Macro Prudential Policy and Interest Rate Stickiness

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Abstract

This paper provides cross country evidence of interest rate sluggishness due to fixed interest rate loan contract.We develop a two sector DSGE model with a detailed banking sector to assess the impact of the interest rate stickiness on the transmission of macro prudential tools.We also attempt to understand possible interactions between capital requirement and LTV limit. The banking sector in the model features residential mortgages and corporate lending, subject to borrower default as well as bank defaults.Key distortions in the model include limited liability,bankruptcy costs and penalty costs for deviation from regulatory capital.We find that interest rate stickiness slows down the effect of a change in capital requirement on the economy and also makes the countercyclical capital regulation less effective.At the same, interest rate stickiness increases the impact of a change in LTV policy. The counter cyclical capital performs better than countercyclical LTV rule even when interest rates are sticky.As regards interaction between the two policy tools, capital regulation has a higher impact on the economy when the LTV limit is higher, whereas the LTV limit has a higher impact when the capital requirement is lower.

1 Introduction

The Financial crisis of 2008 brought to forefront the risks inherent in the financial system and the possible role of macro prudential tools to maintain financial and macroeconomic stability. BIS (2018) suggests that the micro prudential regulation is necessary but not sufficient to maintain financial stability. Regulatory tools which directly track and respond to macro economic developments could enable regulators to deal with boom bust cycles and the resulting threat to the banking system in an effective and timely manner.

As a result, a number of new measures have been added to the regulatory toolkit in different countries eg. Countercyclical capital buffers, Loan to Value (LTV) limit, Loan to Income limit etc in the aftermath of the financial crisis, although the capital adequacy ratio is still the main focus of prudential policy and Basel norms. Capital Adequacy ratio is the minimum capital banks are required to hold as a proportion of their risk weighted

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assets.Counter cyclical capital buffer(CCB) is the additional capital banks are required to hold in response to expansionary credit boom, so as to mitigate the credit growth and stability the financial cycle. The objective of the CCB tool is to enable banks to build up capital in times of a financial boom so as to increase resilience at the time when the boom turns into bust.LTV limit is the maximum amount that a borrower can borrow as a proportion of the value of the underlying asset. The capital requirement is related to the bank's equity whereas the LTV limit is related to the borrower's equity.

There is growing empirical and theoretical literature on the effect of macro prudential policy tools on the macro economy.This paper aims at two objectives. The first is to explore the role of interest rate stickiness on the transmission of macro prudential policy tools such as the capital adequacy ratio, LTV limit, and countercyclical capital and countercyclical LTV limit.

The second objective of the paper is to study how these policies interact with each other.There are very few papers which have more than one such macro prudential tools in the same model.As a result, the literature has not given much attention on the possible interaction between the tools.In this paper, we look at two key policy tools, Capital adequacy ratio and loan to value limit.

Although the literature on interest rate stickiness has existed since the 90s, there has been no attention towards this aspect in the literature on either monetary policy or macro prudential policy. Whereas the idea of price stickiness in the goods market is a key aspect of new Keynesian models, the same has not been discussed in the context of interest rate stickiness in the loan markets except for Gerali et al (2010).

As per Kobayashi (2007), interest-rate stickiness could arise both from (a) the existence of adjustment costs of changing loan rates. This may be due to customer's costs of changing banks (switching costs), menu costs of changing interest costs, highly regulated banking sector or less competitive banking sector (b) the presence of overlapping multi-period contracts.The presence of multi period loan rate contracts, for example a fixed interest mortgage contract would make the adjustment of interest rates sluggish in response to policy actions.

This sluggish adjustment of interest rate could have macro economic implications as interest rate is a key element in the transmission of monetary as well as macro prudential policy.

One of the important channels through which capital regulation affects the economy is through it's impact on the interest rates. As the bank's cost of equity is higher than cost of deposits, an increase in the capital requirement would increase the weighted average cost of capital for the bank and hence would also cause an increase in the lending rate charged by the banks. This could have further macro economic implications as higher interest rate would have a negative impact on credit growth, investment etc. This is also the rationale for using counter cyclical buffers to "lean against the wind" so as to dampen excess fluctuations in the economy. Thus, flexibility or stickiness of the lending rates could have potential impact on the transmission of the macro prudential policy tools

To understand the macroeconomic implications of interest rate stickiness, we build a dynamic stochastic general equilibrium model based on Clerc et al (2015) with a detailed banking sector,financial frictions and macro prudential policy rules. As far as we know, this is the first paper which models interest rate stickiness as in Calvo (1983) in a DSGE framework.

