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House Prices and Macroprudential Policy in an Estimated DSGE Model of New Zealand

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Abstract

We analyse the effects of macroprudential and monetary policies and their interactions using an estimated dynamic stochastic general equilibrium (DSGE) model tailored to New Zealand. We find that the main historical drivers of house prices are shocks specific to the housing sector. While our estimates show that monetary policy has large spillover effects on house prices, it does not appear to have been a major driver of house prices in New Zealand. We consider macroprudential policies, including the loan-to-value restrictions that have been implemented in New Zealand. We find that loan-to-value restrictions reduce house prices with negligible effects on consumer prices, suggesting that they can be used without derailing monetary policy. We estimate that the loan-to-value restrictions imposed in New Zealand in 2013 reduced house prices by 3.8 per cent and that greater forward guidance on their duration would have made them more effective.

JEL-Codes: E320, E440, E520, E580.

Keywords: macroprudential policies, housing, DSGE, Bayesian estimation, New Zealand.

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1. Introduction

New Zealand has recently imposed loan-to-value restrictions on mortgage lending in response to surging house prices. With such policies presently under consideration in many countries, there is much to be learned from this example. We study the interactions of house prices, macroprudential policy, monetary policy and the open economy in New Zealand. These issues are important and timely considering the present concerns about house prices, low interest rates and their possible implications for the broader economy, both globally and especially in the context of New Zealand, where the house price rises in the last two years have been among the largest in the world. We find that monetary policy has potentially large unintended spillovers on house prices, in line with the existing findings for other countries. However, historical decompositions and variance decompositions show that monetary policy has not been a major driver of house prices, which have mostly been caused by shocks specific to the housing sector. We also observe that borrowing-constrained households are an important channel for the effects of monetary policy on output, so macroprudential policy that directly targets the borrowing of these households has implications for the effectiveness of monetary policy.

Focusing on macroprudential policy, we consider the effects of loan-to-value policies, among others. We find that a 1 per cent decrease in the loan-to-value restriction, a tightening of macroprudential policy, leads to a fall in house prices of 1.9 per cent, with negligible effects on consumer prices. This suggests that macroprudential policy can be used to affect house prices without derailing the goals of monetary policy. New Zealand has implemented loan-to-value restrictions of the kind that we model, and evidence based on structural VAR models indicates that the resulting fall in house prices is of the same order as our model predicts, lending credence to our modelling strategy and policy counterfactuals.

We turn now to a discussion of house prices, macroprudential policies and the New Zealand situation. The role of house prices and mortgage debt in the 2007 financial crisis and ensuing great recession was clear in many of the worst affected countries, such as Spain, Ireland and the US. These housing booms were not isolated incidents: Cerutti et al. (2015) document 85 housing booms across 53 countries between 1970 and 2012. However, should governments be worried about such asset price movements? While not all booms and busts in housing are associated with financial crises, those associated with expansions of mortgage debt often are (Jorda et al., 2015). Recessions that follow financial crises are typically much deeper and longer than other recessions (Reinhard and Rogoff, 2009). An extensive IMF (2003, pp. 61–94) study on bubbly episodes finds that, during the post-war period, housing busts occurred on average every 20 years. These price busts entailed significant average price declines of 30 per cent. Furthermore, there is ample evidence that house price changes are closely correlated with – and tend to lead – output growth. In industrialized economies the average housing bust has been associated with GDP losses of about 8 per cent. Why do housing and leverage

play such an important role in severe recessions? In fact, housing is more closely linked to the real economy than other assets because of its unique features. First, housing is the main asset of households and changes in housing wealth have a much stronger wealth effect than changes in other assets. Evidence suggests that the role of house price busts is largely to decrease consumption (Case et al., 2013; Kaplan et al., 2016; Mian et al., 2013). Smith (2010), based on microeconomic data, finds that house prices have an important effect via wealth on consumption in New Zealand. New Zealand also displays a very high correlation between house prices and consumption at the aggregate level, so findings for other countries relating to the end of house price booms, leverage and severe recessions are likely to be relevant to New Zealand.[1] Second, housing provides a flow of services, but because it is also a very illiquid asset, it is employed as collateral. Third, the construction sector, which is mostly labour intensive, comprises an important part of the industrial sector in every economy. We address the challenges related to these issues in the context of our empirical findings.

Macroprudential policies should be employed to mitigate systemic risks and reduce the pro-cyclicality of domestic financial sectors. Beyond the implementation of counter-cyclical capital buffers under Basel III requirements, macroprudential frameworks can be reinforced through a range of instruments, including caps on loan-to-value (LTV) or debt-to-income (LTI) ratios, dynamic provisioning and credible stress tests.[2] In New Zealand such macroprudential regulation is the preserve of the Reserve Bank of New Zealand (RBNZ), which is able to impose restrictions on high-LTV-ratio residential mortgage lending.[3]

Housing is a major purchase in the life of many New Zealanders, with housing and land representing around 59 per cent of net wealth in 2016 Q1.[4] As well as being an important asset, it is also part of their liabilities, with around 40–60 per cent of New Zealand bank liabilities and equity related to financing housing.[5] As such housing and mortgages are an obvious focus for macroprudential regulation in New Zealand. The modelling of house prices in New Zealand suggests that migration and credit conditions play important roles, together with the slow adjustment of the housing supply to changing conditions (Coleman and Landon-Lane, 2007; Grimes and Hyland, 2013). The importance of

[1] The correlation in quarterly data between the annual growth of real per capita consumption and the annual growth of real house prices is 0.35 in New Zealand and 0.41 in the US. Even if a credit boom does not, once again, end in a financial crisis, a mortgage debt overhang can thus weigh on New Zealand's long-term growth, as the necessary deleveraging proceeds gradually.

[2] In a recent study, Arslan et al. (2015) show that macroprudential policies help to moderate fluctuations in house prices and mortgage default rates. For a thorough review of the stream of literature that embeds housing into general equilibrium models, see Piazzesi and Schneider (2016).

[3] The RBNZ has been responsible for macroprudential policy since 1989. According to the most recent Memorandum of Understanding (2013), the RBNZ has four regulatory tools at its disposal: (i) a countercyclical capital buffer, (ii) adjustments to the minimum core funding ratio (CFR), (iii) sectoral capital requirements (SCR) and (iv) restrictions on high loan-to-value (LTV) ratio residential mortgage lending. The other three are not related to housing, nor have they been used much. Hence, we focus here solely on the LTV ratio.

[4] RBNZ data release "C22: Household balance sheet". The behaviour of New Zealand households' net worth, defined as the difference between the value of all assets and the value of all liabilities, mirrors the behaviour of house prices.

[5] RBNZ data release "G1: Summary information for locally incorporated banks".

credit conditions suggests that such macroprudential regulation could prove to be effective in affecting house prices as well as just mortgage lending itself.[6]

Cerutti et al. (2017) document the use of various macroprudential tools across 119 countries over the period 2000–2013. The use of macroprudential tools increased over the period, and for advanced economies LTV restrictions were one of the most popular tools. They find that LTV and LTI restrictions appear to be the most effective at reducing the growth of credit in the household sector. They show that macroprudential policies appear to be less effective in advanced economies, especially open economies, and that the use of non-banking financial channels is an important part of this. Hargraves (2016) emphasizes that the application in New Zealand of LTV restrictions as "speed limits" – restricting only high-LTV loans and intended as temporary restrictions – is in part motivated by a desire to minimize housing finance simply by redirecting it through non-banking channels.

The existing literature applying DSGE models to New Zealand focuses on monetary policy and forecasting. At the heart of all these papers is a New Keynesian small open economy along the lines of Galí and Monacelli (2005), Monacelli (2005) and Faia and Monacelli (2008), and Bayesian estimation of the models from New Zealand data is the standard approach. The (ir)relevance of the exchange rate to monetary policy is a focus of the early contributions. Lubik and Schorfheide (2007) investigate how monetary policy is actually conducted and find that a Taylor rule on interest rates for New Zealand since 1988 is best characterized as not including a term for the exchange rate. Justiniano and Preston (2010) consider optimal Taylor rules for New Zealand and find that the omission of the exchange rate is optimal, due substantially to the absence of pass-through from the exchange rate to local prices. Lees et al. (2011) compare the ability of DSGE-VARs to forecast inflation, output, the exchange rate and other variables with the official forecasts of the RBNZ. The official forecasts of the RBNZ are generated by a mixture of statistical modelling and expert judgement. They find that the DSGE-VARs outperform the official forecasts, for example on the mean-squared forecast error.

An important question then is which factors produce a good DSGE model for New Zealand. Matheson (2010) finds that including both tradable and non-tradable sectors notably improves the model fit while price indexation worsens the fit. He further shows that habit formation appears to be less important in New Zealand than is found for other countries; the same result is observed by Lees et al. (2011) and Kamber et al. (2015). Many papers find a lower value for the Calvo parameter in New Zealand than in other countries, although none of these are based on micro-level price data, purely on fitting aggregate inflation data, so the identification is unclear. Albertini et al. (2012) consider adding a search and matching labour market. They find that, while it performs better on labour market measures, it does not measurably improve the model's ability to explain inflation and output. Kamber et al. (2015) describe the DSGE core of the RBNZ's main policy and forecasting model, known as the

[6] Unlike these studies, our modelling approach has clear theoretical guidance.

NZSIM.[7] This model represents the existing consensus on standard components for a DSGE model of New Zealand, specifically regarding the use of a New Keynesian small open economy model. Two further points worth noting about the model are that it excludes physical capital and that it uses adaptive expectations rather than rational expectations.[8] A recent addition to the literature is the paper by Jacob and Munro (2016), who study New Zealand's "Core Funding Ratio", adopted in 2010. The "Core Funding Ratio" acts as a net stable financing ratio (SFR), which forms part of Basel III and requires banks to raise a share of their funding from more stable retail deposits and long-term wholesale funding rather than short-term wholesale funding. They find that the SFR has few implications for monetary policy except that it increases the impact of bank funding shocks on the economy, which can be moderated if optimal monetary or macroprudential policy responds to credit growth.

The remainder of the paper is organized as follows. Section 2 provides background information on the housing market dynamics and macroprudential measures employed in New Zealand. Section 3 presents the DSGE modelling framework. Section 4 provides the Bayesian estimates of the model, presents the dynamics of the model and analyses macroprudential policies. Section 6 concludes and makes suggestions for future research. Extra tables and graphs are available in an online Appendix.

2. Housing Market Dynamics and Macroprudential Measures in New Zealand

This section presents some stylized facts on house prices and macroprudential policies in New Zealand before delving into the specific channels through which macroprudential measures may have spillovers on house prices. House prices in New Zealand grew at an annual rate in 2016 Q1 of over 10 per cent, the second highest rate globally according to the IMF Global Housing Watch.[9] Such high growth rates of real house prices have occurred in New Zealand for a number of years, as can be seen in Figure 1. Globally, these growth rates of the past few years are not so exceptional in relation to the countries to which New Zealand is often compared, such as Australia, Canada, the UK and the USA, as shown in Figure 1. However, relative to incomes or the cost of renting, the growth of house prices in New Zealand has been very high, as shown in Figures 2 and 3, respectively. The ratio of house prices to income in New Zealand grew by 30 per cent between 2010 and 2016. Judged on the ratio of house prices to income, New Zealand's house price increases have been truly exceptional, growing faster over this period than in any other country in the OECD.[10] The ratio of house prices to rent has

[7] The forecasting model NZSIM replaces the previous-generation model, KITT. NZSIM (KITT) stands for *N*ew *Z*ealand *S*tructural *I*nflation *M*odel (*K*iwi *I*nflation *T*argeting *T*echnology).

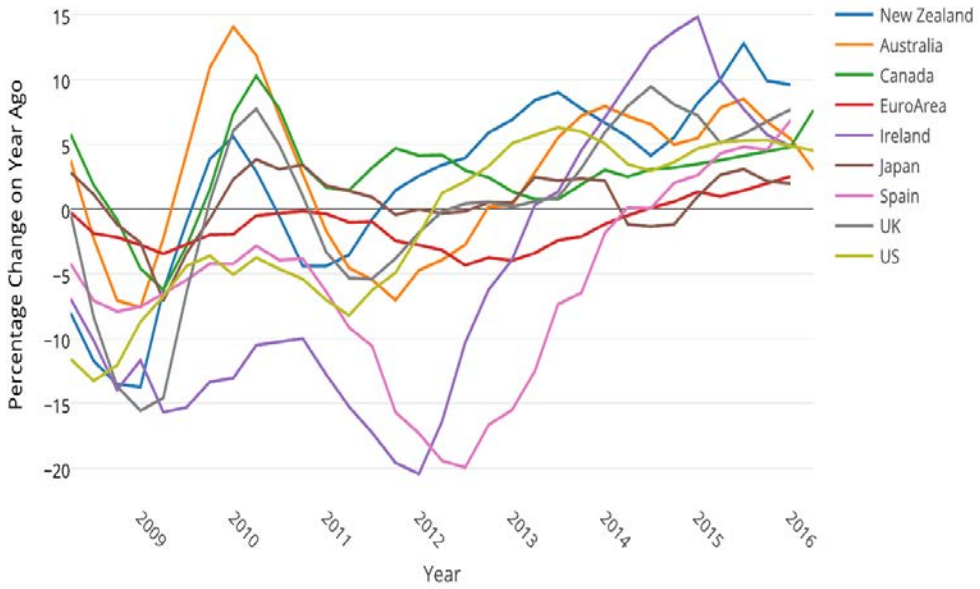
[8] Adaptive expectations help the model to generate a higher level of persistence in inflation, as observed in the New Zealand data.

[9] See http://www.imf.org/external/research/housing/.

[10] IMF (2016, pp. 15–28) traces the evolution and dynamics of house prices in New Zealand from an international perspective.

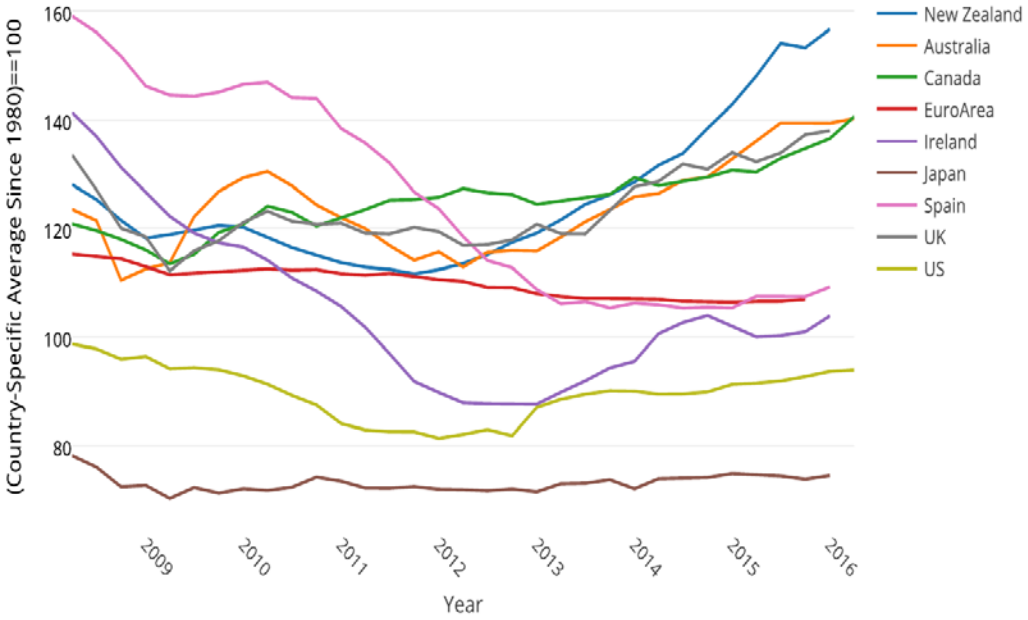
also grown rapidly, increasing by 28.9 per cent between 2010 and 2016. These exceptionally high growth rates of house prices relative to incomes and the cost of renting have led to increasing concern among commentators, within both the New Zealand Government and the New Zealand public as well as international institutions such as the OECD and IMF.

