

# Loan-to-Value Ratio Policy and Business Cycles\*

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## **Abstract**

This paper demonstrates how the effectiveness of loan-to-value (LTV) ratio policies can be evaluated based on their implications for the business cycle. In particular, we assess how key characteristics of the business cycle, such as the duration and amplitude of recessions, change with alternative LTV policies. We study the impacts of these policies in models where housing serves as collateral for either short-term debt, akin to [Iacoviello \[2005\]](#) and [Iacoviello and Neri \[2010\]](#), or long-term mortgages, following [Garriga et al. \[2013\]](#), using the business cycle dating techniques developed by [Harding and Pagan \[2002\]](#). We find that a permanent tightening of LTV policy decreases the depth and frequency of recessions and that the magnitudes of these effects vary with how mortgage debt is modelled. The impact of countercyclical LTV rules on the business cycle is found to be considerably less.

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# 1 Introduction

The global financial crisis (GFC) highlighted that monetary policy focussed on targeting inflation does not ensure financial stability. This is of particular importance given that the real effects of financial crises are large – the associated recessions have been found in the empirical literature to typically be considerably more severe than normal downturns (e.g. [IMF \[2009\]](#), [Reinhart and Rogoff \[2009\]](#) and [Claessens et al. \[2012\]](#)). Facing these concerns, policymakers have turned to implementing a new set of policies - known as macroprudential policies - as a complement to monetary policy with the explicit aim of maintaining financial stability.

In advanced economies housing mortgage loans have drawn particular attention of macroprudential policymakers. Booms and busts of house prices directly affect household wealth, leverage and consumption. As a result, restrictions on highly leveraged mortgage borrowing have been implemented in several developed economies since GFC. For example, the Reserve Bank of New Zealand in October 2013 implemented restrictions on high Loan-To-Value (LTV) ratio lending (see [Wheeler \[2013\]](#)) and in October 2014 the Bank of England introduced loan-to-income restrictions.<sup>1</sup>

The aim of this paper is to demonstrate a method for evaluating the potential benefits and costs of macroprudential policies that is useful for policymakers and to apply this method to LTV ratio-based policies. Because the motivation for macroprudential policies is to lessen the likelihood of financial crises occurring, as these are often associated with severe recessions, a natural way to evaluate them is to assess whether their adoption lessens the severity and frequency with which recessions occur. On the other hand, macroprudential policy also has implications for the expansionary phase of the business cycles. How the policy affects the duration and the amplitude of booms are also in the consideration of policy makers. Our method takes both recessions and expansions into account when evaluating the effectiveness of LTV policies. In particular, we apply the business cycle dating algorithm developed by [Harding and Pagan \[2002\]](#) to data simulated from the theoretical model, which enables us to study how the characteristics of the business cycle, such as the duration and amplitude of recessions and expansions, change with alternative LTV policies. More specifically, we consider the impacts of both a permanent lowering the LTV ratio, and temporary adjustment following a reaction function, similar to the Taylor rule, which allows the LTV ratio to be set in a countercyclical manner or to ‘lean against the wind’ of either house price or credit growth.

In particular, we want to answer two questions through the lens of business cycle dating, namely:

1. Does LTV policy reduce the frequency of recessions, their severity, or both?
2. How does the performance of temporary and permanent LTV policy compare?

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<sup>1</sup>An overview of policies introduced internationally is provided by [C. et al. \[2011\]](#) and [Claessens \[2014\]](#).

To investigate these questions it is necessary to use a model with housing and mortgage debt.

The theoretical model we use in our policy experiments is based on [Iacoviello \[2005\]](#) and [Iacoviello and Neri \[2010\]](#), in which patient households grant one-period loans to impatient households that are subject to a housing collateral constraint. In this framework, LTV policy affects the total stock of household credit, which covers not only housing mortgage but also household credit to finance private consumption. This LTV policy therefore amounts to a general restriction on home equity loan or refinancing mortgage loans. In reality, however, the LTV restrictions that have been implemented by the central banks to date target only the flows of housing mortgage loans. To model this kind of LTV policy more realistically, we extend the baseline model to allowing multiple-period mortgage loans and LTV restrictions being imposed only on new housing purchases as in [Kydland et al. \[2012\]](#) and [Garriga et al. \[2013\]](#). Our approach therefore allows us assess the robustness of our results to different strategies for modelling mortgages.

Our findings suggest that a permanent tightening of LTV policy decreases the severity and depth of recessions, although the extent to which this occurs depends on how loans and the collateral constraint is modelled. For the countercyclical LTV rules, our results generally suggest that their impact on the business cycle is considerably less. Finally, we conduct a range of sensitivity tests on our findings, such as varying the sample and allowing for an easing in credit standards in estimation and allowing for house price expectations to deviate from rational expectations. In general the results with respect to permanent LTV policy remain, although in some instances the amplitude of expansions is adversely affected to a small extent.

The rest of the paper is structured as follows. In [Section 2](#) we lay out the structure of the model, the alternative specifications of the collateral constraint, and discuss its estimation. Subsequently, in [Section 3](#) we discuss the business cycle dating approach and how it can be utilised to evaluate LTV policies. [Section 3](#) presents the results from the variants of the model, and [Section 4](#) the sensitivity analysis. Finally, [Section 5](#) concludes.

## 2 Model

In this section, we construct a median-scale DSGE model with housing collateral constraints that encompasses two types of LTV policies considered in the literature. The first type of mortgages, and hence LTV policies, are motivated by the collateral constraint used in [Iacoviello \[2005\]](#) and [Iacoviello and Neri \[2010\]](#), in which the total amount of borrowing is limited to a fraction of the total value of housing stock owned by the borrowers. In this framework, LTV policy is largely equivalent to a restriction on home equity loan or refinancing mortgage loans. The second type of LTV policies considered in the model is closer to the LTV policy implemented by some central banks in the wake of GFC. In particular, following [Kydland et al. \[2012\]](#) and [Garriga et al. \[2013\]](#), we extend the baseline model to allow for multiple-period mortgage loans and LTV restrictions

being imposed only on new housing purchases.

We now outline the main components of the model.

## 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  $n$

$$E_t \sum_{\tau=0}^{\infty} \beta^\tau \omega_{c,t+\tau} \left[ \log(c_{t+\tau}(j) - \varsigma_c c_{t+\tau-1}) + \omega_{h,t+\tau} \xi_h \log h_{t+\tau}(j) - \xi_n \frac{(n_{t+\tau}(j))^{1+\phi_n}}{1+\phi_n} \right] \quad (1)$$

$\beta \in (0, 1)$ ,  $\xi_h, \xi_n > 0$ ,  $\phi_n \geq 0$

$\varsigma_c$  is the external habit parameter for consumption.  $\phi_n$  is the inverse of the Frisch elasticity of labour while  $\xi_h$  and  $\xi_n$  determine the relative weights of housing and labour in utility. Importantly, the savers' discount factor  $\beta$  is assumed to be higher than that of borrowers, i.e. they place a relatively smaller weight on current consumption in their consumption choice.  $\omega_c$  is a shock that lowers the agent's propensity to postpone consumption to the future and  $\omega_h$  is a housing demand shock which stimulates the intratemporal substitution between consumption and housing services.

The savers' period budget constraint is given by

$$\begin{aligned} & c_t(j) + q_{h,t} [h_t(j) - (1 - \delta_h)h_{t-1}(j)] + \frac{B_t(j)}{R_t P_{c,t}} \\ & + q_{k,t} [k_t(j) - (1 - \delta_k)k_{t-1}(j)] + (1 + \Upsilon_t) \frac{L_t(j)}{P_{c,t}} \\ \leq & r_{k,t} k_{t-1}(j) + \left( \frac{W_t(j)}{P_{c,t}} - \Psi_{w,t}(j) \right) n_t(j) \\ & + \frac{(r_{l,t-1} + \tau_{t-1}) D_{t-1}(j)}{P_{c,t}} + \frac{B_{t-1}(j)}{P_{c,t}} + \Omega_{f,t} \end{aligned} \quad (2)$$

Savers purchase housing services  $h$  from the final housing service producers at the CPI-deflated price  $q_h$ .  $\delta_h$  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. Additional to real investments, savers in the economy purchase two financial assets. The first is a risk-free nominal government bond  $B$  that generates a gross nominal return  $R$ , and the second is consumer loans to borrowers.<sup>2</sup> In particular,  $L_t$  and  $D_t$  denote the flow and the stock of the nominal loan, respectively.  $r_{l,t}$  is the net return on the outstanding loans, while  $\tau$  denotes the amortization rate of the loan. The loan

<sup>2</sup>As specified later in the borrowers' problem, this loan is used both for buying housing and smoothing consumption. As a result, it amounts to a combination of residential mortgage loans and home equity loans.

stock follows the law of motion:

$$D_t(j) = [1 - \tau_{t-1}(j)] D_{t-1}(j) + L_t(j). \quad (3)$$

Following [Kydland et al. \[2012\]](#) and [Garriga et al. \[2013\]](#), we assume that the amortization rate follows the law of motion:

$$\tau_t(j) = \left(1 - \frac{L_t(j)}{D_t(j)}\right) \tau_{t-1}(j)^\alpha + \frac{L_t(j)}{D_t(j)} \kappa, \quad (4)$$

where  $\alpha \in [0, 1)$  and  $\kappa > 0$ . When  $\alpha = 0$  and  $\kappa = 1$ , we have  $\tau_t(j) = 1$  and  $D_t(j) = L_t(j)$  for all  $t$ , such that we recover a one-period loan where all outstanding debt is repaid each period. When  $\alpha > 0$  and  $\kappa < 1$ , Equation (4) expresses that the amortization rate evolves as the weighted average of the amortization rate of the outstanding stock,  $\tau_{t-1}(j)^\alpha$ , and the initial amortization rate of new loans,  $\kappa$ , with the weights being the relative sizes of the current stock and flow in the new stock, respectively. This expression can also capture the realistic feature that the amortization rate is low in the early years of a mortgage such that mortgage payments consist mainly of interest.

