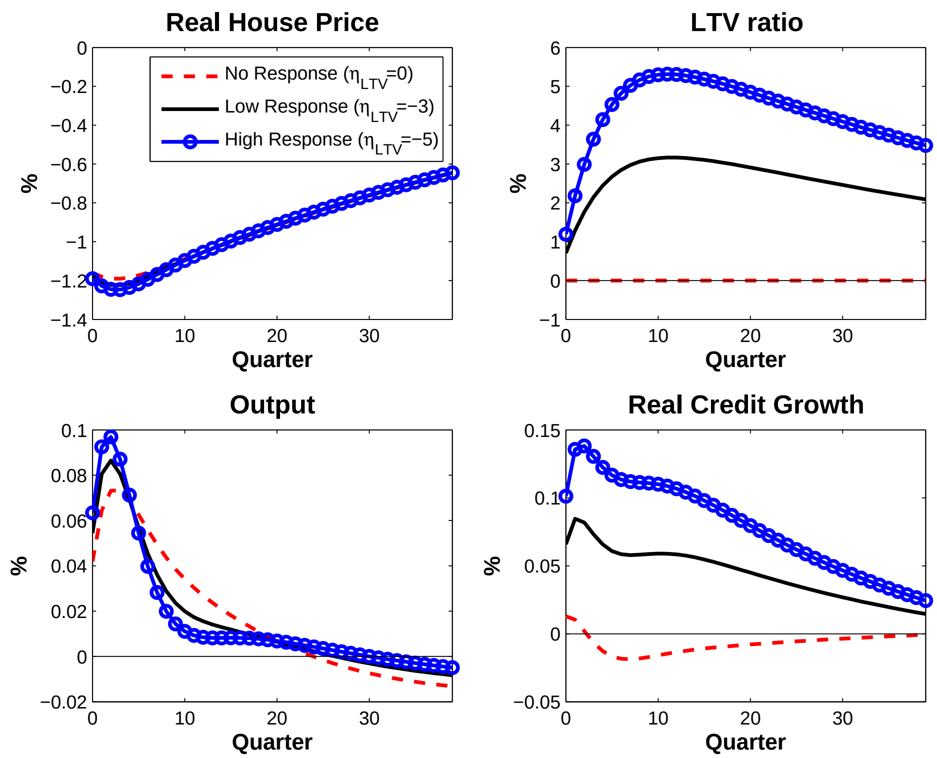


with the strength of the policy response. This partially reflects that the increase in borrowers' stock of housing is increasingly met by savers reducing their holdings rather than residential investment, and that the accompanying monetary policy tightening is larger. The extent of the reinforcement of the real impacts of housing supply shocks increases with η_{LTV} and the more aggressive policy results in the volatility of output growth increasing.

The credit-to-GDP ratio gap has been prominent in discussions of activist macroprudential policy, and now we turn to the consequences for the business cycle of basing a policy rule for the LTV ratio upon it. As shown in the right side of Table 6, it is surprising to see that the credit-to-GDP ratio rule has the opposite implications for the characteristics of the business cycle to the policy based on house prices. In particular, a stronger response to the credit-to-GDP ratio gap leads to longer, more amplified recessions and shorter expansions on average. The volatility of output growth also is larger when the LTV ratio responds strongly to the credit-to-GDP ratio.

What underlies the relatively poor performance of activist policy based on the credit-to-GDP ratio gap? A contributing factor is an important feature of our DSGE model, namely the long-term nature of mortgages. Focusing once again on the response to a negative housing demand shock, as shown in Figure 5 with black solid lines, the credit-to-GDP ratio is a slow moving variable. While output falls quickly in response to the negative housing demand shock, the loan stock falls only

