Macro-Prudential Regulation, Interest Rate Spreads &
Monetary Policy

A Quantitative Analysis of a Dynamic Model

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Declaration

I declare that this submission is my own original work. This thesis has not been submitted for the award of any other degree or diploma at UNSW or any other educational institution. Any contributions made to this thesis by others have been acknowledged where appropriate.

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Peter Rickards
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Abstract

This thesis examines the impact of capital adequacy regulation on the banking sector, macroeconomic aggregates and the conduct of monetary policy. A Dynamic Stochastic General Equilibrium (DSGE) model is calibrated to quarterly Australian sample data to explore the impact of scenarios where banks are required to hold elevated levels of regulatory capital. The model examines the two distinct responses of the banking sector to more stringent regulation: an increase in lending rates or a reduction in the dividend payout ratio. In the more likely scenario where banks increase lending rates, this is found to induce a shift towards a ‘new normal’, where long-term investment, consumption and output levels are lower. Results of counter-factual analysis suggest that the RBA somewhat responded to the widening of spreads throughout the GFC. A revised Taylor rule is proposed in which the central bank responds to lending spreads. The results suggest that a response to spreads in the policy rule can improve upon the standard Taylor rule, however this improvement is dependant on the source of disturbances to the system.
1 Introduction

The impact of macro-prudential regulation has been well documented in economic literature. Stringent increases in mandatory bank capital adequacy ratios have been found to markedly influence bank lending rates, and consequently, economic growth and key macroeconomic aggregates. As a result, macro-prudential regulation has, in the vast literature, been found to influence monetary policy, as the policy rate is estimated to fall in order to offset contractions in economic growth and activity. This thesis seeks to explore the extent to which potential increases in bank capital regulation, as part of wider macro-prudential regulation, impact upon bank lending spreads, macroeconomic aggregates and the conduct of monetary policy.

The Global Financial Crisis (GFC) highlighted the fragility and systematic risk inherent in the globalised financial system. As a result, macro-prudential regulation was again brought to the forefront of macroeconomic and financial discourse around the globe, including Australia. The Australian Prudential Regulation Authority (APRA) implemented the Basel II framework, which lifted capital requirements, in early 2008 prior to the financial crisis. However, following the financial crisis, further measures were implemented to the existing framework in order to target the capital adequacy of the banking sector.

In the five months succeeding the onset of the GFC, increased financial instability and the contraction of activity spurred a period of expansionary monetary policy with the policy rate being reduced by 300 basis points. Lending spreads, which are defined as the spread between retail lending rates on household and commercial loans and the central bank’s policy rate, increased significantly throughout this period. One factor which increased wholesale funding costs, and subsequently lending rates, for Australian banks was the deterioration in global credit conditions. A second proposed factor which further contributed to the widening of lending spreads is the aforementioned targeted increases in capital adequacy in the banking sector. The widening of lending spreads and the actions of the central bank are illustrated in Figure 1.
Increased lending spreads are expected to have a contractionary impact upon macroeconomic activity, as higher lending rates stifle investment and constrain consumption. Indeed, APRA has suggested that targeted increases in capital adequacy are likely to downwardly shift investment and output towards a ‘new normal’, reflecting the structural change in the financial system.\(^1\) However, to the best of my knowledge estimates of the impact capital adequacy regulation will have upon macroeconomic aggregates have not been examined in an Australian context. Additionally, increased lending rates, independent of any explicit involvement from the central bank, may invoke a policy response. The results of this thesis suggest that throughout the GFC, the Reserve Bank of Australia may have taken into account the dramatic widening of spreads when setting monetary policy. The calibrated Gerali et al. (2010) model used in this thesis suggests the steady-state cash rate is not a function of macro-prudential regulation, but rather a function of the steady-state inflation rate, household discount factor and the elasticity of deposits.

As the central bank cannot offset contractionary increases in lending rates through an adjustment of the steady-state cash rate, the standard Taylor policy rule is adjusted in order to target wider lending spreads in the dynamic state. Whilst there is a vast literature surrounding the use of asset prices and credit in augmented Taylor rules, this thesis seeks to address the proposals of Taylor (2008) in light of increased capital regulation, where monetary policy responds to widening spreads. In the model presented in this thesis, the Taylor policy rule is adjusted à la Iacoviello (2005) to

\(^1\)Australian Prudential Regulation Authority (APRA) (2012)
incorporate a reaction to widened lending spreads which may be in response to a permanent increase in capital adequacy regulation or a cyclical financial shock such as the GFC.

A Dynamic Stochastic General Equilibrium (DSGE) model is used in this thesis used to estimate and capture the financial and policy implications of increased macro-prudential regulation in Australia. The model, initially estimated in Gerali et al. (2010) for the European economy, incorporates a stylised banking sector in order to capture the interaction between the financial markets and the rest of the economy. Moreover, the model is rich in the ability to assess bank capital adequacy, and the implications for bank lending rates. Importantly, this model incorporates a Taylor style monetary policy rule. This allows for a platform to assess the performance of revised policy rule responding to lending spreads.

This thesis makes several useful contributions to the literature. The first is an estimation of the impact potential macro-prudential regulation may have upon the Australian banking sector and macroeconomic aggregates which has not been explored by previous literature in an Australian context.

The secondary contribution is an assessment of the implications of macro-prudential regulation on the conduct of monetary policy. Moreover, the impact of revised policy conduct on the response of key macroeconomic variables is illustrated. This thesis finds that for an aggregated variety of shocks, a policy rule responding to lending spreads outperforms the baseline rule and leads to improved stabilisation of policy objectives. Additionally, my model finds that revisions to the baseline Taylor rule have implications for the mechanism of monetary policy and conventional responses to inflation and output.

This thesis proceeds as follows. Section 2 provides a summary of bank capital regulation in Australia. Section 3 provides an overview of the literature on macro-prudential regulation and DSGE models. Section 4 outlines a sketch of the theoretical model, highlighting the implications of the monopolistically competitive banking sector and financial intermediation. Section 5 describes the data and calibration of the model and Section 6 reports the results of the model estimating the impact of potential Australian regulation on lending spreads and macroeconomic aggregates. Section 7
analyses the monetary policy implications of capital adequacy regulation and examines
the consequences of modifying the Taylor rule. In light of the results, Section 8
summarises the key results and concludes.
2 Background of Capital Regulation

In this section, I will provide an overview of the regulatory frameworks which inform the bank capital adequacy requirements. Furthermore, I will provide a background on Australian bank capital regulation and the changing frameworks and objectives of regulation.

A primary element of the Australian Prudential Regulation Authority’s (APRA’s) macro-prudential framework is a set of requirements ensuring Australian Deposit taking Institutions (ADIs) hold sufficient regulatory capital as a buffer against risks undertaken. The capital standards set by APRA largely follow those set by the Basel Committee, which is an international committee of banking supervisory authorities.

2.1 Basel Capital Accords

Prior to the Global Financial Crisis, there were two international capital accords: the Basel Capital Accord in 1988, commonly referred to as Basel I, and the International Convergence of Capital Measurement and Capital Standards, referred to as Basel II. These international accords were designed to increase the standardisation of global regulatory requirements. APRA implemented the measures in Basel II in early 2008.

The Basel II framework has three ‘Pillars’: Pillar 1 sets out the minimum capital requirements; Pillar 2 addresses the supervisory review process; and Pillar 3 imposes disclosure requirements in order to encourage market discipline. Internationally, throughout the financial crisis, particular instruments of capital that were included in the framework did not absorb losses as they were intended to do so. Specifically, under the Basel II framework, a large proportion of the capital requirements were able to be met by low quality capital instruments. These instruments, such as subordinated debt, did not absorb losses as expected.

Following the Global Financial Crisis, where the deficiencies of the Basel II capital reforms were exposed, the Basel Committee endorsed the Basel III capital reforms. The framework of requiring minimum capital requirements and assessing capital on a risk-weighted basis remained the same from the previous Basel Accords. However, Basel III increased the minimum levels of capital to be held against risk-weighted assets and introduced far more stringent criteria for capital to be classed as “regulatory capital”.

Basel III also introduced additional regulations, such as targeting a minimum leverage ratio of banks and introducing liquidity requirements. An assessment of the implications of liquidity and leverage requirements is beyond the scope of this thesis. The focus of this thesis is predominantly on the impact of increased bank capital regulation. Whilst the weaknesses of the Basel II framework were not exposed in Australia (due to policy responses and the fact that the banking sector did not suffer substantial losses), APRA had planned to implement the Basel III reforms, taking effect on 1 January 2013.

2.2 APRA and Basel III

With APRA’s adoption of the Basel III framework, there are now substantial measures in place to increase bank capital levels, with the aim of buffering against risk and future instability in the financial sector. The framework requires an increase in the minimum amount of capital required to be held by banks to 4.5% of Risk-Weighted Assets (RWA) and the Tier 1 Capital Ratio to 6%. Furthermore, a conservation buffer is included above and beyond the previously mentioned minimum capital requirements. 2.5% of additional common equity must be held by banks. The new requirements of Basel III are intended to be phased in globally as of 2013, with a schedule to be completely implemented by the 1st January 2019.2 Furthermore, APRA has proposed an accelerated implementation period for some aspects of the Basel III framework, particularly the minimum capital requirements and the additional capital buffer.

Australian Prudential Regulation Authority (APRA) (2012) highlights that there are long-term economic impacts of the Basel III reforms including: higher funding costs and lower returns on equity for ADIs; increased lending rates from banking institutions; a slower increase in aggregate borrowings; and slower GDP growth. These impacts are quantitatively estimated in Macroeconomic Assessment Group (2010a), Macroeconomic Assessment Group (2010b) and Slovak and Cournède (2011). Whilst some Australian data was included in Macroeconomic Assessment Group (2010a) and Macroeconomic Assessment Group (2010b), the estimates are predominantly made on European data and aggregated across major economies. Furthermore, the contributions by Australian representatives did not include bank-augmented DSGE models. Therefore it is unlikely these estimates will strictly hold in an Australian situation. To the best of my

2See Basel Committee on Banking Supervision (BCBS) (2010) for a detailed explanation of the proposed regulation and timeline
knowledge, no quantitative estimates have been made for the Australian economy using a similar framework. This thesis seeks to address this gap and provide estimates of the increase in lending rates and the subsequent implications for output, consumption, aggregate borrowing and investment for the Australian economy of increased capital regulation.
3 Literature Review

The theoretical and empirical literature on the implications of macro-prudential regulation, particularly bank capital regulation, is vast. This literature can be broadly categorised by the types of models and approaches used to address these implications. This thesis uses a Dynamic Stochastic General Equilibrium (DSGE) model and as a result falls into the category of dynamic models. Models in this category are a branch of general equilibrium theory and aim to explain aggregate macroeconomic dynamics through a model derived from microeconomic foundations.

DSGE modelling is largely comprised of two contrasting schools of thought, Real Business Cycle (RBC) theory and New Keynesian theory. This thesis, and the majority of the models in the macro-prudential literature are developed under New Keynesian assumptions. As a result, this review will focus on New Keynesian DSGE models. These models traditionally have featured limited or no financial flows between agents in equilibrium, based upon the assumptions developed in Modigliani and Miller (1958). The majority of past literature does not address the role of the financial sector in intermediation and the propagation of the business cycle.

3.1 Financial Frictions

The seminal paper of Bernanke et al. (1999) was one of the first models to incorporate financial frictions, challenging previous models based upon Modigliani and Miller (1958), where it is assumed funding activities have no relevance to spending decisions. Financial frictions are incorporated where borrowers face some external finance premium. This premium reflects the different costs faced by the borrower of financing internally versus externally. Importantly, this framework establishes a connection between firms’ borrowing costs and net worth. The external finance premium is countercyclical and therefore amplifies fluctuations in aggregate borrowing, investment and output. Bernanke et al. (1999) therefore develop a model where the financial friction propagates shocks to the economy and serves to intensify fluctuations of the real business cycle. The mechanism developed in this paper is recognised in the literature as the “financial accelerator”.

In reality, firms and households’ ability to borrow is largely determined by their balance sheets. That is, borrowing is commonly collateralised against physical assets. Kiyotaki
and Moore (1997) explore this relationship, where lenders cannot force borrowers to repay debts and as a result, land and capital are used as both factors of production and collateral for loans. The authors find that the collateralised debt obligations act as a substantial transmission mechanism, where shocks are amplified and spill over to other sectors. However, Kiyotaki and Moore (1997) ignore any differences between lending rates and the policy rate, and as a result there was no characterisation of the role of financial intermediaries in the economy.

Iacoviello (2005) integrated the key innovations from both of these papers where the financial accelerator mechanism à la Bernanke et al. (1999) is combined with household collateral debt obligations developed in Kiyotaki and Moore (1997). Nominal debt contracts are included in this framework in order to capture the fact that in low inflation countries, the majority of debt contracts are in nominal terms. Furthermore, the inclusion of nominal debt contracts enables the consideration of the distributional consequences of nominal rigidities, as per Fischer (1993), where spending reacts in a hump-shape to an inflation shock. Iacoviello (2005) finds that the inclusion of these rigidities to the model improves the models’ match to key properties of the data. However, similarly to Kiyotaki and Moore (1997), this framework does not account for the role of financial intermediation in any substantial sense.

The credit frictions introduced into the models of Bernanke et al. (1999), Kiyotaki and Moore (1997) and Iacoviello (2005) all implied that the borrowing constraints were binding. While Kiyotaki and Moore (1997) and Iacoviello (2005) included the concept of collateralised borrowing, these models did not consider the possibility of agents defaulting on loans. Carlstrom and Fuerst (1997) developed a model where costs are endogenous and therefore fluctuate with the business cycle allowing the possibility of defaults to occur in equilibrium. This is developed as lending is enabled to exceed net worth and therefore default is an equilibrium phenomena. The authors, similar to the findings in earlier papers, conclude that the inclusion of financial frictions amplifies macroeconomic fluctuations.

This framework was built upon by Faia and Monacelli (2007), where the authors study optimal monetary policy and question the inclusion of asset prices in the policy rule. The authors use a different method of evaluation of policy rules from that employed in Iacoviello (2005) and the majority of the literature. The optimal policy is determined by
a welfare function which includes workers’ and entrepreneurs’ welfare, as opposed to the conventional method of analysing the trade-off of inflation and output volatility. The methods used by the authors in order to assess optimal policy are similar to those used in Curdia and Woodford (2010), as discussed later. By incorporating the possibility of default, these models introduce an additional aspect that may improve the assessment of the impact credit has upon business cycle fluctuations. These models incorporating the possibility of default introduce an additional aspect that may improve the assessment of credit. This thesis however does not utilise a model enabling equilibrium default, as it follows the assumptions in Iacoviello (2005).

The aforementioned models, whilst incorporating financial frictions, ignore the supply side of credit and focus primarily on demand through exploring the balance sheets of borrowers. Gerali et al. (2010) highlight that while policymakers have highlighted the importance of the supply side of credit, the majority of quantitative macroeconomic models have abstracted from them. In reality, as seen during the GFC, the supply side of credit has the potential to propagate shocks and influence the business cycle. The supply side factors of credit include the degree of competitiveness in the banking sector and the overall financial health of the banking system.

The incorporation of a banking sector into these existing models allows for some aspect of credit supply analysis as the balance sheet of the bank and the market structure of the banking system may provide some transmission and amplification of shocks. Christiano et al. (2007) incorporate a banking sector into a DSGE model in order to capture these effects. The authors find that the financial frictions from the financial accelerator mechanism, developed in Bernanke et al. (1999) play a much larger role in the propagation of shocks and amplification of business cycle fluctuations than the frictions of the banking sector. This result primarily stems from the assumptions of the incorporated banking sector. The banking sector is assumed to be perfectly competitive, and as a result, banks do not have any market power in setting rates for households and firms. The model used in this thesis incorporates an imperfectly competitive market, where banks enjoy market power, and as a result, the frictions of the banking sector are expected to play a larger role, which more closely resembles existing market conditions in the Australian banking sector.

The GFC, and subsequent destruction of bank capital, highlighted the importance of
the balance sheet of banks and the relationship to economic activity. Meh and Moran (2010), similarly to the model explored in this thesis, Gerali et al. (2010), develop a New Keynesian DSGE model where bank capital plays an important role in the propagation of shocks. Interestingly, bank capital is used to mitigate a moral hazard problem between banks and creditors. This bank capital mechanism serves as a constraint on attaining loanable funds. As a result, shocks originating outside the financial sector, primarily technology shocks, are exacerbated by the introduction of the bank capital mechanism. That is, a technology shock will exacerbate moral hazard by reducing the value of project returns, and therefore in order to keep the contracts, banks must de-lever. In this process, investment largely bares the brunt of de-leveraging, which leads to lower bank net worth in the future and propagates the effects of the shock.

Meh and Moran (2010) also find that shocks originating in the banking sector lead to recessionary periods, with substantial contractions in output and investment. Further, they find that economies with higher levels of bank capital ratios experience far smaller contractions in lending and subsequently output. As a result of the interactions between bank capital and macroeconomic aggregates, Meh and Moran (2010) find that bank capital improves the ability of economies to absorb shocks, and as a result, influences monetary policy. This thesis follows on from this analysis of the influence on monetary policy and addresses the possible implications of regulation upon the conduct of monetary policy, both in the steady and dynamic state.

### 3.2 Impact of Macro-prudential Regulation

In response to Basel III regulatory reforms, Dynamic Stochastic General Equilibrium (DSGE) models were developed in order to assess the implications of the proposed regulation. Primarily, these models sought to assess the effect additional regulation may have upon the transmission of monetary policy. The impact of macro-prudential regulation has also been addressed through the use of accounting identities, such as the method in Elliott (2009). However, this review will focus upon the use of DSGE models to estimate the effects of capital adequacy regulation.

The majority of the literature relating to the impact of capital adequacy regulation focuses upon the impact reforms may have upon growth. Following the initial recommendations of additional regulation, the Basel Committee on Banking Supervision (BCBS) assessed the long-term economic impacts of the proposed reforms.
Macroeconomic Assessment Group (2010a) and Macroeconomic Assessment Group (2010b) use a variety of macroeconomic models, including DSGE models in order to assess the costs of the proposed regulation. These publications assess the implications of regulation for bank lending spreads and then infer the impact on economic growth. The authors find that increases in the capital adequacy ratio will yield a median increase in lending spreads of approximately 14 basis points.

The results from the aforementioned papers estimate a contraction of output of roughly 0.15% per 1% increase in the capital adequacy ratio. Angelini et al. (2011) summarise the results from these papers in an assessment of the DSGE models available to explore the implications of the proposed reform. The results found using a variety of calibrated and estimated DSGE models, including the model used in this thesis, are also broadly in line with the findings of Macroeconomic Assessment Group (2010a), Macroeconomic Assessment Group (2010b) and Basel Committee on Banking Supervision (BCBS) (2010), where output is found to contract roughly 0.15% per 1% increase in the capital ratio and lending spreads are found to widen by approximately 13 basis points.