Furthermore, we assume that savers incur monitoring costs when lend to borrowers, which can be motivated by the possibility of default ([Curdia and Woodford \[2011\]](#)). We posit that the monitoring costs depend on the loan-to-value ratio (LTV), based on the housing collateral value. In particular, monitoring costs are larger when the borrower has high leverage:

$$1 + \Upsilon_t = \chi_1 \left( \frac{D_t}{q_{h,t} H_{I,t}} \right)^{\chi_2} \varepsilon_{\Upsilon,t}, \quad (5)$$

where  $\chi_1 > 0$  is a level parameter determining the lending spread at the steady state, while  $\chi_2$  controls the elasticity of the lending spread with respect to leverage and  $\varepsilon_{\Upsilon,t}$  is an AR(1) process. Finally,  $\Omega_f$  is the profits from firms and all nominal variables are deflated by the CPI (represented by  $P_c$ ).

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 (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. We also introduce nominal wage rigidities following [Rotemberg \[1982\]](#) by stipulating that it is costly to change wages and the convex cost function  $\Psi_w(\cdot)$  governs the degree of wage stickiness

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

$$\kappa_w > 0, \quad \iota_w \in [0, 1], \quad \delta_h, \quad \delta_k \in [0, 1].$$

## 2.2 Borrowers

Analogous to the savers, 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,  $\beta'$ .

$$E_t \sum_{\tau=0}^{\infty} (\beta')^{\tau} \omega_{c,t+\tau} \left[ \log (c'_{t+\tau}(j) - \varsigma_c c'_{t+\tau-1}) + \omega_{h,t+\tau} \xi'_h \log h'_{t+\tau}(j) - \xi'_n \frac{(n'_{t+\tau}(j))^{1+\phi_n}}{1 + \phi_n} \right] \quad (7)$$

The borrowers' variables are denoted with an  $'$ . They use income to consume, buy housing services and repay their loans. Their incomes come from their wage ( $W'$ ), and new borrowing ( $L'$ ). The period budget constraint is given by

$$c'_t(j) + q_{h,t} [h'_t(j) - (1 - \delta_h)h'_{t-1}(j)] + \frac{[r_{l,t-1} + \tau_{t-1}(j)] D'_{t-1}(j)}{P_{c,t}} \leq \left( \frac{W'_t(j)}{P_{c,t}} - \Psi'_{w,t}(j) \right) n'_t(j) + \frac{L'_t(j)}{P_{c,t}} \quad (8)$$

where  $L'$  and  $D'$  denote the flow and the stock of the nominal loan, respectively. Symmetric to the saver, wage-setting is subject to quadratic adjustment costs  $\Psi'_{w,t}(j)$ .

### 2.2.1 Collateral Constraints

We specify two types of collateral constraints. The first, which is the most widely used in the literature, applies to a one-period loan, whereas the second specification is applicable to the model with long-term debt.

**1. Iacoviello (2005)** In this specification the capacity to borrow is restricted by the collateral value in the next period when the loan has to be repaid.  $m$  denotes the fraction of the collateral value at which lenders can recover in case of default. Lenders are only willing to lend up to the recoverable value of the housing collateral. Specifically,

$$\frac{L'_t(j)}{P_{c,t}} \leq m E_t \frac{q_{h,t+1} h'_t(j) \Pi_{c,t}}{R_{l,t}} \quad (9)$$

Note that, in one-period loan context, there is no difference between  $L_t$  and  $D_t$ .

Henceforth we will refer to this specification as ‘IAC’.

**2. Garriga, Kydland and Sustek (2013)** The loan is equal to the some fraction of the nominal value of the *additional* housing stock purchased in the period.

$$L'_t(j) = m q_{h,t} P_{c,t} [h'_t(j) - (1 - \delta_h)h'_{t-1}(j)] \quad (10)$$

In this expression,  $m$  resembles the down-payment restriction on new mortgage loans. For example, when  $m = 0.8$ , it means the home buyer need to pay 20% of new housing value in cash.

Henceforth we will refer to this specification as ‘GKS’.

## 2.3 Production

### 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 variety  $y(j)$  using the following technology

$$y_t(j) = k_{t-1}(j)^{\alpha_k} [z_t n_t(j)^{\alpha_n} n'_t(j)^{1-\alpha_n}]^{1-\alpha_k}, \quad \alpha_k, \alpha_n \in [0, 1] \quad (11)$$

$n$  and  $n'$  are the labour bundles from the patient and impatient households respectively, aggregated by the employment agencies and sold to the intermediate goods firm.  $\alpha_n$  governs the share of patient households in the aggregate demand for labour.  $k$  represents the capital stock rented from the patient households and  $\alpha_k$  is the share of capital in production. Finally, labour augmenting technology,  $z$ , follows a random walk process with drift, and we allow for autocorrelation in its growth rate, denoted by  $g$ .

The rest of the production structure is very standard and similar to that of [Christiano et al. \[2005\]](#). The firms sell the intermediate good to a final good 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 firm. In addition, prices are also indexed to inflation at the steady state. We list the relevant equations in Appendix B.

### 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 is described by the following law of motion

$$K_t = \omega_{ik,t} I K_t \left[ 1 - \frac{\kappa_{ik}}{2} \left( \frac{I K_t}{I K_{t-1}} - 1 \right)^2 \right] + (1 - \delta_k) K_{t-1}, \quad \delta_k \in [0, 1], \quad \kappa_{ik} > 0 \quad (12)$$

After capital production, the end-of-period installed capital stock is sold back to patient household at the consumption-based price of  $q_k$ .

Housing investment and house prices are similarly related since 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

$$H_t = \omega_{ih,t} I H_t \left[ 1 - \frac{\kappa_{ih}}{2} \left( \frac{I H_t}{I H_{t-1}} - 1 \right)^2 \right] + (1 - \delta_h) H_{t-1}, \quad \delta_h \in [0, 1], \quad \kappa_{ih} > 0 \quad (13)$$

where  $\omega_{ih}$  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 is influenced by past interest rates and also responds to the current CPI inflation rate, stochastically-detrended output  $\hat{y}_t$  and output growth.

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{r_r} \left[\left(\frac{\pi_{c,t}}{\bar{\pi}_c}\right)^{r_\pi} (y_t)^{r_y} \left(\frac{y_t}{y_{t-1}}\right)^{r_{\Delta y}}\right]^{1-r_r} \exp \omega_{r,t} \quad (14)$$

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

The stochastic shocks in the model are allowed to follow first-order autoregressive processes, and government expenditure is assumed to be exogenous, following [Smets and Wouters \[2007\]](#).

## 2.5 Parameterisation

To parameterise the model we adopt a mixture of calibration, fixing parameters, based on previous studies, and estimation. In particular, 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).

### 2.5.1 Steady-state parameters

An annual inflation target of 2 per cent is assumed. Given this, the discount factor of patient households is calibrated so as the annualised nominal risk-free rate is 5 per cent, yielding  $\beta_p = 0.9967$ . The discount factor for impatient households is set to be 0.99, similar to [Alpanda and Zubairy \[2014\]](#), but higher than [Iacoviello and Neri \[2010\]](#) (0.97). The inverse of the Frisch elasticity of labour supply is assumed to be 2, based on [Smets and Wouters \[2007\]](#).  $\zeta_c$ , the habits parameter, is set to be 0.9, which is similar to the posterior mean estimate of 0.88 obtained by [Alpanda and Zubairy \[2014\]](#). The steady-state LTV,  $m$ , is chosen to be 0.85, and 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, following [Iacoviello and Neri \[2010\]](#). We assume the elasticity of substitution between types of labour is the same.

A wide range of values for the share of patient household's 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 0.7. For the parameters governing monitoring costs there is less evidence, we pick  $\chi_2 = 0.01$ , which is a little higher than [Alpanda et al. \[2014\]](#) select for Canada. We then set  $\chi_1$  so as to the steady-state spread between the lending and Federal Funds rate is 2.25 per cent, which is mid-way between the spread for flexible and fixed-rate loans. This yields



$\chi_1 = 1.0075$  for IAC and 1.25 for GKS. In the GKS model we set the initial amortization rate,  $\kappa$ , to be 0.00162, following Garriga et al. [2013]. The slope parameter was set to 0.99255, which implies a steady-state amortization rate between that of Garriga et al. [2013] and Alpanda and Zubairy [2014].

The implications of this parameterisation for steady-state expenditure ratios are shown in Table 2.5.1. Both models match the data reasonably well, although the consumption-to-output ratio is a little low, and imply that the patient consumers have the same share of total consumption and housing.

Table 1: Steady-state Expenditure Ratios (%)

Ratio	Data	IAC	GKS
$\frac{C}{Y}$	65.84	60.56	60.14
$\frac{X}{Y}$	4.37	4.25	4.67
$\frac{I}{Y}$	12.64	15.53	15.53
Memo items:			
$\frac{c}{c+c'}$	–	0.68	0.68
$\frac{h}{h+h'}$	–	0.74	0.74
Notes: Average over 1983:Q2 - 2014:4.			
Sources: Authors' calculations; for data sources see Appendix A.			

## 2.5.2 Parameters only entering the dynamics

The priors selected for the remaining parameters are standard and are presented in Tables 2 to 4. We set the mean of the prior for the Rotemberg adjustment cost parameters for both prices and wages,  $\kappa_p$  and  $\kappa_w$ , 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,  $\kappa_k$ , 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 an aggressive response to inflation relative to both output and output growth. Finally, loose priors are used for the shock processes.

## 2.5.3 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 growth, hours worked per capita, and the spread between the lending and the Federal Funds rate. The precise data definitions are given in the appendix. The data were de-meaned prior to estimation. The sample is 1985:Q2 – 2008:Q1.