We find that interest rate stickiness dampens the effect of change in capital requirement on the credit growth and investment.On the other hand, interest rate stickiness increases the effectiveness of change in LTV limit. The counter cyclical capital buffer is also less effective in smoothing the credit cycle if the interest rates adjust sluggishly. However, it is still better than a counter cyclical LTV limit for leaning against the wind. Further, we find that the volatility in the macro economic variables in response to key shocks also increases due to interest rate stickiness.

As regards interaction between the two tools, we find that the impact of the change in capital requirement is higher when the LTV limit is higher i.e.for a higher level of LTV limit, the increase in capital requirement causes a higher proportional fall in lending and investment.However, the the change in LTV limit has a higher impact when the capital requirement is lower.

The the paper is organized as follows. Section 2 reviews the existing literature in the area. Section 3 provides empirical evidence for interest rate stickiness for the UK and major economies of the Euro zone. Section 4 describes the model and section 5 summarizes the key results of the model. Section 6 concludes.

2 Literature review

Literature on financial frictions and role of banks in DSGE models has been growing since the financial crisis of 2008. Our model attempts to bring together two streams of literature. One is based on the celebrated Bernanke, Gilchrist and Gertler (1999) where some fraction of borrowers default in equilibrium. Borrowers default due to limited liability and shocks (both aggregate and idiosyncratic) which cause the value of the asset to go below the loan amount. The other stream of literature is based on borrowing constraints as in Kiyotaki and Moore (1997).

Several papers have built upon BGG framework to include the role for the banking sector. As in BGG, most papers assume that return on debt is state contingent, implying that banks or financial intermediaries make a risk free return. Thus, in these models, there is no role for bank capital. Clerc et al (2015) depart from this assumption, and develop a model where banks are exposed to risk and can default in equilibrium. Banks are also prone to taking higher risk due to limited liability and deposit insurance. The model features a meaning trade-off between costs of banking sector defaults on the one hand and higher cost of capital on the other. This is used to perform normative as well as positive analysis of bank capital requirement. Our paper is closely related to Clerc et al (2015). We build upon this model to include interest rate stickiness and Loan to Value limits.This allows us to analyze the interaction between the two tools.However,we would focus on positive aspect of the model.

The model developed by Benes and Kumhof (2014) also features both borrower and bank level default. They study the role of a countercyclical capital in a monetary economy and find significant welfare gains.

Hodbod et al (2016) develop a similar model and show how a countercyclical risk weight can be used as a macro prudential tool to attenuate a financial cycle. Lorez et al (2018) evaluate different rules for setting countercyclical buffers in a small open economy model for the Irish economy.

The other stream of literature on financial friction pertains to models with borrowing constraints in the form of a collateral constraint as in Kiyotaki and Moore (1997). Iacoviello (2005) builds a DSGE model with housing sector and collateral constraint to analyse monetary policy transmission. Mendoza and Bianchi (2008) and Jeanne and Korinek (2008) provide rationale for macro prudential policies due to a pecuniary externality associated with collateral constraints. Gerali et al (2010) explore the role of banking sector related shocks in a model with binding collateral constraint.

Both these strands of literature are mutually exclusive in that they either have a default in equilibrium or an exogenous collateral constraint. In this paper, we bring together both these elements, where borrowers (and banks) can strategically default and borrowers are subject to collateral constraint on the new loans (which appears in the model as LTV limit) .Another paper which attempts to do so is Nukhwoon & Tsomocos (2017).The advantage of this approach is that the collateral constraint can be looked upon as a LTV limit imposed by the bank as well as a policy instrument of the regulator.

Other important papers with a key role for banking sector within a DSGE framework include Goodfriend & McCallum (2007), Curdia and Woodford (2008), Meh and Moran (2010), Cristiano, Motto and Rostagno (2014) Empirical papers.

Gerali et al (2010) is an example of DSGE model which incorporates interest rate stickiness. They do it by introducing quadratic adjustment costs in the profit function of the banks.In this paper, we introduce price stickiness as in Calvo (1983).

Nukhwoon & Tsomocos (2017) attempt to explain the financial crisis with default risk shock and a risk premium shock in a DSGE model, similar to Clerc et al (2015). They analyze the role of macro prudential policy tools such as countercyclical capital buffers, LTV limit and state contingent LTV limit.

There are very few papers which look at different prudential policies in the same model.For example, Boissay & Collard (2016) study the transmission mechanism of liquidity and capital regulations in a DSGE model.They find that both policies reinforce each other and support the Basel III's "multiple metrics" approach.