Figure 1: Annual Growth Rate of Real House Prices



Source: OECD Analytical House Price Indicators. Author's calculation based on Real House Price Indices.

Figure 2: Price-to-Income Ratio



Source: OECD Analytical House Price Indicators.

In late 2013 house prices were rising at 10.2 per cent and loans with a loan-to-value ratio over 80 per cent were making up an increasing share of the total new loans, approaching 25 per cent. This new lending also appeared to be to groups with higher probabilities of future mortgage default, such as those with high debt-to-income ratios (Dunstan and Skillen, 2015). Econometric tests suggest that it is exceedingly difficult to attribute the recent house price developments in several metropolitan areas of New Zealand to changes in economic fundamentals. The recent house price developments in the Auckland metropolitan area can be referred to as "bubbly episodes" (Greenaway-McGrevy and Phillips, 2016). The RBNZ decided in October 2013 to implement restrictions on high-LTV-ratio lending. High-LTV-ratio (> 80 per cent) home loans were limited to at most a 10 per cent share of the total new loans originated by banks. This led to an immediate fall in high-LTV-ratio loans to around a 5 per cent share of the total new loans.[11] The initial announcements by the RBNZ indicated that these high-LTV-ratio restrictions were intended to be temporary in nature.

However, by 2015 the house price increases had returned to double-digit increases and the RBNZ further revised and tightened the restrictions on high-LTV-ratio loans in November 2015 and October 2016. The first of these imposed additional restrictions on *investors*, defined by the RBNZ as those who own but do not live in a house. The second tightened lending to *investors* still further.[12] With the October 2016 revision to the high-LTV-ratio restrictions, lending to *investors* with an LTV ratio over 60 per cent was limited to 5 per cent of new loans to *investors*, and lending to *owner-occupiers* with an LTV ratio over 80 per cent was limited to 10 per cent of new loans to *owner-occupiers*.[13] As of late 2016, the house price increases continue to be over 10 per cent and the high-LTV-ratio restrictions appear to be likely to remain in place for some time. For further reading on the New Zealand experience with the introduction of LVR restrictions, the reader is referred to Hargraves (2016).

While a visual exploration of the house price evolution gives a sense of the situation, it does not provide evidence on the specific effect of the adoption of macroprudential policies. Isolating the effect of macroprudential policies and their impact from complementary policies and/or other economic developments constitutes a significant challenge and requires cautious interpretations. To address this difficulty, a large strand of the literature employs DSGE frameworks. Precisely in this tradition, the next section models the macroprudential toolkit in New Zealand in an open-economy DSGE framework.

[11] Data on high-LTV-ratio loans as a share of new loans from RBNZ data release "C30: New residential mortgage lending by loan-to-valuation ratio (LVR)".
[12] Some restrictions that had previously only applied to Auckland were extended nationwide.
[13] http://www.rbnz.govt.nz/financial-stability/loan-to-valuation-ratio-restrictions.

3. The Conceptual DSGE Framework

3.1. Model Description

This section presents a stylized model of a small open economy with rich macro-housing linkages. The model is designed to shed light on two sets of issues. First, we want a realistic enough model to allow us to understand which shocks were responsible for the performance of the New Zealand economy both before and after the global financial crisis. Second, we want to use the model to perform various counterfactual exercises in relation to macroprudential policy questions. To achieve these objectives, the model needs to remain stylized.[14]

We begin the section by emphasizing the economic relationships incorporated into the model. The latter is built on a heterogeneous two-agent model in which two types of households exist: borrowers and savers.[15] In addition, the modelling framework assumes two types of intermediate goods producers, that is, producers of non-housing goods and producers of housing goods. The output of intermediate goods firms, acting as monopolistic competitors, is used as input by final goods producers, and only the output of final non-housing goods producers is traded internationally (i.e. non-housing goods are assumed to be tradable, whereas housing goods are assumed to be non-tradable).

Both types of households derive utility from consuming a bundle of both non-housing and housing goods, of which the latter can either be consumed instantaneously or used as collateral in the mortgage market. Credit market frictions are introduced by a binding collateral constraint on borrowers. The monetary policy in New Zealand is captured by a standard Taylor rule whereby the RBNZ steers the nominal interest rate as a function of CPI inflation. This implies that the nominal exchange rate is free to float. In addition to the traditional Taylor rule, an LTV constraint and property taxes (stamp duties) are added as policy tools.[16]

We initially borrow key ingredients from Iacoviello (2005) and Monacelli (2008).[17] Next, following Funke and Paetz (2013), we merge this strand of research about housing cycles in DSGE models with

[14] See Linde et al. (2016) for a recent assessment of the DSGE architecture with many references.

[15] Note that we do not consider renters. Mora-Sanguinetti and Rubio (2014) introduce renters into a Iacoviello (2005) type model. Note that renter households' problem is not intertemporal. In other words, they play the role of hand-to-mouth consumers, consuming their disposable income every period.

[16] Crowe et al. (2013) show that in the US property taxes are an effective policy tool to deal with fluctuations originating from the housing market.

[17] As commonly performed in the literature, we abstract from modelling capital accumulation (see e.g. Monacelli (2009) and Funke and Paetz (2013)). In addition, from a modelling viewpoint, the global financial crisis has shown that macroeconomic models based on frictionless financial markets cannot reproduce all the salient features of the business cycle. In particular, those policy models that, in the decade prior to the crisis, implicitly assumed perfectly functioning capital markets were unable to capture the procyclicality of the financial system and to predict the persistence and the intensity of the global recession. As a result, a large theoretical literature published in the most recent years attempts to incorporate financial features and the banking sector into DSGE models. See Gertler and Kiyotaki (2010) for an assessment of this research. Given the macroprudential focus of the paper, we neglect banking sector shocks in the model below. Another reason is that the model is designed to be tractable and to obtain intuitive results.

the small open-economy framework of Gali and Monacelli (2005). Since New Zealand is sufficiently small, we assume that its economy has no impact on the rest of the world while the reverse is not true. Variables pertaining to a single foreign country are denoted by the superscript *i*, while "rest-of-the-world" variables are denoted by an asterisk.

When modelling households, we follow the recent strand of literature introduced by Kiyotaki and Moore (1997) and consider two groups of agents divided according to their discount factors. ω stands for the number of borrowers and $(1-\omega)$ designates the number of savers in the small open economy. The agents are denoted as b and s, respectively.[18] Except for the discount factors, households are assumed to be completely symmetric. The two types of goods in the economy, namely non-housing and housing goods, are denoted by the subscripts *C* and *D*, respectively. When taking out a loan, impatient households (borrowers) face a borrowing constraint. We incorporate a loan-to-value (LTV) ceiling by allowing impatient households to borrow up to a fraction of the value of new housing acquisitions. In addition, the government imposes a stamp duty on housing purchases.[19] For simplicity we assume that the government runs a balanced budget using lump-sum transfers to households to ensure that this balance is respected in each period.

3.2. Households

Borrowers

In the economy there are two groups of households, patient and inpatient. Each of these groups has unit mass. The only difference between these agents is that the patient group's discount factor is higher than the inpatient group's one. The heterogeneity in agents' discount factors provides a simple way to generate financial flows in equilibrium: patient households (savers) purchase a positive amount of saving assets and do not borrow. Impatient households, on the other hand, are the only borrowers in the economy. The representative borrower is infinitely lived and maximizes the expected utility

$$max\ E_0 \sum_{t=0}^{\infty} \beta_b^t \left[\frac{1}{1-\sigma} {X_t^b}^{1-\sigma} - \frac{\nu_b}{1+\varphi}\left(N_t^b\right)^{1+\varphi}\right] \quad (1)$$

which is a function of the consumption bundle X_t^b, and $N_{j,t}$ $(j = C, D)$ represents the labour supply in sector j. Furthermore, φ and σ represent intertemporal elasticities of substitution with respect to labour

[18] In a related paper, Aoki et al. (2004) consider savers and an entrepreneurial housing sector.

[19] The literature on housing-related fiscal policy considers various favourable tax measures distorting investment decisions towards housing and away from capital. For some recent work, see Alpanda and Zubairy (2016).

and consumption, respectively, and β_b denotes the borrowers' discount factor.[20] Following Monacelli (2008) and Funke and Paetz (2013), the welfare-relevant consumption index is a weighted average of the flow of non-housing consumption expenditures and the stock of housing:

$$X_t^b = \tilde{C}_t^{b(1-\gamma\varepsilon^{D,b})} D_t^{b\gamma\varepsilon^{D,b}} \tag{2}$$

where $\tilde{C}_t^b = C_t^b - h_c C_{t-1}^b$, C_t^b is a composite index of non-housing consumption, and the flow of composite housing service consumption (which we model as directly proportional to the stock of housing) is represented by D_t^b . h_c measures the degree of habit formation in non-housing consumption, γ is the share of housing in consumption and $\varepsilon^{D,b} = \exp(e^{D,b})$ is a housing preference shock that affects the marginal rate of substitution between non-housing and housing goods.[21] This shock captures changes in social and institutional norms that shift preferences towards housing.

In line with Notarpietro (2008), borrowers can trade nominal riskless bonds but are unable to tap the international markets to finance their expenditures.[22] Consequently, they face a sequence of budget constraints, given by

$$C_t^b + Q_t(1+\tau_t^D)I_{D,t}^b - B_{H,t}^b = -R_{t-1}\frac{B_{H,t-1}^b}{\Pi_{C,t}} + \frac{W_t N_t^b}{P_{C,t}} + T_t^b \tag{3}$$

where $\Pi_{C,t+1} = \frac{P_{C,t+1}}{P_{C,t}}$ is the CPI-based inflation rate, Q_t are real housing prices, $B_{H,t}^b$ represents the stock of real domestic debt (both denominated with the domestic non-housing price index), R_{t-1} is the nominal interest rate (the lending rate on a loan contract issued in *t*-1), $W_{j,t}$ is the sector-specific nominal wage rate and $I_t^b = D_t^b - (1-\delta)D_{t-1}^b$ defines housing investments.[23] τ^D is the stamp duty,

[20] It is worth recalling that our assumption on utility is convenient for exposition. Several straightforward extensions are also common in the literature. For example, some papers replace time-separable utility with recursive utility using the tractable functional form introduced by Epstein and Zin (1989).

[21] By using a Cobb–Douglas composite consumption index, we implicitly assume a unitary intratemporal elasticity of substitution between housing and non-durable consumption as in Notarpietro (2008) or Monacelli (2009), for example.

[22] According to the recently collected LINZ data, in the first three months of 2016, only 4 per cent of houses were purchased by people who were not tax residents of New Zealand (http://www.linz.govt.nz/land/land-registration/prepare-and-submit-your-dealing/property-tax-compliance-requirements/property-transfers-and-tax-residency-0). Note that a foreigner living and working in New Zealand, but who is not a citizen, is still a tax resident. The LINZ data were collected in January 2016 and thus in a relatively quiet quarter of the year in terms of home sales. However, the (possible) bias is thought to be no more than a few percentage points. Overall one can say that the share of foreign buyers in the New Zealand residential housing market is insignificant.

[23] In New Zealand the predominant mortgage contract is a fixed-rate mortgage. The main alternative is an adjustable-rate mortgage. Adjustable rates are periodically reset as a markup on top of the policy rate. However, it must be said that almost all New Zealand mortgages are effectively adjustable-rate mortgages, as the rate usually changes when a fixed term expires. Figure 2 in Campbell and Cocco (2003) shows the evolution of the share of fixed-rate mortgages, which is strongly negatively correlated with long-term interest rates. Andrews et

which we assume to be constant, ε_t^{τ} denotes a stamp duty shock and δ represents the depreciation rate of the housing stock. The proportional transaction tax applies whenever a household buys a house. This specification is motivated by the rule of thumb that a specific proportion of the house price is typically paid as incidental expenses. This transaction cost is first studied by Flemming (1969) in a deterministic context and by Grossman and Laroque (1990) in a stochastic model. Finally, T_t^b denotes government lump sum transfers. Borrowers do not save and are restricted by the following borrowing constraint:

$$R_{t-1}B_{H,t}^b \leq (1-\chi)(1-\delta)E_t Q_{t+1} D_t^b \Pi_{C,t+1} {\varepsilon_t}^{LTV} \tag{4}$$

where χ represents the fraction of housing that cannot be used as collateral. Thus, $1-\chi$ is the LTV constraint.[24] Equation (4) relates the amount that will be repaid by a borrower in the following period to the expected future value of durable stocks (adjusted for depreciation and the loan-to-value ratio). Assuming that borrowers in New Zealand can only access domestic mortgage markets, the LTV ratio is binding. Furthermore, we ignore international investors. The borrowing household maximizes (1) subject to (3) and (4). The FOCs for this optimization problem can be expressed as:

$$\frac{W_t}{P_{C,t}} = \frac{{X_t^b}^{\sigma} {N_t^b}^{\varphi} {\tilde{C}_t^b}^{\gamma\varepsilon^D}}{(1-\gamma\varepsilon^D){D_t^b}^{\gamma\varepsilon^D}} \tag{5}$$

$$\begin{aligned}(1+\tau_t^D)Q_t = {} & \left(\frac{\gamma\varepsilon^D}{1-\gamma\varepsilon^D}\right)\frac{\tilde{C}_t^b}{D_t^b} + (1-\chi)(1-\delta)\psi_t Q_{t+1}E_t\Pi_{C,t+1} \\ & + \beta_b(1-\delta)E_t\left(\frac{1-\gamma\varepsilon_{t+1}^D}{1-\gamma\varepsilon_t^D}\right)\left(\frac{X_t^b}{X_{t+1}^b}\right)^{\sigma}\left(\frac{D_{t+1}^b}{\tilde{C}_{t+1}^b}\right)^{\gamma\varepsilon_{t+1}^D}\left(\frac{\tilde{C}_t^b}{D_t^b}\right)^{\gamma\varepsilon_t^D} Q_{t+1}(1+\tau_{t+1}^D)\end{aligned} \tag{6}$$

$$R_t\psi_t = 1-\beta_b E_t\left(\frac{1-\gamma\varepsilon_{t+1}^D}{1-\gamma\varepsilon_t^D}\right)\left(\frac{X_t^b}{X_{t+1}^b}\right)^{\sigma}\left(\frac{D_{t+1}^b}{\tilde{C}_{t+1}^b}\right)^{\gamma\varepsilon_{t+1}^D}\left(\frac{\tilde{C}_t^b}{D_t^b}\right)^{\gamma\varepsilon_t^D}\frac{R_t}{\Pi_{C,t+1}} \tag{7}$$

where $\lambda_t\psi_t$ represents the Lagrangian multiplier on the borrowing constraint and ψ_t can be interpreted as the marginal value of borrowing.[25] For $\psi_t = 0$, equation (7) reduces to the standard New Keynesian

al. (2011) provide evidence on mortgage contracts across OECD countries. Calza et al. (2013) present SVAR evidence that monetary policy has larger effects in countries with more variable mortgages.