One aspect to note is that in IAC debt corresponds to both personal and mortgage debt, whereas in GKS it is more closely aligned with housing debt. Consequently, we vary the measure of the spread used in estimation across the models.

#### 2.5.4 Estimates

The priors used are mostly standard. The mean of the prior for the adjustment costs parameters governing stickiness in wages and goods prices was set so as to correspond to a Calvo parameter of 0.7 with an indexation parameter of 0.5. The mean and standard deviation of the priors for the adjustment costs of transforming goods into housing or business investment similar to those used for investment adjustment costs in [Smets and Wouters \[2007\]](#). It is assumed in the prior distributions for the Taylor rule parameters that a considerable amount of interest rate smoothing and a relatively stronger reaction to deviations of inflation from target than output, which is typically found in the literature (e.g. [Smets and Wouters \[2007\]](#)). Also following [Smets and Wouters \[2007\]](#) we allow monetary policy to possibly respond to output growth. Finally, loose priors are used for the parameters governing the shock processes.

Estimates of the posterior were obtained using the random-walk Metropolis Hastings algorithm. Two chains of 500,000 observations long were used, with the first 225,000 observations dropped as burn-in.<sup>3</sup>

The posterior estimates suggest that the Phillips curves for both wages and goods prices are flatter than in the prior. In the IAC model adjustment costs for goods prices are greater than for wages, whereas in GKS there is little difference. In both models the posterior mean for investment adjustment costs are greater than for residential investment. The posterior estimates of the Taylor rule parameters are similar across both models, although in GKS it responds a little more aggressively to both inflation and growth. Turning to the shock processes, the autocorrelation parameters are generally similar across both models; the largest divergence are for preference, cost push and technology shocks. The standard deviation of preference shocks is larger in GKS, whereas for spread shocks it is considerably larger in IAC, although recall different interest rate data were used in estimation.

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<sup>3</sup>This was implemented in the Dynare Matlab pre-processor, version 4.4.3.

Table 2: Parameter Estimates

Parameter	Prior	Posterior Mean and 90 Per Cent Highest Posterior Density Interval	
		IAC (2005)	GKS (2013)
$\kappa_w$	$N(130, 20^2)$	135.26	144.31
		103.85 - 166.43	113.42 - 173.83
$\iota_w$	$B(0.3, 0.1)$	0.23	0.30
		0.10 - 0.35	0.15 - 0.45
$\kappa_p$	$N(130, 20^2)$	156.90	139.26
		128.72 - 185.11	110.12 - 168.54
$\iota_p$	$B(0.3, 0.1)$	0.18	0.12
		0.07 - 0.28	0.05 - 0.20
$\kappa_h$	$N(5, 2^2)$	3.30	2.74
		1.84 - 4.67	1.53 - 3.87
$\kappa_k$	$N(5, 2^2)$	6.84	6.94
		4.27 - 9.34	4.24 - 9.59
$r_r$	$B(0.8, 0.1)$	0.80	0.81
		0.76 - 0.83	0.78 - 0.84
$r_\pi$	$N(1.5, 0.25^2)$	1.87	2.05
		1.59 - 2.16	1.80 - 2.31
$r_{\Delta y}$	$N(0.25, 0.1^2)$	0.31	0.43
		0.19 - 0.44	0.31 - 0.56
$r_y$	$N(0.25, 0.1^2)$	0.10	0.03
		0.07 - 0.13	-0.01 - 0.07

Notes: Beta(a,b) denotes the Beta distribution with mean a and standard deviation b.

Table 3: Shock Processes Parameter Estimates

Parameter	Description	Prior	Posterior Mean and 90 Per Cent HPD Interval	
			IAC (2005)	GKS (2013)
$\rho_m$	Monetary	$B(0.5, 0.2)$	0.38	0.35
			0.25 - 0.51	0.24 - 0.47
$\rho_p$	Cost-push	$B(0.5, 0.2)$	0.94	0.83
			0.92 - 0.97	0.79 - 0.87
$\rho_c$	Preferences	$B(0.5, 0.2)$	0.28	0.35
			0.15 - 0.41	0.25 - 0.46
$\rho_{hd}$	Housing Demand	$B(0.5, 0.2)$	0.95	0.95
			0.92 - 0.99	0.93 - 0.98
$\rho_{ah}$	Housing Technology	$B(0.5, 0.2)$	0.98	0.99
			0.96 - 1.00	0.98 - 1.00
$\rho_{ak}$	Investment Technology	$B(0.5, 0.2)$	0.61	0.67
			0.52 - 0.71	0.57 - 0.77
$\rho_{up}$	Spread	$B(0.5, 0.2)$	0.91	0.93
			0.86 - 0.96	0.92 - 0.93
$\rho_g$	Fiscal	$B(0.5, 0.2)$	0.96	0.93
			0.94 - 0.98	0.91 - 0.95
$\rho_{gz}$	Technology growth	$B(0.5, 0.2)$	0.25	0.30
			0.12 - 0.38	0.16 - 0.42
$\sigma_m$	Monetary	IG(0.25,2)	0.10	0.10
			0.09 - 0.12	0.09 - 0.12
$\sigma_p$	Cost-push	IG(0.25,2)	2.16	2.26
			1.37 - 2.16	1.74 - 2.76
$\sigma_c$	Preferences	IG(0.25,2)	6.91	9.79
			4.28 - 5.53	8.44 - 11.11
$\sigma_{hd}$	Housing Demand	IG(0.25,2)	7.08	6.15
			4.85 - 9.16	4.36 - 7.95
$\sigma_{ah}$	Housing Technology	IG(0.25,2)	1.77	1.54
			1.37 - 2.16	1.27 - 1.81
$\sigma_{ak}$	Investment Technology	IG(0.25,2)	6.34	5.76
			3.82 - 8.80	3.26 - 8.20
$\sigma_{up}$	Spread	IG(0.25,2)	15.28	5.07
			13.45 - 17.16	4.34 - 5.73
$\sigma_g$	Fiscal	IG(0.25,2)	1.97	2.05
			1.73 - 2.21	1.80 - 2.30
$\sigma_{gz}$	Technology growth	IG(0.25,2)	0.66	0.52
			0.58 - 0.74	0.46 - 0.59

Notes: Beta denotes the Beta distribution; IG the Inverse Gamma distribution. The arguments are the mean and standard deviation. HPD denotes Highest Probability Density.

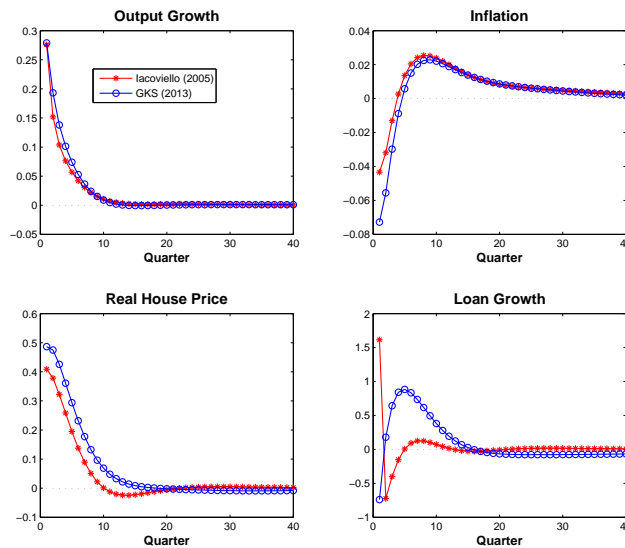
## 2.6 Comparison of Model Dynamics

To demonstrate the dynamics of the models Figures 1 and 2 show the impulse responses to a one standard deviation technology and monetary policy shock.<sup>4</sup>

The effect of a positive one standard deviation productivity growth shock on output growth in both models is similar - an increase of around 0.3 percentage points. Recall that productivity shocks in these models have permanent effects on the level of output. The boost to output growth reflects an increase in all three expenditure components, with residential investment growth increasing the most on impact. Despite this increase in supply, real house prices increase, reflecting increased demand. The main difference in the dynamics between the models is with respect to loans growth - in IAC, the increased demand for housing stimulates credit growth on impact, whereas in GKS there is a more prolonged increase.

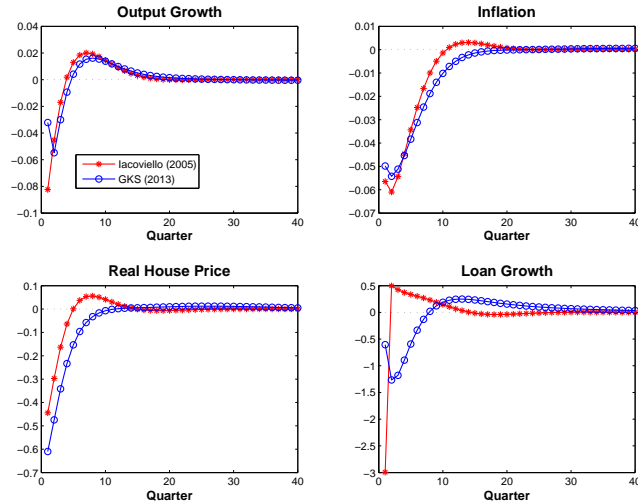
Figure 2 presents the impulse responses of the two models to a one standard deviation monetary policy shock. In both models this is around 10 basis points. As expected, the increase in the interest rate generates falls in both output growth and inflation. Real house prices and credit growth also decrease, in part because of a weakening in housing demand. In IAC the increase in interest rates directly leads to a tightening of the constraint, and loans growth falls sharply. Alternatively, the multiple-period loans in GKS give rise to a more moderate, but also more persistent, falls in loans growth.

*Figure 1: Technology Shock*



<sup>4</sup>The impulse response functions of the other shocks are available on request.

Figure 2: Monetary Policy Shock



### 3 Business Cycle Dating

We now turn to the method that we use to analyse the consequences of alternative LTV policies for the business cycle.