Goodhart et al (2013) study multiple financial regulation in an integrated framework using a simplified model.They analyze combinations of capital regulations, margin requirements, liquidity regulation, and dynamic provisioning to achieve financial stability and maximizing welfare.Popoyan et al(2017) develop an agent-based model to study the macroeconomic impact of alternative macro-prudential regulations and their possible interactions with different monetary policy rules.

We would like to clarify that the interest rate sluggishness that we discuss in this paper is about lending rates and not the sluggishness in the policy rates or Taylor rule inertia as in Rudebusch (2000,2006). As regards interest rate stickiness, there is literature from the 90s, which tries to explain the rationale for interest rate stickiness. For example the presence of a highly regulated or less-competitive financial sector (Hannan and Berger, 1991, Neumark and Sharpe, 1992),administrative/menu costs in changing loan rates (Mester and Saunders, 1991), customer's costs of changing banks (Neumark and Sharpe, 1992),etc.

Lowe & Rohling (1992) provide theory and evidence on interest rate stickiness.They consider theories are based on equilibrium credit rationing, switching costs, implicit risk sharing and consumer irrationality. Their empirical evidence provides support for the switching cost explanation.

In recent times,Driscoll and Judson (2013) examine the dynamics of eleven different deposit rates for a panel of over 2,500 branches of about 900 depository institutions observed weekly over ten years. They find that rates are downwards-flexible and upwards-sticky, and show that a simple menu cost model can generate this behavior. Bernstein & Fuentes(2004) provide evidence that the lending rates in Chile are flexible as compared to most other countries.

Moazzami (2010) finds that lending rates in the US have been stickier than those in Canada. However, the US lending rate rigidity, has decreased in recent years.

Sorenson & Werner (2006) investigate the pass-through between market interest rates and bank interest rates in the euro area.They find heterogeneity in interest pass through across loan products and that the speed of adjustment of interest rates is slow.

Nakajima & Teranishi (2009) show that the loan rates are sticky to a policy interest rate in all Eurozone countries for all loan maturities, the degree of stickiness differs across the countries, and the degree of difference is more prominent for longer loan maturities.Andries and Billon (2014) provide a survey of the empirical literature on interest rate pass through.The results show that although there is complete long run pass through of interest rates, there is an incomplete short-run pass-through and a heterogeneous adjustment of bank interest rates across bank products and euro zone countries.

In the empirical section of this paper, we explore one of the sources of interest stickiness related to the nature of loan contract i.e.fixed interest loans. Macro economic models with banking sector generally assume a one period loans and thereby all loans to have a variable interest rate. In reality, there are both fixed interest and variable interest loans for different maturities. The existence of fixed rate contracts and longer term loan contracts has been neglected by the literature except for Bluwstein et al (2018), Greenwald (2017) etc. With fixed interest contracts, change in policy (whether monetary or macro prudential) would impact variable interest loans and new fixed interest loans but not the existing stock of outstanding fixed interest loans.

3 Interest rate stickiness in the data

Although interest rate stickiness could arise due to number of reasons highlighted by the literature such as market power, level of competition, regulation, switching/menu costs etc, we highlight the importance of interest rate stickiness emanating from the nature of loan contract i.e. existence of long term loans and fixed interest loans.

In this section, we compare the response of (effective)lending rates for different terms of interest rate fixation to change in policy rates. The following graph depicts the movement of mortgage rates (for different maturities) over the period of last 20 years:

Figure 1: Mortgage lending rates in the UK

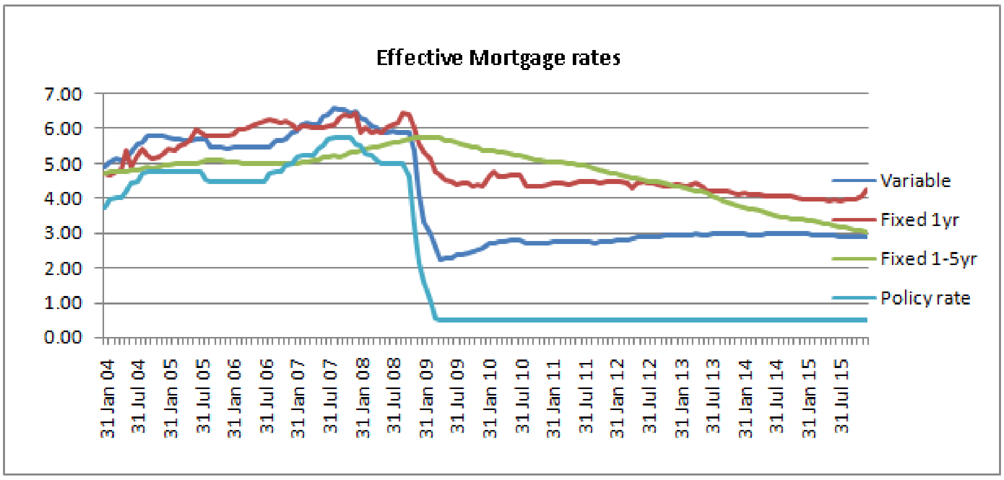
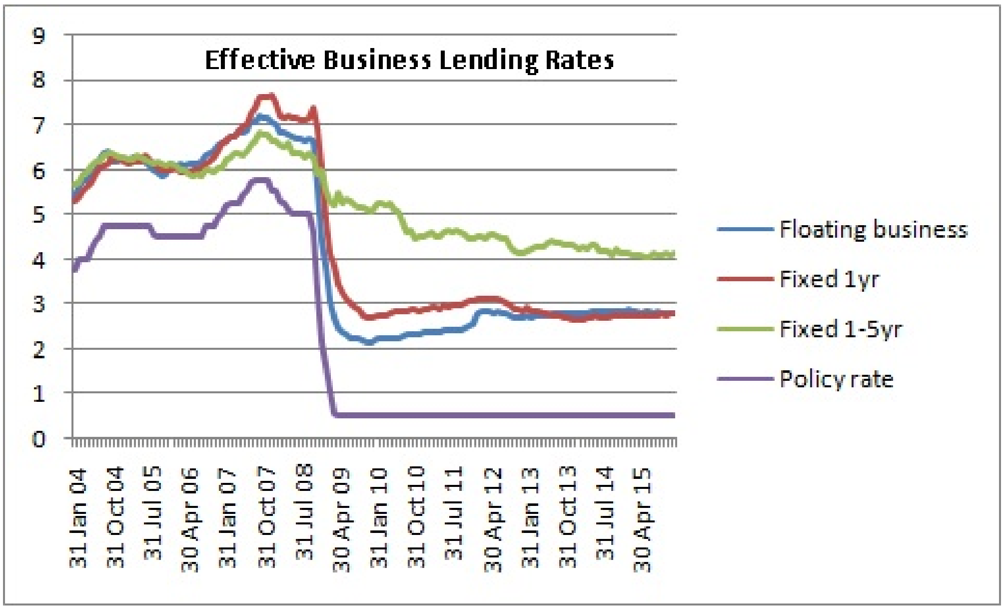


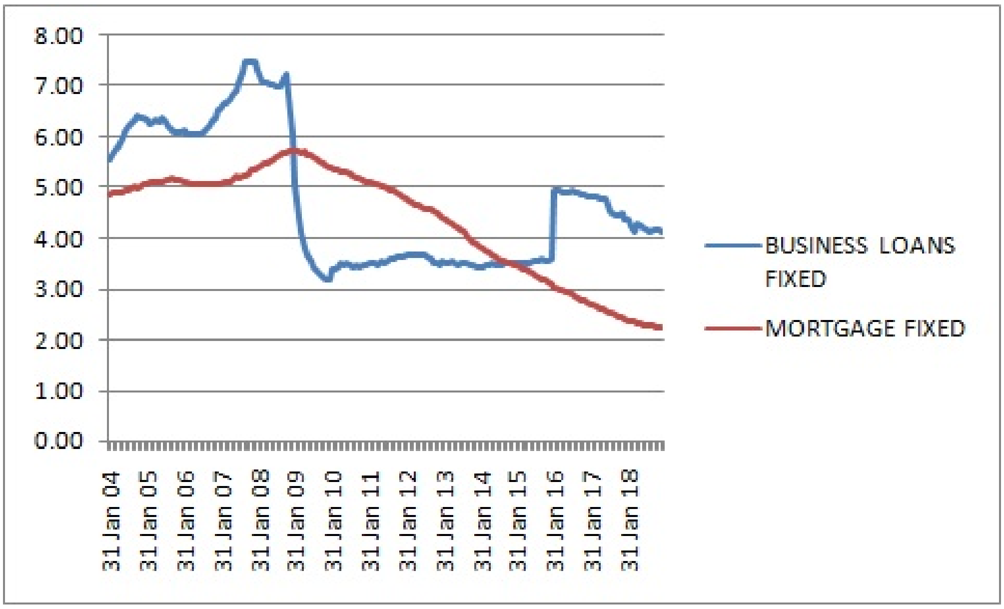
Figure 2: Business lending rates in the UK