[24] The LTV constraint always binds in the deterministic steady state. Below we assume that the constraint continues to bind in a sufficiently small neighbourhood of the steady state, so the DSGE model can be solved by taking a first-order approximation.

[25] Note that the optimality condition (6) is widely interpreted as equating the marginal rate of substitution between durable and non-durable consumption $\frac{U_{D,t}}{U_{C,t}}$ to the "user cost" of durables. See Monacelli (2008) for a detailed discussion.

Euler equation. Thus, a rise in ψ_t represents a tightening of the collateral constraint. The first condition represents the standard labour–leisure trade-off, equating the marginal disutility of an additional unit of labour to the marginal utility received from additional consumption, equation (6) equates the marginal utility of non-durable consumption to the shadow value of durable services and the last equation is a consumption Euler equation adjusted to capture the borrowing constraint.

Savers

Patient savers are able to make intertemporal decisions in the standard way. The representative patient household maximizes the expected utility

$$max\ E_0 \sum_{t=0}^{\infty} \beta_s^t \left[\frac{1}{1-\sigma} {X_t^s}^{1-\sigma} - \frac{\nu_s}{1+\varphi} (N_t^s)^{1+\varphi}\right] \tag{8}$$

subject to

$$C_t^s + Q_t(1+\tau_t^D) I_{D,t}^s - B_{H,t}^s - \mathfrak{E}_t B_{F,t}^s = -R_{t-1} \frac{B_{H,t-1}^s}{\Pi_{C,t}} - {R^*}_{t-1} \frac{\mathfrak{E}_t B_{F,t-1}^s}{\Pi_{C,t}} + \sum_{j=C,D} \frac{F_{j,t}}{P_{C,t}} + T_t^s \tag{9}$$

where $\mathfrak{E}_t$ represents the nominal exchange rate, $B_{F,t}^s$ foreign bond holdings, R_t^* the foreign interest rate and $F_{j,t}$ the profits earned by savers for owning intermediate goods firms, and all the other variables are defined in the same way as for the borrowers.[26] Optimization yields

$$\frac{W_t}{P_{C,t}} = \frac{(X_t^b)^{\sigma} N_t^{s\varphi} \tilde{C}_t^{s\gamma\varepsilon^{D,s}}}{(1-\gamma\varepsilon^{D,s}) D_t^{s\gamma\varepsilon^{D,s}}} \tag{10}$$

$$(1+\tau_t^D) Q_t = \left(\frac{\gamma\varepsilon^D}{1-\gamma\varepsilon^D}\right) \frac{\tilde{C}_t^s}{D_t^s} + \beta_s(1-\delta) E_t \left(\frac{1-\gamma\varepsilon_{t+1}^D}{1-\gamma\varepsilon_t^D}\right) \left(\frac{X_t^s}{X_{t+1}^s}\right)^{\sigma} \left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\varepsilon_{t+1}^D} \left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\varepsilon_t^D} Q_{t+1}(1+\tau_{t+1}^D) \tag{11}$$

$$1 = \beta_s E_t \left(\frac{1-\gamma\varepsilon_{t+1}^D}{1-\gamma\varepsilon_t^D}\right) \left(\frac{X_t^s}{X_{t+1}^s}\right)^{\sigma} \left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\varepsilon_{t+1}^D} \left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\varepsilon_t^D} \frac{R_t}{\Pi_{C,t+1}} \tag{12}$$

$$1 = \beta_s E_t \left(\frac{1-\gamma\varepsilon_{t+1}^D}{1-\gamma\varepsilon_t^D}\right) \left(\frac{X_t^s}{X_{t+1}^s}\right)^{\sigma} \left(\frac{D_{t+1}^s}{\tilde{C}_{t+1}^s}\right)^{\gamma\varepsilon_{t+1}^D} \left(\frac{\tilde{C}_t^s}{D_t^s}\right)^{\gamma\varepsilon_t^D} \frac{\mathfrak{E}_{t+1}}{\mathfrak{E}_t} \frac{R_t{}^*}{\Pi_{C,t+1}} \tag{13}$$

[26] One can think of $B_{F,t}$ and R_t^* as weighted averages over all the single-country variables that make up the world.

Similar to the borrowers' case, equation (10) equalizes the real wage in units of non-durables to the savers' marginal rate of substitution between consumption and leisure. In addition, since patient households do not face a borrowing constraint, the equations exactly mirror those of the impatient households for $\psi_t = 0$.[27] Equation (11) equates the purchase price of a durable good to the pay-off (the marginal rate of substitution between durable and non-durable consumption) plus the expected resale value, while (12) and (13) are conventional Euler equations, adjusted for housing in the consumption index.

Tradable Goods Sector: Helpful Definitions and Identities

Before proceeding, we offer some helpful definitions and identities used extensively in the following sections.[28] Non-durable and durable consumption indices are given by

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{14}$$

where

$$C_H \equiv \left[\int_0^1 C_H(k)^{\frac{\epsilon_C-1}{\epsilon_C}} dk\right]^{\frac{\epsilon_C}{\epsilon_C-1}} \qquad C_F \equiv \left[\int_0^1 C_{i,t}^{\frac{\zeta-1}{\zeta}} di\right]^{\frac{\zeta}{\zeta-1}}$$

$$C_{i,t} \equiv \left[\int_0^1 C_{i,t}(k)^{\frac{\epsilon_C-1}{\epsilon_C}} dk\right]^{\frac{\epsilon_C}{\epsilon_C-1}}$$

and η represents the intratemporal substitution elasticity between domestic and foreign goods, ζ the intratemporal substitution elasticity between goods produced in the "rest of the world", ϵ_C the intratemporal substitution elasticity between differentiated goods within one country in the tradable goods sector and α the degree of openness. Consequently, the price indices are given by

$$P_{C,t} = \left[(1-\alpha) P_{C,H,t}^{1-\eta} + \alpha P_{C,F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{15}$$

The sector-specific bilateral terms of trade between the domestic country and country *i* represent the price of country *i*'s goods in terms of domestic goods and is given by $S_{i,t} = \frac{P_{C,i,t}}{P_{C,H,t}}$, that is, the price of

[27] Note that the first-order conditions for internationally traded bonds imply the uncovered interest parity.
[28] We drop the superscripts *b* and *s*, as all the arguments hold for borrowers, savers and aggregates.

country *i's* goods. Thus, the effective terms of trade (i.e. the price of foreign goods in terms of home goods) are given by $S_t = \frac{P_{C,F,t}}{P_{C,H,t}} = \left(\int_0^1 S_{i,t}^{1-\zeta}\right)^{\frac{1}{1-\eta}}$, which can be approximated by $s_t = \log(S_t) \approx \int_0^1 s_{i,t}\, di$. Moreover, log-linearizing the domestic price indices under the assumption of a symmetric steady state satisfying the PPP provides a relationship between the inflation, the inflation of domestically produced goods and the sectorial terms of trade in the consumption goods sector. The latter is given by $\hat{\pi}_{C,t} = \hat{\pi}_{C,H,t} + \alpha\Delta\hat{s}_t$. Assuming that the law of one price (LOOP) holds on the brand level, aggregation over all tradable products and countries yields $P_{C,F,t} = \mathfrak{E}P^*_{C,F,t}$, $P_{C,H,t} = \mathfrak{E}P^*_{C,H,t}$, $P_{C,t} = \mathfrak{E}P^*_{C,t}$. Log-linearization of $P_{C,F,t}$ around a symmetric steady state yields $\hat{p}_{C,F,t} = \int_0^1 (\widehat{e}_{i,t} + \hat{p}_{C,i,t})di = \widehat{e_t} + \hat{p}^*_{C,t}$, where $\hat{p}^*_{C,t}$ represents the log world price index in the tradable goods sector.[29]

International Risk Sharing

Although borrowers are constrained, we assume that savers are able to share country-specific risks internationally via the trading of bonds on complete security markets. By equating domestic and foreign optimality conditions with respect to consumption and linearizing the result around a symmetric steady state under the assumption of symmetric initial conditions, we obtain

$$\left(\frac{X_t^{S,*}}{X_t^S}\right)\left(\frac{\tilde{C}_t^{S,\varepsilon_t^D}}{\tilde{C}_t^{S,*,\varepsilon_t^{D,*}}}\right)^{\gamma}\left(\frac{D_t^{S,\varepsilon_t^D}}{D_t^{S,*,\varepsilon_t^{D,*}}}\right)^{\gamma} = \mathcal{R}_t \tag{16}$$

where $\mathcal{R}_t$ is the consumer price-based real effective exchange rate, $\tilde{C}_t^{S,*}$ is the composite index of foreign savers' non-durable consumption accounting for habit persistence and $D_t^{S,*}$ stands for the index of non-durable consumption. In addition, $X_t^{S,*}$ denotes the index of foreign savers' total consumption and $\varepsilon_t^{D,*}$ represents the foreign counterparts to domestic shocks.

3.3. Firms

The focal point of this subsection will be the micro-structure of firms. We assume a two-stage production process in each sector, in which intermediate goods (wholesale sector) are used to produce final goods (retailers) according to a CES technology.[30]

[29] Note that the world CPI and PPI are the same, as we assume that each country is of measure zero.

[30] To retain analytical tractability of the model and retain the focus of the discussion, we assume that intermediates are non-tradable.

Retailers

Perfectly competitive retail firms in sector j produce final goods with the following production function:

$$Y_{j,t} = \left(\int_0^1 Y^{\frac{1}{\mu_t{}^j}}(k)dk \right)^{\mu_t{}^j} \tag{17}$$

where $Y_{j,t}$ denotes the aggregate output, $Y_{j,t}(k)$ is the input produced by intermediate goods firm k (both expressed in per capita terms) and $\mu_t{}^j$ captures the time-varying, sector-specific markup of prices over the marginal cost in the wholesale sector. Since each retailer is a price taker, she decides on the optimal number of final goods to be produced to maximize her profits:

$$Max\ P_{j,H,t}Y_{j,t} - \int_0^1 P_{j,H,t}(k)Y_{j,t}(k)\,dk \tag{18}$$

subject to equation (17). Thus, we obtain the standard downward-sloping demand curve for product k:

$$Y_{j,t}(k) = \left(\frac{P_{j,H,t}(k)}{P_{j,H,t}} \right)^{-\epsilon_j} Y_{j,t} \tag{19}$$

where $P_{j,H,t} = \left(\int_0^1 P_{j,H,t}(k)^{\,1-\epsilon_j}\,dk \right)^{\frac{1}{1-\epsilon_j}}$.

The Wholesale Sector

At the bottom of the production process, there is a continuum of intermediate goods producers operating in a monopolistically competitive environment. The production of each intermediate goods producer j is assumed to follow a stochastic constant returns to scale production function $Y_{j,t}(k) = A_{j,t}N_{j,t}(k)$, where $A_{j,t}$ denotes sector-specific labour productivity and $N_{j,t}$ is the labour input.[31] The real marginal cost in each sector is derived from each sectorial firm's cost minimization problem, whereby the latter are given by:

$$Min\ W_t N_{C,t}(k) \tag{20}$$

[31] Jones (2015) shows that the Cobb–Douglas production function forms a valid approximation in the aggregate for a variety of underlying micro firm production functions.

s.t.

$$A_{c,t}N_{C,t}(k) \geq \left(\frac{P_{C,H,t}(k)}{P_{C,H,t}}\right)^{-\epsilon_c} Y_{C,t} \tag{21}$$

and

$$Min\, W_t N_{D,t}(k) \tag{22}$$

s.t.

$$A_{D,t}N_{D,t}(k) \geq \left(\frac{P_{D,t}(k)}{P_{D,t}}\right)^{-\epsilon_D} Y_{D,t} \tag{23}$$

are given by $\frac{\left(\frac{W_t}{P_{H.j,t}}\right)}{MPN_{j,t}}$, where $MPN_{j,t}$ represents the marginal product of labour in each sector. After aggregating the optimal labour–leisure decision of borrowers and savers, the real marginal cost in each sector is represented by the following two equations:

$$MC_{C,t} = \frac{{X_t}^b {N_t^b}^{\varphi} {\widetilde{C}_t}^{b^{\gamma\varepsilon_t^D}} S_t^{\alpha}}{(1-\gamma\varepsilon_t^D){D_t}^{b^{\gamma\varepsilon_t^D}} A_{C,t}} \tag{24}$$

$$MC_{D,t} = \frac{{X_t}^b {N_t^b}^{\varphi} {\widetilde{C}_t}^{b^{\gamma\varepsilon_t^D}}}{(1-\gamma\varepsilon_t^D){D_t}^{b^{\gamma\varepsilon_t^D}} A_{D,t}Q_t} \tag{25}$$

Price Setting

The price adjustment of the monopolistically competitive intermediate firms is assumed to follow a variant of the characteristic of Calvo pricing in accordance with Gali and Gertler (1999). A randomly selected fraction of firms in each sector $(1-\theta_j)$ adjusts its prices, while the remaining fraction of firms θ_j does not adjust them. In addition, we follow Justiniano and Preston (2010) and assume that those firms that do not reoptimize in the current period adjust their prices according to the following rule:

$$\log P_{H,C,t}\,(i) = \log P_{H,C,t-1}\,(i) + \iota_j \Pi_{H,C,t-1} \tag{26}$$

$$\log P_{D,t}\,(i) = \log P_{D,t-1}\,(i) + \iota_j \Pi_{D,t-1} \tag{27}$$

where $0 \leq \iota_j \leq 1$ stands for the degree of indexation to the past period's inflation. As is customary, the above assumptions yield the conventional markup rule, whereby firms set the price as a markup over the current and future real marginal costs subject to the price indexation. This yields the familiar

New Keynesian Phillips curves, which now comprise both forward-looking and backward-looking elements.[32] Taking first-order log-linear approximation around the steady state yields:

$$(1+\beta_s\iota_C)\hat{\pi}_{H,C,t} = \beta_s E_t\hat{\pi}_{H,C,t+1} + \iota_C\hat{\pi}_{H,C,t-1} + \kappa_C\widehat{mc}_{C,t} + \varepsilon_t^{\mu_C} \quad (28)$$

$$(1+\beta_s\iota_D)\hat{\pi}_{D,t} = \beta_s E_t\hat{\pi}_{D,t+1} + \iota_D\hat{\pi}_{D,t-1} + \kappa_D\widehat{mc}_{D,t} + \varepsilon_t^{\mu_D} \quad (29)$$

where $\kappa_j = \frac{(1-\theta_j)(1-\theta_j\beta_s)}{\theta_j}$ is the slope of the New Keynesian Phillips curve, $\widehat{mc}_{j,t}$ denotes the real marginal cost in log-deviation from the steady state and $\varepsilon_t^{\mu_j}$ stands for a cost-push shock in the spirit of Smets and Wolters (2007).