As mentioned previously, these papers analyse the impact of macro-prudential on lending spreads and output. Macroeconomic Assessment Group (2010b) identify that the contraction of output can be offset by an easing of monetary policy, where the central bank responds to output and inflation. However, the authors do not consider the implications for monetary policy of the introduction of regulation and any conflicts that may arise between the policies. The vast majority of the literature does not examine the implications for monetary policy outside of any response to output loss.

Angelini et al. (2011) assess the interactions between monetary policy and macro-prudential policy. Macro-prudential policy is modelled to follow capital regulation, where banks are required to hold a specific target ratio of bank capital to loans. Furthermore, monetary policy is assumed to follow a standard Taylor rule; responding to deviations of inflation from the target rate and the growth rate of output. Angelini et al. (2011) introduce the possibilities of cooperation between the macro-prudential authority and the central bank. The authors find that the central bank’s strong reaction to output growth and the pro-cyclicality of macro-prudential policy implies substantial problems of coordination under a policy of non-cooperation between monetary policy and macro-prudential policy. Angelini et al. (2011) find that in periods of no financial
stress, macro-prudential policy has little to contribute to macroeconomic stability, and should not be treated as a substitute for monetary policy, but as a tool to compliment the conduct of monetary policy when dealing with specific shocks, particularly financial in nature.

Angelini et al. (2011) identify that when the economy is hit by a financial shock, macro-prudential policy is effective in stabilising key macroeconomic aggregates. The authors conclude that monetary policy can “lend a hand” to the macro-prudential authority in the case of financial shocks. These results further provide scope for the analysis undertaken in this thesis. While macro-prudential regulation appears to be effective in the presence of financial shocks, there still exists co-ordination issues between the central bank and these regulatory authorities. These co-ordination issues are found to increase the volatility of policy objectives which results in sub-optimal outcomes for macroeconomic aggregates. This thesis seeks to side-step the issue by widening the scope of monetary policy to include financial variables in the policy rule and assess the relative performance of the revised rule.

Roger and Vlcek (2011) develop a DSGE similar to that employed by Angelini et al. (2011) in order to assess the implications of higher capital and liquidity requirements on the macroeconomy. The findings are also broadly in line with those from Angelini et al. (2011), however the methods employed highlight some interesting characteristics associated with macro-prudential regulation not indicated in the earlier literature. Roger and Vlcek (2011) consider the transitional impacts of introducing higher capital requirements, whereas the majority of literature focuses upon the immediate impacts of capital regulation. Importantly, Roger and Vlcek (2011) find that the macroeconomic costs of higher capital requirements will be moderate if they are phased in over an extended period of time. The authors identify different strategies for banks to adjust to capital regulation and find that implementing regulation over a longer period enables banks to adopt strategies that do not drastically reduce lending.

Roger and Vlcek (2011) illustrate that a longer implementation schedule improves the ability of monetary policy to mitigate the effects of regulation. This finding corroborates the results in Angelini et al. (2011), where the authors find that monetary policy is more effective in stabilising the economy than macro-prudential regulation in the case of non-financial shocks. This thesis seeks to continue this analysis, where the effectiveness of
monetary policy in stabilising shocks is assessed with the addition of an indicator of financial stability in the policy rule.

Angelini and Gerali (2012) use the DSGE model estimated in Gerali et al. (2010) in order to assess the implications of capital regulation upon the European banking sector. The authors build upon the framework of Roger and Vlcek (2011) and identify various strategies available to banks in order to adjust to more stringent regulation. Angelini and Gerali (2012) illustrate that the reaction of the banking sector to regulation may have a non-negligible impact upon the macroeconomic outcome. The results suggest that the banking sector, in its profit maximising role, prefers to pass on the burden of increased regulation to the consumer in the form of higher lending rates. The authors identify three widely debated options available to banks to react to increased regulation. The analysis conducted in later sections builds upon this framework in assessing the implications regulation may have upon the Australian banking sector in the steady-state.

3.3 Optimal Taylor Rule

The Taylor rule was first proposed by John Taylor in his seminal paper; Taylor (1993). However, there is much discussion in economic literature regarding modifications to the standard Taylor rule and the implications for economic performance.

Monetary Policy targeting and the intricacies of various policies are studied in a New Keynesian framework in an influential paper; Gertler et al. (1999). The authors identify that optimal monetary policy will implicitly incorporate inflation targeting. Moreover, commitment to inflation targeting is found to improve the transition of inflation to the optimum, relative to discretionary policy. However, the authors question how the central bank could deal with financial stability through monetary policy rules. Gertler et al. (1999) postulate that following the 1987 U.S stock market crash, the Federal Reserve Board reduced interest rates, but this was based largely on intuition without any guiding policy rule.

As Gertler et al. (1999) find, when the central bank follows a rule of commitment, the variables of interest, namely inflation, are improved. In late 2007 and early 2008, a simple Taylor rule would suggest the Federal Reserve would not have any ground for expansionary action, however during this period the Fed aggressively reduced its
policy rate target\textsuperscript{3}. Curdia and Woodford (2010) suggest that the Federal Reserve was paying attention to indicators highlighting problems in the financial sector.

In light of the benefits of commitment and worsening conditions of the financial sector spilling over into the real economy, Taylor (2008) proposed a revision to the baseline Taylor rule suggesting the incorporation of credit indicators into the systemic component of monetary policy. Taylor highlights the importance of the banking sector spreads to the monetary policy transmission mechanism and illustrates that incorporating financial market spreads into the policy rule will improve transparency and predictability in periods of financial stress. Taylor suggests subtracting “a smoothed amount of this spread from the interest rate target that would otherwise be implied by developments with inflation and real GDP growth”\textsuperscript{4}.

In reaction to the proposals of Taylor (2008) and in the aftermath of the global financial crisis, a segment of DSGE literature constituting revised policy rules with financial components has evolved. Curdia and Woodford (2010) developed a DSGE model incorporating financial frictions and studied the implications and desirability of revised policy rules in response to a variety of disturbances and shocks. A spread adjusted Taylor rule is found to improve upon the standard Taylor rule, for particular shocks, by maximising expected average utility of households. Curdia and Woodford (2010) find the optimal size of the response to spreads is far smaller than that proposed by Taylor, where he suggests a one-for-one pass through of movements in spreads to the target policy rate. The framework developed in Curdia and Woodford (2010) models the financial sector as an exogenous interest rate spread. This differs from the framework employed in this thesis, where the financial accelerator mechanism and a stylised banking sector are incorporated in order to generate an endogenous interest rate spread.

Gertler and Kiyotaki (2010) build upon the framework developed in Bernanke et al. (1999), however identify the role of financial intermediaries and the agency problem between these intermediaries and borrowers. This is done in order to develop an endogenous spread between interest rates on deposits and loans. Gertler and Kiyotaki (2010) develop upon the literature surveying the impact of monetary policy that reacts to financial indicators. However, unlike Curdia and Woodford (2010), the authors

\textsuperscript{3}Curdia and Woodford (2010)\textsuperscript{4}Taylor (2008)
focus upon credit policies available to the central bank in the form of unconventional monetary policy, such as quantitative easing.

The literature has yet to develop upon DSGE models with imperfectly competitive banking sectors with revised Taylor rules incorporating financial aspects and targets. Bhattarai et al. (2013) also develop a financial imperfections DSGE model incorporating a revised Taylor rule, where (in addition to the standard transmission mechanism) asymmetric net asset positions are introduced to generate a wealth redistribution role for monetary policy.

Bhattarai et al. (2013) find that with the introduction of the wealth redistribution role and the standard interactions between nominal and financial frictions, a simple Taylor rule targeting zero inflation is never optimal. Furthermore, as found in Curdia and Woodford (2010), the introduction of a financial disturbance that widens the banking spread results in a deep cut to monetary policy, however the standard Taylor rule allows for a “significant output gap and a negative response of inflation”. Bhattarai et al. (2013) find that the performance of the revised Taylor rule improves in response to a financial disturbance, as the nominal interest rate, through reacting to the spread is able to track the efficient rate of interest in the market and thus mitigate the negative output and inflation responses to the shock.

Recently, the model developed in Gerali et al. (2010) has been simplified in order to assess the implications of monetary policy ‘leaning against the wind’ in Gambacorta and Signoretti (2013). The authors simplify the original model excluding the existence of impatient households. Gambacorta and Signoretti (2013) investigate the optimal policy considering a policy response to asset prices, à la Iacoviello (2005) and a response to the growth of aggregate credit. In contrast to Iacoviello (2005), the authors find substantial improved macroeconomic stabilisation where the policy rate responds to asset prices. Moreover, the authors identify that responding to aggregate credit does not appear to improve the objective of the policy marker. This result is interesting given the restrictions placed upon the model in the simplification. The analysis in this thesis looks at the non-simplified Gerali et al. (2010) model and addresses the question of whether or not responding to lending spreads appears to improve stabilisation.

The introduction of revised Taylor rules following the Financial Crisis have enabled

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policy evaluation, however thus far have not been incorporated into models with a structural banking system and macro-prudential requirements. This thesis aims to assess and evaluate the existence of macro prudential regulation and its implications for revised policy rules. A simple set of policy rules incorporating spreads are also proposed as in the literature, however, with the existence of the banking sector and macro prudential regulation, the revised rules may have varying implications.

3.4 Australian Literature

In the Australian literature, the “financial accelerator” mechanism, such as that developed initially in Bernanke et al. (1999), has only very recently been incorporated into small and medium-scale DSGE models. Robinson and Robson (2012) build upon the framework developed in Iacoviello and Neri (2010), where a financial accelerator mechanism is augmented with key aspects of housing construction. The authors incorporate open-economy features and estimate the model using Australian data. Robinson and Robson (2012) use the framework to investigate how housing shocks propagate through the real economy, and whether the inclusion of the financial accelerator mechanism enables the model to more accurately reflect the properties of the data. The authors identify that housing sector specific shocks do not have substantial influence on developments outside the housing sector. Moreover, they highlight the inclusion of the financial accelerator mechanism leads to consumption dynamics that are broadly consistent with wealth effects from housing.

Similarly to the international literature, this model does not allow for a substantial role of financial intermediaries. Instead, only the demand side of credit is considered. The authors identify that incorporating a banking sector would likely improve the model fit and enable the analysis of international funding of domestic financial institutions. Furthermore, the incorporation of a banking sector enables the investigation of questions regarding the financial stability of financial intermediaries and house prices.

The Australian General Equilibrium literature therefore does not have any contributions pertaining to the conditions of the supply side of credit markets, and how these interactions explain shifts in key macroeconomic variables. Moreover, there have not, to my knowledge, been any substantial estimates of the impact of macro-prudential regulation upon lending spreads, macroeconomic aggregates or monetary policy. APRA highlight that an increase in the amount of regulatory capital required to be held
by banks is likely to result in an increase in bank lending rates, lower GDP growth and reduced lending growth.\textsuperscript{5} However, no substantial estimates of the impact of this regulation have been made for the Australian specific situation. As a result, this thesis seeks to calibrate a General Equilibrium model, encompassing both financial frictions and a stylised banking sector, to the Australian macroeconomy in order to explore the implications of macro-prudential regulation on economic aggregates and monetary policy.

\textsuperscript{5}Australian Prudential Regulation Authority (APRA) (2012)
4 The Theoretical Model

This thesis derives and extends upon a Dynamic Stochastic General Equilibrium model developed in Gerali et al. (2010) as a framework for analysis and extensions proposed in later chapters. This framework is chosen as it seeks to illustrate the role of credit supply factors in business cycle fluctuations. Moreover, within this banking sector, banks are required to hold exogenous target levels of capital in order to satisfy regulators. This provides a dynamic platform in order to explore the implications of macro-prudential regulation upon financial markets and monetary policy.

Microeconomic theory generally finds market power and imperfect competition as a key feature of the banking sector. Claessens and Laeven (2004) find using bank-level data for 50 countries that most banking markets can be seen as monopolistically competitive. Australian bank concentration was estimated far higher than the sample averages of 50 countries. It is therefore clear to see the necessity in Australia to model an imperfectly competitive banking market. The measure of market power throughout this thesis is the interest rate elasticity of loan and deposit demand.

4.1 Sketch of the Model

The model developed departs from the standard New Keynesian assumption of a representative household, as households differ in preferences and behaviour. The derivations of the equations presented in this section and the entire model are presented in Appendix 2. This model is solved in Dynare by linearising the structural equations in Appendix 2 around their respective steady-state. The steady-state equations are presented in Appendix 3.

4.1.1 Households

The economy is comprised of two groups of households, Patient and Impatient. The difference in preferences is largely determinative of the balance sheet of the household. Impatient households accumulate housing stock funded by debt. The representative patient household does not borrow and in fact is a source of funding for the banking sector. Patient households therefore have a higher discount factor than that of impatient households and entrepreneurs. Impatient households face borrowing constraints tied to the value of assets à la Iacoviello (2005). The borrowing constraint the impatient
Households faces is as below:

\[(1 + r_{B}H) \cdot b_{I}^{t}(i) \leq m_{I}^{t} E_{t} \left[q_{H}^{t} h_{I}^{t}(i) \pi_{t+1}\right] \tag{1}\]

where \(r_{B}H\) is the retail rate on housing loans, \(b_{I}^{t}\) is the loan value, \(m_{I}^{t}\) is the Loan to Value ratio, \(h_{I}^{t}\) is the housing stock and \(q_{H}^{t}\) is the real house price. The amount that can be borrowed is a function of the quality of the loan, the LTV ratio, and the expected value of the asset.

Households as a whole face budget constraints while maximising expected utility derived from consumption, housing and leisure. The budget constraint for patient households is as below:

\[c_{I}^{P}(i) + q_{H}^{t} h_{I}^{t}(i) + d_{I}^{P}(i) \leq w_{I}^{P} l_{I}^{P} + \frac{(1 + r_{d}^{t-1})d_{I-1}^{P}(i)}{\pi_{t}} + t_{I}^{P}(i) \tag{2}\]

where \(c_{I}^{P}\) is consumption, \(d_{I}^{P}\) is the volume of deposits, \(w_{I}^{P} l_{I}^{P}\) is total income, the term \(\frac{(1 + r_{d}^{t-1})d_{I-1}^{P}(i)}{\pi_{t}}\) is interest income from bank deposits and \(t_{I}^{P}\) is dividends received from profits of the retail and banking sector. The differences between the Patient Household and Impatient Household budget constraint are that the impatient households must fund interest payments on debt; do not receive dividends; and also face borrowing constraints.

4.1.2 Entrepreneurs

Entrepreneurs produce homogenous intermediate goods using a combination of capital and labour. Capital is sourced from capital good producers, whereas labour is supplied by households. Entrepreneurs also maximise expected utility derived from consumption subject to budget constraints. Furthermore, entrepreneurs, like impatient households, face borrowing costs constrained by collateral, which in the case of entrepreneurs, is capital not commercial property. The production function of the entrepreneur is as follows:

\[y_{I}^{E}(i) = a_{I}^{E} \left[k_{I-1}^{E}(i) u_{I}(i)\right]^\alpha l_{I}^{E}(i)^{1-\alpha} \tag{3}\]

where \(y_{I}^{E}\) is the wholesale good, \(a_{I}^{E}\) is stochastic TFP, \(\alpha\) is the share of capital in the production function, \(k_{I}^{E}\) and \(l_{I}^{E}\) represent the capital and labour inputs available to firms and \(u\) is the utilisation rate of capital.
4.1.3 Labour Market

Workers, comprised of patient and impatient households, sell their slightly heterogenous labour types through unions. For each labour type, there are unions for patient and impatient households. The union sets nominal wages by maximising utility derived from wages and leisure subject to adjustment costs faced for changing wages. The labour unions maximise utility subject to demand for labour from entrepreneurs. The labour choice for households of type $s$ is illustrated by the following wage Phillips Curve:

$$\kappa_w \left( \pi_t^{ws} - \pi_{t-1}^{ws} \pi_{t-1}^{1-\epsilon_w} \right) \pi_t^{ws} = \beta_s E_t \left[ \frac{\lambda_t^{s+1}}{\lambda_t^s} \kappa_w \left( \pi_t^{ws} - \pi_{t-1}^{ws} \pi_{t-1}^{1-\epsilon_w} \right) \frac{\pi_{t+1}^{ws} - \pi_t^{ws}}{\pi_{t+1}^{ws}} ^2 \right]$$

$$+ (1 - \epsilon^l) l_t^f + \frac{\epsilon^l l_t^{s+1+\phi}}{\omega_t^s \lambda_t^s}$$

where $\omega_t^s$ is the real wage and $\pi_t^{ws}$ is nominal wage inflation for the respective households. $\phi$ represents labour disutility, $\epsilon^l$ is the mark-up in the labour market and $\lambda^s$ is the multiplier of the budget constraint for the representative household. $\kappa_w$ represents adjustment costs for changing wages.

4.1.4 Banks

As a result of the heterogeneity between the discount factors of households, financial flows exist in equilibrium. Patient households (who do not borrow) purchase assets in the form of deposits from the banking sector. Impatient households and Entrepreneurs borrow a positive volume of loans. A key distinction in this model to other New Keynesian models with financial frictions is that the banking sector is monopolistically competitive and as a result, sets the prices on loans and deposits so as to maximise profits. The lending of the banking sector is financed by patient household deposits and capital. Capital is accumulated from the profits of the bank as below

$$\pi_t K_t^b = (1 - \delta) K_{t-1}^b + (1 - \omega^b) J_{t-1}^b$$

where $(1 - \omega^b) J_{t-1}^b$ is profits following the payment of dividends, $\delta$ is the depreciation rate of capital, $K^b$ is bank capital and $\pi_t$ is the inflation rate.

The banking sector, or model bank, given the symmetric equilibrium assumption, is separated into three components; the Wholesale bank, the lending side of the retail bank and the deposit taking side of the retail bank. This is a simplifying assumption
in order to separate utility functions. The Wholesale bank can be thought of as the ‘Head Office’ of the bank; where the lending and deposit activities are aggregated in order to maximise utility of the banking sector subject to constraints.