#### 3.1 Method

The business cycle - sometimes referred to as the *classical* business cycle - refers to fluctuations in the *level* of aggregate activity. In the United States the National Bureau of Economic Research (NBER) separates the cycle into expansions and contractions (recessions) by judgmentally identifying turning points in a range of indicators of economic activity.

Harding and Pagan [2002] developed an algorithm, drawing on Bry and Boschan [1971], which identifies the turning points in a series and, applied to Real GDP, well approximates the decisions made by the NBER Business Cycle Dating Committee. This algorithm builds on the rule-of-thumb that a recession occurs when there is two or more consecutive quarters of falls in Real GDP, also applying censoring rules, namely that a phase must have a minimum length, and is known as Bry-Boschan Quarterly (BBQ).<sup>5</sup> More precisely, as discussed in Pagan and Harding [Forthcoming], p.31, a peak,  $\wedge$ , and a trough,  $\vee$  in the series  $y_t$  are defined as

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

<sup>5</sup>The BBQ algorithm is available from <http://www.ncer.edu.au/data/data.jsp> in Matlab, Excel and Gauss.

which is equivalent to

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

where  $\Delta$  is the first difference operator and  $\Delta_2$  denotes six-monthly growth. As aforementioned, these are subject to additional criteria, such as with respect to the minimum length of the cycle. Note also that by focusing on turning points it is not necessary to extract the low frequency components of  $y_t$  in order to analyse the business cycle; for example, permanent technology shocks, which generate the low frequency component in many models, also influence real GDP growth and hence turning points.

The BBQ algorithm allows the business cycle properties of a model to be analysed. To implement this, a long series of the level of output can be simulated from the model, by repeatedly drawing shocks from their estimated multivariate distribution, and then passed through the model.<sup>6</sup> We then use BBQ to identify turning points in the simulated series, and to calculate key characteristics of the business cycle, such as the average duration and amplitude of recessions.<sup>7</sup> A long simulated series is used so as to focus on population characteristics, rather than sample estimates.<sup>8</sup>

These turning points can be used in at least two ways. First, we compare the properties of the business cycle from the model to that evident in the actual GDP data. This essentially is a way of evaluating the model, and in our opinion is a useful adjunct to traditional approaches such as Bayes factors or comparing the model's second moments to those in the data. Second, we can examine how the business cycle characteristics change as we vary parameters of the model. This, we believe, provides useful additional insights compared with examining how the impulse responses change to particular shocks change. This is as the business cycle characteristics reflect the turning points in aggregate output. These turning points will depend on the response of output growth to all shocks which affect it - rather than just one - and as [Pagan and Robinson \[2014\]](#) argue, these business cycle characteristics therefore combine the impulse responses in a meaningful way. Relatedly, the turning points can be used to examine other properties of the model, such as, the relationship between other endogenous variables and the probability or severity of a recession.

The business cycle dating framework, we believe, is particularly suitable to macroprudential policy and a useful complement to welfare analysis. The [Bank for International Settlements \(BIS\) \[2010\]](#), for example, suggests that macroprudential policy is designed to contain systemic risks, as the associated disruptions to the financial system have potentially serious negative consequences for the real economy. Relatedly, the historical record clearly demonstrates that financial crises result

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<sup>6</sup>As the models were estimated using Bayesian methods, we fix the parameters of the models at the mean of their posterior.

<sup>7</sup>This method is univariate, whereas the NBER examine multiple output indicators. It is possible to apply the algorithm separately to multiple series, and then to construct a reference cycle; see [Harding and Pagan \[2006\]](#). Also see [Stock and Watson \[2010\]](#) and [Pagan and Harding \[Forthcoming\]](#).

<sup>8</sup>In this paper we use 100,000 observations.

in recessions that are considerably more severe than recessions stemming from other sources (e.g. [Claessens et al. \[2012\]](#)). The role in financial factors amplifying the business cycle has led to some to refer to the “financial cycle” (e.g. [Borio \[2012\]](#)). These financial factors are of considerable importance, but as this importance stems from the consequences of financial instability for the business cycle we consider it best to focus on these real effects when evaluating macroprudential policies. This lessens the need to define intermediate targets - such as a particular level of leverage - as an objective when evaluating macroprudential policies. For example, [Alpanda et al. \[2014\]](#) compares the effectiveness of various macroprudential policies, namely LTV and increased capital requirements, with monetary policy by the peak loss of output associated with a reduction of household debt. Instead, we think it is more informative to evaluate whether these policies lessen the severity or frequency of recessions.

### 3.2 Business Cycle Properties

We begin by comparing the business cycle properties of the models. The table below shows several key characteristics of the US business cycle and the comparable statistics from the models with the various specifications of credit constraints.

*Table 4: Business Cycle Properties*

	Data	Model	
		IAC	GKS
<i>Durations (qtrs)</i>			
Expansions	16.45	15.83	11.77
Recessions	4.45	3.94	4.05
<i>Amplitude (%)</i>			
Expansions	11.60	9.67	8.60
Recessions	-3.00	-1.48	-2.10
<i>Cumulative amplitude (%)</i>			
Expansions	82.60	90.78	77.70
Recessions	-64.85	-74.66	-68.85

Note: Data is 1957:2 - 2014:4

These results suggest that all the models replicate the business cycle characteristics reasonably well. This stands in contrast to the [Iacoviello and Neri \[2010\]](#) model, which was found by [Pagan and Robinson \[2014\]](#) to not replicate the average business cycle characteristics well.<sup>9</sup> Looking across the models, in both the durations of expansions and contractions are too short, implying

<sup>9</sup>In particular, expansions were too short and had insufficient amplitude.



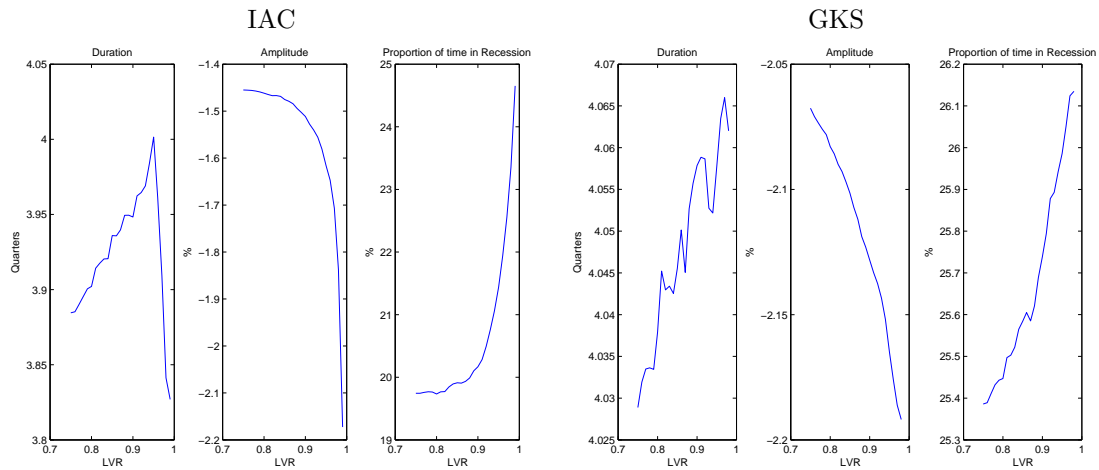
that complete cycles happen more frequently in the data. The divergence is greatest for the length of expansions in the model with long-term debt, although it does match the duration of recessions slightly better. In both models the average amplitudes of both expansions and contractions also are too small; this is particularly the case for recessions, although the divergence is less for the GKS model.

### 3.3 Does LTV policy reduce the frequency of recessions, their severity, or both?

#### 3.3.1 Permanent LTV policy

As pointed out by [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. To study the potential macroeconomic impacts of such a policy, Figure 3 presents several of the characteristics of recessions - namely the average duration and amplitude, as above, together with the proportion of time the economy is in recession - and how they vary as the steady-state LTV is permanently altered. To implement this we hold all other parameters at their estimated value, alter the LTV parameter, simulate the model, and apply the dating algorithm to the simulated output data. 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 focussed upon (e.g. [Alpanda et al. \[2014\]](#)).

Figure 3: Recession Characteristics



The average duration of recessions appears to generally increase with the LTV, although the magnitude of any change is small. It has a more sizeable effect on the average depth of recessions,

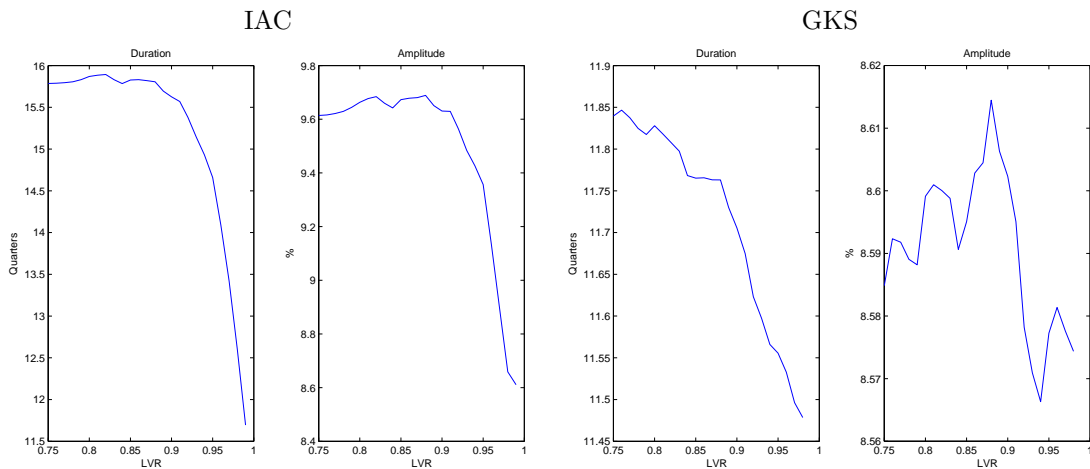
most notably in the IAC model, where it sharply increases at high LTVs. The proportion of time that the economy is in recession also increases with the LTV, once again most notably in the baseline model.