3.4. Market Clearing

Aggregate goods market clearing for each good *k* in each sector *j* requires

$$Y_{C,t}(k) = C_{H,t}(k) + \int_0^1 C_{H,t}^i(k)di \quad (30)$$

$$Y_{D,t}(k) = I_t(k) \quad (31)$$

In addition, the aggregate consumption of both non-durables and housing stock is given by:

$$C_t = \omega C_t^b + (1-\omega)C_t^s \quad (32)$$

$$D_t = \omega D_t^b + (1-\omega)D_t^s \quad (33)$$

and

$$I_t = D_t + (1-\delta)D_{t-1} \quad (34)$$

$$\sum_j N_{j,t} = \omega N_t^b + (1-\omega)N_t^s \quad (35)$$

$$A_t = A_{C,t} = A_{D,t} \quad (36)$$

We can approximate (30) and (31) around a symmetric steady state by

$$\hat{y}_{C,t} = (1-\alpha)\hat{c}_t + \alpha\hat{c}_t^* + \alpha\,\nu\hat{s}_{C,t} \quad (37)$$

$$\hat{y}_{D,t} = \hat{\imath}_{D,t} \quad (38)$$

[32] For a complete exposition of the maximization problems and the respective optimality conditions, see Justiniato and Preston (2010).

where $\nu = \zeta + \eta(1-\alpha)$. Obviously, the aggregated real output (denominated with the aggregated producer price index $P_{H,t}$) must fulfil $P_{H,t}Y_t = P_{C,H,t}Y_{C,t} + P_{D,H,t}Y_{D,t}$. Finally, we follow Monacelli (2009) and abstract from redistribution via fiscal policy. As a result,

$$T_t^b = T_t^s = 0 \tag{39}$$

3.5. Monetary Policy

In the current policy environment, inflation remains the foremost goal of monetary policy. In line with this, we assume a Taylor-type rule, which is given by:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_r} \left[\left(\frac{\Pi_{C,t}}{\Pi_C}\right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_\alpha}\right]^{1-\rho_r} \varepsilon_t^m \tag{40}$$

where the first (second) term implies that the central bank responds to movements of inflation (output growth).[33] The Taylor rule in equation (40) allows us to investigate the efficacy of conventional monetary policy in situations of sector-specific house price increases. It is important to stress that the key question to be addressed in this paper is the role of macroprudential regulation. We will therefore conduct a comparative analysis of the efficacy of traditional monetary policy and macroprudential policy tools in stabilizing house prices. In particular, we will investigate whether conventional monetary policy is too blunt an instrument to stabilize abnormal house price increases.

3.6. Exogenous Processes

When solving the model, we apply local solution methods whereby we linearize all the equilibrium conditions by means of a first-order Taylor approximation. Hence, all the variables are presented in terms of log-deviations from their steady-state levels. The model's dynamics is represented by six exogenous processes that capture reasons for moving that are exogenous to the model. They have the following functional forms:

$$a_{j,t} = \rho_a a_{j,t-1} + \nu_{j,t}^a \tag{41}$$

$$\epsilon_t^m = \nu_t^m \tag{42}$$

$$\hat{c}_t^{\,*} = \rho^* \hat{c}_{t-1}^* + \nu_t^* \tag{43}$$

[33] We choose output growth instead of deviations of output from its natural counterpart to avoid the complexities of specifying a measure of the output gap. In addition, Villaverde (2010) argues that, whereas an output gap specification in the Taylor rule is always somewhat arbitrary, output growth fits the evidence better.

$$\epsilon_t^{\mu_i} = \rho_{\mu_j}\epsilon_{t-1}^{\mu_i} + \nu_t^{\mu_i} \quad (44)$$

$$\epsilon_t^{\gamma} = \rho_{\gamma}\epsilon_{t-1}^{\gamma} + \nu_t^{\gamma} \quad (45)$$

$$\epsilon_t^{LTV} = \rho_{LTV}\epsilon_{t-1}^{LTV} + \nu_t^{LTV} \quad (46)$$

$$\epsilon_t^{\tau} = \rho_{\tau}\epsilon_{t-1}^{\tau} + \nu_t^{\tau} \quad (47)$$

where $\nu_t^i \sim \mathcal{N}(0, \sigma_i^2)$. Equation (41) represents a standard stochastic process for technology in sector *j*, whereas equation (42) accounts for a monetary policy shock. In addition, equation (43) accounts for the foreign demand of domestically produced tradable goods, which is an autoregressive process of order 1 and is subject to random disturbances denoted by ϵ_t^*. Sector-specific cost push shocks are accounted for by equation (44). Finally, the model also allows for an exogenous perturbation to the marginal rate of substitution between the consumption of tradable goods and the consumption of non-tradable goods in the utility function in the form of a housing preference shock represented by equation (45). Furthermore, we conduct macroprudential policy analysis by considering two additional stochastic processes that do not take part in the estimation stage since they either have not been implemented over the whole sample period in New Zealand or not been implemented at all. That is, we shed light on the impact of a positive LTV shock and negative property tax shock on the model economy as macroprudential tools for stabilizing house prices. The latter are represented by equations (46) and (47), respectively.

4. Calibration and Estimation

Policy models aimed at analysing actual macroprudential policy issues should fit the main characteristics of the data and allow for policy analysis and counterfactuals. Model parameters are derived through a combination of calibration and estimation. The parameters determining the steady state are calibrated to obtain reasonable values for some key steady-state values and ratios. We estimate the parameters that are difficult to calibrate, or the ones that we have very little information about, using a Bayesian approach. Estimation of the implied posterior distribution of the parameters is performed using the Metropolis–Hastings algorithm. We use six observed series: real GDP per capita, real consumption per capita, overnight interbank cash rate, CPI inflation, house price inflation and employment. The data sample runs from 1993 Q2 to 2016 Q1, since, as noted by Kamber et al. (2015), this time range covers most of the inflation-targeting period. Real output per capita, consumption, real housing investment and employment are detrended using the one-sided Hodrick–Prescott filter, whereas CPI inflation and house price inflation are only demeaned.[34] Finally, the overnight cash rate is given in an annualized form. As a result, it is first transformed into quarterly series to match the

[34] See Pfeifer (2015) for details.

frequency of the DSGE model and subsequently demeaned.[35] All the variables are seasonally adjusted by means of the X-12 ARIMA procedure.

The RBNZ implements monetary policy by setting the Official Cash Rate, which is reviewed eight times a year. Since data for the Official Cash Rate are only available after March 1999, we employ the overnight cash rate as a proxy for the policy rate.[36] The RBNZ does not publish data on the average LTV ratio in New Zealand. Instead it publishes data on the percentage of mortgages that have a high LTV (LTV ratio ≥ 80 per cent). LTV restrictions in New Zealand are implemented at the level of banks (as they are for financial stability purposes). Therefore, banks can still make a few high-LTV loans as long as there are only a few high-LTV loans in their total portfolio. Figure 9 in Thornley (2016, p. 14) provides the percentage of high-LTV mortgages (over 80 per cent) for the period 2009–2016. The IMF (2016, p. 20) proclaims that the average LTV ratio in New Zealand is currently 55 per cent and has declined from 60 per cent in the last decade.

4.1. Calibrated Parameters

As noted earlier, we apply Bayesian techniques for the estimation of some parameters in the model. The reason why standard maximum likelihood has not become the preferred estimation method is the so-called "dilemma of absurd parameters".[37] Hence, we opt for a combination of calibration and estimation to account for the stylized facts implied by the data. Table 1 summarizes the values of the calibrated parameters in the model.

The discount factor of the borrowers is set to 0.99, implying an annual rate of return of around 4 per cent, whereas the discount factor of borrowers is assumed to be 0.98 in accordance with much of the literature on borrowing constraints. Following Funke and Paetz (2013), the rate of depreciation of residential stock, δ, is set to 0.01, giving an annual depreciation rate of 1 per cent. The loan-to-value ratio is equal to 0.57, which corresponds to the IMF's estimate for the sample period implying $\chi = 0.43$. The elasticities of substitution between domestically produced goods and between goods produced in the entire continuum of foreign countries are somewhat difficult to estimate, since they tend to be related to the sector-specific degrees of openness. Accordingly, we keep the model tractable and set $\zeta = \eta = 1$. The degree of openness, α, is set to 0.5, which is roughly in line with the import/GDP ratio for New Zealand over the sample period. We fix the elasticity of substitution in both sectors to 6, which yields a markup value of 1.2. The property tax parameter is set based on the

[35] As regards nominal interest rates, their stationarity is widely debated in empirical macroeconomics. Nonetheless, Clarida et al. (2000) and Davig and Leeper (2007) argue that, in developed economies where the generalized Taylor rule holds, the nominal interest rate is stationary.

[36] Cassino (2012) determines how changes in the policy rate are transmitted to the mortgage rates. The empirical results suggest that mortgage rates have full pass-through of the marginal funding cost in the long run.

[37] See An and Schorfheide (2007).

ancillary costs (notary fees, land registry costs, etc.) of buying real estate in New Zealand, which roughly amount to 5 per cent.

Table 1: Calibrated Parameters

Parameter	Value	Definition
β_s	0.99	Discount factor of savers
β_b	0.98	Discount factor of borrowers
ϵ_C	6	Elasticity of substitution between differentiated non-durable goods
ϵ_D	6	Elasticity of substitution between differentiated durable goods
δ	0.01	Depreciation rate of residential stock
$1-\chi$	0.57	LTV ratio
γ	0.2	Share of housing in utility
τ	0.05	Property tax
α	0.5	Degree of openness
ζ	1	Elasticity of substitution between goods produced in different foreign countries
η	1	Elasticity of substitution between domestic and foreign goods

The share of housing consumption in the utility function is chosen to match the steady-state ratio of housing investment to aggregate production. Finally, the hours worked preference parameters are set so that both types of households work one-third of their time in the steady state.

4.2. Prior and Posterior Distributions

The prior distribution, mean and standard deviation of all the estimated parameters are summarized in column 1 of Table 2. The crucial role that priors play in Bayesian estimation entails their careful selection. A vast majority of prior distributions and moments are based on Kamber et al. (2015), who employ a large-scale DSGE model and thus estimate a wide range of structural parameters for the New Zealand economy. Table 2 illustrates both first and second moments of the prior and posterior distributions of the estimated parameters. We estimate two versions of the model with two different priors for the share of borrowers in the economy. It should be noted that the identification of this parameter with the aggregate consumption data is quite cumbersome. As a result, we take into account two scenarios. Our benchmark version draws from Iacoviello and Neri (2010) and considers a beta distributed prior with mean 0.35. Our alternative scenario follows Paries and Notarpietro (2008) as well as Funke and Paetz (2012) by assuming an uninformative prior for the share of borrowers that is uniformly distributed.

From Table 2 it becomes obvious that most of the estimated parameters are in line with the literature. The risk aversion coefficient has a posterior mean slightly larger than unity, which is a standard value in the literature. Furthermore, the posterior mean of the inverse of the Frisch elasticity of labour supply

is slightly larger than 2, whereas the habit persistence parameter takes on a relatively small value. This is nevertheless consistent with the finding that consumption in New Zealand does not seem to be highly persistent. Furthermore, as documented by Kamber et al. (2015), the degree of price stickiness in the tradable sector is higher than that in the housing industry. In the case of New Zealand, firms in the consumption industry seem to be stuck with their prices on average for three quarters, whereas firms in the housing industry are able to adjust slightly more often. It is also important to mention that the estimation results imply that both tradable goods inflation and house price inflation are not only forward- but also backward-looking. In addition, the posterior mean of the output growth coefficient in the Taylor rule does not substantially differ from that found by Kamber et al. (2015), which is around 0.2.

4.3. Model Properties

This section elaborates on the properties of the model for our baseline scenario. The log data density values are -1336 and -1543 for the baseline and alternative scenarios, respectively. This speaks strongly in favour of our benchmark case, and in the following we report the results only for this benchmark scenario. Nevertheless, even with an uninformative prior, the data do not reject the presence of borrowers in the economy, which endorses the plausibility of the modelling framework that we chose. Table 4 shows the relative standard deviations of both the data and the model. The model performs well for most variables, although house prices are insufficiently volatile and housing investment overly volatile in the model relative to the data; this issue is common in the DSGE housing literature. A vast majority of the estimated correlations reported in Table 5 are close to those observed in the data, which strongly accounts for the model's ability to replicate salient features of the New Zealand economy. We emphasize the model's ability to reproduce the comovements in house prices, housing investment, output and consumption that are core to our focus on macroprudential policy. We also perform variance decomposition analyses with different horizons to shed light on the drivers of business cycles in the main New Zealand variables. Table 6 presents the results. Output is mostly driven by technology shocks (both in the consumption and the housing industry). That the foreign demand shock plays a small role in output's variation may seem surprising, since New Zealand is largely open to the rest of the world, although this result is in line with business cycle accounting for New Zealand (Gunaratna and Kirkby, 2017). Nonetheless, foreign demand shocks account for a substantial share of consumption, CPI inflation and nominal interest variability, which highlights their importance for the New Zealand economy. As regards property price inflation, Table 6 unequivocally illustrates that it is housing technology shocks that mostly drive house prices. While it is still not clear in the literature how exactly these shocks could be interpreted, it is quite likely that they capture the effect of the emergence and subsequent bust of a housing bubble.