The key informative constraint for this thesis relates to the leverage position of the bank. That is, banks face an adjustment cost and penalty when capital adequacy ratios do not meet the targets set by an exogenous regulator.

\[ R_b^t = r_t - \kappa_{Kb} \left( \frac{K_b^t}{B_t} - v^b \right) \left( \frac{K_b^t}{B_t} \right)^2 \]  

(6)

where \( R_b^t \) is the wholesale lending rate, \( v^b \) is the exogenous capital adequacy target, \( \frac{K_b^t}{B_t} \) is the current capital adequacy ratio, \( \kappa_{Kb} \) is the adjustment cost for deviating from the target ratio and \( r_t \) is the policy rate. The wholesale lending rate is therefore a function of the nominal interest rate and the penalty associated for deviating from the capital adequacy target. In the steady state, the wholesale lending rate and wholesale deposit rate are equal to the nominal interest rate as a result of the no-arbitrage lending facility at the central bank. It is therefore clear to see that this relationship is central to the analysis of target capital adequacy ratios and the implications for lending rates explored in this thesis.

The banking sector generates profit through the spread between lending rates and deposits rates as below

\[ j_b^t = r_t b^H_t + r_t b^E_t - d_t - \frac{\kappa_{Kb}}{2} \left( \frac{K_b^t}{B_t} - v^b \right)^2 K_b^t - Adj_b^t \]  

(7)

where \( b^H_t, b^E_t, d_t \) are household and commercial lending volumes and deposit volumes and \( Adj_b^t \) relates to the adjustment costs for changing interest rates on loans and deposits. As the bank deviates from the target capital ratio, bank profitability falls. This provides an incentive to meet regulatory capital adequacy ratios.

**4.1.5 Capital & Final Goods Producers**

The capital goods firms are perfectly competitive and buy undepreciated capital from entrepreneurs. This industry is included in order to generate a market for capital and thus determine the real price of capital. The retail goods market is assumed to be monopolistically competitive. Firms in this industry purchase intermediate goods from
entrepreneurs, differentiate these goods and price them subject to sticky prices. Retail firms’ FOC introduce a non-linear Phillips curve as below:

\[
1 - \epsilon_t^y + \frac{\epsilon_t^y}{x_t} - \kappa_p \left( \pi_t - \pi_{t-1}^{ip} \pi_{t-1}^{1-\epsilon_p} \right) \pi_t + \beta_p E_t \left[ \lambda_{t+1}^{1-\epsilon_p} \kappa_p \left( \pi_{t+1} - \pi_t^{ip} \pi_1^{1-\epsilon_p} \right) \pi_t \frac{y_{t+1}}{y_t} \right] = 0
\]  

where \(\epsilon_t^y\) is demand price elasticity, \(\frac{1}{x_t}\) is the relative price of the good and \(\kappa_p\) is the adjustment cost of prices.

4.1.6 Monetary Policy

The central bank follows a Taylor style inflation targeting Monetary Policy rule, where inflation and output are the key targets, with reliance upon the inertia of nominal interest rates, as below:

\[
(1 + r_t) = (1 + r_{t-1})^{1-\phi_R} \left( \frac{\pi_t}{\pi} \right)^{\phi_R} \left( \frac{y_t}{y_{t-1}} \right)^{\phi_y(1-\phi_R)} \epsilon_t^r
\]

4.2 Proposed Extensions

In later sections, following the initial steady-state results, Equation 9 is revised. The policy response rule is adjusted to include a response to spreads.

\[
(1 + r_t) = (1 + r_{t-1})^{\phi_R} \left[ (1 + r) \left( \frac{\pi_t}{\pi} \right)^{\phi_x} \left( \frac{y_t}{y_{t-1}} \right)^{-\phi_y} \left( \omega_t^s \omega_s^s \right)^{-\phi_s} \right]^{1-\phi_R} \epsilon_t^r
\]

where \(\phi_s\) is the weighting applied to spreads in the policy rule and \(\omega_s^s\) is representative of lending spreads. As always, variables without time subscripts are steady state variables.

Of note is the negative sign governing the policy response to a deviation of lending spreads from steady state. This implies an increase in the lending rate from its steady state value should be met by a reduction in the policy rule.
5 Calibration

The key parameters of the model are calibrated to Australian sample data over the period 1993:Q1 to 2013:Q1. The sample period is selected in order to explore the entirety of the Australian business cycle. However, the sample period starting in 1993 does not capture two full business cycle periods in Australian history that may have been explored using data from the 1980s and capturing the “recession that Australia had to have” in 1990. Whilst incorporating earlier data may have made analysis more robust, given the importance of the Taylor rule in later analysis, calibrating inflation and nominal interest rates to the pre inflation targeting era may harm inference.

5.1 Borrowed Parameters

Some parameters are not calibrated to reflect the features of the Australian economy. These parameter values are borrowed from the estimation of the model in Gerali et al. (2010) to Euro Area data and are set to the median of the posterior distribution. These parameters are not calibrated as there is no real data to estimate their values for Australia. These parameters govern price and wage stickiness and the adjustment costs faced by banks to changing loan rates. A sensitivity analysis to these borrowed parameters is conducted in a later section.

| Table 1: Borrowed Parameters - Gerali et al. (2010) |
|-------------------------|--------|--------|
| Parameters | Description | Value |
| $\kappa_p$ | Price stickiness | 28.65 |
| $\kappa_w$ | Wage stickiness | 99.90 |
| $\kappa_i$ | Investment adjustment costs | 10.18 |
| $\kappa_d$ | Deposit Rate adjustment cost | 3.5 |
| $\kappa_{bE}$ | Firms lending rate adjustment cost | 9.36 |
| $\kappa_{bH}$ | Households lending rate adjustment cost | 10.09 |
| $\kappa_{Kb}$ | Bank capital deviation cost | 11.07 |
| $\iota_p$ | Price indexation | 0.16 |
| $\iota_w$ | Wage indexation | 0.28 |

Furthermore, the parameters governing the standard deviation and persistence of shocks are borrowed from Gerali et al. (2010) as the model is not estimated on Australian data.\(^6\)

\(^6\)The standard deviation of shocks and the AR coefficients of persistence are calibrated to the values
5.2 Banking Parameter Calibration

Banking parameters of the model are calibrated to replicate the sample averages of interest rates and spreads in the data across the sample period of 1993:Q1 to 2013:Q1. The primary parameter driving interest rates and spreads is the elasticity of demand to loan & deposit rates. The steady-state markdown / markup is specified as a function of the elasticities of demand to loan & deposit rates. For the deposit rate, the steady state markdown on the policy rate is specified as $\frac{\epsilon_d}{\epsilon_d - 1}$, where $\epsilon_d$ is the elasticity of demand to deposit rates. Given an average deposit rate of 432 basis points and an average spread between retail deposit rates and the policy rate of 85 basis points in annualised terms, $\epsilon_d$, the elasticity of demand to deposit rates is calibrated at -5.10. Using a similar technique for the steady state markups of loan rates, $\frac{\epsilon_{bs}}{\epsilon_{bs} - 1}$, $\epsilon_{bH}$, housing loans, and $\epsilon_{bE}$, commercial loans, are calibrated at 3.27 and 3.52 respectively.

The calibration above makes intuitive sense, as commercial loan rates are far more elastic than household loans. Household loans are largely comprised of mortgages, which are sticky and fluctuations in rates is unlikely to provoke any substantial bank switching behaviour. Furthermore, there exist almost no substitutes for mortgages, whereas firms may approach the capital markets for funding and as a result the elasticity of demand for loans to firms is higher. The parameter $\delta^b$ is calibrated to ensure that the ratio of bank capital to total loans matches the target capital adequacy ratio set by regulators.

Loan to Value (LTV) ratios are calibrated using aggregated banking data, however given the lack of depth of this data, LTV ratios are calibrated to a sample of 2008 to 2013. The sample is restrictive due to the commercially sensitive nature of the LTV ratio to the banking sector. Data is collected from APRA and proprietary bank research of Credit Suisse.\(^7\)

The discount factor of households, $\beta^P$, is found within the literature to have any value around 0.99 for patient households. In order to calibrate a steady state nominal interest rate of approximately 5% to match the sample Australian data, $\beta^P$ is calibrated imposing the following steady state equation for the nominal interest rate on the data; in Gerali et al. (2010). The parameters chosen, as in Gerali et al. (2010), are set to the median of the posterior distribution.

\(^7\)APRA’s Quarterly Authorised Deposit-taking Institution Property Exposures (QPEX) publication (2013)
\[ r = \left( \frac{\pi}{\beta^P} - 1 \right) \left( \frac{e^d - 1}{e^d} \right) \]  

(11)

As the steady-state markdown on the policy rate is calibrated to sample data as above, \( \beta^P \) is calibrated to 0.9958. Gross Inflation in the steady-state is set at 1.00658 to match the quarterly inflation rate of 0.658% in the sample period. With the steady state inflation rate, this calibrates the nominal interest rate at 5.18%, which coincides with the nominal interest rate of 5.17% in the sample data. \( \beta^I \), the discount factor of the impatient households, is set to 0.975 as in Iacoviello (2005).

### 5.3 Monetary Policy Rule Calibration

Iacoviello (2005) calibrates parameters for the monetary policy rule using estimates from an OLS regression of the Federal Funds rate on its own lag, past inflation and detrended output. This method is used to calibrate the parameters governing the monetary policy rule. For the period 1993:Q1 to 2013:Q1, an OLS regression of the Reserve Bank of Australia’s Official Cash rate on its own lag, inflation and output growth is conducted in order to calibrate monetary policy response weights.

Table 11 details the coefficient estimates of the OLS regression, with standard errors in parentheses. The values found for the sample period of Australian data are similar to those Iacoviello estimated for the U.S economy between 1974Q1 and 2003Q2. However, Australian sample data infers a higher degree of policy rate inertia.

The estimated coefficients are not directly translated to the calibrated parameters as a result of the specification of the policy rule in Gerali et al. (2010). The equation below highlights that the calibrated parameters of \( \phi_\pi \) and \( \phi_y \) also interact with the policy rate inertia. As a result, in order to calibrate the values estimated by OLS, the parameters are scaled upwards by \( 1 - \phi_R \).

\[
(1 + r_t) = (1 + r)^{1 - \phi_R} (1 + r_{t-1})^{\phi_R} \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi (1 - \phi_R)} \left( \frac{y_t}{y_{t-1}} \right)^{\phi_y (1 - \phi_R)} e_t^r
\]

(12)

Table 3 outlines the calibrated values for the parameters governing the policy rule. This OLS method may be susceptible to issues of endogeneity, as the error term in the monetary policy rule acts like a shock, however the shock is expected to adjust the policy rule, and as a result inflation. However, the policy weightings to responses
calibrated to Australian sample data over the period 1993:QI to 2013:QI are broadly in line with the Australian literature, and as a result, these endogeneity issues are looked over. Robinson and Robson (2012) estimate the policy inertia rate to be slightly lower, at a median of 0.79, inflation reaction to also be slightly lower at a median of 1.6 and find a similar weighting to output growth with a median of 0.35. As a result of the importance of policy inertia, the parameter $\phi_R$ is calibrated at 0.77, in line with the values in Robinson and Robson (2012) and Gerali et al. (2010).

Table 2: Monetary Policy Rule - Australian Sample Data Calibration

<table>
<thead>
<tr>
<th>Policy Rule</th>
<th>1993:QI - 2013:QI</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_R$</td>
<td>0.769</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>1.913</td>
</tr>
<tr>
<td>$\phi_y$</td>
<td>0.355</td>
</tr>
</tbody>
</table>

5.4 Investment Calibration

5.4.1 Fixed Capital Depreciation Rate

To calibrate the depreciation rate for fixed capital, the law of motion for the capital stock in steady state is imposed to the data, $\delta k = i$. The Annual National Accounts data published by the Australian Bureau of Statistics (ABS) is then used to infer a quarterly depreciation rate for physical capital (excluding housing investment). For the period 1993:QI to 2013:QI, a quarterly depreciation rate of 0.025 is found, similarly to Robinson and Robson (2012).

5.4.2 Weight of housing in utility function

The weight of housing in the utility function is calibrated using the method in Kulish et al. (2011) and values in Robinson and Robson (2012). 2011-2012 mean household disposable income per week was estimated at $1,550, implying an annual income of roughly $80,000.\(^8\) Based on 2011-2012 weekly housing data, average weekly housing costs for all households was $239.\(^9\) This implies a weighting of housing in the household utility function of 0.15. This is similar to the value found in Kulish et al. of 0.14 for 2007-2008 data samples. Robinson and Robson (2012) estimate the weight of housing at 0.2. Whilst the parameter calibration may fluctuate, the economic interpretations

\(^8\)ABS Cat No. 6253
\(^9\)ABS Cat No. 1301
are robust to changes in the parameter of housing. The weight is calibrated at 0.2 as in Gerali et al. (2010) and Iacoviello (2005).

5.4.3 Capital Share in Production Function

The capital share in the Australian production function takes differing values in the literature $\alpha \in [0.25, 0.5]$. Mean values of the capital share of income across the sample period estimates the capital share at 0.44.\(^{10}\) However, Gollin (2001) finds that employee compensation underestimates the labour share of income as it excludes the income of those who are not employees, but rather self employed. To account for this, varying multi-factor productivity data is also used in order to estimate the sample mean. The capital share is calibrated to 0.42, within the band of the literature and broadly in line with 0.35 calibrated in Robinson and Robson (2012).

5.5 Household Dynamics

As in Robinson and Robson (2012), the unconstrained share of households is estimated based upon the percentage of Australian households with outstanding mortgage debt. The share of unconstrained households, $\mu$, is set to 0.65 to reflect that approximately 35% of Australian households have outstanding housing debt.\(^{11}\) Whilst this rate has risen and fluctuated throughout the sample period, the results are robust to this parameter.

5.6 Elasticities & Markups

Outside of the banking sector, there are markups in the labour market and in the goods market, reflecting various elasticities of substitution. The steady state markup in the goods market, or the elasticity of substitution of goods is calibrated following Robinson and Robson (2012) and Gerali et al. (2010). Robinson and Robson (2012) calibrate both imported goods and domestic good elasticities of substitution, however this model does not distinguish between the two. The model is therefore calibrated as the midpoint between the imported and domestic good elasticities of substitution at $\epsilon^y = 6$, which also reflects the Gerali et al. (2010). The intrasectoral elasticity of substitution, which defines the markup in the labour market, is calibrated to values found in Robinson and Robson (2012), where $\epsilon^l = 4$. Again, this value is broadly in line with the Gerali et al. (2010) calibration.

\(^{10}\)ABS Cat No. 5260. Multi-factor Productivity Data
\(^{11}\)ABS Cat No. 1301.0 - Year Book Australia
### 5.7 Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta^P$</td>
<td>Patient Households’ discount factor</td>
<td>0.996</td>
</tr>
<tr>
<td>$\beta^I$</td>
<td>Impatient Households’ discount factor</td>
<td>0.975</td>
</tr>
<tr>
<td>$\beta^E$</td>
<td>Entrepreneurs’ discount factor</td>
<td>0.975</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Inverse of the Frisch elasticity</td>
<td>1.0</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Share of unconstrained households</td>
<td>0.65</td>
</tr>
<tr>
<td>$\epsilon^h$</td>
<td>Weight of housing in the utility function</td>
<td>0.2</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Capital share in the production function</td>
<td>0.42</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate of physical capital</td>
<td>0.025</td>
</tr>
<tr>
<td>$\epsilon^g$</td>
<td>Markup in the goods market</td>
<td>6.0</td>
</tr>
<tr>
<td>$\epsilon^l$</td>
<td>Markup in the labour market</td>
<td>4.0</td>
</tr>
<tr>
<td>$m^H$</td>
<td>Households’ LTV ratio</td>
<td>0.7</td>
</tr>
<tr>
<td>$m^E$</td>
<td>Entrepreneurs’ LTV ratio</td>
<td>0.35</td>
</tr>
<tr>
<td>$\epsilon^d$</td>
<td>Markdown on the deposit rate</td>
<td>-5.104</td>
</tr>
<tr>
<td>$\epsilon^{bH}$</td>
<td>Markup on housing loan rate</td>
<td>3.27</td>
</tr>
<tr>
<td>$\epsilon^{bE}$</td>
<td>Markup on commercial loan rate</td>
<td>3.52</td>
</tr>
<tr>
<td>$\delta^b$</td>
<td>Cost for managing bank’s capital position</td>
<td>0.0217</td>
</tr>
<tr>
<td>$\omega^b$</td>
<td>Dividend yields in the banking sector</td>
<td>0.7</td>
</tr>
<tr>
<td>$\phi_R$</td>
<td>Monetary Policy: Inertia</td>
<td>0.875</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>Monetary Policy: Response to Inflation</td>
<td>1.913</td>
</tr>
<tr>
<td>$\phi_y$</td>
<td>Monetary Policy, Response to Output growth</td>
<td>0.355</td>
</tr>
</tbody>
</table>
5.8 Evaluation of Parameters

In order to evaluate the calibration of parameters, the key macroeconomic ratios computed by the model are compared to the data. The main macroeconomic ratios are consumption to total output and investment to total output.

Table 4: Nominal Macroeconomic Variables to Value-added - Australian Sample Data

<table>
<thead>
<tr>
<th>Nominal Ratio</th>
<th>1993Q1 - 2013Q1</th>
<th>1993Q1 - 2008Q1</th>
<th>Model Implied Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Consumption</td>
<td>0.76</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Non-residential Investment</td>
<td>0.18**</td>
<td>0.19</td>
<td></td>
</tr>
</tbody>
</table>

** Non-residential investment has increased substantially over the sample period as a result of resources investment. The value is calibrated to 0.18 as in Robinson & Robson (2012). True sample mean 0.13.

As can be seen above, the key ratios predicted by the model are broadly in line with the characteristics of the data.
6 Steady State Results

6.1 Regulatory impact upon spreads & banking conditions

Macro-prudential regulation in Australia is proxied in this model by an increase in the required capital adequacy ratio of the Australian banking sector. Capital requirements are assumed to target Tier 1 Capital, widely seen as the core capital of banks and comprised of common equity and retained earnings. While global capital adequacy initiatives, such as Basel III, impose specific ratios of capital, this analysis focuses on potential incremental increases in capital ratios and the implications for the Australian banking sector.

Tightened bank capital regulation is expected to be passed on by banks to consumers in the form of higher lending rates. The majority of literature focuses solely on this response, whereas this thesis diverges and explores other strategies available to banks. These possible bank reactions are understandably diverse, however one key alternative strategy stands out; an adjustment to the dividend policy of the bank.