An aspect to note in interpreting Figure 4 is that the steady-state LTV in all of the models was calibrated to be 0.85, following [Iacoviello and Neri \[2010\]](#). Consequently, the effect of a permanent tightening of macroprudential policy is a lowering, for example, from 0.85 to 0.80, in which the estimated impact on the business cycle characteristics shown in Figure 3 is relatively small, even though some change dramatically at high LTVs. [Iacoviello and Neri \[2010\]](#), however, note that this is a conservative calibration, and others have used 0.90 (e.g. [Iacoviello \[2015\]](#)).

Figure 3 focusses on the average characteristics of recessions. Kernel density estimates of the duration and amplitude are skewed to the right and deliver a similar message, namely that the impact of these policies are small and greater on amplitudes than on durations.

Turning to the characteristics of expansions, Figure 4 demonstrates that a very high LTV ratio adversely affects expansions. This is most notable in the one-period debt specification, where there is both a sharp shortening of the average duration of expansions and lessening of their amplitude. However, around the steady-state ratio of 0.85, the effect of either reducing or increasing the LTV is slight. Consequently, somewhat surprisingly it appears that these models suggest there is not a trade-off from introducing tighter LTV policy. Alternatively, [Pagan and Robinson \[2014\]](#) found when reducing the LTV in the [Iacoviello and Neri \[2010\]](#) from 0.85 to 0.5 - admittedly, a more dramatic change than considered here - that the amplitude of expansions decreased, and their durations increased. Comparing the results from the two models, it appears the introduction of long-term debt tends to mute the impact of varying the LTV on the characteristics of expansions.

Figure 4: Expansion Characteristics



One aspect explaining these changes is that the volatility of output growth increases with the LTV in both of the models, as was noted for the [Iacoviello and Neri \[2010\]](#) model by [Pagan and Robinson \[2014\]](#). An increase in the variance raises the probability of a negative growth rate, and

hence a turning point, occurring. Interestingly, the increase from when the LTV is 0.7 to 0.9 is only modest, and surprisingly proportionally larger in the long-term debt model. Alternatively, when the LTV increases further to 0.98 the variance of output growth increases markedly in the short-term debt model - by around one quarter - but by considerably less in GKS. In both models the increase in volatility in nominal credit growth is much more stark than for output growth, and this is particularly the case for the GKS model.

A permanent change in the LTV has implications for the steady state, and these differ across the models. Apart from reducing indebtedness, lowering the LTV reduces the steady-state consumption of impatient households in both models. In the short-term debt model, impatient households also reduce their holdings of housing (relative to income), and consequently residential investment also falls. Alternatively, in the long-term debt model the fall is concentrated in the impatient households' consumption.

In addition to altering the steady-state of the economy, its dynamics change with the lower LTV ratio. To demonstrate this, Figures 5 and 6 show the impulse responses to a housing demand shock in the IAC and GKS models respectively. Note that we are considering the dynamics of the economy at the new steady-state, rather than the transition to it.

Focussing initially on the IAC model, a reduction in the LTV ratio dampens the response of output growth to the housing demand shock. This stems largely from the response of impatient consumers' consumption decisions changing, as patient households reduce their holdings of housing so as to facilitate the increased demand for housing by less at the lower LTV, and there is little change in the response of housing supply. As expected, the tighter LTV policy mutes the response of credit growth. In the GKS model, despite the dynamics of credit growth also being muted, the impact on output growth is slight.

There is little difference in the impulse responses between the two different policies for many of the other shocks in both models. In IAC, the lower LTV mutes the impact of a monetary policy shock; this is less evident in GKS. A difference does exist in the reaction to a housing supply shock in the IAC model, with the increased supply of housing depressing prices. The difference stems from that the lower LTV mutes the impact of this decline in the value of collateral on borrowing, and hence the subsequent falls in consumption of the impatient households. Alternatively, varying the LTV has little impact on the response to a housing technology shock in the GKS model, as this collateral effect is limited only to new borrowing, rather than all outstanding debt.

In summary, the effects of permanently changing the LTV on the business cycle characteristics of these models generally appear to be small.<sup>10</sup> The most sizable impacts are found in the one period loan model. In both models the largest impact, in an absolute sense, appears to be reducing

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<sup>10</sup>Relatedly, [Iacoviello and Neri \[2010\]](#) conduct sub-sample analysis, re-estimating their model over the latter period with a higher assumed steady-state LTV, and find only modest differences with respect to the impulse response functions to a housing demand shock.

the proportion of time that the economy is in recession. Tighter LTV policy does mitigate the impact of housing shocks on growth, primarily by altering the consumption responses of impatient consumers.

Figure 5: Impulse Responses to Housing Demand Shocks in IAC

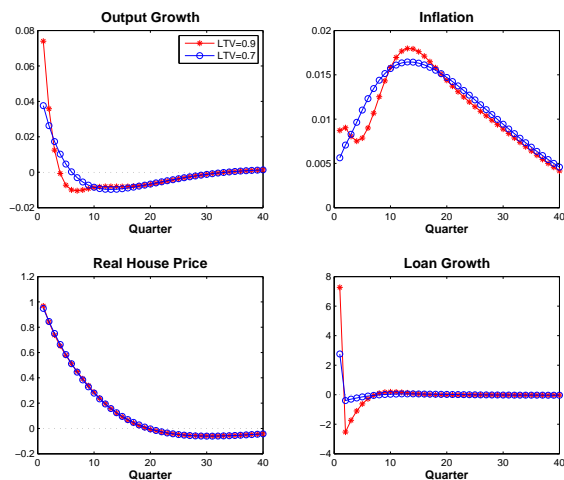
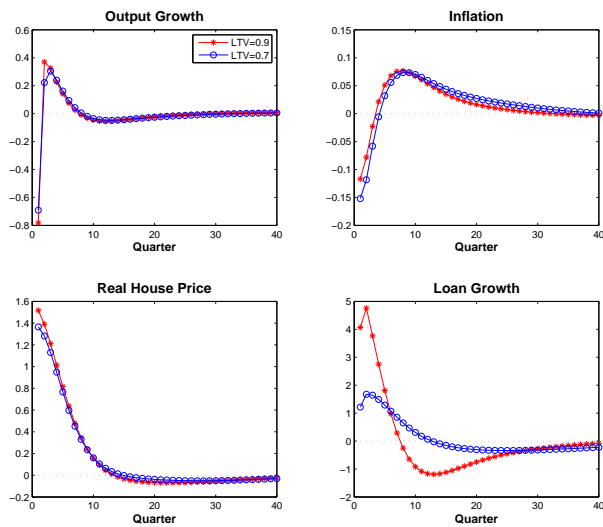


Figure 6: Impulse Responses to Housing Demand Shocks in GKS



### 3.3.2 Temporary LTV policy

An objective of macroprudential policy, as discussed by [Bank for International Settlements \(BIS\) \[2010\]](#), is to actively limit the build-up of financial risks. To this end, some countries, such as New Zealand, have implemented macroprudential policies, including lowering the LTV ratio, which are explicitly temporary in nature (see [Wheeler \[2013\]](#)).

One possible way to model a temporary lowering in the LTV ratio, such as has been implemented in New Zealand, is to treat it as a temporary regime change. As the end date of the tight macroprudential policy is unknown it could be treated as an additional parameter to be estimated. This essentially is how forward guidance of monetary policy is modelled in [Kulish et al. \[2014\]](#).<sup>11</sup>

In this paper, however, we adopt a different approach. We explore modelling LTV policy using a reaction function, akin to the standard Taylor rule used for monetary policy. In particular, we model the absolute deviation of the LTV from its steady-state,  $\hat{m}_t$ , as:

$$\hat{m}_t = \rho_{LTV}\hat{m}_{t-1} + (1 - \rho_{LTV})\eta_{LTV}\tilde{f}_t, \quad (15)$$

where  $\rho_{LTV}$  is a smoothing parameter, and  $\eta_{LTV}$  is the parameter governing the reaction to the variable  $\tilde{f}_t$ , where  $\tilde{\cdot}$  denotes a log deviation from steady state. We consider several possible variables for  $\tilde{f}_t$ , namely:

- stochastically-detrended output,
- the level or growth of real house prices, both quarterly and year-ended, and,
- the credit-to-GDP gap.

The first effectively allows LTV policy to be set in a countercyclical way, similar to monetary policy. The second reflects that many of the macroprudential policies that have been adopted worldwide have been motivated by concerns about developments in house prices. Essentially, these policy rules allow the LTV to be set so as to ‘lean against the wind’. Finally, [Borio and Drehmann \[2009\]](#) proposed that the countercyclical capital buffer - another macroprudential policy instrument - be set with reference to the credit-to-GDP ratio. An aspect to note is that while the introduction of these policy reaction functions does not alter the steady state of the model, it does necessitate the addition of  $\hat{m}_t$  as an endogenous variable in the model, which alters several of the existing equations.

To examine the implications of these reaction functions, we use a similar approach to above, namely we simulate output from the model, varying only the parameters governing the temporary

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<sup>11</sup>This, however, would not fully reflect how macroprudential policy is conducted in New Zealand, most notably, that the LVR limit does not apply to all new loans, but only a fraction of them, which has been described as a ‘speed limits’ approach (see [Wheeler \[2013\]](#)).

LTV policy, namely  $\rho_{LTV}$  and  $\eta_{LTV}$ , identify recessions and expansions and study their average characteristics. As there are two parameters being varied we constructed contour plots. Intuitively, we expect LTV policy to be highly persistent, as in empirical estimates of Taylor rules typically a large amount of smoothing is found, and consequently we examined values of  $\rho_m$  of 0.75 or greater. The range of  $\eta_{LTV}$  considered was selected so as to make negative values for the LTV unlikely.<sup>12</sup> Reflecting the variability of some of the series this means the interval of  $\eta_{LTV}$  used sometimes is quite narrow, although this encompasses quite aggressive macroprudential policy.