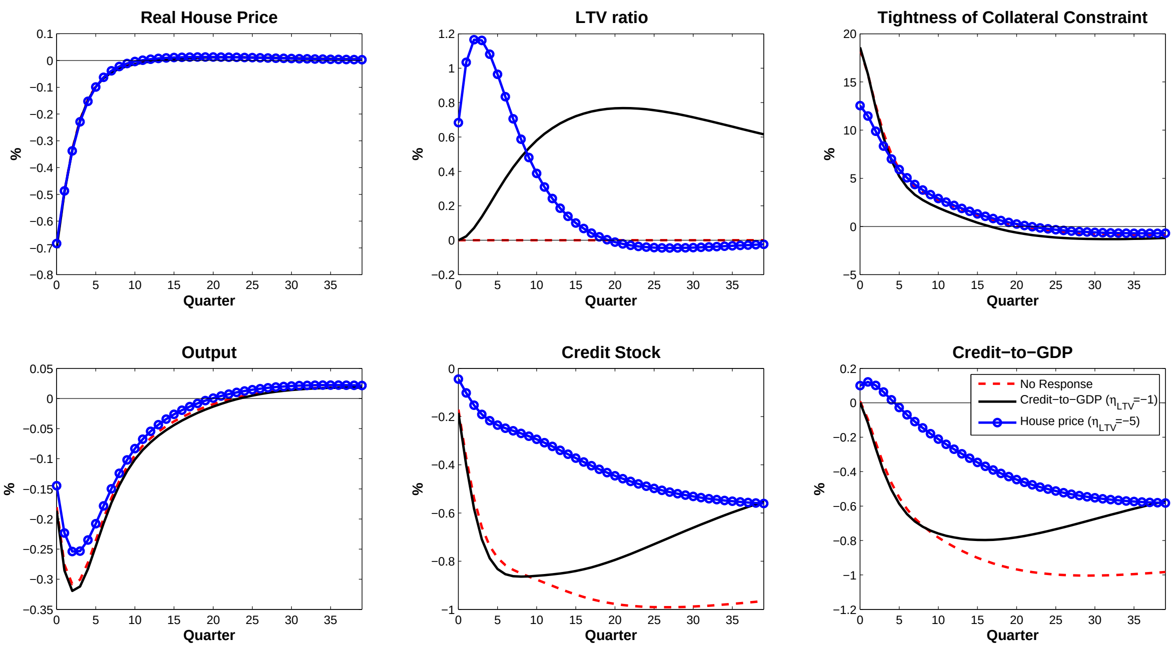
Figure 4: Impulse responses to a housing investment technology shock under a reaction rule on house prices



slowly. This difference in the speed of responses of the two variables makes the credit-to-GDP ratio less useful as a targeting variable for the countercyclical LTV ratio policy. In particular, while the collateral constraint has effectively tightened, the relaxation of the LTV ratio based on the credit-to-GDP ratio gap occurs only slowly and with a significant lag compared to the policy settings under the house price based rule. This substantial delay results in the near-term fall in output being exacerbated by the credit-to-GDP ratio gap rule.

Figure 5: Impulse Responses to a Negative Housing Demand Shock

1 standard deviation



6.2 Effects on credit cycles

We now turn to the effects of countercyclical LTV policy rules on credit cycles, which are summarized in Table 7.

Focussing initially on the implications of the LTV rule responds to house prices, there is no monotonic relationship between the strength of the response, η_{LTV}, and the characteristics of the credit cycle. When the response parameter rises modestly from zero, it improves the characteristics of both credit recessions and expansions. However, when η_{LTV} increases further, a more aggressive response leads to a deterioration in the characteristics of credit recessions, although expansions continue to improve.

Table 7: Credit Cycle Consequences of LTV Rules

	LTV Rule with House Prices						LTV Rule with Credit-to-GDP					
	Recessions			Expansions			Recessions			Expansions		
η_{LTV}	0	-3	-5	0	-3	-5	0	-0.5	-1	0	-0.5	-1
Duration (qtr)	4.35	4.31	4.45	10.96	11.15	11.42	4.35	4.33	4.33	10.96	10.82	10.65
Amplitude (%)	-7.98	-7.74	-7.95	29.89	29.85	30.67	-7.98	-8.15	-8.35	29.89	29.83	29.79

η_{LTV}	0	-3	-5	0	-0.5	-1
Volatility (%)	2.89	2.84	2.84	2.89	2.95	3.00
Proportion of time in recession (%)	28.38	27.85	28.02	28.38	28.59	28.90

To understand why the credit recession characteristics might exhibit such a non-monotonic relationship with the strength of the activist LTV policy, it is useful to look once again at the response of the economy to both housing demand and supply shocks (Figures 3 and 4). Consider first the case where the LTV ratio rule responds only weakly to house prices; in this instance the effect of a housing demand shock on credit growth is amplified by the collateral constraint, whereas housing supply shocks have little impact on credit growth. As the policy becomes more aggressive, it dampens the impact of housing demand shocks on credit growth but amplifies the impact of housing supply shocks, with very aggressive policy increasing the volatility of credit growth.