This analysis follows the method employed in Angelini and Gerali (2012). In the initial calibration, $\delta^b$ (bank capital depreciation) was chosen in order to ensure the target capital ratio, $v$, was equal to the ratio of banks capital to assets. In the following analysis the target capital ratio, $v$, is increased, and therefore an additional condition is imposed to ensure the ratio of bank capital to assets continues to meet the target:

$$\frac{K^b}{B} = v$$  \hspace{1cm} (13)

By including an extra constraint and equation in the model (in order to ensure the model is closed and can find an equilibrium), a free parameter is endogenised. The choice of the parameter endogenised depends upon the bank strategy assumed. The steady-state capital accumulation equation is given by equation (14):

$^{12}$These additional conditions are not necessary for the simple analysis of the impact bank capital may have upon lending spreads. However, they are required in order to explore the different possible strategies banks may take in reaction to the regulation. Simplistically, the capital ratio can be increased for a given cost structure of the banking system and lending spreads will widen, however banks will also remain somewhat under-capitalised, as in the profit maximising conditions of the bank, the cost of holding additional capital is weighed against the benefit of expanding lending. Therefore, in order to explore a scenario where banks meet the target requirements and explore varying strategies, the following conditions are imposed.
\[ K^b = (1 - \omega^b) \frac{j^b (\epsilon^b)}{\pi + 1 - \delta^b} \]  

(14)

where \( \omega^b \) is the dividend ratio, \( j^b \) is profits as a function of elasticities and \( \delta^b \) is the bank capital depreciation rate. Therefore, the level of bank capital in the steady state is a function of the dividend ratio, the bank capital depreciation rate and the degree of competition in the banking sector \( \epsilon^b \), which determines profits.

Depending on the parameter chosen, the model can be used to compare potential bank reactions to regulatory reform. The parameters chosen have an economic interpretation that relate to the debate regarding what reactions banks may have to more stringent regulation. Moreover, these strategies are assumed to be mutually exclusive, in that the banking sector will adopt a single strategy rather than some combination of the two.

6.1.1 Increasing profits by raising lending spreads

Increased capital requirements can be offset in the banking sector through an increase in lending rates and lending standards. In this model, this scenario is captured by lower values of the elasticity of demand to loans, \( \epsilon^b \). As can be seen in equation (14), keeping the dividend ratio fixed and the cost structure of banks fixed, the increase in bank capital results from an increase in profits, which are a function of elasticity. Therefore, this will increase the lending spreads and as a result, profitability. Capital levels are therefore increased as capital accumulates through retained earnings. The ratio of profits to capital, or Return on Equity, remains the same.

Table 5: Bank Adjustment through Increased Lending Spreads

<table>
<thead>
<tr>
<th>Target Capital Ratio (%)</th>
<th>Policy Rate (%)</th>
<th>Housing Rate Spread (%)</th>
<th>Commercial Rate Spread (%)</th>
<th>Return on Equity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00</td>
<td>5.18</td>
<td>2.29</td>
<td>2.07</td>
<td>9.44</td>
</tr>
<tr>
<td>9.50</td>
<td>5.18</td>
<td>2.49</td>
<td>2.23</td>
<td>9.44</td>
</tr>
<tr>
<td>10.00</td>
<td>5.18</td>
<td>2.68</td>
<td>2.38</td>
<td>9.44</td>
</tr>
<tr>
<td>10.50</td>
<td>5.18</td>
<td>2.87</td>
<td>2.54</td>
<td>9.44</td>
</tr>
<tr>
<td>11.00</td>
<td>5.18</td>
<td>3.07</td>
<td>2.69</td>
<td>9.44</td>
</tr>
<tr>
<td>11.50</td>
<td>5.18</td>
<td>3.27</td>
<td>2.84</td>
<td>9.44</td>
</tr>
<tr>
<td>12.00</td>
<td>5.18</td>
<td>3.47</td>
<td>3.00</td>
<td>9.44</td>
</tr>
</tbody>
</table>

Table 5 above, outlines the expected impacts upon key banking metrics as a result of
increased capital regulation. Furthermore, these estimations rely on the banking system completely passing through all costs of additional capital regulation to the consumer in the form of higher lending rates.

An increase in Tier 1 regulatory capital holdings of 1 percentage point can be offset by the Australian banking system through an increase in household and commercial lending rates of roughly 40 basis points and 30 basis points respectively. The divergence between the two rates is to be expected, as commercial lending rates are found in the data to be more elastic than housing lending rates, and as a result, the two rates do not increase uniformly.

This finding is also in line with the existing non-dynamic literature, as consumer loans, particularly housing loans, are generally found to be insensitive to price changes that are small enough to be expressed in basis points\textsuperscript{13}. Much of this insensitivity derives from the structure of the banking system, where a considerable proportion of consumer loans are housing mortgages, for which there are very little, or incomplete substitutes. Commercial loans however are far more sensitive to price changes.

6.1.2 Adjusting Dividend Payout Policy

In the face of increased capital adequacy regulation, the banking system may trim dividends paid out to shareholders (patient households) to increase capital. The strategy of decreasing the dividend payout ratio allows banks to pay out less profits through dividends and as a result, accumulate more capital through retained earnings. In the model, this scenario is simulated by allowing $\omega^b$ to be exogenous and increasing the capital adequacy requirements. This strategy is simulated assuming all revenues and profits are unchanged, and as a result, the Return on Equity decreases, given greater equity accumulated. Moreover, the values estimated assume a complete pass through of all additional costs of holding capital to a reduced dividend payout ratio.

\textsuperscript{13}Elliott (2009)
Table 6: Bank Adjustment through Dividend Payout Policy

<table>
<thead>
<tr>
<th>Target Capital Ratio (%)</th>
<th>Policy Rate (%)</th>
<th>Bank Dividend Payout Ratio (%)</th>
<th>Return on Equity (ROE) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00</td>
<td>5.18</td>
<td>70.00</td>
<td>9.44</td>
</tr>
<tr>
<td>9.50</td>
<td>5.18</td>
<td>68.53</td>
<td>9.00</td>
</tr>
<tr>
<td>10.00</td>
<td>5.18</td>
<td>67.09</td>
<td>8.61</td>
</tr>
<tr>
<td>10.50</td>
<td>5.18</td>
<td>65.66</td>
<td>8.25</td>
</tr>
<tr>
<td>11.00</td>
<td>5.18</td>
<td>64.24</td>
<td>7.92</td>
</tr>
<tr>
<td>11.50</td>
<td>5.18</td>
<td>62.85</td>
<td>7.63</td>
</tr>
<tr>
<td>12.00</td>
<td>5.18</td>
<td>61.48</td>
<td>7.35</td>
</tr>
</tbody>
</table>

Interestingly, a reduction in the dividend payout ratio in order to completely account for tightened capital regulations, results in the same contraction in Return on Equity (ROE) that can be estimated by purely allowing bank costs to rise. Table 6 illustrates an initial increase in the target Tier 1 Capital ratio of 1 percentage point is offset by a reduction in the dividend payout ratio of roughly 300 basis points.

The fall in the bank dividend payout ratio translates to a reduction in ROE of approximately 80 basis points. This appears to be lower than in Elliott (2009), however this comes as a result of the steady state of capital regulation in Australia coming off a higher base than the values Elliott (2009) assumes. Assuming some level of linearity, the estimates of Elliott (2009), calibrated to U.S banking data find ROE to fall roughly 100 basis points due to an increase in capital from 9% to 10%. Therefore, the values found in Australia are roughly in line with the findings in Elliott (2009) for the U.S banking system.

6.2 Long-term Macroeconomic Impact

In the previous section, more stringent bank capital regulation is found to result in a widening of lending spreads or a decrease in the dividend ratios of the banking sector, depending upon the reaction of banks to the reform. Table 7 below illustrates the steady-state impacts of widened lending spreads in reaction to increased bank capital regulation. An increase of the capital ratio of 1%, from 9% to 10%, results in a contraction of lending, and as a result, investment, consumption and output. These results suggest that the introduction of further capital regulation may result in a ‘new normal’, where consumption, investment and output are all lower in the steady-state due to wider lending spreads and higher borrowing rates. The findings of a ‘new normal’
corroborate the findings of APRA that the economic costs of higher regulator capital include a reduction in borrowing and output.\(^{14}\) Furthermore, the values found are also broadly in line with those found in the empirical literature. Whilst no estimates have been made for the Australian economy, Slovik and Cournède (2011) estimate a -0.3% change in output following a 1 percentage point increase in bank regulation for the European economy. Furthermore, Angelini and Gerali (2012) estimate a -0.36% change in output for European data. Slovik and Cournède (2011) estimate that a 100 basis point increase in bank lending rates will on average across the United States, Japan and the Euro Area, reduce the output level by 1.45%.

These results are therefore in line with those across the average of three OECD economies as an increase of banking lending rates of 35 basis points on average in Australia, as shown in the graph below, results in a contraction of output by 0.52%. Therefore a 100 basis point increase is projected to results in a contraction of output by 1.37%. However, a substantial difference emerges when considering the impact that a one percentage point increase in the capital ratio has upon lending spreads. The impact in Australia is far larger as a result of a lower markup on loan rates when compared to Europe, as outlined in Section 5. Therefore, the estimated impact of a 1 percentage point increase in the capital ratio upon borrowing volumes, output and investment are far larger in Australia than those found in Macroeconomic Assessment Group (2010a) and Slovik and Cournède (2011).

<table>
<thead>
<tr>
<th>Size of capital ratio increase (%)</th>
<th>Change in Consumption (%)</th>
<th>Change in Investment (%)</th>
<th>Change in Output (%)</th>
<th>Change in Lending (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.50</td>
<td>-1.36</td>
<td>-0.52</td>
<td>-2.85</td>
</tr>
<tr>
<td>2</td>
<td>-0.90</td>
<td>-2.45</td>
<td>-0.93</td>
<td>-5.02</td>
</tr>
<tr>
<td>3</td>
<td>-1.33</td>
<td>-3.65</td>
<td>-1.37</td>
<td>-7.28</td>
</tr>
</tbody>
</table>

When banks react to increased regulation by reducing the dividend payout ratio, the long-term economic impacts are minimal. Table 8 below illustrates that when banks reduce the dividend payout ratio in response to regulation, lending marginally increases and therefore there is no substantial contraction in long-term economic activity. Furthermore, there does not appear to be a considerable fall towards a ‘new normal’.

\(^{14}\)Australian Prudential Regulation Authority (APRA) (2012)
Table 8: Impact of Regulation on Macroeconomic Aggregates - Lower Dividend Ratio

<table>
<thead>
<tr>
<th>Size of capital ratio increase (%)</th>
<th>Change in Consumption (%)</th>
<th>Change in Investment (%)</th>
<th>Change in Output (%)</th>
<th>Change in Lending (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.06</td>
<td>-0.01</td>
<td>-0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>-0.12</td>
<td>-0.02</td>
<td>-0.09</td>
<td>0.03</td>
</tr>
<tr>
<td>3</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.14</td>
<td>0.06</td>
</tr>
</tbody>
</table>

However, the banking sector is far more likely to adopt the former strategy, due to the minimal impact upon profitability. Furthermore, the major Australian banks are all publicly listed companies, and as a result may face substantial backlash to lower returns if the dividend payout ratio is reduced. The estimates of APRA corroborate these assumptions, as they find that the capital requirements will predominantly be generated from retained earnings “without serious erosion of dividend pay-out ratios”\(^\text{15}\). As a result, it is likely that in reaction to more stringent bank capital regulation, there may be a shift towards a ‘new normal’, where consumption, investment and output are all lower than prior to the reform. The central bank therefore may want to intervene in order to offset the contractionary impacts of the proposed reforms.

6.3 Impact upon Monetary Policy

In the previous analysis, lending spreads are found to widen in the event of increased capital adequacy regulation if the banking sector does not accept a lower Return on Equity. Interestingly, the steady state of the cash rate does not appear to be influenced by changes to capital regulation. This can be illustrated by referring to the equation governing the steady-state rate of nominal interest in the model:

\[
r = \left(\frac{\pi}{\beta^P} - 1\right) \left(\frac{\epsilon^d - 1}{\epsilon^d}\right)
\]

(15)

where \(r\) is the steady-state (SS) nominal rate of interest, \(\pi\) is the SS inflation rate, \(\beta^P\) is the discount rate for patient households and \(\epsilon^d\) is the elasticity of demand of deposit rates.

Therefore, it is clear that changes to the capital adequacy ratio in the banking sector will not impact upon the policy rate in the steady state, as the capital ratio does not appear in the steady-state cash rate rule. However, as found earlier, the change

\(^{15}\text{Australian Prudential Regulation Authority (APRA) (2012)}\)
in capital regulation does impact upon the steady state lending rates of the banking sector. As a result, lending spreads in the steady-state widen.

The widening of lending spreads is of vital importance to the Central Bank for a variety of reasons. Primarily, an increase in retail lending rates, independent of any monetary policy change, will effectively create contractionary monetary conditions, as illustrated in Table 7. That is, consumers and firms face higher lending rates and thus will, on aggregate, borrow less. This will constrict commercial investment and, for impatient households facing higher interest bills on debt, will stifle consumption. Therefore, wider spreads will impact the economy through the conventional transmission channels devoid of any policy changes.

The initial hypothesis of this thesis was that the Central Bank may be able to adjust to banking regulation through an adjustment of the steady-state cash rate in order to account for wider lending spreads. However, the findings above suggest an increase in capital adequacy regulation cannot change the steady-state cash rate, but does invoke adjustments to other rates throughout the economy.

In light of these findings, as the Central bank cannot offset the widening of lending spreads in the steady-state, the dynamics of the policy rule are explored. Specifically, whether or not the central bank can respond to lending spreads, and the impact that a revised policy rule may have.
7 Dynamic Results

In the previous section, when banks reacted to increased capital adequacy regulation by increasing lending spreads, this action was found to constrict consumption, investment, output and lending volumes in the steady state. This section aims to address the impact macro-prudential regulation can have upon the conduct of monetary policy. A revised policy rule incorporating lending spreads is proposed and compared against the actual policy decisions of the central bank. Furthermore, the implications for the response of key variables to shocks are compared across the rule responding to spreads and a standard Taylor rule. Lastly, the optimality of such a rule is considered.

Targeted increases in regulatory bank capital levels was estimated in Section 6 to have substantial implications for the long-term levels of output, investment and borrowing. In a short-term dynamic setting, these regulatory increases are also estimated to have implications for the stabilisation of key macroeconomic variables.

Table 9: Standard Deviation of Key Variables to Regulation (Technology Shock)

<table>
<thead>
<tr>
<th>Bank Capital Ratio (%)</th>
<th>Consumption (%)</th>
<th>Investment (%)</th>
<th>Output (%)</th>
<th>Inflation (%)</th>
<th>Lending Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00</td>
<td>1.728</td>
<td>3.472</td>
<td>2.048</td>
<td>0.305</td>
<td>3.353</td>
</tr>
<tr>
<td>10.00</td>
<td>1.729</td>
<td>3.449</td>
<td>2.042</td>
<td>0.305</td>
<td>3.296</td>
</tr>
<tr>
<td>11.00</td>
<td>1.730</td>
<td>3.429</td>
<td>2.037</td>
<td>0.305</td>
<td>3.243</td>
</tr>
<tr>
<td>12.00</td>
<td>1.731</td>
<td>3.414</td>
<td>2.032</td>
<td>0.306</td>
<td>3.195</td>
</tr>
</tbody>
</table>

Table 9 illustrates several results. Primarily, macro-prudential reform, in the shape of capital adequacy regulation, appears to reduce the cyclical volatility of all of the key variables, except for inflation and consumption. Whilst the standard deviation of inflation does not appear to increase substantially, this is largely a function of the small base. A 3 percentage point increase in the bank capital ratio is estimated to increase the standard deviation of inflation by 0.5%. Moreover, the same increase in bank capital is estimated to decrease the volatility of output by 1.6%.

Whilst the magnitudes of the increase may not appear to be substantial, it is significant that the volatility of these two key variables move in opposite directions. As the volatility of inflation is increased and the volatility of output is decreased, the central
bank is forced to make some trade-off between the variability of the two. Furthermore, as found in the steady state results, the widening of lending spreads stifles consumption, investment and lending volumes. Therefore, the central bank may aim to improve the stabilisation of inflation and output and offset some of the dampening effects of regulation by responding to lending spreads in the policy rule.

The following sections assess a potential way the central bank could respond to lending spreads and the implications of a revised policy rule.

7.1 Adjusted Taylor Rule

In order to explore the dynamics and consequences of a policy rule responding to bank lending spreads, the traditional Taylor rule must be revised to incorporate deviations of the spread from its steady state level. This type of revision was suggested by Taylor, when he questioned “whether and by how much monetary policy should adjust to financial market disturbances to prevent spillovers to the rest of the economy”\(^{16}\). This revision of the Taylor rule follows the method of Iacoviello (2005), where asset price deviations are incorporated into the Taylor Rule.

The revised Taylor Rule is thus generalised to the following linearised form

\[
\hat{R}_t = \phi_R \hat{R}_{t-1} + (1 - \phi_R) [\phi_n \hat{\pi}_t + \phi_y (Y_t - Y_{t-1}) - \phi_{s} s \hat{p}_t] 
\]

where variables denoted with an accent are deviations from their steady-state values and \( s \hat{p}_t = \hat{R}_t - \hat{R}_t \), where \( \hat{R}_t \) is the deviation of the loans rate from steady state.

The negative sign in the revised rule illustrates the fact that the nominal interest rate should be lowered if lending spreads widen, in order to avert any adverse impacts of widening spreads to macroeconomic aggregates.

Prior to simulations, the key equations driving bank behaviour are decomposed in order to assess the expected implications of the inclusion of credit and financial indicators in the policy rule. Equation (7) can be expressed in log-linearised form:

\[
\hat{r}_b = \hat{r}_t + \kappa_k b \frac{v}{1 + r} \left( \hat{B}_t - \hat{K}_t \right) 
\]

\(^{16}\)Taylor (2008)
as a result, \( \kappa_{Kb} \frac{\nu^3}{1+r} \left( \hat{B}_t - \hat{K}^b_t \right) \) is the deviation of the spread from steady state.

Furthermore, the revised and simplified policy rule can be incorporated into the lending supply curve equation, (16), in order to illustrate how the weightings on \( \phi_s \) offset increases in lending rates.

\[
\hat{r}_t^b = \phi_x \hat{\pi}_t + \phi_y (Y_t - Y_{t-1}) - \phi_s \left( \kappa_{Kb} \frac{\nu^3}{1+r} \left( \hat{B}_t - \hat{K}^b_t \right) \right) + \kappa_{Kb} \frac{\nu^3}{1+r} \left( \hat{B}_t - \hat{K}^b_t \right)
\]

(18)

As the weighting on \( \phi_s \) approaches 1, it is clear that the impact of spreads in the lending supply curve equation, which in equilibrium partially determines the price of credit, approaches 0. Furthermore, as \( \phi_s \) approaches 1, the increase in lending spreads is offset by a reduction in the policy rate of the same magnitude, as suggested by Taylor (2008). Therefore, by including the reaction to spreads in the policy function, any substantial movements in variables impacting upon spreads, such as bank capital and lending levels, will have less of a transmission effect on lending rates, and subsequently, the real economy.