The results from across the models and variables are surprisingly uniform, and consequently we show only one set of contour plots, namely for the credit-to-GDP gap from the GKS model (Figure 7).<sup>13</sup> The consistent message is that the potential gains from temporary LTV policy implemented in this way - even quite aggressively - are slight. The amplitude of the average recession does decrease as the policy becomes more active, and for some values the proportion of time the economy is in a recession falls, but the impact is slight. In this instance, however, more active policy also leads to recessions which are, on average, longer. We expected a trade-off also with the characteristics of expansions might exist - for example, that the policy led to a lower average amplitude, but this appears to generally not be the case, probably reflecting the symmetric nature of the policy rules being considered. In general, the characteristics of recessions or expansions, on average, are not sizeably influenced by the smoothing parameter.

The implications of the inclusion of these LTV policy rules for the dynamics of the models appear to be slight. For example, the impulse response functions to a housing demand shock in both models are little changed when the LTV rate is set in response with respect to the credit-to-GDP gap (Figures 8 and 9).

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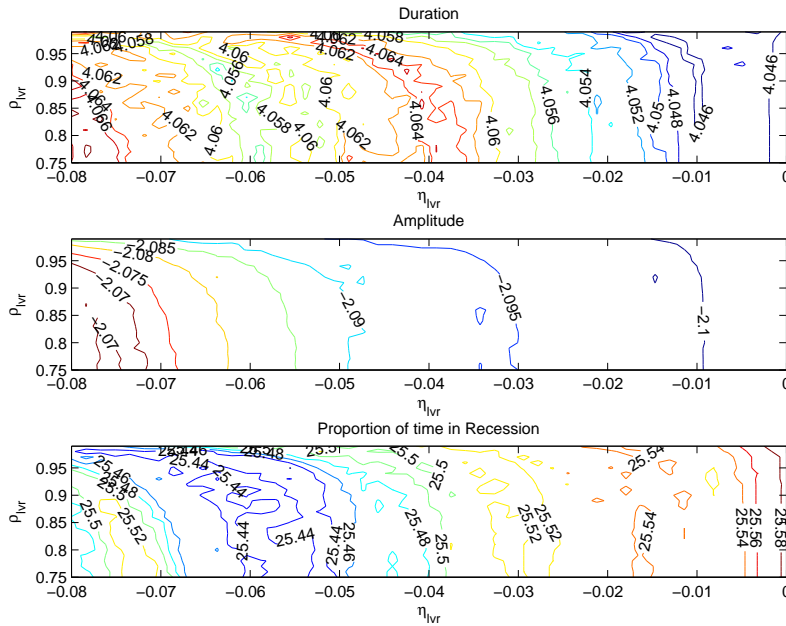
<sup>12</sup>More precisely, we set  $\rho_{LTV}$  to 0.85, roughly the mid-point of the range, and then find  $\eta_{LTV}$  such that the standard deviation of  $\hat{m}_t$  is approximately 0.4.

<sup>13</sup>All are available in the on-line appendix to this paper.

Figure 7: Business Cycle Characteristics and Temporary LTV Policy

Credit to GDP Gap

Recessions



Expansions

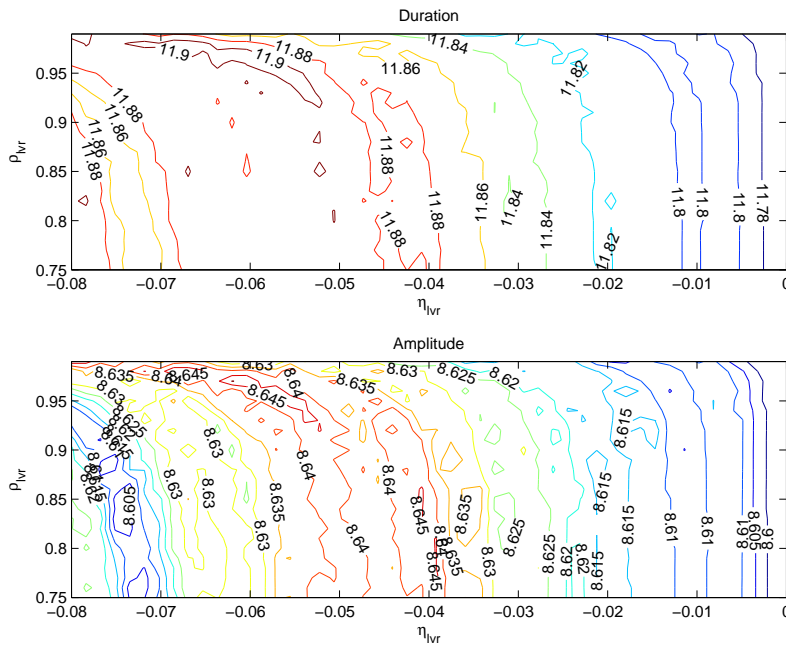


Figure 8: Impulse Responses to Housing Demand Shocks in Iacoviello (2005)

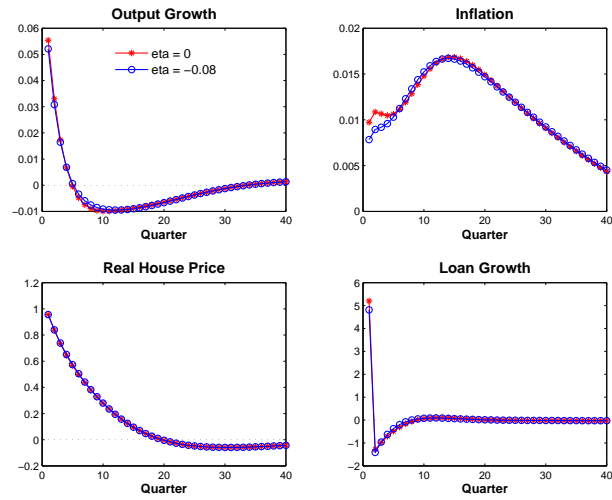
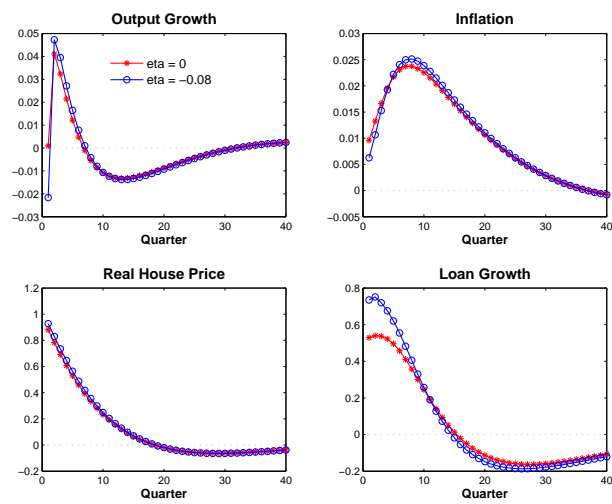


Figure 9: Impulse response to house demand shock in GKS model





## 4 Sensitivity Analysis

In the analysis above we focussed upon how macroprudential policy impacts on the business cycle characteristics in models with a variety of collateral constraints. We now consider the implications of other plausible potential variations in the model.

### 4.1 Relaxing credit standards

Credit standards, as captured by the LTV ratio, were assumed to be constant when the models above were estimated. Typically in such models the housing market is found to be largely driven by housing-sector specific shocks, in particular, the housing-preference shock (e.g. [Iacoviello and Neri \[2010\]](#)). An alternative narrative to the run up in house prices prior to the GFC is that it was not entirely demand driven, and that a decline in credit standards played a role. [Justiniano et al. \[2015\]](#) study whether a decline in credit standards can explain the observed pattern in household leverage, and find that it is instead better explained by shocks impacting on house prices, and therefore the value of collateral. Alternatively, [Gelain et al. \[2014\]](#) find that when adaptive, rather than rational, expectations are used then a greater role is found easing credit standards, rather than housing preference shocks.

A simple way to examine the role of an easing in credit standards is to allow the LTV to follow an exogenous autoregressive process in estimation, which adds a shock to the model. Doing so in GKS has little impact on the parameter estimates. The autocorrelation parameter of the LTV shock does not differ substantially from its prior, suggesting that it may not be well identified. The business cycle properties of the model changes only modestly, most notably the average duration of expansions increases, but still is less than observed in the data, whereas recessions shorten (Table 5).

The qualitative effect of permanent LTV policy when temporary LTV shocks are also incorporated in the GKS model is similar to that presented above, although the impact of an increase on the amplitude and proportion of time in recession is more modest.