Alternatively, when the rule responds even moderately to the credit-to-GDP ratio an increase in the volatility of the credit growth is apparent (see the right-hand side of Table 7). The intuition for this is the same as for its performance stabilizing the business cycle - the slow moving nature of the credit-to-GDP ratio means that the resulting adjustments to the LTV ratio are incorrectly timed to moderate credit cycles, and the more active the policy rule the greater the counterproductive results are for the credit cycle.

In summary, these results suggest that some caution is appropriate when using countercyclical LTV ratio policies to stabilise the economy. First, the macroprudential authority needs to choose the indicator variable for the policy carefully. As shown in the example above, given the financial friction in our model, house prices are a better indicator of how to appropriately set the LTV ratio than the credit-to-GDP ratio, primarily due to the slow-moving nature of the stock of mortgage debt. This result, however, does not imply that credit is irrelevant for LTV ratio policy in general. We also experimented with policy rules responding to the growth of credit or new loans. These both had better stabilisation properties than the credit-to-GDP ratio. This reflects that while the stock is slow-moving, growth in credit or new loans are not.[14] Second, the strength of the response to the indicator variable that is desirable from the perspective of its implications for the business

[14]The business cycle characteristics based on these rules are available upon request.

cycle characteristics depends on the mix of shocks typically hitting the economy. An aggressive response to house price developments is more desirable in economies where housing demand, rather than supply, shocks play a larger role. Third, it is evident from comparing Tables 6 and 7, that while strongly responding to house prices improves the business cycle characteristics, it can worsen the credit cycle. Consequently, it appears that policymakers can face a trade-off between stabilising the real and financial sectors.

7 Conclusions

The recent financial crisis and its significant real impacts have lead to LTV ratio policies being increasingly used or considered in many nations. Understanding their macroeconomic consequences therefore is of considerable importance. The focus of this paper is to assess the consequences of LTV ratio policies for the business and credit cycles.

We found that a permanent reduction in the LTV ratio reduces the average amplitude of recessions, and, in particular, the frequency with which they occur. The latter occurs primarily as the characteristics of expansions improve, namely they last for longer on average. While these changes occur for both the business and credit cycles, they are larger for the credit cycle. A possible interpretation of these results is that they demonstrate the primary importance of getting the incentives right in the financial system, of which setting a permanently lower LTV ratio might be one aspect of a policy response.[15]

Activist LTV ratio policy was found to also be able to improve the characteristics of the business and credit cycles. However, the extent of the improvements tends to be small and the indicator variable for the policy rule needs to be chosen carefully. An ideal indicator variable is one that provides a timely signal; reacting sluggishly may worsen both the business and credit cycle characteristics. In addition, the strength of the response of the LTV ratio that improves these cycle characteristics depends on the mix of shocks typically hitting the economy.

In this paper we have assumed that monetary policy is conducted following the same Taylor rule as in the past. An extension to this analysis would be to consider the implications of coordination between the monetary and macroprudential policymakers for the characteristics of the business and credit cycles. It would also be desirable to assess the performance of the countercyclical LTV ratio rules in a range of different models embodying alternative assumptions about the nature of real-financial interactions or modelling approaches, akin to the analysis conducted in Taylor [1999] for monetary policy.

In summary, in this paper we have assessed the likely consequences of a variety of LTV ratio policies for the business and credit cycles. Our analysis has highlighted the potential improvements

[15] We thank Frank Warnock for this interpretation.

to the characteristics of these cycles that LTV ratio policies can deliver, together with the difficulties and trade-offs that macroprudential policymakers face.

8 Appendix A - Data Definitions

The data used were all obtained from the Federal Reserve of St Louis FRED database and are defined as follows.