7.2 Reserve Bank of Australia’s Policy Rule

While the aforementioned revisions to the Taylor rule may alter the responses of key macroeconomic variables to disturbances, it is important to consider how the Reserve Bank of Australia conducted policy throughout the period of widened lending spreads. As identified in Gertler et al. (1999), the Federal Reserve Board appeared to have responded to financial indicators throughout the crisis period when setting the cash rate and it may be possible the Reserve Bank of Australia also diverged from strictly targeting inflation and output. It is therefore an important exercise to consider whether recent Australian monetary policy has been consistent with a standard Taylor rule, or whether a rule responding to lending spreads more precisely tracks the actual policy movements.

In order to compare the actual policy rate with the predictions, the Taylor rule is imposed upon output and inflation expectations data from 1993:QII to 2013:QI. The coefficients found earlier are used to compute the predicted policy rule if the RBA had been following a standard Taylor rule. The augmented Taylor rule takes the form of Equation 16 and using the same coefficients, the predicted policy rule is computed.
The coefficient on $\phi_s$ is assumed to be 1. As $\phi_s$ is increased, the predicted policy rate throughout the period is lower as is expected. The inferences drawn are robust to moderate changes in the parameters chosen to reflect the weights on inflation and output.

**Figure 2: Actual & Predicted Policy Rate**

Referring to Figure 2, the standard Taylor Rule and the Augmented Taylor rule quite closely track the actual policy actions throughout the sample. The key period of interest is during the global financial crisis, where lending spreads widened, as can be seen by the divergence between the augmented Taylor rule and the standard Taylor rule. The policy rule responding negatively to lending spreads appears to far more closely track the actual policy actions throughout and following the crisis period. Whilst these movements may be reflective of the correlation in other variables throughout this time, it appears that the RBA responds to lending spreads. Therefore, the widening of spreads throughout this period, either a cyclical widening due to the GFC or a structural widening due to macro-prudential regulation appears to have altered the conduct of monetary policy. As highlighted earlier, this policy rule does not aim to suggest the best way to respond to spreads, but rather it is a qualitative tool to assess the implications of a policy that reacts to spreads.
As the RBA appears to have responded to spreads in the past, it is informative to assess the impact this policy will have upon the macroeconomy. The proceeding sections assess the implications of a policy rule responding to spreads. The impulse response functions of key macroeconomic variables to a variety of shocks are compared across a baseline Taylor rule where there is no weighting to spreads and a revised policy rule where the central bank responds to spreads, $\phi_s = 1$. The two rules are compared across a technology shock, financial shock, inflation shock and a demand shock.

### 7.3 Technology Shock

The transmission of a positive technology shock to the system is studied by examining the impulse response functions of the key macroeconomic and financial variables. A technology shock in the model is a disturbance to the Total Factor Productivity in the firms production equation:

$$
y_t^E = a_t^E \left[ k_{t-1}^E u_t \right]^\alpha l_t^{E1-\alpha}
$$

where $a_t^E$ is stochastic total factor productivity and the log of $a_t^E$ follows an AR(1) process.

#### 7.3.1 Baseline Rule

Figure 3 illustrates that a positive technology shock initially places downward pressure on prices due to the increase in productivity and thus supply of goods. The central bank therefore responds to the contraction in inflation through an easing of monetary policy. The decline in the policy rate then triggers a fall in lending rates, however of a lesser magnitude due to bank lending markups.

Investment is therefore stimulated by the initial improvement in productivity as a result of technology and also by access to cheaper credit. Reduced lending rates also boost consumption as impatient households are less constrained in making debt repayments. Furthermore, the existence of the collateral channel amplifies these effects. As the lending rate falls, entrepreneurs and impatient households are able to borrow more in order to purchase capital and housing stock. This in turn pushes asset prices up. As asset prices increase, the borrowing constraints facing entrepreneurs and impatient households are again relaxed as the collateral values improve.
Banking sector dynamics dampen the increase in economic activity following a positive technology shock. This is an expected and desirable result of the banking reforms. As the policy rate falls, the bank interest rate intermediation margin falls, and as a result, bank profits fall. A reduction of bank profits results in less bank capital due to the capital accumulation equation. A fall in bank capital implies a lower capital adequacy ratio, and as a result, the banking sector must constrict lending in order to comply with the target capital ratio. Therefore, whilst the overall impact of the technology shock is an increase in borrowing as a result of cheaper access to credit and an expansionary policy stance, the banking sector dynamics moderate these fluctuations.
7.3.2 Revised Rule

Figure 3: Impulse Response Functions to a Technology Shock

Note: Values are percentage deviations from steady state

A technology shock, under a standard Taylor rule, invokes an expansionary policy response from the central bank as a result of falling levels of inflation. As a result
of the movements of the policy rate, and subsequently bank retail rates, the lending spread between these rates widens, as shown in the last frame of Figure 3.

Therefore, where the central bank responds to lending spreads, the monetary response to a technology shock incorporating lending spreads in the policy rule is expected to be looser as a result of responding negatively to a widening of spreads. This response is seen in Figure 3. Interestingly, the revised rule increases the fluctuations of lending spreads following a technology shock. This is to be expected as the policy rate falls further in the case of the revised policy rule and as bank lending rates are a proportional mark-up on the policy rate, the retail lending rates do not fall as far as the policy rate. Therefore, the lending spread widens.

The move to a more expansionary monetary policy stance spurs a decrease in bank lending rates to households and entrepreneurs, as banks set rates based on a markup of the policy rate. Investment under the revised rule therefore benefits from easier and cheaper access to credit. This is illustrated in 3, as the initial increase in investment is marginally higher under the revised rule. Moreover, lower bank lending rates increase household consumption, as impatient household interest repayments fall and the budget constraint facing these households becomes relatively less restrictive. Furthermore, lower household lending rates spurs an increase in borrowing, resulting in an increase in house prices. As in the base case, the collateral channel amplifies these fluctuations, as higher house prices and borrowing relaxes the binding collateral constraint on borrowing, and therefore households are able to borrow larger amounts spurring further demand.

The banking sector dynamics, found to dampen activity in the baseline rule, do not substantially change under the revised rule. However, after the initial increase in spreads following the technology shock, lending spreads fall after roughly five quarters and slightly fall below their steady-state level. As a result, the policy rate reacts and is more contractionary than the baseline rule. This dynamic explains the movements in investment and household lending volumes after approximately five quarters. More contractionary monetary policy flows through to the banking sector, resulting in a relative increase in bank lending rates. Household lending volumes contract to their values under the baseline rule, however investment falls below the baseline rule. Investment contracts as a result of restricted access to credit, and as in the baseline
rule, entrepreneurs face the brunt of contractions in lending volume.

The responses of key variables illustrated in Figure 3 suggest that a Taylor rule responding to lending spreads reduces the variance of key variables following a technology shock. Interestingly, this is not the case for the actual lending spread. This result is in contrast to the findings of Curdia and Woodford (2010) for a similar technology shock. The authors found that by increasing the weight on spreads, the stance of monetary policy became more contractionary as a result of an inflationary boom. The differences between the findings of Curdia and Woodford (2010) and the results above are likely due to the inclusion in the model used in this thesis of a stylised banking sector where the bank is a profit maximising firm and the spread as a result is derived from this relationship. Instead, the financial framework used in Curdia and Woodford (2010) is captured by a reduced form interest rate spread without the inclusion of a banking sector. Moreover, the framework used in Curdia and Woodford (2010) does not incorporate a financial accelerator mechanism à la Bernanke et al. (1999). As a result, shocks are not expected to propagate through the economy in the same way and the responses of variables to adjusted policy rules are unlikely to be the same.

Furthermore, where the policy rate responds negatively to widened lending spreads, one would assume as the weight on this response increases in an environment of wider lending spreads, the policy rate would fall. This relationship holds in the results found.

### 7.4 Financial Shock

A financial shock is proxied in the model by a negative shock to the Loan to Value ratio for firms and households. Intuitively, this shock represents a tightening in lending standards, where a restriction is placed upon potential borrowers whom do not meet more stringent criteria. This represents a financial shock, as the volume of credit and lending will substantially contract due to stricter loan requirements. In the case of a commercial LTV ratio shock, this will impact the system through the collateralised borrowing constraint:

\[
(1 + r^bE_t) b^E_t(i) \leq m^E_t E_t \left[ q^{k}_{t+1} \pi_{t+1} (1 - \delta) k^E_t(i) \right]
\]

where \( m^E_t \) is a stochastic LTV ratio shock and the log of \( m^E_t \) follows an AR(1) process.
7.4.1 Baseline Rule

A negative stochastic shock to the LTV ratio will decrease the volume of lending, as the binding borrowing constraint above becomes more restrictive. This is illustrated in Figure 4 Entrepreneurial lending volumes decline, reducing commercial production, consumption and investment in capital. As a result, output and inflation both decline following an initial contraction in the LTV ratio. Furthermore, the collateral channel amplifies the contraction in investment, as lower initial levels of investment place downward pressure on the price of capital. As the borrowing constraints of entrepreneurs are tied to the future price of capital, the borrowing capacity of entrepreneurs is constricted by the contraction in the price of capital. Therefore, commercial borrowing is restricted, which in turn reduces investment.

As per the policy rule, the nominal interest rate falls to respond to the initial contraction in output and inflation. As banks set lending rates as markups of the policy rate, bank retail lending and deposit rates also decline. The decline in lending rates, as can be seen in the equation above, will offset the initial LTV ratio shock by relaxing the borrowing constraints binding entrepreneurs. As a result, commercial lending and investment levels begin to increase from the initial contraction.

The bank capital channel does not substantially influence the real economy in the case of a LTV shock. The initial contraction in the policy rate slightly reduces the banking sector intermediation margin and as a result, profits. Whilst the reduced profit levels results in a contraction in bank capital levels, as a result of the capital accumulation equation, the contraction in lending more than offsets this. Therefore, bank capital ratios increase as a result of this shock, spurring banks to increase lending to entrepreneurs in order to lower the capital ratio to meet the target set by an exogenous regulator.

Moreover, as the policy rate falls substantially, and bank retail lending rates are a proportional mark-up on the policy rule, the spread between the policy rate and lending rates widens. This is illustrated in Figure 4. Increased lending volumes and reduced bank rates spur investment and consumption following the initial contraction, and as a result of higher rates of inflation and output, the policy rate increases. The policy rate, inflation and investment reach their peaks approximately two and a half years after the initial shock.
7.4.2 Revised Rule

The initial contraction in bank lending as a result of a shock to the LTV ratio is the same under a revised policy rule incorporating spreads. In the baseline rule, an expansionary response from the policy rule widened lending rates, as the policy rate fell far more than the bank retail rates. In the case of the revised policy rule, this expected reaction from lending spreads results in a more expansionary policy rule. That is, inflation and output do not need to fall as substantially in order to trigger a policy rate cut of the same magnitude. Figure 4 illustrates this, as the policy rate initially falls further when the policy rule responds to lending spreads.

A marginally more expansionary policy stance under the revised rule reduces borrowing costs in the economy, as bank lending rates are a function of the policy rate. Moreover, investment, output and consumption all marginally increase relative to the baseline rule as a result of easier access to credit and lower funding costs. This is illustrated in Figure 4, as household borrowing does not contract as substantially.

As a result of a more expansionary policy stance, inflation increases relative to the baseline rule. Approximately 1 year after the shock, increased rates of inflation spurs a move to a more contractionary policy stance relative to the baseline rule. As the policy rate increases, access to funding falls and while investment increases relative to the steady state, investment relative to the baseline rule contracts. The increase in funding costs also impacts upon household borrowing and consumption levels. As the policy rate increases, the interest payments on outstanding household debt increases, reducing the disposable income available for consumption. Figure 4 shows this, as household borrowing is lower under a revised rule, in the periods after a shock, due to more restrictive budget constraints.

On aggregate, output falls relative to the baseline rule as a result of lower investment and consumption levels. The fluctuations of the spread are again higher as a result of the movements in the policy rate relative to the baseline rule. The responses of the key variables in Figure 4 suggest that a Taylor rule responding to lending spreads reduces the variance of investment and output, however increases the variance of the policy rate and inflation. Therefore, it is unclear from this analysis as to whether the revised rule improves upon the baseline rule.
Therefore, under the revised rule, the policy rate falls more substantially than under the baseline rule, and as a result, has a slightly more expansionary impact upon the wider economy. As the policy rate falls further, retail lending rates also follow, resulting in a relative increase in the volume of investment.

Importantly, the revised policy rule responding to lending spreads does not appear to unambiguously improve upon the standard Taylor rule. As shown in Figure 4, a policy rule responding to spreads invokes a far greater inflationary boom than under the standard Taylor rule. This is largely due to the more expansionary policy setting. However, the revised rule appears to control the expansion in output more than under the standard Taylor rule. Assuming that the central bank aims to stabilise inflation and output, the revised policy rule does not appear to substantially improve upon the baseline rule, due to the undesirable increases in inflation fluctuations.
Figure 4: Impulse Response Functions to a Financial Shock

Note: Values are percentage deviations from steady state
7.5 Inflation Shock

An inflation shock in the model is simulated through a positive cost-push inflation shock, where the mark-up of goods is exogenously shocked. The firms mark-up enters the following equation:

\[ 1 - \epsilon_t^y + \frac{\epsilon_t^y}{x_t} - \kappa_p \left( \pi_t - \pi_{t-1}^{\pi} \pi_1^{1-\pi} \right) \pi_t \\
+ \beta P E_t \left[ \lambda_{t+1}^{\lambda_e} \kappa_p \left( \pi_{t+1} - \pi_t^{\pi} \pi_1^{1-\pi} \right) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0 \]

where \( \epsilon_t^y \) represents the markup. \( \epsilon_t^y \) is a stochastic shock and the log of \( \epsilon_t^y \) follows an AR(1) process.

7.5.1 Baseline Rule

Figure 5 illustrates that a positive exogenous shock to the mark-up of retail firms results in an instantaneous increase in inflation. The central bank responds to the spike in inflation by increasing the policy rate. As the banking sector sets retail rates based upon a markup of the policy rate, retail lending rates also increase, resulting in a contraction of consumption and investment due to increased funding costs and reduced lending volumes. As a result of the collateral channel outlined in earlier sections, the initial responses of consumption and investment are magnified. House and capital prices contract due to decreased demand and restricted access to credit.

The bank capital channel further dampens economic activity. Deposit rates rise relatively higher than the retail lending rates and as a result, the bank intermediation margin falls. Bank profits therefore fall, reducing the retained earnings used to accumulate bank capital. As bank capital levels fall, and assuming lending remains fixed (for the moment), the capital adequacy ratio of the bank falls substantially. In order to ensure the bank capital ratio meets the target ratio, the banking sector must reduce lending. As in the case of a technology shock, the contraction in lending largely impacts upon entrepreneurs, further contracting investment. The contraction in lending also impacts upon the housing sector, as can be shown in Figure 5.

The cost-push inflation shock does not persist as long as other shocks, and inflation falls back to its steady state level after approximately one year, before overshooting into a deflationary period. The policy rate therefore responds and falls roughly to the
steady-state cash rate level, also overshooting into a more expansionary stance in order to offset the aforementioned deflation. Easier access to credit stimulates borrowing and consequently, investment, resulting in an increase in investment relative to the steady state. Output roughly mirrors the response of consumption to the inflation shock, decreasing initially due to the dampening effect of increased credit costs and moving back towards the steady state as access to credit improves.

### 7.5.2 Revised Rule

Under the baseline rule, inflation increases and lending spreads contract immediately following an exogenous shock to the markup of retail firms. The lending spread contracts as the policy rate increases far more than bank retail rates. Under a revised rule responding negatively to spreads, the policy rate is therefore expected to be increased more aggressively.

As shown in Figure 5, the policy rate increases far more under the revised rule as a result of negative responding to spreads, which in the case of the inflation shock, narrow. The more contractionary policy therefore limits the expansion of inflation through the standard transmission channels. As a result, there is a slight reduction in the deviation of inflation.

Investment under the revised rule is therefore constricted due to an increase in the cost of credit. This can be seen in Figure 5, as contraction in investment is far higher under the revised rule. Furthermore, the increased cost of funding impacts upon household consumption. Impatient households face increased interest repayments on debt and therefore the budget constraint facing the household becomes relatively more restrictive. The collateral channel also serves to magnify the contraction in investment and consumption.

After approximately five quarters, the policy rate is relatively more expansionary under the revised rule. This occurs as a result of the dynamics of the lending spread. Initially, the spread narrows, however over time the spread increases back towards the steady state level but marginally increases above this rate. As the policy rate responds these movements, the policy rate falls more than under the baseline rule. This serves to explain the dynamics of investment after approximately two years. Investment is marginally higher under the revised rule as a result of cheaper credit.
Importantly, in the case of a cost-push inflation shock, responding to spreads does not appear to improve upon the stabilisation of key macroeconomic variables. The revised policy rule does not substantially alter the response of inflation but results in a far more considerable contraction of output. Furthermore, the initial contraction of household borrowing is almost twice as large under a policy responding to lending spreads. As a result of the greater contraction in borrowing, the initial contraction in investment is also far larger when the policy rule responds to spreads.

As in the case of a technology shock, the volatility of spreads increases under the revised rule as a result of adjustments to the policy rate. Finally, it appears that responding to spreads in the case of a cost-push inflation shock worsens the stabilisation of inflation and output. Furthermore, the substantial contraction of economic activity under a revised rule does not appear to be optimal when compared to the baseline Taylor rule.
Figure 5: Impulse Response Functions to an Inflation Shock

Note: Values are percentage deviations from steady state
7.6 Demand Shock

A positive demand shock is simulated by a shock to consumer preferences, $\epsilon_t^z$. As in the case of the other shocks, the log of $\epsilon_t^z$ follows an AR(1) process. The transmission of this shock is then compared across the two policy rules. A consumer preference shock impacts upon both patient and impatient households by increasing consumption through the following equation:

$$\lambda_s^t = \frac{\epsilon_t^z (1 - \alpha^s)}{(c_s^t - \alpha^s c_{t-1})}$$  \hspace{1cm} (22)

where $s$ represents either a patient or impatient household, $a^s$ is group consumption habits and $c^s$ is consumption.

7.6.1 Baseline Rule

A positive preference shock initially increases household consumption, resulting in an inflationary spike due to increased demand for goods. This is illustrated in Figure 6. In response to higher rates of inflation, the central bank intervenes and increases the nominal interest rate in order to reduce inflation back towards the target rate.