Table 5: Business Cycle Properties

	Data	GKS Variants	
		Baseline	LTV Shocks
<i>Durations (qtrs)</i>			
Expansions	16.45	11.77	12.51
Recessions	4.45	4.05	3.75
<i>Amplitude (%)</i>			
Expansions	11.60	8.60	8.51
Recessions	-3.00	-2.10	-1.80
<i>Cumulative amplitude (%)</i>			
Expansions	82.60	77.70	73.17
Recessions	-64.85	-68.85	-64.67

Note: Data is 1957:2 - 2014:4

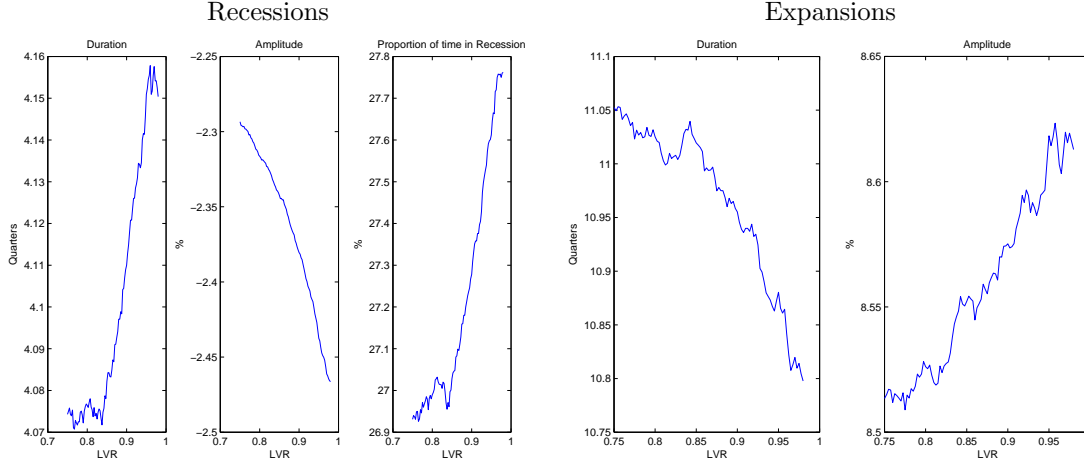
## 4.2 Long Estimation Sample

The results previously were obtained from models estimated over a sample ending in 2008:Q1. In this section we examine the implications of including the financial crisis, namely extending it until 20014:Q4. In these estimates for simplicity we ignore the zero lower bound on the nominal Federal Funds rate. Several alternative methods exist for taking this into account; for example, [Gust et al. \[2013\]](#) utilise the particle filter, whereas [Kulish et al. \[2014\]](#) treat it as a regime change. The latter find that the structural parameters of the [Smets and Wouters \[2007\]](#) model are little changed, although the estimates of the shock processes do change. These results here therefore are only indicative.

Similar to the findings to the [Kulish et al. \[2014\]](#), the impact of the zero lower bound regime on the parameter estimates of the GKS model is modest.<sup>14</sup> Focussing on the shock processes, the persistence and standard deviation of the consumption preference shocks both increase slightly, and the standard deviation of the housing-related shocks also increase. The implications of these changes for the business cycle are slight. The consequences of permanent LTV policy also are similar, although a trade-off is evident - permanently lowering the LTV not only moderates recessions, but decreases the amplitude of expansions (although their duration increases).

<sup>14</sup>These are presented in the on-line appendix. The structural most affected are adjustment costs governing the stickiness of wages and goods prices, which both rise. Alternatively, the adjustment costs for residential investment and capital goods both fall.

Figure 9: Business Cycle Characteristics of the GKS Model -  
Long Estimation Sample



### 4.3 House Price Expectations

Previously developments in house prices were assumed to be based on fundamental shocks. Alternatively, it is possible the house prices may not always reflect fundamentals and there are periods of excessive optimism or pessimism. To examine this possibility, we add “confidence shocks”, following [Hall et al. \[2013\]](#).<sup>15</sup> The new IMF macroprudential model also simulate asset price bubbles in a similar manner (see [Beneš et al. \[2014\]](#)).

To introduce confidence shocks to the model we alter the model as follows. Let a superscript  $r$  denote variables relating to the rational expectations. There are two blocks to the model - one (as before) with rational expectations. In the second, expectations of real house prices,  $q_t$ , are assumed to be

$$E_t(q_{t+1}) = E_t(q_{t+1}^r) + v_t,$$

where  $v_t$  follows a first order autoregressive process. Essentially, the expectations,  $E_t(q_{t+1})$ , are allowed to potentially persistently deviate from those obtained from a rational expectations block of the model  $E_t(q_{t+1}^r)$ . The observed data is linked to the part of the model which includes these “confidence” or expectation shocks.<sup>16</sup> Naturally, this is just one approach to incorporating deviations from rational expectations in house prices. Other alternatives might include introducing myopic behaviour, adaptive expectations ([Gelain et al. \[2014\]](#)) or explicit learning mechanisms ([Kuang \[2014\]](#)). The advantage of this approach is that it is simple and intuitive.

Introducing deviations from rational expectations for house prices as described above in the GKS model yields very similar parameter estimates to those obtained previously. The confidence

<sup>15</sup>We thank Adrian Pagan for the idea of using this approach.

<sup>16</sup>The structural parameters and the other structural shocks are common to both parts of the model.

shocks are found to be very persistent.<sup>17</sup> Interestingly, the only sizeable change in the parameters relate to the housing preference shock - it becomes less persistent and there is a considerable drop in its standard deviation. The housing preference shock is often found to be extremely persistent and thought to not truly represent changes in preferences, but rather acts as a ‘catchall’ - for example, [Iacoviello and Neri \[2010\]](#) conclude that “...the results provide some evidence that some of the models omitted variables capture part of the preference shock” (p. 152). Our results suggest a possible interpretation for much of the variation in this shock, namely that they reflect expectations about future developments in house prices.

The alternative assumption of expectations alters the business cycle characteristics of the model, most notably it makes expansions on average last longer, and better match the data, although the mismatch with the duration of recessions increases, somewhat similar to the results obtained when LTV shocks were added. Indeed, when the model is estimated with both, the parameters governing the LTV shocks appear to no longer be identified.

The consequences of permanent LTV policy with the alternative expectations assumption are qualitatively similar to before, although the amplitude of expansions decreases marginally when the LTV ratio is set tighter than 0.85. (Figure 10)

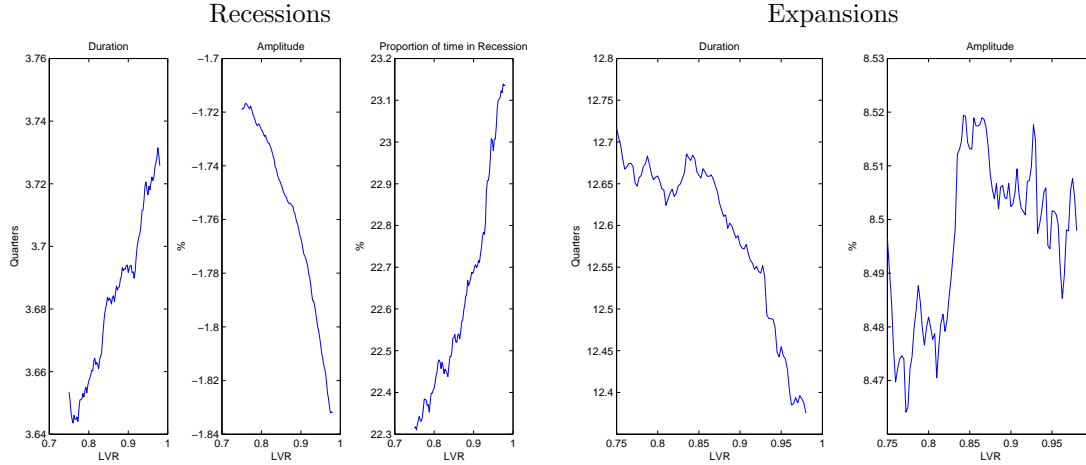
*Table 6: Business Cycle Properties*

	Data	GKS Model Variants	
		Baseline	Alternative expectations
<i>Durations (qtrs)</i>			
Expansions	16.45	11.77	12.66
Recessions	4.45	4.05	3.68
<i>Amplitude (%)</i>			
Expansions	11.60	8.60	8.51
Recessions	-3.00	-2.10	-1.75
<i>Cumulative amplitude (%)</i>			
Expansions	82.60	77.70	75.80
Recessions	-64.85	-68.85	-65.70

Note: Data is 1957:2 - 2014:4

<sup>17</sup>The posterior means of the autocorrelation coefficient and the standard deviation of the innovation are 0.91 and 0.67.

Figure 10: Business Cycle Characteristics of the GKS Model - Allowing Deviations from Rational Expectations



## 5 Conclusions

Macroprudential policies are being adopted worldwide as a way of preserving financial stability. Financial stability is of fundamental importance due to the considerable real costs of financial crises. This paper proposes that a useful way of evaluating these policies is through the lens of business cycle dating. This is easy to implement both with linear and non-linear models - it is only necessary to be able to simulate from the model. These methods directly answer questions of relevance to policymakers, namely does macroprudential policy lessens the severity of recessions, such as their duration and amplitude, or the frequency with which they occur? And are there trade-offs - do the policies adversely effect the characteristics of expansions? These are questions that are difficult to answer by inspecting impulse response functions, and business cycle dating is a useful complement to welfare analysis.

We have demonstrated our approach by examining one particular type of macroprudential policy, namely LTV policy, which has been implemented in several countries worldwide, such as Canada and New Zealand. We have studied two possible types of policy, namely a permanent lowering of the LTV or setting it following a reaction function akin to a Taylor rule. These policy experiments were conducted in models of the US economy which have features from the recent academic literature (e.g. Garriga et al. [2013]) and are included in macroprudential policy models at central banks (e.g. Alpanda et al. [2014]).

We found that permanent LTV policy does reduce the average amplitude of recessions, and the frequencies with which they occur. The magnitudes of these effects was found to depend on how debt is modelled, with long-term debt muting the impact relative to short term debt, although overall in both approaches the effects were modest.

Alternatively, there appears to be little improvement in the business cycle characteristics from setting the LTV in a countercyclical manner, or leaning against increases in house prices or the credit-to-GDP gap, when these are implemented using a rule similar to a Taylor rule for the LTV.

In this paper we have assessed the robustness of these findings by conducting sensitivity analysis across several dimensions of the model, such as the specification of the collateral constraint and how expectations about house prices are modelled. Our results suggest that the housing demand shocks, which are typically found to drive the housing sector variables in these models, may in part reflect house price expectations deviating from fundamentals.

The literature on how credit is integrated into macroeconomic models is rapidly expanding and such models are being increasingly utilised at central banks. We believe that the methods demonstrated in this paper could be fruitfully applied to these new models to answer questions of considerable policy relevance, such as the potential impact of macroprudential policies being considered for the business cycle.