- Population: Civilian Non-institutional Population (mnemonic: CNP16OV).
- Output: Real Gross Domestic Product, 3 decimal (GDPC96).
- Consumption: Real Personal Consumption Expenditure (PCECC96).
- Business investment: Real private fixed investment: Nonresidential (chain-type quantity index) (B008RA3Q086SBEA).
- Residential investment: Real private fixed investment: Residential (chain-type quantity index) (B011RA3Q086SBEA).
- Federal Funds rate: Effective Federal Funds Rate (FEDFUNDS).
- Inflation: GDP Implicit Price Deflator (GDPDEF).
- House prices: S&P/Case Shiller U.S. National Home Price Index (CSUSHPISA), deflated by the GDP deflator.
- Hours worked: Non-farm Business Sector: Hours of All Persons (HOANBS).
- Credit: GKS: Households and Nonprofit Organizations; Home Mortgages; Liabilities, Level (HHMSDODNS).
- Spread: 30-year Conventional Mortgage Rate (MORTG) less the Federal Funds rate.

9 Appendix B - Dynamic Equations

In this appendix, we list dynamic equations that are used in our simulation except for the shock processes. Note that all variables are detrended from the trend growth of the productivity shock when necessary.

9.1 Saver

$$C \quad : \quad \hat{\lambda}_t = \omega_{c,t}\left(c_t - \varsigma_c c_{t-1} g_t^{-1}\right)^{-1} \tag{25}$$

$$H \quad : \quad q_{h,t} + \kappa_{HP}\left(\frac{h_t}{h_{t-1}} - 1\right) = \frac{\xi_h \omega_{c,t}\omega_{h,t}}{\hat{\lambda}_t h_t} + (1-\delta_h)\beta E_t\left[\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t g_{t+1}} q_{h,t+1}\right] \tag{26}$$

$$K \quad : \quad q_{k,t} + \kappa_E\left(\frac{k_t}{k_{t-1}} - 1\right) = E_t\left[\beta\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t g_{t+1}}\left(r_{k,t+1} + (1-\delta_k)q_{k,t+1}\right)\right] \tag{27}$$

$$B \quad : \quad 1 = E_t\left[\beta\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t g_{t+1}}\frac{R_t}{\Pi_{t+1}}\right] \tag{28}$$

$$D \quad : \quad 1 + \Upsilon_t = E_t\left[\beta\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t g_{t+1}}\frac{R_{F,t} + (1-\tau)\Upsilon_{t+1} - (1-\tau)\Omega_{t+1}\left(R_{F,t+1} - R_{F,t}\right)}{\Pi_{t+1}}\right] \tag{29}$$

$$R_L \quad : \quad \Omega_t = E_t\left[\beta\frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t g_{t+1}}\frac{1 + \Omega_{t+1}(1-\tau)}{\Pi_{t+1}}\right] \tag{30}$$

$$\begin{aligned} W \quad : \quad & E_t\left[\beta\frac{\hat{\lambda}_{t+1}N_{t+1}}{\hat{\lambda}_t g_{t+1}\Pi_{t+1}N_t}\frac{\Pi^2_{Pw,t+1}}{\left(\Pi_{Pw,t}\right)^{\iota_w}\bar{\Pi}_{Pw}^{1-\iota_w}}\kappa_w\left(\frac{\Pi_{Pw,t+1}}{\left(\Pi_{Pw,t}\right)^{\iota_w}\bar{\Pi}_{Pw}^{1-\iota_w}} - 1\right)\right] \\ = \quad & \kappa_w\left[\left(\frac{\Pi_{Pw,t}}{\left(\Pi_{Pw,t-1}\right)^{\iota_w}\bar{\Pi}_{Pw}^{1-\iota_w}}\right)^2 - \frac{\Pi_{Pw,t}}{\left(\Pi_{Pw,t-1}\right)^{\iota_w}\bar{\Pi}_{Pw}^{1-\iota_w}}\right] - \eta_{w,t}\frac{\kappa_w}{2}\left(\frac{\Pi_{Pw,t}}{\left(\Pi_{Pw,t-1}\right)^{\iota_w}\bar{\Pi}_{Pw}^{1-\iota_w}} - 1\right)^2 \\ & -\frac{\xi_n\eta_{w,t}\omega_{c,t}\omega_{n,t}}{\hat{\lambda}_t w_t}N_t^{\sigma_n} + \eta_{w,t} - 1 \end{aligned} \tag{31}$$

$$: \quad d_t = (1-\tau)\frac{d_{t-1}}{\Pi_t g_t} + l_t \tag{32}$$

$$: \quad R_{L,t} = \left[1 - \frac{l_t}{d_t}\right]R_{L,t-1} + \frac{l_t}{d_t}R_{F,t} \tag{33}$$