The contractionary policy stance then feeds through to the banking sector, where lending rates on loans to consumers and firms increase. As a result of increased funding costs, firms begin to switch from capital to labour, and as a result, investment is crowded out. Furthermore, the increased demand for labour, due to the relative increase in capital costs, pushes up wages and increases wage inflation. Aggregate output then increases as the increase in household consumption (due to higher wages) more than offsets the contraction in investment.

The contraction of investment is magnified by the existence of the collateral channel. The initial contraction of investment in reaction to higher funding costs reduces the demand for capital and as a result, with the supply remaining fixed, the price of capital falls. As commercial borrowing is collateralised and tied to the price of capital, the contraction in capital prices further reduces the borrowing capacity of firms.

In the case of a positive demand shock, the bank capital channel somewhat alleviates the crowding out of investment. As the policy rate increases, the bank intermediation margin also increases as banks charge a markup over the policy rate on loans and a
markdown on deposits. Higher profit levels therefore generate more capital for the banking sector, allowing the bank to extend more loans and still maintain the target capital ratio. The increased volume of lending is, as in the case of other shocks, targeted at the commercial sector, and somewhat alleviates the contraction in lending.

7.6.2 Revised Rule

As shown in Figure 6, the lending spread between the rate at which banks lend and the policy rate narrows as a result of the exogenous demand shock. As the revised policy rule responds negatively to a widening of spreads, the policy rule increases more than the baseline rule. Consequently, banking costs increase and investment initially contracts further relative to the baseline rule. The contraction in lending behaviour also constricts household borrowing more than under the simple Taylor rule. Inflation under the revised rule marginally increases as firms allocate more resources to relatively cheaper labour, stimulating higher wages and wage inflation. Whilst higher wages somewhat stimulate consumption, higher lending rates and a larger contraction in investment result in a slight contraction of output relative to the baseline rule.

As the policy rate moves back towards the steady state level in response to lower inflationary pressures, the lending spread widens. The policy rule responding to spreads therefore falls back towards a steady state level more rapidly than under the baseline rule. The more expansionary policy increases investment, relative to the baseline rule, as bank funding costs begin to decline in line with the policy rate. Therefore, the overall contraction in investment is less in the case of the policy rule responding to lending spreads.

The fluctuations of the lending spread are increased as a result of the movements of the policy rate. The revised policy rule does not appear to substantially improve upon the baseline rule when considering the responses of inflation and output to a demand shock.
Figure 6: Impulse Response Functions to a Demand Shock

Note: Values are percentage deviations from steady state
7.7 Evaluation of Revised Policy Rule

A policy rule responding to lending spreads, when compared to the baseline Taylor rule, is found to markedly change the responses of key variables to various shocks. Furthermore, dependant on the nature of the shock, the revised rule either amplifies or dampens the impact of the shock on these variables. However, the previous analysis falls short of addressing the optimality of the revised policy rule; whether the revised rule substantially improves upon the baseline rule in stabilising output and inflation.

The inflation-output volatility frontiers are computed for alternative parameterisations of the proposed Taylor rule. This analysis follows the method proposed in Levin et al. (1999), where the central bank loss function is expressed as:

\[ L = \lambda Var(\pi) + (1 - \lambda) Var(Y) \]  

(23)

Two efficient frontiers are computed. The first frontier assumes \( \phi_s \) is fixed at 0, whereas the second frontier allows the policy rate to respond to spreads, \( \phi_s > 0 \). The optimal policy frontiers are computed allowing the parameters governing the response to inflation, \( \phi_\pi \), output, \( \phi_y \), and spreads, \( \phi_s \) to adjust. However, the parameter governing the policy lag, \( \phi_R \), is fixed at the calibrated value. The method used to find the optimal policy searches over a grid of parameters in order to find the combination of parameters that minimises the loss function for a given \( \lambda \).\(^{17}\)

Figure 7 below illustrates that the frontier obtained by responding to lending spreads shifts inwards quite substantially. Therefore, for a given volatility of inflation, the volatility of output is lower under the revised rule and vice versa. For a given weight on the loss function, \( \lambda = 0.85 \), the loss function is approximately 4% smaller under a revised rule. Importantly, the revised policy rule cannot perform worse than the baseline rule in an optimal policy frontier as the central bank could set the weight on \( \phi_s \) to 0. However, for the given shocks, the optimal weight to spreads, \( \phi_s \) is at the maximum bound; 1. The results suggest that for an aggregated variety of shocks; an inflation shock, a technology shock, a financial shock and a demand shock, responding to spreads in the policy rule yields improved stabilisation.

\(^{17}\)This may be seen as a ‘brute force’ method, and has some drawbacks. The primary consideration is that the optimal parameters to minimise the loss function may lie between the incremental parameters chosen in the grid search. The grid step for the frontiers was 0.1 for \( \phi_\pi \), 0.03 for \( \phi_y \) and 0.1 for \( \phi_s \).
This is an interesting result when considering the Impulse Response Functions in the previous section. When the policy rule responded to an inflation shock, the responses of key variables under the revised rule did not appear to be optimal. The previous analysis assumed the aggregation of all shocks considered in order to assess the optimal policy. This is more reflective of the conditions faced by the central bank, as they are unlikely to be perfectly able to distinguish the sources of business cycle fluctuations. However, as a technology shock has far larger implications for the volatility of inflation and output, it is possible that the revised rule is optimal in the case of a technology shock but sub-optimal in the case of other shocks, particularly a cost-push inflation shock. This would imply that the optimality of a policy rule responding to spreads is state or disturbance dependant. This result was highlighted in Curdia and Woodford (2010).

Computing the loss functions for each individual shock highlights that the optimality of a policy rule responding to lending spreads is dependant upon the disturbances to the economy. As expected, the revised rule improves upon the stabilisation of output and inflation in the case of a technology and demand shock, however does not improve upon the baseline rule in response to a financial or cost-push inflation shock.
When computing the loss functions for the financial and inflation shocks individually, the optimal weighting on spreads approached 0 as the weight on output stabilisation increased. Therefore, whilst the revised policy rule when computing loss functions cannot do worse than the baseline Taylor rule, as the weighting on spreads approaches 0, this suggests the optimal rule is the baseline Taylor rule. As a result, the Taylor curves computed for these two shocks converge. However, in the case of the demand and technology shock, the optimal weighting on spreads remained at the upper bound, 1, suggesting the optimal policy is to respond to lending spreads.

These results were illustrated in the previous section, where the revised policy rule increased the volatility of inflation in the case of a financial shock and increased the volatility and contraction of output in response to an inflation shock. However, in the case of a technology shock, the volatility of output and inflation are reduced. These findings suggest that a policy response to reduce the policy rate when spreads widen will not always be the optimal rule to stabilise inflation and output.

These results corroborate the findings in Curdia and Woodford (2010), where a policy rule responding to lending spreads can improve upon the baseline Taylor rule, however the revised rule is not desirable regardless of the source of the shock. The revised policy rule in Curdia and Woodford (2010) was found to improve upon the baseline rule in the case of disturbances originating in the financial sector, however when considering other disturbances, the conclusions were more varied. Interestingly, the nature of the shocks for which the revised rule is desirable varies between the results in this thesis and those in Curdia and Woodford (2010).

The differences in results may stem from a variety of factors. Firstly, as identified previously, the framework used in Curdia and Woodford (2010) differs substantially from the model used in this thesis. In Curdia and Woodford (2010), financial intermediation is captured by a reduced form interest rate spread, whereas in this thesis, the role of financial intermediation is emphasised, with the inclusion of a financial accelerator mechanism and a stylised banking sector. As a result, the response of variables to similar shocks and the revised policy rules are found to vary due to the different mechanisms in the models.

\[18\]See Appendix B.1 for the converged Taylor curves for an Inflation and Financial Shock
Secondly, Curdia and Woodford (2010) employ different methods to those used in this thesis in order to determine the optimal policy. Curdia and Woodford (2010) identify the objective of monetary policy is to maximise the average ex ante expected utility of households. Furthermore, the authors compare the performance of revised Taylor rules to the performance of the Ramsey Policy (the optimal policy considering the objective) to a variety of shocks. In the above results, the optimal policy is determined by assessing the minimum loss function of the central bank, where the objective of the central bank is to minimise inflation and output volatility. Furthermore, the responses of the optimal policy to shocks are not considered in this analysis.

7.8 Indeterminancy Analysis

In the previous sections, monetary policy has responded to lending spreads yielding changes in the responses of variables to shocks. Moreover, it has been found that a revised Taylor rule incorporating a response to spreads may lead to improved stabilisation outcomes. While this policy appears optimal, it is desirable that monetary policy is conducted in a way that ensures a unique equilibrium for the system. That is, the system is able to find a unique Rational Expectations Equilibria (REE) and fulfil the Blanchard Khan conditions as opposed to finding multiple equilibria or being unable to find an equilibrium.

In conventional New Keynesian DSGE models, indeterminacy can arise if the central bank does not respond aggressively enough to inflation in the policy rule. Indeterminacy can result in the lack of a unique Rational Expectations Equilibria (REE). Moreover, indeterminacy may result in ‘sunspot’ equilibria (not a fundamental equilibrium) that are not present under determinacy. The revision of the Taylor rule to incorporate lending spreads may have stability and indeterminacy implications as outlined previously.

As indeterminacy is primarily the result of the response to inflation in the policy rule, this analysis will focus upon this parameter. When comparing the feasibility ranges of the baseline Taylor rule to the spread-augmented Taylor rule as in Figure 8, the revised policy rule appears to improve the determinacy region for the parameter governing the response to inflation. Where 1 indicates determinacy and 0 indeterminacy, the revised rule widens the regions of feasibility for the parameter governing the response to inflation.
A primary reason for this widened feasibility range is that the inclusion of lending spreads in the policy function markedly influences the key parameters of the rule. The following linearised policy rule equation illustrates this:

$$\hat{R}_t = \phi_R \hat{R}_{t-1} + (1 - \phi_R) \left[ \phi_\pi \hat{\pi}_t + \phi_y (Y_t - Y_{t-1}) - \phi_s \left( \hat{R}_b^t - \hat{R}_t \right) \right]$$  \hspace{1cm} (24)

where hatted variables denote deviations from the steady state, $R_t$ is the nominal interest rate and $R^b_t$ is the bank lending rate.

As the lending spread is a function of the policy rate itself, the equation can be re-written in order to assess the impact of the inclusion of spreads in the policy rule:

$$\hat{R}_t (1 - (1 - \phi_R) \phi_s) = \phi_R \hat{R}_{t-1} + (1 - \phi_R) \left[ \phi_\pi \hat{\pi}_t + \phi_y (Y_t - Y_{t-1}) - \phi_s \left( \hat{R}_b^t \right) \right]$$  \hspace{1cm} (25)

Equation (25) illustrates that by responding to spreads in the policy function, the parameter governing inflation is altered. When $\phi_s = 0$, the policy rule resembles the baseline Taylor rule. However, as $\phi_s$ increases, the policy rule becomes a response to the deviation of lending rates from their steady state values and more importantly, the parameter governing the response to inflation is increased by the factor of $\frac{1}{(1-(1-\phi_R)\phi_s)}$. Therefore, when $\phi_s$ approaches 1, the factor increases to $\sim 1.3$. As a result, the
parameter governing inflation, $\phi_\pi$, is actually increased by 1.3 times when $\phi_s = 1$. As identified earlier, if the policy response to inflation is not aggressive enough, indeterminacy may result. In this case, the inclusion of spreads in the policy reaction function increases the response to inflation.

As is illustrated in Figure 8, the inclusion of lending spreads in the policy rule does not appear to violate the Blanchard Khan conditions and therefore ensures a unique Rational Expectations Equilibria (REE) for the system. As a result, the revision to the policy rule can improve upon the standard Taylor rule dependant on the nature of the business cycle fluctuations.
8 Sensitivity and Robustness Analysis

This section outlines the sensitivity of the results found in Section 7 to assumptions made regarding the reactions banks may have to reforms and the parameters borrowed from Gerali et al. (2010). Furthermore, a VAR model is estimated à la Iacoviello (2005) in order to evaluate whether the model matches the properties of the data.

8.1 Bank Reactions

The results from section 7 suggest that if the banking sector responds to capital regulation by increasing lending rates, a revised policy rule improves upon the stabilisation of inflation and output relative to the baseline Taylor rule. Whilst it is likely the banking sector responds in this manner, it is informative to assess the performance of the revised policy rule under an alternative reaction. Given the central bank cannot perfectly predict the reaction of the banking sector to further capital regulation, the revised policy rule must not increase instability in the case of an unlikely response from the banking sector.

Two policy frontiers are again computed when $\phi_s = 0$ and $\phi_s > 0$. In this scenario, the banking sector is assumed to respond to regulation by decreasing the dividend payout ratio and as a result, lowering Return on Equity.
As shown by Figure 9, the frontier obtained by enabling the policy rule to respond to lending spreads shifts inwards markedly. Again it is important to note that by construction, the policy rule responding to lending spreads cannot do worse than a baseline rule in an optimal setting, as the policy maker can set $\phi_s = 0$. However, the optimal $\phi_s$ was computed at the upper bound, 1.

Therefore, a policy rule responding to lending spreads improves upon the baseline rule in both the expected bank response and unexpected bank response scenarios to increased capital regulation. As a result, the revised rule appears to be optimal in response to increased capital regulation.

### 8.2 VAR Analysis

The estimation and calibration of Dynamic Stochastic General Equilibrium (DSGE) models is commonly accompanied by the estimation of Vector Autoregression (VAR) models in order to evaluate the performance of the structural model. A VAR model is estimated in this section in order to evaluate the performance of the calibrated DSGE model in being able to explain the key properties of the sample data. As the model used
in this thesis is not estimated, and therefore the standard deviation and persistence of shocks are not matched to Australian data, this analysis ensures that the results from which qualitative inferences were drawn in Section 7 are in line with the properties of the data.

Iacoviello (2005) estimates an unrestricted VAR model in order to illustrate the key relationships of variables in the data and uses the VAR and 90% confidence bands in order to evaluate the estimated and calibrated DSGE model to U.S data. The parameters of the DSGE are then manipulated in order to match the IRFs from the VAR to the DSGE model. This thesis does not manipulate the parameters in order to minimise the difference between the VAR and DSGE. The comparison is simply an evaluation of the consistency of the calibrated DSGE model with the data.

The VAR is estimated over the period 1993:Q2 to 2013:Q1 with first differenced Real GDP \(Y\), Inflation Expectations \(\pi\), first differenced Real house prices \(q\) and the RBA Policy rate \(R\)\(^{19}\). The sample period is marginally shorter compared to data calibrated to the DSGE model as a result of data availability for inflation expectations. One lag of each of the variables was chosen according to the Schwartz information criterion. The Choleski ordering of the Impulse Response Functions follows that of Iacoviello (2005). Whilst the ordering does not substantially impact upon the inference derived from the VAR, this ordering more accurately reflects the structure of the DSGE model.

\(^{19}\)The VAR also included a time trend, the RBA commodity index and a constant. Structural break dates were not considered due to the limited length of the sample.

\(^{20}\)All data was tested for a stationarity using an Augmented Dickey Fuller (ADF) unit root test. Series that were not stationary were transformed through a first differencing of the log of the series. The results of these tests are in Appendix A.3.
Figure 10: VAR Evidence, Australia

Note: VAR Estimated from 1999:QII to 2013:Q1. Values are percentage deviation from steady state. Time periods in quarters. Choleski Ordering R, π, q, Y. Dashed lines indicate 95% confidence bands

The results of the VAR illustrate the following key features of the data:

1. Contractionary monetary policy prompts a negative response to inflation, real house prices and real GDP.

2. The policy rate, inflation and real house prices respond negatively to an output shock

3. A positive inflationary shock motivates tighter monetary policy and a contraction in real house prices.

The Impulse Response Functions from the DSGE model are then compared to those from the VAR for a variety of shocks in order to assess whether or not the calibrated model captures the key properties of the data. Importantly, only 2 of the shocks
from the VAR are compared to the Impulse Response Functions from the VAR model: a monetary policy shock and an inflation shock. This is due to the fact that the DSGE model does not incorporate an exogenous shock to house prices. Furthermore, the DSGE model features a demand shock, through consumers’ preferences, and a technology shock. However, these shocks are not representative of the aggregate output shock that is estimated in the VAR model. More importantly, the emphasis of this exploration is on a monetary policy shock, as explored in Christiano et al. (2005) and an inflation shock, which is found to be important in the determination of optimal policy in Section 7.

Figure 11 shows the DSGE model impulse response functions for the 2 shocks and compares them with the impulse responses generated from the VAR model. The first column shows the responses to contractionary monetary policy. The findings are similar to those in Iacoviello (2005). The increase in the policy rate is not as substantial in the model as in the data. The responses of inflation and output to a policy rate shock in the model are immediate. The persistence of the shock appears to be the difference between the model and the data, as the VAR impulse responses of output and inflation adjust quickly to a policy rate shock. Moreover, as Iacoviello (2005) finds, there appear to be differences in the lag of shocks between the VAR impulse responses and the model. The response of house prices appears to be consistent with the key properties of the data following a policy rate shock.

The second column illustrates the responses to an inflationary shock and the model does well at capturing these responses. The policy rate is increased in order to offset the inflation and the initial expansion of inflation is captured by the model in line with the VAR estimates. Moreover, the initial contraction in real house prices due to an inflation shock also appears to be well specified in the model. The response of output appears to have far more persistence in the model as in the data.
These results highlight a caveat for the quantitative use of the model. The responses of these key variables, particularly to a contractionary policy shock do not appear to quantitatively match the responses of the data. This is largely due to the differences in persistence of shocks and the lag structure of shocks, where the data appears to respond to shocks with some lag, whereas the model responds immediately. Again, these findings are in line with the results in Iacoviello (2005). The qualitative aspects of the model match the data well. A contractionary policy shock increases the policy rate and inflation, house prices and output all contract initially. Furthermore, an inflation
shock leads to an increase in the policy rate, sharp increase in inflation, a contraction in house prices and a contraction in output.

Therefore, whilst the model does not appear to completely quantitatively match the VAR model, the key properties of the data are qualitatively captured. This is likely a result of the fact the model is not estimated on Australian data, and as a result the persistence and standard deviation of shocks are not optimal. As a result, this illustrates somewhat of a caveat for the quantitative results found in Section 8. However, the results in Section 8 are intended as a qualitative analysis, rather than a strict quantitative prescription as to the optimal conduct of monetary policy.