## 6 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: Private Non-residential Fixed Investment (PNFI).
- Residential investment: Private Residential Fixed Investment (PRFI).
- 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).
- Spread: All are with respect to the Federal Funds rate. GKS: 30-year Conventional Mortgage Rate (MORTG). IAC: 1-year Adjustable Mortgage Rate in the United States (MORTGAGE1US).

## 7 Appendix B - Optimality conditions

### 7.1 Savers:

The saver  $j$  chooses consumption, nominal wages, government bonds, consumer lending, physical capital stock and housing stock to maximise the discounted expected utility function (1), subject

to the budget constraint (2). In a symmetric equilibrium, the optimality conditions are given as

$$c_t : \omega_{c,t} (c_t - \varsigma_c c_{t-1})^{-1} = \lambda_t \quad (16)$$

$$\begin{aligned} W_t &: E_t \beta \frac{\lambda_{t+1}}{\lambda_t \pi_{c,t+1}} \frac{n_{t+1}}{n_t} \frac{\pi_{w,t+1}^2}{\pi_{w,t}^{\iota_w} \bar{\pi}_w^{1-\iota_w}} \kappa_w \left( \frac{\pi_{w,t+1}}{\pi_{w,t}^{\iota_w} \bar{\pi}_w^{1-\iota_w}} - 1 \right) \\ &= \frac{\pi_{w,t}}{\pi_{w,t-1}^{\iota_w} \bar{\pi}_w^{1-\iota_w}} \kappa_w \left( \frac{\pi_{w,t}}{\pi_{w,t-1}^{\iota_w} \bar{\pi}_w^{1-\iota_w}} - 1 \right) + \nu \left[ 1 - \frac{\omega_{c,t} \xi_n n_t^{\sigma_n} P_{c,t}}{\lambda_t W_t} - \frac{\kappa_w}{2} \left( \frac{\pi_{w,t}}{\pi_{w,t-1}^{\iota_w} \bar{\pi}_w^{1-\iota_w}} - 1 \right)^2 \right] - 1 \end{aligned} \quad (17)$$

$$B_t : 1 = \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\Pi_{c,t+1}} \right] \quad (18)$$

$$L_t : 1 + \Upsilon_t = \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_{l,t} + \Upsilon_{t+1} (1 - \tau_t)}{\Pi_{c,t+1}} \right] \quad (19)$$

$$k_t : q_{k,t} = E_t \beta \left[ \frac{\lambda_{t+1}}{\lambda_t} (r_{k,t+1} + (1 - \delta_k) q_{k,t+1}) \right] \quad (20)$$

$$h_t : q_{h,t} = \omega_{c,t} \omega_{h,t} \frac{\xi_h}{\lambda_t h_t} + \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} (1 - \delta_h) q_{h,t+1} \right] \quad (21)$$

Equation (16) expresses  $\lambda$  the marginal utility of income as an inverse function of consumption. In (17), nominal wage adjustment costs introduce a time-varying wedge between the real wage and the marginal rate of substitution between consumption and leisure. Equation (18) ties down intertemporal changes in the marginal utility of income - and hence consumption - to the *ex-ante* real interest rate. Equation (19) connects the lending spread to the monitoring cost  $\Upsilon$ . Equation (20) 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. Finally, equation (21) 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 and discounted expected value of the undepreciated housing stock in the ensuing period.

## 7.2 Borrowers

Taking prices as given, the borrower  $j$  chooses consumption, wages, loans and housing to maximise the discounted lifetime utility function (7) subject to the budget constraint (8) and the borrowing constraint. Let  $\lambda'$  be the marginal utility of real income at time  $t$ , and  $\lambda\gamma'$  is the Lagrangian multiplier on the borrowing constraint. The optimality conditions for consumption and wages simply mirror that of the saver and hence are not exhibited here. The key point of departure from the case of the patient household, lies in the interaction between the tightness of the collateral constraint and the demand for housing. This is evident from the optimality conditions for housing and loans.



### 7.2.1 Collateral Constraint 1:

$$c'_t : \omega_{c,t} (c'_t - \varsigma_c c'_{t-1})^{-1} = \lambda'_t \quad (22)$$

$$(23)$$

$$h'_t : q_{h,t} = \omega_{c,t} \omega_{h,t} \frac{\xi'_h}{\lambda'_t h'_t} + E_t \beta' \frac{\lambda'_{t+1}}{\lambda'_t} (1 - \delta_h) q_{h,t+1} + \gamma'_t \mu' E_t \frac{q_{h,t+1}}{R_{l,t}/\Pi_{c,t+1}} \quad (24)$$

$$L'_t : 1 - \gamma'_t = \beta' E_t \left[ \frac{\lambda'_{t+1}}{\lambda'_t} \frac{R_{l,t}}{\Pi_{c,t+1}} \right] \quad (25)$$

A binding collateral constraint, *i.e.*  $\gamma' > 0$ , generates additional benefits from consuming housing services in equation (22). Accumulating housing stock generates more collateral to borrow against in the following period. Observe that when the collateral constraint does not bind, *i.e.*  $\gamma' = 0$ , this channel is muted and the optimality condition is identical in structure to that of the save.

### 7.2.2 Collateral Constraint 2:

Taking prices as given, the impatient household  $j$  maximizes the discounted lifetime utility function, subject to the budget constraint, the amortization equation (4) and the borrowing constraint (9). Let  $\lambda_{I,t}$  be the marginal utility of real income at time  $t$ ,  $\lambda_{I,t} \gamma_{Ibc,t}$  is the Lagrangian multipliers on the borrowing constraint, and  $\lambda_{I,t} \mu_t$  the Lagrange multiplier on the law of motion for the endogenous amortization rate (4).  $R_{L,t} \equiv r_{L,t} + 1$  The first order conditions with respect to  $C_{I,t}(j), H_{I,t}(j), D_t(j)$  and  $\tau_t(j)$  are

$$c'_t : \omega_{c,t} (c'_t - \varsigma_c c'_{t-1})^{-1} = \lambda'_t \quad (26)$$

$$h'_t : (1 - \gamma'_t m_t) q_{h,t} = \frac{\xi_{hI} \omega_{c,t} \omega_{h,t}}{\lambda_{I,t} H_{I,t}} + (1 - \delta_h) \beta' E_t \left[ \frac{\lambda'_{t+1}}{\lambda'_t} (1 - \gamma'_{t+1} m_{t+1}) q_{h,t+1} \right] \quad (27)$$

$$D'_t : 1 - \gamma'_t = \beta' E_t \frac{\lambda'_{t+1}}{\lambda'_t} \left[ \frac{R_{l,t}}{\Pi_{c,t+1}} - \frac{\gamma'_{t+1} (1 - \tau_t)}{\Pi_{c,t+1}} \right] \quad (28)$$

### 7.2.3 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 is described by the following law of motion

$$K_t = \omega_{ik,t} I K_t \left[ 1 - \frac{\kappa_{ik}}{2} \left( \frac{I K_t}{I K_{t-1}} - 1 \right)^2 \right] + (1 - \delta_k) K_{t-1}, \delta_k \in [0, 1], \kappa_{ik} > 0 \quad (29)$$

After capital production, the end-of-period installed capital stock is sold back to patient household at the consumption-based price of  $q_k$ . The capital producer chooses investment to maximise profits.

$$\max_{IK_t} E_t \sum_{\tau=0}^{\infty} \beta^\tau \frac{\lambda_{t+\tau}}{\lambda_t} \left\{ q_{k,t+\tau} \omega_{ik,t+\tau} \left[ 1 - \frac{\kappa_{ik}}{2} \left( \frac{IK_{t+\tau}}{IK_{t+\tau-1}} - 1 \right)^2 \right] - 1 \right\} IK_{t+\tau}$$

Optimality implies

$$\begin{aligned} \frac{1}{q_{k,t} \omega_{ik,t}} &= 1 - \frac{\kappa_{ik}}{2} \left( \frac{IK_t}{IK_{t-1}} - 1 \right)^2 - \frac{IK_t}{IK_{t-1}} \kappa_{ik} \left( \frac{IK_t}{IK_{t-1}} - 1 \right) \\ &+ E_t \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{k,t+1}}{q_{k,t}} \frac{\omega_{ik,t+1}}{\omega_{ik,t}} \left( \frac{IK_{t+1}}{IK_t} \right)^2 \kappa_{ik} \left( \frac{IK_{t+1}}{IK_t} - 1 \right) \end{aligned} \quad (30)$$

Equation (30) is a supply curve for business investment goods. For a given path of expected investment growth, current investment responds positively to an increase of the relative price of investment to that of physical capital, with the response decreasing in the investment adjustment cost. Housing investment and house prices are similarly related since 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

$$H_t = \omega_{ih,t} IH_t \left[ 1 - \frac{\kappa_{ih}}{2} \left( \frac{IH_t}{IH_{t-1}} - 1 \right)^2 \right] + (1 - \delta_h) H_{t-1}, \quad \delta_h \in [0, 1], \quad \kappa_{ih} > 0 \quad (31)$$

where  $\omega_{ih}$  is the investment-specific technology shock affecting housing. The supply curve for housing is given as

$$\begin{aligned} \frac{1}{q_{h,t} \omega_{ih,t}} &= 1 - \frac{\kappa_{ih}}{2} \left( \frac{IH_t}{IH_{t-1}} - 1 \right)^2 - \frac{IH_t}{IH_{t-1}} \kappa_{ih} \left( \frac{IH_t}{IH_{t-1}} - 1 \right) \\ &+ E_t \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{ih,t+1}}{q_{ih,t}} \frac{\omega_{ih,t+1}}{\omega_{ih,t}} \left( \frac{IH_{t+1}}{IH_t} \right)^2 \kappa_{ih} \left( \frac{IH_{t+1}}{IH_t} - 1 \right) \end{aligned} \quad (32)$$

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