We use the monthly data on effective interest rates (between January 2004 to January 2016) for mortgage loans in the United Kingdom (for different terms of interest rate fixation) from Bank of England database. As can be seen in figure below, the response of effective variable interest rate mortgages (to changes in the policy rate) is faster than the effective fixed interest mortgages (as expected).So also the response of the fixed interest mortgages decreases with the increase in the initial term of interest rate fixation. The effective interest rates for longer term of initial interest rate fixation, change slowly as compared to the shorter term of initial interest rate fixation because of the fixed nature of the interest rate for the respective term. The effective interest rate implies that a given portfolio of loans has a mix of older loans (which are being repaid over a period of time) which pay interest rate at the interest rates fixed in the past whereas the fresh loans pay interest at the current market rates (depending upon the interest rate pass through). As a result, even if the market interest rates change, the effective interest rates would not change immediately. They change slowly as the older loans are repaid and fresh loans are added to the loan portfolio over a period of time. The same can be observed in the graph for business interest rates

Interest rate stickiness arising due to fixed term loan contracts can vary across different sectors, depending upon the proportion of long term contracts in the portfolio. The following figure presents the effective lending rate for the overall portfolio of all fixed interest loans (i.e.this includes different fixed term contracts) in case of business loans and mortgage loans. We find that the interest rate pass through is slower for the mortgage loan portfolio as compared to the business loan portfolio due to higher proportion of longer term fixed interest loan contracts.

Figure 3: Mortgage lending rates v/s Business lending rates in the UK



3.1 Econometric Methodology

As a first step to investigate the extent of sluggishness in the movement of interest rates, we attempt to find out how lending rates change in response to change in central bank policy rate.Following the empirical literature on interest rate pass-through models, we run a vector error correction model, where policy interest rates are considered to be the most direct determinants of retail bank lending rates. We run the following vector error correction model based on Johansen (1991):

$$\Delta R_t = \sum_{k=1}^{K} \delta_k \Delta R^m_{t-k} + \sum_{q=1}^{Q} \gamma_q \Delta i_{t-q} + \alpha(\mu + R^m_t - \beta i_t) + u_t \tag{1}$$

Where R_t is the effective lending rate (mortgage loans), i_t is the Bank of England policy interest rate,coefficient β is the long run equilibrium relationship between bank lending rate and policy rate and the coefficient α is the speed of adjustment of the lending rate to the long run equilibrium. The coefficients of the lags of the first difference of policy rate capture the short-run response of mortgage lending rates to the policy rate. We conduct this exercise for three different lending rates, variable interest rate, fixed interest for a term of up to 1 year and fixed interest rate for a term of 1 to 5 years. Results are summarized in the following table.

Table 1: Regression of UK Bank lending rate on BOE policy rate

Regressor	Floating rate	Fixed < 1 year	Fixed 1 to 5 year
$\imath_t$	0.016***	0.0057	0.0025
$\Delta\ \imath_{t-1}$	0.896***	0.435***	0.018
$\Delta\ \imath_{t-2}$	0.016	-0.293***	-0.0158
$\Delta\ \imath_{t-3}$	-0.008	0.242***	0.0097
$\Delta\ \imath_{t-4}$	-0.196***	-0.037	0.0054
constant	0.1366***	-	-

In case of floating interest rate loans, the response on impact is very low. However,around 90 percent of the pass through takes place in the following month.

The above table highlights that the response of floating interest rate (as depicted by coefficient γ_q) on the central bank policy rate is higher than the response of 1 year fixed rate loans, which in turn is higher than the response of the 1 to 5 year fixed rate loans.

In case of fixed term of up to 1 year, the response on impact is very low (less than 0.01 percentage point) and around 45 per cent of the pass through takes place in the following month.

The pass through for the 1 to 5 year fixed term loans is very low. However,there exists a long term co-integration relationship between the two interest rates.For the fixed rate loans, the sum of short run coefficients is less than 1 suggesting an incomplete pass through of policy interest rate.

[0]*** is 1 per cent, ** is 5 per cent and * is 10 per cent level of significance

Thus, the pass through to the fixed interest loans is not only sluggish but also incomplete, whereas the pass through to variable interest loans is faster and almost complete.However, in all the cases including floating interest rate, the response of lending rate on impact is very low (less than 2 percent).