8.3 Structural & Estimated Parameters

The model is estimated with Bayesian methods in Gerali et al. (2010), with 13 structural parameters estimated based on 10 chains, each with 100,000 draws based on the Metropolis Hastings algorithm. The need for this section arises as whilst the original model is estimated on European Data, this thesis does not use any estimation methods. The rationale behind this decision lies in the difficulty and intricacies of estimating and calibrating parameters such as wage and price stickiness, given that these are not true variables that can be easily accessed. As a result, the initial estimated parameters of Gerali et al. (2010) determining adjustment costs and stickiness of prices and wages are used in the calibration of the model. The sensitivity of the inferences drawn in the previous chapters to these estimated parameters is tested in this section.

It is important to note that these parameters govern responses to various shocks in the dynamic state of the model. The parameters taken from the estimation in Gerali et al. (2010) do not influence the steady-state of the model. The sensitivity analysis is conducted using the same shocks as in the primary analysis. The structural parameters are all increased by 50% and Taylor curves are estimated as in Section 7 in order to test the sensitivity of the results to the increase in the structural parameters individually.

The following analysis separates each parameter and explores the sensitivity of the results to changes in this parameter.
8.3.1 Price Stickiness

An increase in the stickiness of prices dampens the response of inflation to shocks, as prices do not respond as quickly. In the case of a technology shock, an increase in the stickiness of prices will result in smaller reduction in prices following the initial increase in production. The policy rate therefore would not be cut as aggressively to respond to the contraction in prices. A relatively less expansionary policy stance therefore reduces consumption, investment and output deviations through the channels outlined earlier.

Price stickiness is increased by 50% in the model, however the inferences drawn regarding the improvement of the revised rule to the baseline rule over an aggregate of shocks still apply. For a given value $\lambda$ in the loss function, the loss function is roughly 4% lower under the revised rule, in line with the figure estimated in Section 7 with the original parameter values. Therefore the inferences drawn in section 7 do not appear to be sensitive to moderate changes in price stickiness ($\kappa_p$).

8.3.2 Wage Stickiness

Increasing the stickiness of wages does not appear to substantially change the responses of variables to a technology shock. Wage inflation falls marginally further as a result of wage stickiness in the event of a technology shock. Moreover, wage inflation does not recover as substantially with increased stickiness. This slightly reduces consumption due to the relative reduction of household wages.

Wage stickiness is also increased by 50% in the model, however, as in the case of price stickiness, the qualitative inferences drawn from earlier results are not changed. For the same $\lambda$, the loss function is 3.6% lower under the revised rule. Therefore while a 50% increase in wage stickiness marginally changes the result, the inferences drawn from this are robust to moderate changes in the parameter.

8.3.3 Investment Adjustment Costs

An increase in the investment adjustment cost intuitively reduces the increase in investment following a technology shock. This impact is also magnified due to the collateral borrowing constraint, as less investment reduces the demand for capital and therefore the price of capital. In the case of other shocks, investment will be slower to react to either stimulation or contraction. The inference derived from earlier results
is robust to changes in the investment adjustment parameter. The loss function, for
the same $\lambda$ as earlier, the loss function is again roughly 4% lower, illustrating that a
moderate change in the investment adjustment parameter does not substantially change
the results found in Section 7.

8.3.4 Price Indexation

Price indexation relates to the monopolistically competitive retail goods market. Retail
prices are assumed to be sticky and indexed to both a combination of past inflation and
steady state inflation. Price indexation determines the relative weights. As a result,
price indexation may increase or decrease the level of inflation, depending upon the
past values of inflation.

\[
1 - \epsilon_t^y + \frac{\epsilon_t^y}{x_t} - \kappa_p \left( \pi_t - \pi_{t-1} \pi^{1-\epsilon^p} \right) \pi_t
+ \beta P E_t \left[ \frac{\lambda P_{t+1}}{\lambda t} \kappa_p \left( \pi_{t+1} - \pi_t^{1-\epsilon^p} \pi^{1-\epsilon^p} \right) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0
\]  

In the case of a technology shock, as the past value of inflation is lower than the steady
state rate of inflation, this will result in an overall increase in the prices of retail goods.
Changes in price indexation do not appear to have substantial impacts upon the results
from Section 7. Where price indexation is increased by 50% for a given $\lambda$ in the loss
function, the loss function under a revised Taylor rule is 4.2% lower. Therefore, where
price indexation increases, the revised rule appears to perform marginally better. As
in the previous cases, the results appear to be robust to a change in this parameter.

8.3.5 Wage Indexation

Wage indexation, similarly to price indexation, determines the relative weight applied
to the steady state of wage inflation and previous period inflation. An increase in wage
indexation in the case of a technology shock will further enhance wage deflation. The
results in Section 7 are robust to moderate changes in this parameter. A 50% increase
in wage indexation (to previous period wage inflation) does not result in substantial
changes to the loss function for a given $\lambda$. Therefore, the revised rule, for the aggregated
shocks, still improves upon the baseline rule by approximately 4%.
8.3.6 Banking Adjustment Costs

The parameters that govern banking adjustment costs include: an adjustment cost for deposits ($\kappa_d$); adjustment costs for commercial and household loans ($\kappa^{BE}, \kappa^{BH}$); and an adjustment cost for deviating from the target capital ratio ($\kappa_{Kb}$). An increase in each parameter by 50%, for a given $\lambda$ in the loss function (23), does not substantially alter the results in Section 7. The aforementioned increases improve the loss function for $\kappa_d, \kappa^{BE}, \kappa^{BH}$ and $\kappa^{Kb}$ by 4.5%, 3.5%, 3.8% and 3.5% respectively. Therefore, by increasing the parameter values substantially, the results only marginally change. Thus, the qualitative inferences drawn in Section 7 are robust to these moderate changes in banking parameter values.
9 Conclusion

9.1 Discussion of Results

This thesis investigates the impacts of macro-prudential regulation, in the form of capital adequacy reform, upon lending rates, macroeconomic aggregates and monetary policy. A Dynamic Stochastic General Equilibrium (DSGE) model is calibrated to Australian quarterly sample data over the period 1993 to 2013 in order to examine this. The steady-state results suggest that increases in the target capital adequacy ratio of the banking sector may infer a move to a ‘new normal’, dependant upon the reaction of the banking sector to the reforms.

Where the banking sector responds to more stringent regulation through an increase in lending rates, the steady-state values of consumption, investment and output are all estimated to fall towards a ‘new normal’ steady-state. The results suggest that an increase in the bank capital ratio by 1 percentage point will constrict long term lending by approximately 3% and output by 0.5%. However, when the banking sector responds to reform by reducing the dividend payout ratio, there is no substantial reduction in the long-term value of these key variables.

Where the baseline Taylor rule is adjusted to incorporate a response to lending spread, the responses of key macroeconomic aggregates to various shocks are markedly influenced. Whilst the focus of this thesis is on the impact of regulation on monetary policy and not specifically exploring the optimality of policy, the results suggest that when responding to increasing lending spreads, the central bank is able to achieve improved stabilisation of inflation and output. Depending on the nature of the shock, the revised rule may or may not improve upon the standard Taylor rule.

The results in the literature are obtained without the inclusion of a stylised financial sector and without financial intermediation. However, it is interesting to note that the inclusion of the banking sector does not substantially alter the qualitative results. Furthermore, the revised policy rule, in the context of the linearised model, is found to ensure a unique equilibrium where the Blanchard Khan conditions are satisfied. The results in Section 7 are found robust to the potential responses from the banking sector and the initial calibration of parameters.
The results in this thesis may be informative to the implementation of capital adequacy regulation and future monetary policy decisions. Targeted increases in bank capital adequacy are found to have a moderate impact upon the long term levels of borrowing, output and investment in the Australian economy. Furthermore, monetary policy that responds in some way to this regulation, through targeting widened lending spreads, appears to improve upon the standard Taylor rule. However, this is dependant upon the source of the shocks in the economy. In practice, the central bank is unlikely to be able to perfectly distinguish the source of business cycle fluctuations. Counter-factual analysis suggests the RBA may have responded to widened lending spreads in the past. The results of this thesis suggest some caution as to responding to lending spreads, as the optimality of the policy rule depends upon the nature of shocks.

It is important to note that these results regarding the optimality of policy are intended to be qualitative in nature and do not seek to provide a quantitative suggestion as to the optimal weighting of policy. There are a variety of factors for this caution. Firstly, often the parameters found as optimal in these scenarios are not empirically feasible or empirically consistent. Secondly, the optimisation of rules was conducted using a grid search of parameters, where the grid itself was finite and the optimal policy parameters may lie between the incremental parameters chosen in the grid. Finally, in Section 8, the impulse response functions of the model do not quantitatively match those of the estimated VAR model for Australian data. However, the qualitative results from the DSGE model match the key properties of the data.

9.2 Extensions & Further Research

The aforementioned conclusions indicate potential avenues of future research. Beau et al. (2012) identify that in the development of particular DSGE models, including the framework used in this analysis, an important assumption is that the economy is isolated from the rest of the world. However, in reality, it is likely that activity, financial stability and monetary policy actions are influenced by events in the rest of the world, particularly major trading partners. Moreover, as the Australian economy is largely a resources exporting small-open economy, the assumption of isolation may be too simplifying. This may be captured by the simplistic inclusion of a Terms of Trade (TOT) shock through the banking sector in the existing model, where the banking sector experiences a substantial inflow of investment and capital in a positive TOT shock.
Alternatively, the model may be adjusted to incorporate an importing and exporting sector in order to more extensively capture export and import shocks. This alternative has been suggested in previous Australian literature (Robinson and Robson (2012)) as an important direction for future research, where the banking sector is included in a model incorporating an import and export sector.

The revised policy rule incorporating lending spreads was found to improve upon the baseline rule in certain circumstances. However, this result is largely a function of the objective of the policy maker. Whilst the aim of this thesis was not the exploration of optimal policy, the objectives of the central bank may be altered in order to ensure the results are robust to these changes. Curdia and Woodford (2010) suggest that the policy maker maximises the ex ante welfare of individuals in the economy. By altering the objective of the policy maker, incorporating spreads in the policy rule may result in a more substantial improvement. Whilst responding to lending spreads somewhat improves the stabilisation of output and inflation, it was found to markedly influence the volatility of lending spreads. Therefore, if the central bank is assumed to have a financial stability objective, the results of these optimality exercises may change.

Finally, much attention in the literature has been drawn to the interactions between macro-prudential and monetary policy. Beau et al. (2012) highlight that having two separate sets of instruments in order to pursue financial stability and price stability may introduce compounding or conflicting effects on the objectives targeted. The results of this thesis suggest that optimal monetary policy may also take into account financial factors. Therefore, introducing a specific macro-prudential rule into the system where monetary policy responds to financial indicators may magnify the conflicting effects found in Angelini et al. (2011).

### 9.3 Concluding Remarks

This thesis further extends the research into the impact of capital adequacy regulation on bank behaviour and macroeconomic aggregates. A key contribution of this thesis is that the steady-state results provide the first estimates of the impact of incremental capital reforms on the long-term levels of investment, consumption, output and borrowing in Australia. Furthermore, this thesis includes an analysis of the impact that macro-prudential regulation has upon the conduct of monetary policy. Throughout the financial crisis the central bank was found to divert from a standard Taylor rule. This
type of policy is captured in this thesis by a revision to the standard Taylor rule in the model to include a policy rule that also responds negatively to widening lending spreads.

The estimates of the calibrated DSGE model suggest that the response of key macroeconomic variables to various shocks differ substantially under the revised rule. Furthermore, the policy rule responding to spreads is found to improve upon the standard Taylor rule depending upon the source of the shocks to the business cycle. These results suggest that macro-prudential regulation, primarily through capital adequacy reform, is estimated to have a substantial influence on banking sector behaviour, long-term macroeconomic aggregates and the conduct of monetary policy.
A Data

A.1 Data Sources

**Inflation Rate:** Two values of inflation rate data are used: All Groups Quarterly Inflation data excluding interest charges and the tax changes of 1990/2000, Reserve Bank of Australia; Melbourne Institute Inflationary Expectations series, Quarterly, Reserve Bank of Australia.

**Fixed Capital Depreciation Rate:** The fixed capital depreciation rate is derived from Annual End year net-capital stock figures and Annual fixed capital formation data produced by the Australian Bureau of Statistics. Both data series are chain volume measures.

**Capital Share of Production Function:** The Capital share of the production function data is derived through Australian Bureau of Statistics estimates of Multi-factor productivity, two period average income shares. ABS 5260

**Real Consumption:** Households Final Consumption Expenditure, Current prices, Seasonally Adjusted, Quarterly, Australian Bureau of Statistics.

**Real Investment:** Gross Fixed Capital Formation, Quarterly, Current Prices, Seasonally Adjusted, Australian Bureau of Statistics.

**Real GDP:** Gross Domestic Product, Quarterly, Current Prices, Seasonally Adjusted, Australian Bureau of Statistics.

**Real House Prices:** Median Detached House Price Estimates, All Capital Cities, Quarterly, UNSW.

**Nominal Interest Rate:** Australian Official Policy Rate, Quarterly, Reserve Bank of Australia.

**Housing Lending Rates:** Quarterly, Annualised Standard Variable Bank Housing Rate, Reserve Bank of Australia Indicator Lending Rates.
Commercial Lending Rates: Quarterly, Annualised Weighted-Average Interest Rate on Credit Outstanding, Reserve Bank of Australia Bank Lending to Business - Selected Statistics

Deposit Rates: Quarterly, Annualised Weighted-Average Interest Rate on $10,000 term deposits across all terms at the five largest banks. Includes advertised 'special' and regular rates. Reserve Bank of Australia

Commodities Prices: RBA Index of Commodities Prices, All items, SDR, Monthly

A.2 Policy Rule Estimates

<table>
<thead>
<tr>
<th>Policy Rule</th>
<th>1993Q1 - 2013Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.202</td>
</tr>
<tr>
<td></td>
<td>(0.246)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.875***</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.240**</td>
</tr>
<tr>
<td></td>
<td>(0.092)</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>0.044***</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
</tr>
</tbody>
</table>

$R^2 = 0.852$

* 5%, ** 1%, *** 0.01% significance levels

A.3 Unit Root Tests

<table>
<thead>
<tr>
<th></th>
<th>Level (X)</th>
<th>$\Delta \ln (X)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>0.720</td>
<td>0.000</td>
</tr>
<tr>
<td>Investment</td>
<td>0.638</td>
<td>0.000</td>
</tr>
<tr>
<td>RBA Index of Commodities</td>
<td>0.338</td>
<td>0.000</td>
</tr>
<tr>
<td>Real House Prices</td>
<td>0.666</td>
<td>0.000</td>
</tr>
<tr>
<td>Output</td>
<td>0.791</td>
<td>0.000</td>
</tr>
</tbody>
</table>
A.4 Raw Data

Figure 12: Raw Data: Sample Period 1993:Q1 to 2013:Q1
A.5 Transformed Data

Figure 13: Transformed Data - Sample Period 1993:Q1 to 2013:Q1

- Output
- Real House Price
- Investment
- Consumption
- RBA Index of Commodity Prices
B Additional Figures

B.1 Policy Frontiers

Figure 14: Policy Frontiers & Spread Responses: Disaggregated Shocks

[Graphs showing the relationship between volatility of inflation and volatility of output for financial and inflation shocks, with different weights on spreads.]
C Derivation of Gerali Model

The equations describing the equilibrium of the model are derived following the guidelines provided in Gerali et al (2010).

Patient Households

The representative patient household $i$ maximises the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_t \left[(1 - \alpha_P) \epsilon_t \log(c_t^P(i) - \alpha_P c_{t-1}^P) + \epsilon_t^h j \log h_t^P(i) - \frac{l_t^P(i)^{1+\phi}}{1+\phi}\right]$$

subject to the following budget constraint

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) \leq w_t^P t_t^P + \frac{(1 + r_{t-1}^d) d_{t-1}^P(i)}{\pi_t} + t_t^P(i)$$

The variables subject to maximisation are consumption ($c_t^P$), housing ($h_t^P$) and bank deposits ($d_t^P$). Using Lagrangian methods for constrained optimisation and aggregating over households, the First Order Conditions (FOC) are derived:

$$\lambda_t^P = \frac{\epsilon_t (1 - \alpha_P)}{(c_t^P - \alpha_P c_{t-1}^P)}$$

(29)

$$\lambda_t^P q_t^h = \epsilon_t^h \frac{j}{h_t^P} + \beta^P E_t \left[\lambda_{t+1}^P q_{t+1}^h\right]$$

(30)

$$\lambda_t^P = \beta^P E_t \left[\frac{\lambda_{t+1}^P (1 + r_t^d)}{\pi_{t+1}}\right]$$

(31)

Impatient Households

The representative impatient household $i$ maximises the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_t \left[(1 - \alpha_I) \epsilon_t \log(c_t^I(i) - \alpha_I c_{t-1}^I) + \epsilon_t^h j \log h_t^I(i) - \frac{l_t^I(i)^{1+\phi}}{1+\phi}\right]$$

subject to the following budget constraint

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + \frac{(1 + r_{t-1}^H) b_{t-1}(i)}{\pi_t} \leq w_t^P t_t^P + b_t^I(i)$$

(33)
and subject to a borrowing constraint (where $s^I_t$ is a multiplier)

$$\left(1 + r^bH_t\right) b^I_t(i) \leq m^I_t E_t \left[ q^h_{t+1} h^I_t(i) \pi_{t+1} \right]$$ (34)

The variables subject to maximisation are consumption ($c^E_t$), housing ($h^I_t$) and housing loans ($b^I_t$). Using Lagrangian methods for constrained optimisation and aggregating over households, the First Order Conditions (FOC) are derived:

$$\lambda^I_t = \frac{c^I_t (1 - \alpha^I)}{c^I_t - \alpha^I c^I_{t-1}}$$ (35)

$$\lambda^I_t q^h_t = \frac{\epsilon^I_t}{H^I_t} + E_t \left[ \beta^I \lambda^I_{t+1} q^h_{t+1} + s^I_t q^h_{t+1} m^I_t \pi_{t+1} \right]$$ (36)

$$\lambda^I_t = s^I_t \left(1 + r^hH_t\right) + \beta^I E_t \left[ \frac{\lambda^I_{t+1} \left(1 + r^bH_t\right)}{\pi_{t+1}} \right]$$ (37)

### Entrepreneurs

The representative entrepreneur $i$ maximises the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta^E_t \log \left(c^E_t(i) - \alpha^E c^E_{t-1} \right)$$ (38)

subject to the following budget constraint

$$c^E_t(i) + w^E_t l^E,P_t(i) + w^E_t l^E,I_t(i) + \left(1 + r^E_{t-1}\right) b^E_{t-1}(i) b^E_{t-1}(i) + q^E_t k^E_t(i)

+ \phi(u_t(i)) k^E_{t-1}(i) \leq \frac{y^E_t(i)}{x_t} + b^E_t(i) + q^E_k (1 - \delta) k^E_{t-1}(i)$$ (39)