Table 2: Structural Parameter Estimates

Parameter	Distribution	Baseline		$\omega \sim U(0,1)$	
		Posterior Mean	90% Interval	Posterior Mean	90% Interval
σ	$\Gamma(1, 0.1)$	1.13	(0.98, 1.27)	1.99	(1.75 2.24)
φ	$\Gamma(2, 0.1)$	2.16	(2.00, 2.33)	2.15	(1.98 2.31)
h	$\beta(0.4, 0.05)$	0.19	(0.15, 0.23)	0.47	(0.39 0.54)
ω	$\beta(0.35, 0.05)$	0.19	(0.15, 0.23)	0.64	(0.62 0.66)
ρ_r	$\beta(0.5, 0.1)$	0.78	(0.74, 0.82)	0.63	(0.57 0.69)
ϕ_π	$\Gamma(2, 0.1)$	2.03	(1.87, 2.19)	1.99	(1.83 2.15)
ϕ_y	$\Gamma(0.2, 0.1)$	0.27	(0.11, 0.42)	0.64	(0.52 0.76)
θ_c	$\beta(0.75, 0.05)$	0.65	(0.59, 0.72)	0.93	(0.91 0.94)
θ_d	$\beta(0.65, 0.05)$	0.43	(0.37, 0.48)	0.86	(0.83 0.89)
ι_c	$\beta(0.5, 0.1)$	0.35	(0.21, 0.48)	0.12	(0.07 0.17)
ι_d	$\beta(0.5, 0.1)$	0.27	(0.14, 0.39)	0.04	(0.02 0.05)
ρ_{a_C}	$\beta(0.5, 0.1)$	0.96	(0.94, 0.97)	0.69	(0.65 0.73)
ρ_{a_D}	$\beta(0.5, 0.1)$	0.50	(0.42, 0.58)	0.50	(0.42 0.58)
ρ^*	$\beta(0.5, 0.1)$	0.66	(0.60, 0.73)	0.65	(0.55 0.75)
ρ_{μ_c}	$\beta(0.5, 0.1)$	0.43	(0.37, 0.50)	0.31	(0.25 0.37)
ρ_{μ_d}	$\beta(0.5, 0.1)$	0.57	(0.50, 0.64)	0.14	(0.10 0.18)
ρ_γ	$\beta(0.5, 0.1)$	0.75	(0.69, 0.81)	0.93	(0.91 0.95)
		Log data density: -1336		Log data density: -1543	

Table 3: Shock Standard Deviation Estimates

Parameter	Distribution	Baseline		$\omega \sim U(0,1)$	
		Posterior Mean	90% Interval	Posterior Mean	90% Interval
σ_{a_c}	$\Gamma^{-1}(1, 2)$	2.22	(1.96, 2.49)	2.22	(2.18, 2.85)
σ_{a_d}	$\Gamma^{-1}(1, 2)$	3.58	(3.02, 4.14)	3.58	(11.89, 19.57)
σ_m	$\Gamma^{-1}(1, 2)$	0.24	(0.20, 0.27)	0.24	(0.31, 0.44)
σ_{μ_c}	$\Gamma^{-1}(1, 2)$	1.34	(1.13, 1.54)	1.34	(0.70, 1.21)
σ_{μ_d}	$\Gamma^{-1}(1, 2)$	1.52	(1.17, 1.86)	1.52	(0.44, 0.64)
σ^*	$\Gamma^{-1}(1, 2)$	4.27	(3.15, 5.36)	4.27	(2.52, 3.40)
σ_γ	$\Gamma^{-1}(1, 2)$	5.42	(4.67, 6.15)	5.42	(5.62, 7.75)

Table 4: Relative Standard Deviations

	Relative Standard Deviations	
	Data	*Model*
Output	1.00	1.00
Interest rate	0.41	0.13
CPI inflation	0.47	0.17
Property price inflation	1.94	0.48
Consumption	1.02	0.69
Housing investment	8.33	18.72
Employment	1.49	0.54

Table 5: Correlations

Correlations	Data	Model
y, π_D	0.03	0.11
y, i_D	0.61	0.61
R, π_C	0.31	0.57
R, c	-0.22	-0.59
y, c	0.50	0.31
π_C, c	-0.14	-0.31
π_D, R	-0.11	0.26
π_D, i_D	0.33	0.10
id, n	0.53	0.88

Table 6: Variance Decomposition

Variable	Horizon	σ_{ac}	σ_{aD}	σ_{m}	σ_{C^*}	$\sigma_{\mu c}$	$\sigma_{\mu D}$	σ_{γ}
y	1	0.41	0.00	0.03	0.00	0.06	0.46	0.03
	2	0.34	0.18	0.02	0.01	0.03	0.39	0.02
	4	0.39	0.26	0.01	0.01	0.02	0.29	0.02
	8	0.45	0.30	0.01	0.01	0.02	0.21	0.01
	∞	0.55	0.29	0.01	0.00	0.01	0.14	0.01
π_c	1	0.02	0.10	0.21	0.33	0.13	0.02	0.19
	2	0.02	0.09	0.17	0.28	0.17	0.11	0.16
	4	0.03	0.11	0.16	0.26	0.16	0.12	0.15
	8	0.04	0.12	0.15	0.26	0.17	0.12	0.14
	∞	0.04	0.13	0.15	0.25	0.17	0.12	0.14
π_D	1	0.04	0.69	0.05	0.02	0.06	0.09	0.05
	2	0.04	0.67	0.05	0.02	0.06	0.09	0.06
	4	0.04	0.64	0.05	0.03	0.07	0.10	0.06
	8	0.04	0.63	0.05	0.03	0.08	0.11	0.07
	∞	0.04	0.64	0.05	0.03	0.08	0.11	0.06
c	1	0.11	0.06	0.02	0.31	0.29	0.07	0.14
	2	0.16	0.09	0.01	0.20	0.33	0.10	0.12
	4	0.26	0.14	0.01	0.12	0.29	0.09	0.09
	8	0.40	0.18	0.01	0.08	0.20	0.06	0.07
	∞	0.58	0.15	0.00	0.05	0.13	0.04	0.04

Historical Shock Decompositions

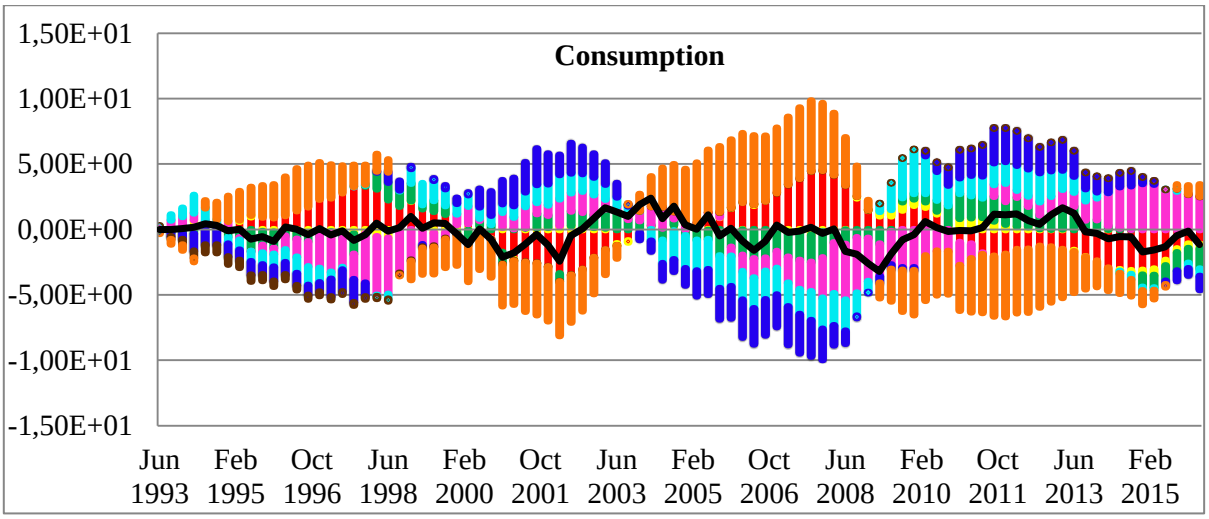
Figure 4 illustrates the historical shock decompositions with respect to consumption, CPI inflation and house price inflation. We focus on consumption following Iacoviello and Neri (2010), who point to consumption as an important channel through which the housing sector affects the rest of the economy, and it fits well with the LTV regulation analysis that we perform later on, which is in part concerned with how highly credit-constrained households cut back sharply on consumption in response to a fall in house prices (Mian, Rao and Sufi, 2013).

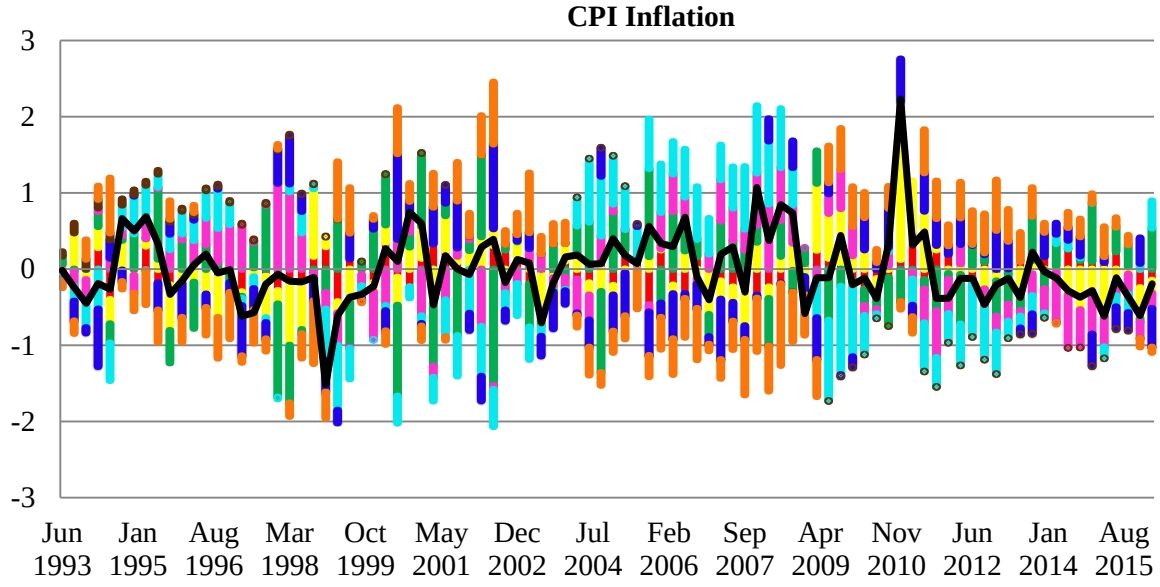
We begin with consumption. The historical shock decomposition confirms the variance decomposition results, indicating that technology shocks in the non-durables industry are the main driver of consumption deviations from the balanced growth path. The demand for tradable goods in a small and highly open economy such as New Zealand is expected to be influenced by foreign demand shocks, and this is confirmed for consumption in Figure 4 as well as the variance decomposition results. Cost-push shocks in the consumption industry and housing preference shocks are other major drivers of consumption cycles in New Zealand. The overflow of house price increases (decreases) into consumption is also clearly visible in the form of the role played by housing technology shocks. We saw already that these shocks play a major role in the variation of house price inflation. The historical shock decompositions show that these housing technology shocks boost consumption during periods of high house price rises, such as 1993–97 and 2003–08.[38] House price falls correspond to a large switch in the effect of housing technology shocks towards a drag on consumption, further supporting our focus on consumption as the channel of interest for macroprudential policy targeting house prices and debt.

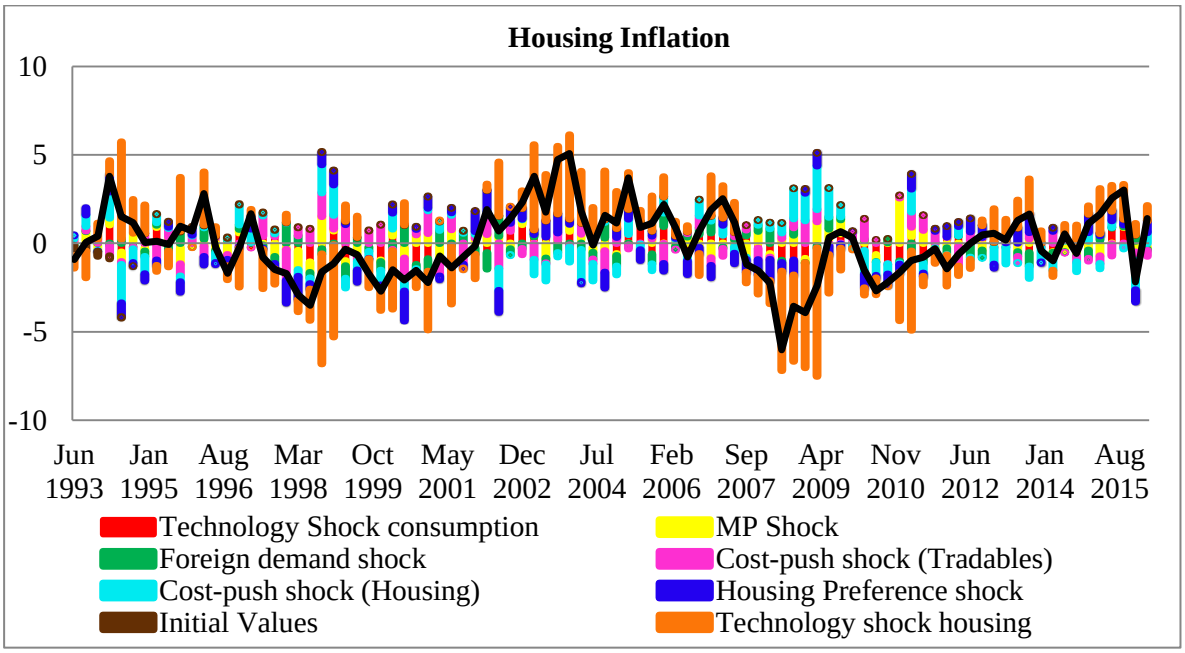
CPI inflation, in contrast, is strongly influenced by monetary policy shocks. This is nevertheless to be expected, since our data sample begins from the moment when the CPI inflation targeting in New Zealand was already credibly announced by the RBNZ. By looking at the unconditional variance decomposition, however, we see that it is foreign demand shocks that play the most vital role in explaining CPI inflation movements. Finally, it is interesting to note that house price inflation in New Zealand is largely dominated by housing supply shocks (i.e. housing technology ones) rather than demand shocks. We posit that this role for housing supply shocks may pick up the important role of net migration in New Zealand house prices observed in the VAR literature (Coleman and Landon-Lane, 2007). This is in contrast to Paries and Notarpietro (2008), who find that preference shocks in the housing industry are the main driver of house prices in both the US and the euro area.

[38] The historical decomposition suggests that recent increases in house prices are beginning to have the same effect on consumption; however, much of this increase occurs after the end of our model estimates (in late 2015 and 2016).

Figure 4: Historical Shock Decompositions







Impulse Response Functions

To illustrate the dynamic properties of the model, we provide impulse responses, focusing on the impact of a technology shock, a monetary policy shock and a housing preference shock. The impulse responses of the model economy to a technology shock in the housing sector are shown in Figure 5. The results are largely standard, as output and housing investment rise whereas the prices in both sectors fall. The decline in prices is particularly prominent in the housing sector, which induces agents to shift their demand away from consumption goods towards housing. Turning to the open economy, the effect of a technology shock in the housing sector is largely driven by the response of monetary policy. The corresponding rise in real interest rates leads to a real appreciation of the domestic currency, which tends to exert a negative impact on the foreign demand for domestically produced consumption goods and thus the current account.