9.2 Borrower

$$C' \quad : \quad \hat{\lambda}'_t = \omega'_{c,t}\left(c'_t - \varsigma_c c'_{t-1} g_t^{-1}\right)^{-1} \tag{34}$$

$$H' \quad : \quad (1-\gamma_t m) q_{h,t} + \kappa_{HI}\left(\frac{h'_t}{h'_{t-1}} - 1\right) = \frac{\xi'_h \omega'_{c,t}\omega'_{h,t}}{\hat{\lambda}'_t h'_t} + (1-\delta_h) E_t\left[\beta' \frac{\hat{\lambda}'_{t+1}}{\hat{\lambda}'_t g_{t+1}} (1-\gamma_{t+1} m) q_{h,t+1}\right] \tag{35}$$

$$D' \quad : \quad 1-\gamma_t = E_t\left[\beta' \frac{\hat{\lambda}'_{t+1}}{\hat{\lambda}'_t g_{t+1}} \frac{R_{F,t} - (1-\tau)\gamma_{t+1} - (1-\tau)\Omega'_{t+1}(R_{F,t+1} - R_{F,t})}{\Pi_{t+1}}\right] \tag{36}$$

$$R_L \quad : \quad \Omega'_t = E_t\left[\beta' \frac{\hat{\lambda}'_{t+1}}{\hat{\lambda}'_t g_{t+1}} \frac{(1+\Omega_{rI,t+1}(1-\tau))}{\Pi_{t+1}}\right] \tag{37}$$

$$W' \quad : \quad E_t\left[\beta' \frac{\hat{\lambda}'_{t+1} N'_{t+1}}{\hat{\lambda}'_t g_{t+1} N'_t} \frac{\Pi^2_{Iw,t+1}}{(\Pi_{Iw,t})^{\iota_w}\bar{\Pi}_{Iw}^{1-\iota_w}} \kappa_w \left(\frac{\Pi_{Iw,t+1}}{(\Pi_{Iw,t})^{\iota_w}\bar{\Pi}_{Iw}^{1-\iota_w}} - 1\right)\right] \tag{38}$$

$$= \kappa_w\left[\left(\frac{\Pi_{Iw,t}}{(\Pi_{Iw,t-1})^{\iota_w}\bar{\Pi}_{Iw}^{1-\iota_w}}\right)^2 - \frac{\Pi_{Iw,t}}{(\Pi_{Iw,t-1})^{\iota_w}\bar{\Pi}_{Iw}^{1-\iota_w}}\right] - \eta_{w,t}\frac{\kappa_w}{2}\left(\frac{\Pi_{Iw,t}}{(\Pi_{Iw,t-1})^{\iota_w}\bar{\Pi}_{Iw}^{1-\iota_w}} - 1\right)^2$$

$$-\frac{\xi'_n \eta_{w,t}\omega'_{c,t}\omega'_{n,t}}{\lambda'_t w'_t} N_t'^{\sigma_n} + \eta_{w,t} - 1$$

$$: \quad l_t = m q_{h,t}\left[h'_t - (1-\delta_h) h'_{t-1} g_t^{-1}\right] \tag{39}$$

$$: \quad c'_t + q_{h,t}\left[h'_t - (1-\delta_h) h'_{t-1} g_t^{-1}\right] + \frac{[R_{L,t-1} - 1 + \tau]}{\Pi_t g_t} d_{t-1} = \left[w'_t - \Psi_w\left(\frac{w'_t}{w'_{t-1}}\right)\right] N'_t + l_t \tag{40}$$

9.3 Intermediate good producer

$$w_t = \eta_l \frac{(1-\eta_k) y_t}{N_t} rmc_t \tag{41}$$

$$w'_t = (1-\eta_l)\frac{(1-\eta_k) y_t}{N'_t} rmc_t \tag{42}$$

$$y_t = k_{t-1}^{\eta_k}\left[N_t^{\eta_l} N_t'^{1-\eta_l}\right]^{1-\eta_k} \tag{43}$$

$$rmc_t = \frac{(r_{k,t})^{\eta_k}[w_t]^{\eta_l(1-\eta_k)}[w'_t]^{(1-\eta_l)(1-\eta_k)}}{\eta_k^{\eta_k}[\eta_l(1-\eta_k)]^{\eta_l(1-\eta_k)}[(1-\eta_l)(1-\eta_k)]^{(1-\eta_l)(1-\eta_k)}} \tag{44}$$