Wholesale good $y^E_t$ is produced according to the technology

$$y^E_t(i) = a^E_t \left[k^E_{t-1}(i) u_t(i)\right]^{\alpha} t^E_t(i)^{1-\alpha}$$ (40)

The variables subject to maximisation are consumption ($c^E_t$), physical capital ($k^E_t$), capacity utilisation rate ($u_t$), labour inputs for patient ($l^E,P_t$) and impatient ($l^E,I_t$) households and commercial loans ($b^E_t$). Using Lagrangian methods for constrained optimisation and aggregating over entrepreneurs, the First Order Conditions (FOC) are derived:
\[ \lambda_t^E = \frac{(1 - \alpha^E)}{(c_t^E - \alpha^E c_{t-1}^E)} \]  

(41)

\[ \lambda_t^E q_t^k = E_t \left[ s_t^E m_t^E q_{t+1}^k \pi_{t+1} (1 - \delta) + \beta^E \lambda_{t+1}^E (r_{t+1}^k u_{t+1} + q_{t+1}^k (1 - \delta) - \phi (u_{t+1})) \right] \]  

(42)

\[ \lambda_t^E = s_t^E (1 + r_t^E) + \beta^E E_t \left[ \frac{\lambda_{t+1}^E (1 + r_t^E)}{\pi_{t+1}} \right] \]  

(43)

\[ w_t^P l_t^{E,P} = \frac{(1 - \alpha) y_t^E \mu}{x_t} \]  

(44)

\[ w_t^I l_t^{E,I} = \frac{(1 - \alpha) y_t^E \mu}{x_t} \]  

(45)

\[ r_t^k = \xi_1 + \xi_2 (u_t - 1) \]  

(46)

\[ r_t^k = \alpha a_t^E \left[ k_t^{E,i} u_t \right]^{\alpha-1} l_t^E (i)^{1-\alpha} \]  

(47)

Labour Market

Each union sets nominal wages by maximising

\[ E_0 \sum_{t=0}^{\infty} \beta_t^S \left\{ \lambda_t^S \left[ \frac{W_t^S(m)}{P_t} l_t^S(i,m) \right]^{\alpha} - \frac{\kappa_w}{2} \left( \frac{W_t^S(m)}{W_{t-1}^S(m)} - \pi_t^{\alpha} \alpha^{1-\alpha} \right)^2 \frac{W_t^S}{P_t} - \frac{l_t^S(i,m)^{1+\phi}}{1 + \phi} \right\} \]  

(48)

subject to demand for labour

\[ l_t^S(i,m) = l_t^S(m) = \left( \frac{W_t^S(m)}{W_t^S} \right)^{-\epsilon l_t^S} l_t^S \]  

(49)

The variable subject to maximisation is nominal wages \((W_t^S)\). Using Lagrangian methods for constrained optimisation and imposing a symmetric equilibrium, the First Order Conditions (FOC) are derived:
\[ \kappa_w \left( \frac{\pi_t^{w_p}}{\pi_{t-1}^{w_p}} - \pi_{t-1}^{w_p} \right) \pi_t^{w_p} = \beta P E_t \left[ \frac{\lambda^{t+1}}{\lambda^t} \kappa_w \left( \frac{\pi_t^{w_p}}{\pi_{t-1}^{w_p}} \right) \pi_{t+1}^{w_p} \right] \]
\[ + \left( 1 - \epsilon^t \right) l_t^P + \frac{\epsilon^t l_{t+1}^{1+\phi}}{\omega_t^P \lambda_t^P} \]  \hspace{1cm} (50)

\[ \kappa_w \left( \frac{\pi_t^{w_f} - \pi_{t-1}^{w_f}}{\pi_{t-1}^{w_f}} \right) \pi_t^{w_f} = \beta I E_t \left[ \frac{\lambda^{t+1}}{\lambda^t} \kappa_w \left( \frac{\pi_t^{w_f}}{\pi_{t-1}^{w_f}} \right) \pi_{t+1}^{w_f} \right] + \left( 1 - \epsilon^t \right) l_t^I + \frac{\epsilon^t l_{t+1}^{1+\phi}}{\omega_t^I \lambda_t^I} \]  \hspace{1cm} (51)

Where \( \omega_t^P \) and \( \omega_t^I \) is the real wage and \( \pi_t^{w_p} \) and \( \pi_t^{w_f} \) is nominal wage inflation for the respective households. Nominal wage inflation is equal to:

\[ \pi_t^{w_p} = \frac{w_t^{w_p}}{w_{t-1}^{w_p}} \pi_t \]  \hspace{1cm} (52)

\[ \pi_t^{w_f} = \frac{w_t^{w_f}}{w_{t-1}^{w_f}} \pi_t \]  \hspace{1cm} (53)

**Banks**

Bank capital is accumulated out of retained earnings

\[ \pi_t K_t^b = (1 - \delta) K_{t-1}^b + (1 - \omega^b) J_{t-1}^b \]  \hspace{1cm} (54)

Bank profits are the earnings of all 3 groups within the banking system

\[ J_t^b = r_t^{bH} b_t^H + r_t^{bE} b_t^E - r_t^d d_t - \frac{\kappa K_b}{2} \left( \frac{K_t^b}{B_t} - v^b \right)^2 K_t^b - Adj_t^B \]  \hspace{1cm} (55)

**Wholesale Banking**

The Wholesale bank chooses loans and deposits to maximise

\[ E_0 \sum_{t=0}^{\infty} \beta_t^P \lambda_t^P \left[ (1 + R_t^b) B_t - \pi_{t+1} B_{t+1} + (1 + R_t^d) D_t + (K_{t+1} B_{t+1} - K_t^b) - \frac{\kappa K_b}{2} \left( \frac{K_t^b}{B_t} - v^b \right)^2 K_t^b \right] \]  \hspace{1cm} (56)

subject to
The variables subject to maximisation are total loans \(B_t\) and total deposits \(D_t\). Using Lagrangian methods for constrained optimisation, the First Order Conditions (FOC) are derived:

\[
R^b_t = R^d_t - \kappa_K B_t^b \left( \frac{K_t^b}{B_t^b} - v^b \right) \left( \frac{K_t^b}{B_t^b} \right)^2
\]

The no arbitrage lending facility at the central bank ensures \(R_t^d = r_t\) and (75) becomes

\[
R_t^b = r_t - \kappa_K B_t^b \left( \frac{K_t^b}{B_t^b} - v^b \right) \left( \frac{K_t^b}{B_t^b} \right)^2
\]

**Retail Banking: Loan Branch**

The retail bank maximises the rates charged on loans

\[
E_0 \sum_{t=0}^{\infty} \beta^t P_t \left[ r_t^{BH}(j)b_t^l(j) + r_t^{BE}(j)b_t^E(j) - R_t^b B_t(j) - \frac{\kappa_{bH}}{2} \left( \frac{r_t^{BH}(j)}{r_{t-1}^{BH}(j)} - 1 \right)^2 r_t^{BH} b_t^l \right]
\]

subject to

\[
b_t^l(j) = \left( \frac{r_t^{BH}(j)}{r_t^{BH}} \right)^{-\epsilon_t^{BH}} b_t^l
\]

\[
b_t^E(j) = \left( \frac{r_t^{BE}(j)}{r_t^{BE}} \right)^{-\epsilon_t^{BE}} b_t^E
\]

The variables subject to maximisation are household lending rates \((r_t^{BH}(j))\) and commercial lending rates \((r_t^{BE}(j))\). Using Lagrangian methods for constrained optimisation and imposing symmetric equilibrium, the First Order Conditions (FOC) are derived:

\[
1 - \epsilon_t^{BH} + \epsilon_t^{BH} \frac{R_t^b}{r_t^{BH}} - \kappa_{bH} \left( \frac{r_t^{BH}}{r_{t-1}^{BH}} - 1 \right) + \beta P E_t \left\{ \frac{\lambda_{t+1}^p}{\lambda_t^p} \kappa_{bH} \left( \frac{r_t^{BH}}{r_{t-1}^{BH}} - 1 \right) \left( \frac{r_t^{BH}}{r_{t-1}^{BH}} \right)^2 \right\} = 0
\]

(63)

\[
1 - \epsilon_t^{BE} + \epsilon_t^{BE} \frac{R_t^b}{r_t^{BE}} - \kappa_{bE} \left( \frac{r_t^{BE}}{r_{t-1}^{BE}} - 1 \right) + \beta P E_t \left\{ \frac{\lambda_{t+1}^p}{\lambda_t^p} \kappa_{bE} \left( \frac{r_t^{BE}}{r_{t-1}^{BE}} - 1 \right) \left( \frac{r_t^{BE}}{r_{t-1}^{BE}} \right)^2 \right\} = 0
\]

(64)
Retail Banking: Deposit Branch

The retail bank maximises the rates over the deposit rate

\[ E_0 \sum_{t=0}^{\infty} \beta_t^p \lambda_t^P \left[ r_t D_t(j) - r_t^d(j) d_t^P(j) - \frac{\kappa_d}{2} \left( \frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right] \]  

(65)

subject to \( D_t(j) = d_t^P(j) \) and

\[ d_t^P(j) = \left( \frac{r_t^d(j)}{r_t^d} \right)^{-\epsilon_t} d_t \]  

(66)

The variable subject to maximisation is deposit rates \((r_t^d(j))\). By imposing symmetric equilibrium, the First Order Conditions (FOC) are derived:

\[ \epsilon_t^d - 1 - \epsilon_t^d \frac{r_t}{r_t^d} - \kappa_d \left( \frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right) \frac{r_t^d}{r_{t-1}^d} \]
\[ + \beta P E_t \left[ \frac{\lambda_{t+1}^p}{\lambda_t^P} \kappa_d \left( \frac{r_{t+1}^d}{r_t^d} - 1 \right) \left( \frac{r_{t+1}^d}{r_t^d} \right) \frac{d_{t+1}}{d_t} \right] = 0 \]  

(67)

GoodsRetailers

The retail goods market is assumed to be monopolistically competitive and choose \( P_t(j) \) to maximise

\[ E_0 \sum_{t=0}^{\infty} \beta_t^p \lambda_t^P \left[ P_t(j)y_t(j) - P_t^W y_t(j) - \frac{\kappa_p}{2} \left( \frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^p \pi_{1-\epsilon_p} \right)^2 P_t y_t \right] \]  

(68)

subject to demand

\[ y_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\epsilon_t^y} y_t \]  

(69)

The variable subject to maximisation is retail prices \((P_t(j))\). By imposing symmetric equilibrium, the First Order Conditions (FOC) are derived:

\[ 1 - \epsilon_t^y + \epsilon_t^y \frac{x_t}{x_t} - \kappa_p \left( \pi_t - \pi_{t-1}^p \pi_{1-\epsilon_p} \right) \pi_t \]
\[ + \beta P E_t \left[ \frac{\lambda_{t+1}^p}{\lambda_t^P} \kappa_p \left( \pi_{t+1} - \pi_{t}^p \pi_{1-\epsilon_p} \right) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0 \]  

(70)

Retailers’ profits
\[ j_t^R = y_t \left[ 1 - \frac{1}{x_t} - \frac{\nu}{2} \left( \pi_t - \pi_{t-1} \pi^{1-\nu} \right)^2 \right] \] (71)

**Capital Goods Producers**

Perfectly competitive firms maximise

\[ E_0 \sum_{t=0}^{\infty} \beta_t E_t \left[ q_t^k \Delta x_t - i_t \right] \] (72)

subject to

\[ \bar{x}_t = \bar{x}_{t-1} + \left[ 1 - \frac{\kappa_i}{2} \left( \frac{i_t \epsilon^k_{t}}{i_{t-1}} - 1 \right)^2 \right] i_t \] (73)

where

\[ \Delta \bar{x}_t = k_t - (1 - \delta) k_{t-1} \] (74)

From the constraints, the amount of new capital that can be produced

\[ k_t = (1 - \delta) k_{t-1} \left[ 1 - \frac{\kappa_i}{2} \left( \frac{i_t \epsilon^k_{t}}{i_{t-1}} - 1 \right)^2 \right] i_t \] (75)

The variable subject to maximisation is the units of final goods \((i_t)\). Using the Lagrangian method for constrained optimisation, the First Order Conditions (FOC) are derived:

\[ 1 = q_t^k \left[ 1 - \frac{\kappa_i}{2} \left( \frac{i_t \epsilon^k_{t}}{i_{t-1}} - 1 \right)^2 - \kappa_i \left( \frac{i_t \epsilon^k_{t}}{i_{t-1}} - 1 \right) \left( \frac{i_t \epsilon^k_{t}}{i_{t-1}} \right)^2 \right] + \beta_t E_t \left[ \frac{\lambda_{t+1} E_t q_t^k}{\lambda_t E_t q_{t+1}^k i_{t+1} \kappa_i} \left( \frac{i_{t+1} \epsilon^k_{t+1}}{i_t} - 1 \right) \left( \frac{i_{t+1}}{i_t} \right)^2 \right] \] (76)
Monetary Policy & Market Clearing

The central bank sets the policy rate \( r_t \) according to

\[
(1 + r_t) = (1 + r)^{1-\phi_R} (1 + r_{t-1})^{\phi_R} \left( \frac{\pi_t}{\pi} \right)^{\phi_R(1-\phi_R)} \left( \frac{y_t}{y_{t-1}} \right)^{\phi_R(1-\phi_R)} \epsilon_t^r \tag{77}
\]

The market clears through the following equations

\[
y_t = c_t + q_t^k [k_t - (1 - \delta) k_{t-1}] + k_{t-1} \phi (u_t) + \delta^b \frac{K^b_{t-1}}{\pi_t} + \text{Adj}_t \tag{78}
\]

\[
c_t = c_t^P + c_t^I + c_t^E \tag{79}
\]

\[
\bar{h} = h_t^P(i) + h_t^I(i) \tag{80}
\]

\[
k_t = k_t^E \tag{81}
\]

\[
y_t = y_t^E \tag{82}
\]

\[
l_t^P = l_t^{E,P} \tag{83}
\]

\[
l_t^I = l_t^{E,I} \tag{84}
\]
D Steady State of Gerali Model

The model is derived in the steady state in order to explore interactions between variables of interest without dynamics. Furthermore, the system of equations describing the model derived in the previous section are log-linearised around these steady state values in order to solve the model.

D.1 Patient Households in Steady State:

\[ \lambda^P = \epsilon^C c^P \]  

\[ j^P \frac{\epsilon^h}{h^P} - \lambda^P q^h (1 - \beta^P) = 0 \]  

\[ \pi = \beta^P (1 + r^d) \]  

\[ c^P + d^P - w^P l^P - \frac{(1 + r^d)^P}{\pi} - j^R = 0 \]

D.2 Impatient Households in Steady State:

\[ \lambda^I = \epsilon^C c^I \]  

\[ j^I \frac{\epsilon^h}{h^I} - \lambda^I q^h (1 - \beta^I) + s^I m^I q^h \pi = 0 \]  

\[ \frac{\lambda^I \beta^I (1 + r^{bH})}{\pi} - s^I (1 + r^{bH}) = 0 \]  

\[ c^I + \frac{(1 + r^{bH}) b^I}{\pi} - w^I l^I - b^I = 0 \]  

\[ (1 + r^{bH}) b^I - m^I q^h h^I \pi = 0 \]

D.3 Labour Markets in Steady State:

\[ l^{P\phi} = \frac{\epsilon^I - 1}{c^I} w^P \lambda^P \]
\[ l^\phi = \frac{e^l - 1}{e^l} w^l \lambda^l \]  

(95)

\[ \pi = \pi^{w'} \]  

(96)

\[ \pi = \pi^{w \lambda} \]  

(97)

**D.4 Entrepreneurs in Steady State:**

\[ \lambda^E = \frac{1}{c^E} \]  

(98)

\[ s^E m^E q^K \pi (1 - \delta) + \beta^E \lambda^E (q^K (1 - \delta) + r^k u_l) - \lambda^E q^K = 0 \]  

(99)

\[ w^P = \frac{\mu (1 - \alpha) y^E}{l^{E,P} x} \]  

(100)

\[ w^I = \frac{\mu (1 - \alpha) y^E}{l^{E,I} x} \]  

(101)

\[ \lambda^E - s^E (1 + r^bE) - \frac{\beta^E \lambda^E (1 + r^bE)}{\pi} = 0 \]  

(102)

\[ \xi_1 = r^k \]  

(103)

\[ c^E + \frac{(1 + r^bE) b^E}{\pi} + w^P l^{E,P} + w^I l^{E,I} + q^K k^E - \frac{y^E}{x} - b^E - q^K (1 - \delta) k^E = 0 \]  

(104)

\[ y^E - a^E (u_k^E)^\alpha \left( (l^{E,P})^\mu (l^{E,I})^{1-\mu} \right)^{1-\alpha} = 0 \]  

(105)

\[ (1 + r^bE) b^E - m^E q^K \pi k^E (1 - \delta) = 0 \]  

(106)

\[ r^k = \frac{\alpha a^E (u_k^E)^{\alpha-1} \left( (l^{E,P})^\mu (l^{E,I})^{1-\mu} \right)^{1-\alpha}}{x} \]  

(107)
D.5 Banks in Steady State:

\[ R^b = r \]  
\( K^b \pi - (1 - \delta) K^b - j^B = 0 \)

\[ d = d^P \]

\[ b^H = b^I \]

\[ B = D + K^b \]

\[ r^{bH} = \frac{e^{bH}}{e^{bH} - 1} R^b \]

\[ r^{bE} = \frac{e^{bE}}{e^{bE} - 1} R^b \]

\[ r^d = \frac{e^d}{e^d - 1} r \]

\[ J^B = r^{bH} b^H + r^{bE} b^E - r^d d \]

D.6 Retailers in Steady State:

\[ j^R = y \left( 1 - \frac{1}{x} \right) \]

\[ x = \frac{e^y}{e^y - 1} \]

D.7 Capital Goods Producers in Steady State:

\[ k - (1 - \delta) k = i \]

\[ q^K = 1 \]
D.8 Aggregation in Equilibrium:

\[ c = c^P + c^I + c^E \]  
(121)

\[ B = b^I + b^E \]  
(122)

\[ D = d^P \]  
(123)

\[ y = y^E \]  
(124)

\[ t^E.P = t^P \]  
(125)

\[ t^E.I = t^I \]  
(126)

\[ h = h^I + h^P \]  
(127)

\[ k = k^E \]  
(128)

\[ y - c - (k - (1 - \delta)k) = 0 \]  
(129)
References


Elliott, D. J. (2009, September). Quantifying the Effects on Lending of Increased Capital Requirements.