Figure 5: Impulse Responses to a One-Standard-Deviation Technology Shock in the Housing Sector

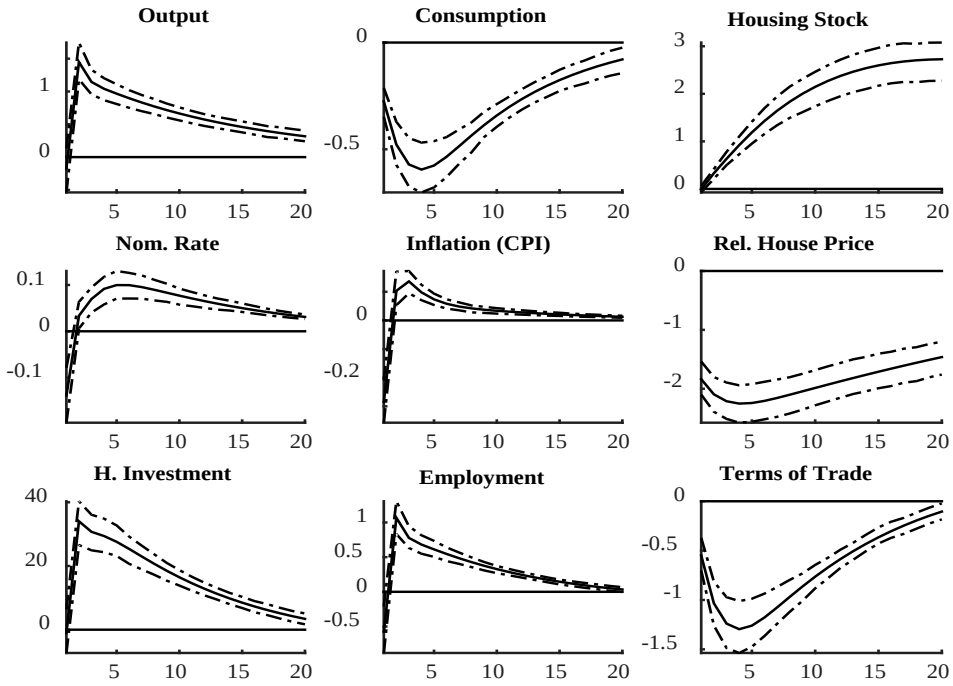
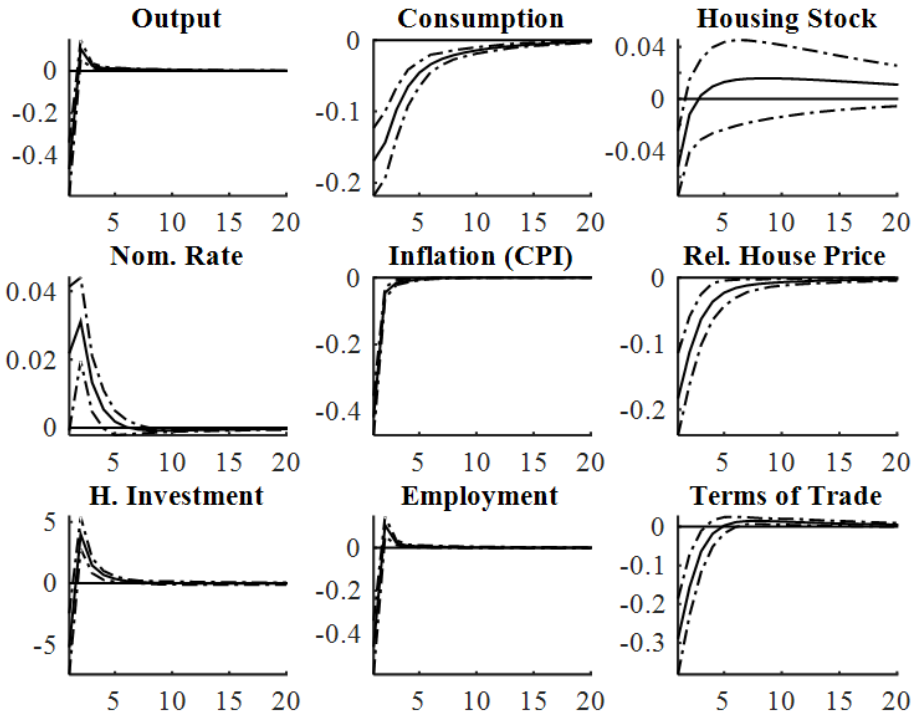


Figure 6 illustrates the effect of a one-standard-deviation rise in the nominal interest rate. Our results are in line with both calibrated new Keynesian models with a housing sector (e.g. Monacelli, 2009) and estimated studies such as those by Paries and Notarpietro (2008) and Iacoviello and Neri (2010). That is, output and consumption experience a significant drop, which is amplified by real exchange rate appreciation. It is the borrowers who are most adversely affected by the contractionary monetary

policy shock. The rise of the nominal interest rate increases the ex post value of existing debt, and in addition the fall of the relative house price reduces the real value of borrowers' collateral, which induces them to reduce their borrowing, amplifying the negative effect on their demand for housing and the relative house price. The number of borrowers in the economy is sufficient to generate a small but very persistent drop in both the aggregate demand for housing and the real housing investment.

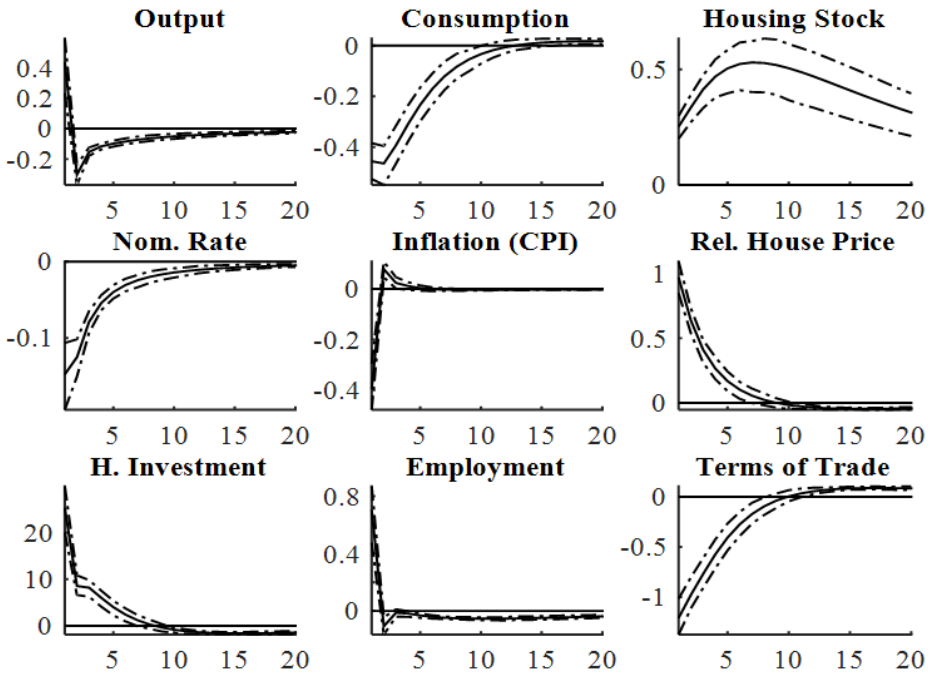
Figure 6: Impulse Responses to a One-Standard-Deviation Contractionary Monetary Policy Shock



The effects of a housing preference shock are shown in Figure 7.[39] On impact there is a large increase in house prices, while the supply of housing (as captured by both housing investment and housing flow consumption) is slow to respond. Over time the housing supply increases in response to the increase in the housing demand captured by the housing preference shock. Both housing investment and housing flow consumption increase gradually, and as they do so house prices moderate. These findings fit closely with those of the literature on the drivers of New Zealand house prices, which finds that the housing supply reacts slowly to increases in demand, with higher house prices during the transition (e.g. Grimes and Heyland, 2013). A housing preference shock also leads to a temporary shift away from other sectors of the economy with decreases in output, consumption and employment.

[39] In recent years there has been a growing interest in the relationship between asset prices and the macroeconomy. This interest has been motivated by the development of macroeconomic models with financial frictions, in which asset prices play an important role in determining the level of financial intermediation and economic activity. In Figure 7 house prices are not only a channel through which shocks are transmitted but also the source of shocks themselves.

Figure 7: Impulse Responses to a One-Standard-Deviation Housing Preference Shock



4.4 Counterfactual Macroprudential Policy Simulations

We consider two macroprudential instruments that could potentially have a substantial impact on the housing sector in New Zealand: the LTV ratio and stamp duty taxes. The estimated DSGE model is used to explore the efficacy of macroprudential policy in influencing house prices. We consider the channels through which such policies might operate as well as possible side effects on the broader economy.

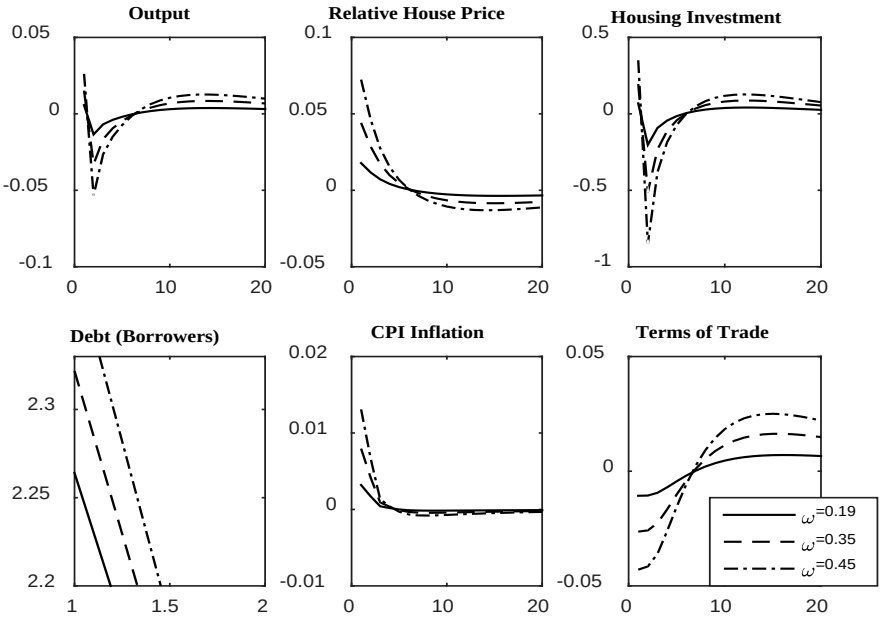
LTV Ratio Policy

Households that take out a mortgage must make a large enough downpayment so that the LTV ratio remains below the threshold. Exogenous variation in the LTV ratio is a popular example of a macroprudential policy that tightens (or loosens) the household borrowing capacity.[40] Stated differently, the LTV ratio imposes a cap on the mortgage that can be raised (lowered). The intention of

[40] The counterfactual analysis assumes that the policymakers do not slavishly follow a fixed macroprudential rule. Instead they learn how the economy reacts to small macroprudential policy changes and discern appropriate policy adjustments. This is in line with the actual conduct of macroprudential policy in New Zealand that we aim to model, which is discretionary and is intended to be temporary in nature (so modelling it as a transitory shock seems to be appropriate).

LTV ratio restrictions is to hinder households from engaging in excessive risk taking and aggressive real estate borrowing. Figure 8 presents impulse response functions for a one percentage point increase in the LTV constraint: a loosening of macroprudential policy. It must be borne in mind that the share of borrowers ω is an exogenous parameter in the model. Therefore, our estimates centre on the intensive borrowing margin. The reality, however, is more complex. The extensive margin creates another channel through which LTV changes might influence house prices: the constraint switching effect. A higher (lower) LTV ratio allows more (fewer) borrowers to obtain a loan and thus the share of borrowers ω increases (decreases). More (fewer) borrowers are able to pay a collateral premium for housing, leading to a rise (decline) in the housing demand.[41] This channel is complementary to, but separate from, the intensive mortgage credit channel.[42] Figure 8 further illustrates how the model economy response to a positive one-per cent LTV shock changes for different shares of borrowers with the aim of additionally shedding light on the extensive channel.

Figure 8: IRFs of a One-Percentage-Point Increase in the LTV Ratio



[41] The extensive margin effect of tightening the LTV ratio tends to fall disproportionately on first-time home buyers. Potential first-time buyers will not have the private assets that they need and will have to accumulate sufficient savings before being able to afford housing. This will reduce the demand for real estate, thereby weighing down house prices, all other things being equal. Furthermore, this will make the financial position of first-time buyers more resilient and banks' real estate funding less vulnerable.

[42] Bilbiie et al. (2007) provide a seminal contribution on the effect of financial frictions on the extensive margin of firm activity in a tractable dynamic setting. The authors show how economic expansions induce higher entry rates and how the sluggish response in the number of producers (due to sunk entry costs and a time-to-build lag) generates a new and potentially important endogenous propagation mechanism for real business cycle models and monetary policy decisions in a DSGE environment. Financial intermediaries play a key role in the birth of new firms by relaxing the financial constraint of entrepreneurs over their net wealth. An analogous impact channel operates in the housing market.

First, as expected, relaxing the LTV policy induces borrowers to borrow more. As a result, they increase the level of accumulated debt by a large margin, not only because of the relaxation of the LTV constraint but also due to the so-called "valuation effect".[43] That is, since borrowers are able to increase their borrowing, they demand more of both goods, which drives up the relative house price. A higher real estate price in turn raises the value of the collateral that borrowers have to pledge to obtain a mortgage, which exerts a positive effect on their borrowing ability.

Furthermore, Paries and Notarpietro (2008) point out that the valuation effect is absent among savers and thus the rise in house prices leads to a higher user cost of housing for them. This induces savers to substitute consumption for housing, which exerts pressure on CPI inflation. In turn, the Central Bank responds by raising interest rates, which results in real exchange rate appreciation and deterioration of the current account. Focusing on the extensive margin, Figure 8 unambiguously indicates that increasing the number of borrowers amplifies the financial accelerator effect due to the collateral constraint. As a result, all the variables exhibit stronger steady-state deviations and return more slowly to their long-run equilibrium values.

According to RBNZ research (Price, 2014), the imposition of macroprudential regulation cut the growth rate of house prices by 3.5 percentage points, with house price growth slowing to 4.8 per cent in 2014 Q3. Hargraves (2016) refers to these results, which are based on an SVAR relating house prices to credit restrictions, as evidence that the use of the "speed limits" on high-LTV loans is having the desired effects: reducing risky lending and house prices without damaging the wider economy. Our baseline model estimate for the impact of this macroprudential regulation is that it cut the growth rate of house prices by 3.8 percentage points. We calculate this as follows. Imposing LTV restrictions on high-LTV loans (< 80 per cent) in late 2013 led to a fall in the share of new loans with a high LTV ratio from 25 per cent to 5 per cent. In terms of our model, a 20 per cent reduction in high-LTV loans corresponds to a 2 per cent fall[44] in the average LTV, and our estimates show that this would lead to a fall in house prices on impact of 3.8 per cent.[45] The fact that our DSGE estimate and that of the RBNZ based on an SVAR are similar lends credence to the estimates and suggests that our model produces quantitatively credible estimates of the effects of macroprudential policy.

Forward Guidance

[43] We adjust the scale for the IRF plot of debt due to the large response in all three scenarios relative to all the other variables considered in the macroprudential analysis.

[44] Based on the assumption that high-LTV loans previously averaged 90 per cent and were reduced to exactly 80 per cent. Thus, a 0.2 share times the 10 per cent fall gives us 2 per cent.

[45] Figure 8: the baseline model IRF for the immediate impact of the change in LTV on house prices.

We now discuss the role of a credibly announced longer-term LTV shock versus a more transitory one. That is, we aim to capture the effects of "forward guidance", which has played a prominent role in macroprudential policy over recent years.