9.4 New Keynesian Phillips Curve

$$\left[1 - \kappa_{Ph}\frac{\Pi_t}{(\Pi_{t-1})^{\iota_{Ph}}\bar{\Pi}^{1-\iota_{Ph}}}\left(\frac{\Pi_t}{(\Pi_{t-1})^{\iota_{Ph}}\bar{\Pi}^{1-\iota_{Ph}}} - 1\right)\right]$$
$$-\eta_t\left[1 - \frac{\kappa_{Ph}}{2}\left(\frac{\Pi_t}{(\Pi_{t-1})^{\iota_{Ph}}\bar{\Pi}^{1-\iota_{Ph}}} - 1\right)^2 - rmc_t\right]$$
$$+\kappa_{Ph}E_t\left[\beta_P \frac{\hat{\lambda}_{t+1}}{\hat{\lambda}_t \Pi_{t+1}} \frac{y_{t+1}}{y_t}\left(\frac{\Pi_{t+1}}{(\Pi_t)^{\iota_{Ph}}\bar{\Pi}^{1-\iota_{Ph}}} - 1\right)\frac{\Pi^2_{t+1}}{(\Pi_t)^{\iota_{Ph}}\bar{\Pi}^{1-\iota_{Ph}}}\right] = 0, \tag{45}$$

9.5 Final investment goods producers

$$\frac{1}{q_{h,t}A_{h,t}} = \left[1-\frac{\kappa_h}{2}\left(\frac{x_t}{x_{t-1}}g_t-g\right)^2-\kappa_h\left(\frac{x_t^2}{x_{t-1}^2}g_t^2-\frac{x_t}{x_{t-1}}g_t\right)\right] \tag{46}$$

$$+\kappa_h E_t\left[\beta\frac{\hat{\lambda}_{t+1}A_{h,t+1}q_{h,t+1}}{\hat{\lambda}_t A_{h,t}q_{h,t}}\left(\frac{x_{t+1}^3}{x_t^3}g_{t+1}^2-\frac{x_{t+1}^2}{x_t^2}g_{t+1}\right)\right] \tag{47}$$

$$h_t=(1-\delta_h)h_{t-1}g_t^{-1}+A_{h,t}x_t\left[1-\frac{\kappa_h}{2}\left(\frac{x_t}{x_{t-1}}g_t-1\right)^2\right]$$

$$\frac{1}{q_{k,t}A_{k,t}} = \left[1-\frac{\kappa_k}{2}\left(\frac{i_t}{i_{t-1}}g_t-g\right)^2-\kappa_k\left(\frac{i_t^2}{i_{t-1}^2}g_t^2-\frac{i_t}{i_{t-1}}g_t\right)\right] \tag{48}$$

$$+\kappa_k E_t\left[\beta\frac{\hat{\lambda}_{t+1}A_{k,t+1}q_{k,t+1}}{\hat{\lambda}_t A_{k,t}q_{k,t}}\left(\frac{i_{t+1}^3}{i_t^3}g_{t+1}^2-\frac{i_{t+1}^2}{i_t^2}g_{t+1}\right)\right] \tag{49}$$

$$k_t=(1-\delta_k)k_{t-1}g_t^{-1}+A_{k,t}i_t\left[1-\frac{\kappa_k}{2}\left(\frac{i_t}{i_{t-1}}g_t-1\right)^2\right]$$

9.6 Monetary Policy

$$R_t=R_{t-1}^{rr}\left[R\left(\frac{\Pi_t}{\Pi}\right)^{r_\pi}\left(\frac{y_t}{y_{t-1}}\right)^{r_{\Delta y}}\right]^{1-rr}\exp(\omega_{r,t}), \tag{50}$$

9.7 Resource Constraint

$$y_t=c_t+i_t+x_t+g_t+a(u_t)K_{t-1}$$

9.8 Aggregation

$$c_t = c_t+c_t' \tag{51}$$

$$h_t = h_t+h_t' \tag{52}$$

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