Figure 9: IRFs of a One-Percentage-Point Increase in the LTV Ratio: Forward Guidance

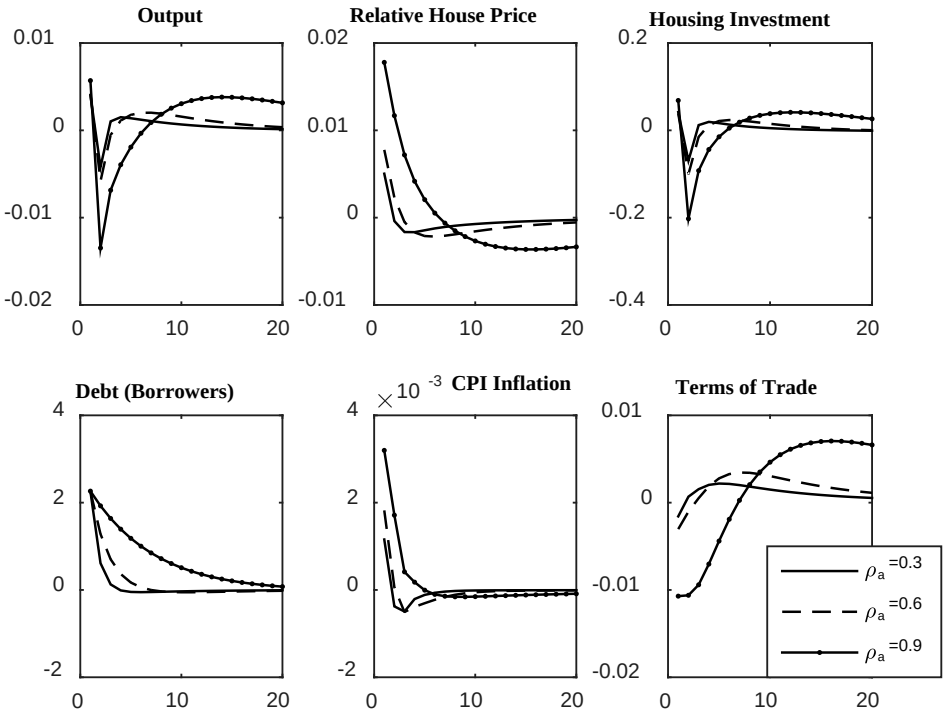


Figure 9 demonstrates the business cycle effects of having a more persistent LTV shock. When the LTV policy loosening is very persistent, borrowers are able to raise a higher real debt level, which exerts positive pressure on the housing demand. House prices thus increase substantially compared with a more transitory LTV policy. CPI inflation also exhibits a stronger positive response due to savers' higher demand for consumption goods rather than housing. Consequently, a very persistent negative LTV shock will have a very strong stabilization impact on house prices and a weaker stabilization impact on consumer prices. That means that a credibly announced LTV policy could complement standard monetary policy as a means of achieving price stability, especially as far as real estate prices are concerned.[46]

The LTV restrictions first put in place by the RBNZ in 2013 were announced as being temporary. They remain in place and have been tightened periodically. Our results suggest that better initial

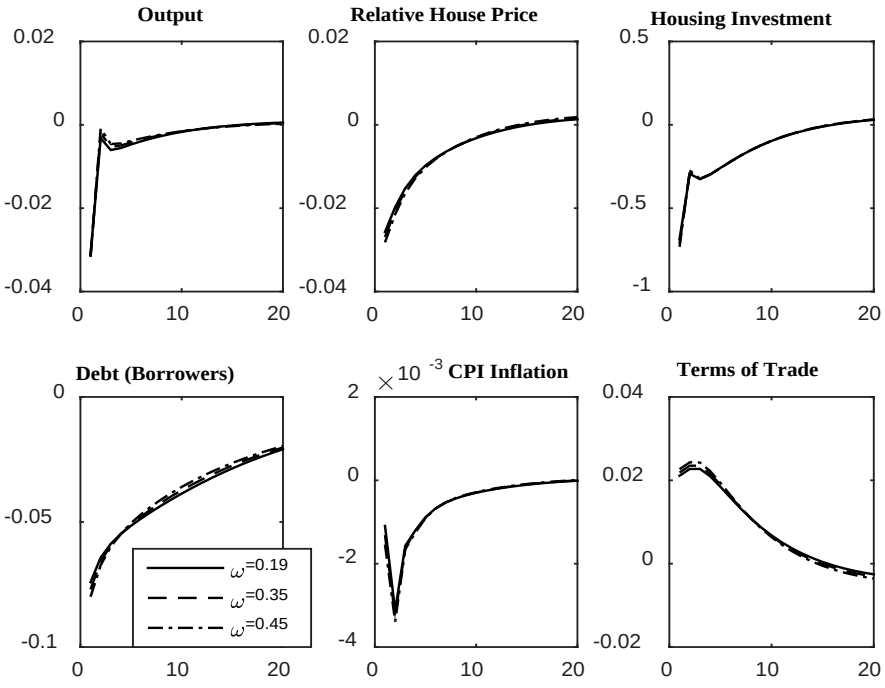
[46] Forward guidance policies could be read in different ways: a central bank statement that rates are likely to remain low for a long time could mean that economic growth is expected to remain too weak to justify interest rate rises, in which case investors have good reason to stay pessimistic. However, it could also represent a commitment not to raise interest rates even as growth accelerates, lifting expectations of future inflation and providing an incentive to borrow and invest in the present. Failure to distinguish between the two risks steers markets in the wrong direction.

guidance from the RBNZ on how long their restrictions would remain in place would have made the LTV restrictions more effective in achieving their goals in terms of constraining house price inflation.

Stamp Duty Tax

This section deals with the impact that property tax increases have on house prices and how that affects the rest of the economy. Figure 10 highlights the impulse responses of a percentage increase in the property tax rate. Figure 10 reveals that raising the stamp duty tax rate engenders a significant substitution effect away from housing towards non-durable goods. As a result, house prices decline, which, through the collateral channel, reduces the ability of borrowers to acquire a mortgage, resulting in a lower debt level. Borrowers significantly reduce their housing demand, which dampens real housing investment and thus output. CPI inflation and interest rates fall below the steady state, which accounts for an improvement in the terms of trade and thus real exchange depreciation. In a small open economy like New Zealand, this tends to have a positive impact on the foreign demand for domestically produced goods and thus mitigates the aggregate output decrease to a certain extent.

Figure 10: IRFs of a One-Percentage-Point Increase in the Property Tax Rate



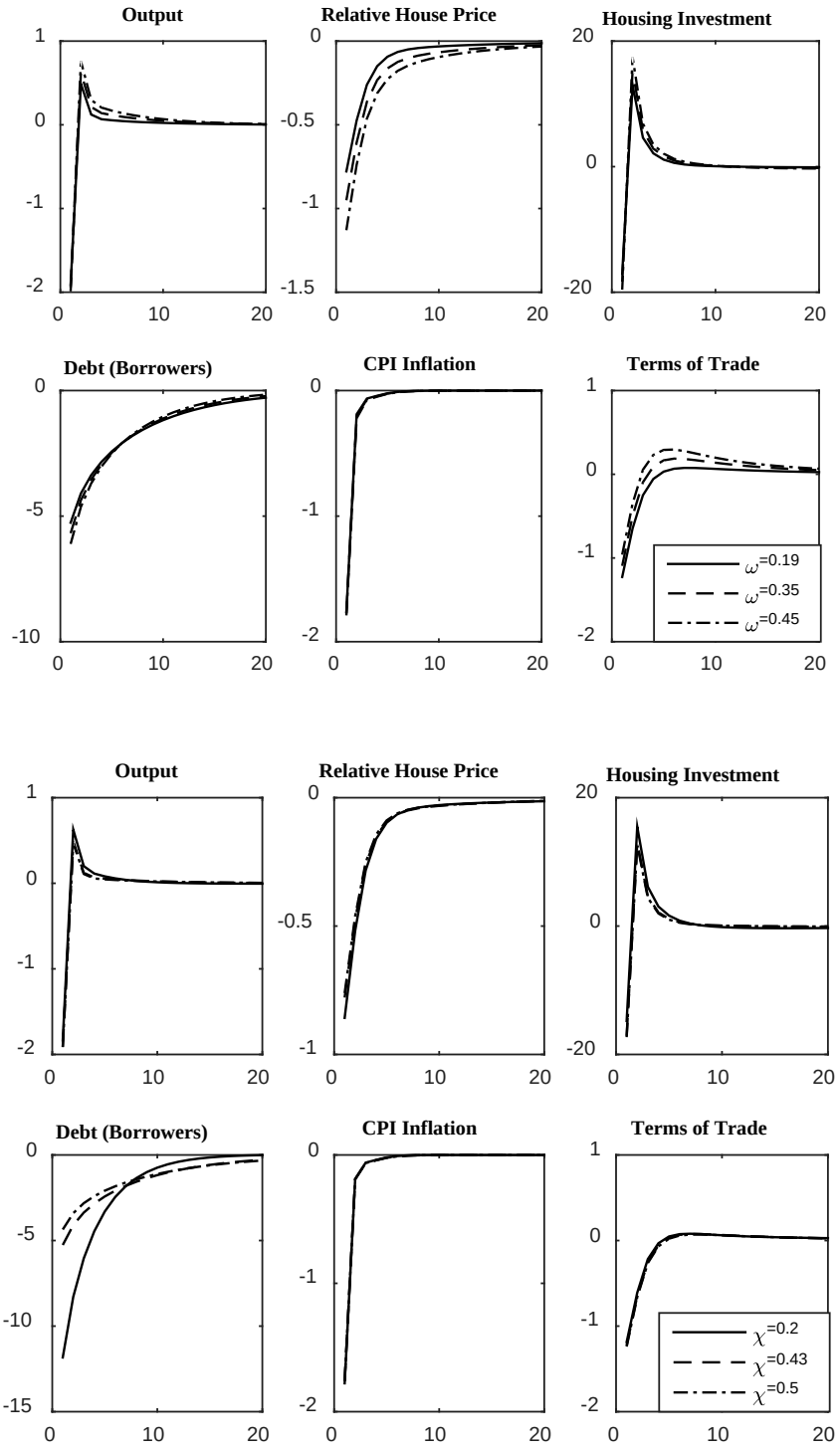
Policy Interactions

Our results suggest that employing multiple macroprudential tools can enhance their effectiveness, help to overcome the shortcomings of a single policy tool and allow the adjustment of the overall policy response to a range of risk profiles while reducing the potential for circumvention. Furthermore, our estimates of the effects of temporary LTV policy tightening predict an effect on house prices and a largely negligible effect on the price of consumption goods. Therefore, macroprudential policy provides both a way to target house prices directly in situations in which changes in house prices are considered to be concerning and a way to mitigate the effects of monetary policy on house prices with minimal interference in the intended effects of monetary policy on inflation. This finding is of particular interest in the current New Zealand environment, in which the possible role of loose monetary policy in high house prices is a topic of public concern.

While macroprudential policy does not derail the objectives of monetary policy, a natural concern is that it may still reduce the effectiveness of monetary policy by weakening the channels through which monetary policy acts. Macroprudential policy will lead to changes in both the fraction of borrowers in the economy, ω, and the level of their borrowing constraints, χ; indirectly, through these two channels, it also affects the average levels of debt and leverage in the economy. Since the consumption reactions of borrowers are an important channel for monetary policy (Iacoviello and Minetti, 2008; Hedlund et al., 2016), imposing macroprudential policy might weaken the effectiveness of monetary policy. To investigate this concern, Figure 11 presents IRFs to an interest rate shock under different values of ω and χ. We find that, whilst this channel of monetary policy is weakened, with changes in interest rates having smaller effects on house prices and debt levels, the overall effectiveness of monetary policy experiences only a negligible reduction. The main effects of monetary policy on the economy come from the existence of sticky prices leading changes in nominal interest rates to affect real interest rates and relative prices and in turn consumption and production decisions. These effects remain largely unchanged by macroprudential policy, as shown by the consistency of the IRF responses of output and CPI inflation. The smaller effects of a change in interest rates on house prices and debt levels also suggest that macroprudential policy can help to reduce concerns about the spillover effects of monetary policy on house prices and debt (Iacoviello, 2005).

Putting these findings together suggests that, while coordination between macroprudential and monetary policies will obviously produce superior outcomes to the absence of coordination, the gains from coordination are likely to be small. Macroprudential policy can be used to target house prices as well as levels of indebtedness and leverage. It can also help to reduce unintended spillovers from monetary policy into house prices and debt. When such macroprudential interventions in house prices and debt are judged to be appropriate, they can be carried out separately from the operation of monetary policy without impairing the effectiveness of monetary policy or derailing its goals in terms of output and CPI inflation.

Figure 11: Contractionary Monetary Policy Shocks under Different Macroprudential Regimes (Different Values of ω and χ)



5. Conclusion

The global financial crisis has highlighted the need for a better understanding of macrofinancial linkages and underscored the importance of macroprudential policies in addition to standard monetary

policy and microprudential regulation. Against this background we analyse the effects of various housing-related macroprudential policies on the economy using a DSGE framework estimated with Bayesian methods. We find that the historical drivers of house prices in New Zealand were mostly shocks specific to the housing sector. While monetary policy has large spillover effects on house prices, it does not appear to have been a major driver of house prices in New Zealand.

We use our model to study macroprudential regulation, especially LTV ratio restrictions of the kind imposed by the Reserve Bank of New Zealand in October 2013, which remain in place at the time of writing. We find that such policies have large impacts on house prices but only a small effect on consumer prices, suggesting that their use does not derail the use of monetary policy. We estimate that the impact of the LTV ratio restrictions imposed in New Zealand reduced house prices by 3.8 per cent. Clearer guidance from the Reserve Bank of New Zealand on the duration of the LTV ratio restrictions – forward guidance on macroprudential policy – would have led them to have a greater effect on house prices. We conclude that LTV ratio restrictions provide a useful macroprudential tool in situations when controlling house prices is judged to be a goal of economic policy.

Finally, we are aware that a number of potential extensions could affect the findings reported in this paper. First, in the model we do not allow households to switch type as a result of macroprudential policies. Thus, our model simulations capture how macroprudential policies affect housing at the intensive margin but not the extensive margin. Second, we do not consider the possible introduction of capital gains taxation as a macroprudential tool. Third, we do not model statutory amortization requirements, that is, the portion of the mortgage that must be repaid each period. Fourth, much of the literature on housing and business cycles builds on macro models with limited heterogeneity. It should be said that there is considerable promise in modelling frameworks that allow for richer heterogeneity. An interesting direction is to incorporate geography explicitly. A well-known feature from urban economics is that housing markets differ by geography as well as other attributes.[47] This geographic disconnection can present problems for macroprudential policies. What are the challenges faced by policy makers and regulators in a situation of uneven house price dynamics across regions? In this context it would be interesting to develop a prototype multi-regional DSGE model to analyse exuberant house price dynamics in specific metropolitan centres like Auckland in the face of national versus region-specific macroprudential measures. Disaggregating not only the household sector but also the housing stock into a two-region DSGE model with out-of-sync sub-national housing markets may provide valuable insights into the transmission of shocks and alter macroprudential policy conclusions. New Zealand's regional house price differences may ultimately indicate that there is no one-size-fits-all national macroprudential policy. Instead city-specific macroprudential policies might be advisable. Finally, international spillovers of macroprudential policies like LTV limits are

[47] See, for example, Van Nieuwerburgh and Weill (2010). It must be emphasized, however, that this is easier said than done. Ultimately this research project requires a spatial two-region DSGE model in which region-specific fundamental and/or policy shocks spill over across localized metropolitan regions.

unchartered territory ("terra incognita").[48] We have added these remaining open questions to our future research agenda.

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[48] For some recent work on the strength of such international macroprudential spillovers, see Avdjiev et al. (2016).

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Appendix

Log-linear Model Equations

$$[-\sigma+\gamma(\sigma-1)]\hat{\tilde{c}}_t^b+\gamma(1-\sigma)\hat{d}_t^b=[-\sigma+\gamma(\sigma-1)]E_t\hat{\tilde{c}}_{t+1}^b+\gamma(1-\sigma)E_t\hat{d}_{t+1}^b+\hat{r}_t-E_t\hat{\pi}_{c,t+1}+\frac{\bar{\psi}}{\beta_b}\left(\hat{\psi}_t+\hat{r}_t\right)-\frac{\gamma}{1-\gamma}(\rho_\gamma-1)\epsilon_t^\gamma \quad (A.1)$$

$$(1+\tau)\hat{q}_t=\frac{\gamma}{1-\gamma}\frac{\bar{\tilde{C}}^b}{\bar{D}^b}\bar{Q}^{-1}\left(\hat{\tilde{c}}_t^b-\hat{d}_t^b\right)+\beta_b(1-\delta)(1+\tau)\big([-\sigma+\gamma(\sigma-1)]\left(\hat{\tilde{c}}_t^b-E_t\hat{\tilde{c}}_{t+1}^b\right)+\gamma(1-\sigma)(\hat{d}_t^b-E_t\hat{d}_{t+1}^b)+E_t\hat{q}_{t+1}\big)+(1-\chi)(1-\delta)\bar{\psi}\left(\hat{\psi}_t+E_t\hat{q}_{t+1}+E_t\hat{\pi}_{c,t+1}\right)+\frac{\gamma}{1-\gamma}\Big[1+\tau+\frac{\bar{\tilde{C}}^b}{\bar{D}^b}+\bar{Q}^{-1}-(\,(1-\chi)(1-\delta)\bar{\psi}\,)-\beta_b(1-\delta)(1+\tau)\rho_\gamma\Big]\epsilon_t^\gamma \quad (A.2)$$

$$\hat{r}_t+\hat{b}_t^b=E_t\hat{q}_{t+1}+\hat{d}_t^b+E_t\hat{\pi}_{c,t+1} \quad (A.3)$$

$$\frac{\bar{C}^b}{\bar{D}^b}\hat{c}_t^b+\bar{Q}^{-1}\left[\delta\hat{q}_t+\hat{d}_t^b-(1-\delta)\hat{d}_{t-1}^b\right]+\beta^{-1}\frac{\bar{B}^b}{\bar{D}^b}\left(\hat{r}_{t-1}+\hat{b}_{t-1}^b-E_t\hat{\pi}_{c,t}\right)=\frac{\bar{B}^b}{\bar{D}^b}\hat{b}_t^b+\frac{1}{\mu^c}\frac{\bar{N}^b}{\bar{D}^b}\left[[\sigma(1-\gamma)+\gamma]\hat{c}_t^b+\gamma(1-\sigma)\hat{d}_t^b+(1+\varphi)\hat{n}_t^b\right] \quad (A.4)$$

$$[-\sigma+\gamma(\sigma-1)]\hat{\tilde{c}}_t^s+\gamma(1-\sigma)\hat{d}_t^s=[-\sigma+\gamma(\sigma-1)]E_t\hat{\tilde{c}}_{t+1}^s+\gamma(1-\sigma)E_t\hat{d}_{t+1}^s+\hat{r}_t-E_t\hat{\pi}_{c,t+1}-\frac{\gamma}{1-\gamma}(\rho_\gamma-1)\epsilon_t^\gamma \quad (A.5)$$

$$(1+\tau)\hat{q}_t=\frac{\gamma}{1-\gamma}\frac{\bar{\tilde{C}}^b}{\bar{D}^b}\bar{Q}^{-1}\left(\hat{\tilde{c}}_t^s-\hat{d}_t^s\right)+\beta(1-\delta)(1+\tau)\big([-\sigma+\gamma(\sigma-1)]\left(\hat{\tilde{c}}_t^s-E_t\hat{\tilde{c}}_{t+1}^s\right)+\gamma(1-\sigma)\left(\hat{d}_t^s-E_t\hat{d}_{t+1}^s\right)+E_t\hat{q}_{t+1}\big)-\beta(1-\delta)(1+\tau)\rho_\gamma\epsilon_t^\gamma \quad (A.6)$$

$$(1+\beta\iota_c)\hat{\pi}_{C,H,t}=\beta E_t\hat{\pi}_{C,H,t+1}+\iota_c\hat{\pi}_{C,H,t-1}+\kappa_C\widehat{mc}_{C,t}+\epsilon_t^{\mu_C} \quad (A.7)$$

$$(1+\beta\iota_D)\hat{\pi}_{D,t}=\beta E_t\hat{\pi}_{D,t+1}+\iota_c\hat{\pi}_{D,t-1}+\kappa_D\widehat{mc}_{D,t}+\epsilon_t^{\mu_D} \quad (A.8)$$

$$\hat{\pi}_{C,t}=\hat{\pi}_{C,H,t}+\alpha\widehat{\Delta s_t} \quad (A.9)$$

$$\hat{y}_{C,t}=a_{C,t}+\hat{n}_{C,t} \quad (A.10)$$

$$\hat{y}_{D,t}=a_{D,t}+\hat{n}_{D,t} \quad (A.11)$$

$$\widehat{mc}_{C,t}=[\sigma+\gamma(\sigma-1)]\hat{\tilde{c}}_t^b-\gamma(1-\sigma)\hat{d}_t^b+\varphi\hat{n}_t^b+\alpha\hat{s}_t-a_t+\frac{\gamma}{1-\gamma}\epsilon_t^\gamma \quad (A.12)$$

$$\widehat{mc}_{D,t} = [\sigma + \gamma(\sigma - 1)]\hat{\tilde{c}}_t^b - \gamma(1-\sigma)\hat{d}_t^b + \varphi\hat{n}_t^b - a_t - \hat{q}_t + \frac{\gamma}{1-\gamma}\epsilon_t^\gamma \quad \text{(A.13)}$$

$$\hat{y}_{C,t} = (1-\alpha)\hat{c}_t + \alpha\hat{c}_t^* + \alpha[\zeta + \eta(1-\alpha)]\hat{s}_t \quad \text{(A.14)}$$

$$[\sigma + \gamma(\sigma - 1)]\hat{c}_t^s + \gamma(\sigma - 1)\hat{d}_t^s = \hat{c}_t^* + (1-\alpha)\hat{s}_t \quad \text{(A.15)}$$

$$\hat{y}_{D,t} = \hat{\imath}_t^d \quad \text{(A.16)}$$

$$\delta\hat{\imath}_t^d = \hat{d}_t - (1-\delta)\hat{d}_{t-1} \quad \text{(A.17)}$$

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + (1-\rho_r)\left[\phi_\pi\hat{\pi}_t + \phi_y(\hat{y}_t - \hat{y}_{t-1})\right] \quad \text{(A.18)}$$

$$\hat{q}_t = \hat{\pi}_{D,t} - \hat{\pi}_{C,t} - \hat{q}_{t-1} \quad \text{(A.19)}$$

$$\hat{n}_t = \frac{\bar{N}_C}{\bar{N}}\hat{n}_C + \frac{\bar{N}_D}{\bar{N}}\hat{n}_D \quad \text{(A.20)}$$

$$\hat{c}_t = \omega\frac{\bar{C}^b}{\bar{C}}\hat{c}_t^b + (1-\omega)\frac{\bar{C}^s}{\bar{C}}\hat{c}_t^s \quad \text{(A.21)}$$

$$\hat{d}_t = \omega\frac{\bar{D}^b}{\bar{D}}\hat{d}_t^b + (1-\omega)\frac{\bar{D}^s}{\bar{D}}\hat{d}_t^s \quad \text{(A.22)}$$

$$[\sigma - \gamma(\sigma - 1)]\hat{\tilde{c}}_t^b - \gamma(1-\sigma)\hat{d}_t^b + \varphi\hat{n}_t^b = [\sigma - \gamma(\sigma - 1)]\hat{\tilde{c}}_t^s - \gamma(1-\sigma)\hat{d}_t^s + \varphi\hat{n}_t^s \quad \text{(A.23)}$$

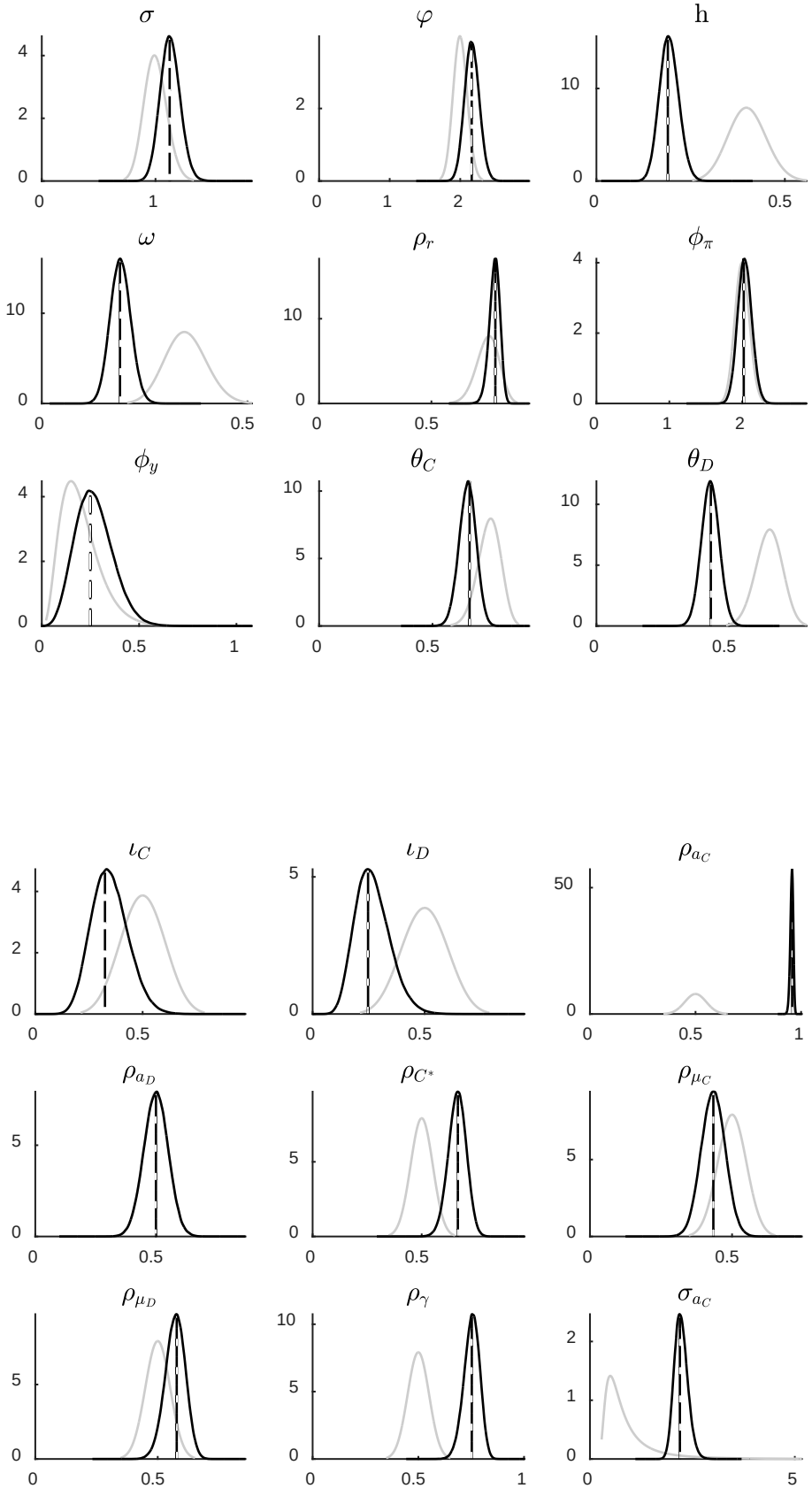
$$\hat{n}_t = \omega\frac{\bar{N}^b}{\bar{N}}\hat{n}_t^b + (1-\omega)\frac{\bar{N}^s}{\bar{N}}\hat{n}_t^s \quad \text{(A.24)}$$

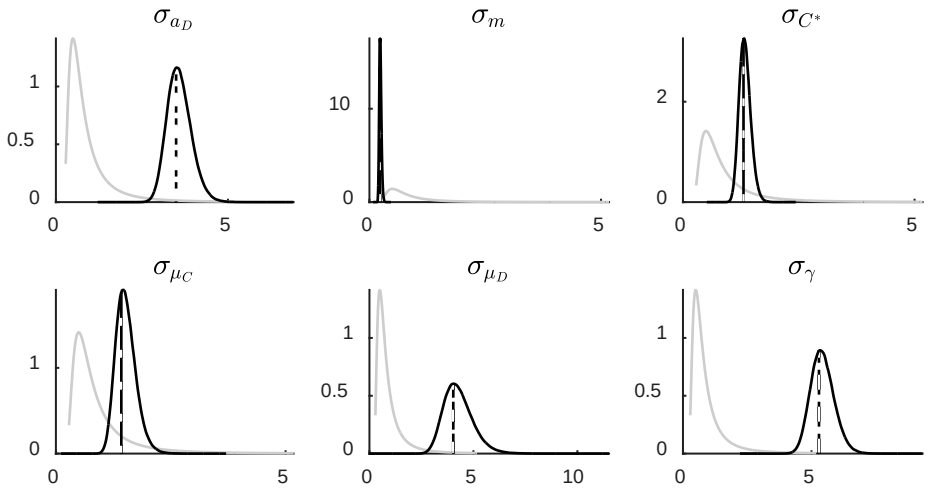
$$\hat{y}_t = \frac{\bar{C}}{\bar{Y}}\hat{y}_{C,t} + \frac{\bar{I}^d}{\bar{Y}}\hat{y}_{D,t} - \alpha\left[\frac{\bar{C}}{\bar{Y}} - (1-\gamma)\right]\hat{s}_t + \left(\frac{\bar{I}^d}{\bar{Y}} - \gamma\right)\hat{q}_t \quad \text{(A.25)}$$

$$\hat{\tilde{c}}_t^b = (1-h)^{-1}(\hat{c}_t^b - h\hat{c}_{t-1}^b) \quad \text{(A.26)}$$

$$\hat{\tilde{c}}_t^s = (1-h)^{-1}(\hat{c}_t^s - h\hat{c}_{t-1}^s) \quad \text{(A.27)}$$

Figure A1: Priors and Posteriors




σ_{a_D}
σ_m
σ_{C^*}
σ_{μ_C}
σ_{μ_D}
σ_γ