The fact that floating interest rates adjust faster than the fixed term interest rates,implies that the existence of fixed rate contract is an important source of interest rate sluggishness. So also,the pass through of interest rate changes on impact (i.e. the speed of adjustment) is very small implies that other sources of stickiness such as switching costs, menu costs, market structure/competition, regulation could also be relevant.

3.2 Cross country evidence

We do a similar econometric exercise for France, Germany, Italy and Spain. We regress the monthly lending rate with 1 to 5 years of initial rate fixation on ECB policy rate and compare this with the regression of interest floating rate loans on ECB policy rate. We use the data from ECB Statistical Data warehouse.For the fixed rate loans, we use effective interest rate data for loans to corporations with an initial rate fixation period of over one to five years. For the floating rate loans, we use effective interest rate data for loans to corporations of (over EUR 1M) and an initial rate fixation period of up to one year.

We find similar results for the Eurozone countries. The response of the lending rate on impact (i.e. during the same month) is very small. In case of variable interest rate loans,the bulk of adjustment takes place in the following period, whereas the adjustment in fixed rate loans is reflected over a longer period.

Table 2: Regression of 1 to 5 year lending rate on ECB policy rate

Regressor	France	Germany	Italy	Spain
$\imath_t$	0.054***	0.015***	0.014**	0.0027
$\Delta\ \imath_{t-1}$	0.257***	0.246***	0.258***	0.151**
$\Delta\ \imath_{t-2}$	0.316***	-0.009	0.124***	0.215**
$\Delta\ \imath_{t-3}$	0.294***	0.134***	0.17***	0.203**
$\Delta\ \imath_{t-4}$	-0.249*	-0.04	-0.119**	-0.049
$\Delta\ \imath_{t-5}$	0.366***	0.033	-0.09	-0.047**
constant	0.105***	0.035***	0.046**	0.014

Table 3: Regression of floating year lending rate on ECB policy rate

Regressor	France	Germany	Italy	Spain
$\imath_t$	0.0729***	0.137***	0.034**	0.045**
$\Delta\ \imath_{t-1}$	0.766***	0.481***	0.597***	0.670**
$\Delta\ \imath_{t-2}$	- 0.009	0.389***	0.251***	0.203
$\Delta\ \imath_{t-3}$	0.577***	0.1915	0.284***	0.466**
$\Delta\ \imath_{t-4}$	-0.07	-0.157	0.049	-0.333*
$\Delta\ \imath_{t-5}$	0.09	0.017	0.0165	-0.0165
constant	0.139***	0.158***	0.08**	0.153**

The above table shows that the interest rate pass through in France.In response to 1 percentage point change in policy rate, there is less than 0.05 percentage point change in the fixed term lending rate on impact. Around 0.25 percentage point change in interest rate is passed through during the following month and around 0.3 percentage point change is passed through during the third and fourth months after the policy rate change.

For the floating interest rate loans, the response on impact is also low. However,around 76 percent of the pass through takes place in the following month and there is a complete pass through by the end of four months.

The above table shows that the interest rate pass through in Germany.In response to 1 percentage point change in policy rate, there is less than 0.015 percentage point change in the fixed term lending rate on impact. Around 0.25 percentage point change in interest rate is passed through during the following month and around 0.13 percentage point change is passed through during the fourth month after the policy rate change.

For the floating interest rate loans, the response on impact is also low. However,around 48 percent of the pass through takes place in the following month and there is a complete pass through by the end of four months.

The above table shows that the interest rate pass through in Italy.In response to 1 percentage point change in policy rate, there is less than 0.015 percentage point change in the fixed term lending rate on impact. Around around 0.26 percentage point change in interest rate is passed through during the following month and around 0.12 and 0.17 percentage point change is passed through during the third month and fourth months after the policy rate change.

For the floating interest rate loans, the response on impact is also low. However,around 60 percent of the pass through takes place in the following month and there is a complete pass through by the end of four months.

The above table shows that the interest rate pass through in Spain.In response to 1 percentage point change in policy rate, there is less than 0.01 percentage point change in the fixed term lending rate on impact. Only around 0.15 percentage point change in interest rate is passed through during the following month and around 0.2 change is passed through during the third month and fourth months after the policy rate change

For the floating interest rate loans, the response on impact is also low. However,around 67 percent of the pass through takes place in the following month and there is a complete pass through by the end of four months.

To sum up,there is a clear pattern which emerges for all the four Eurozone economies.The response of fixed term lending rates on impact is very low.Around 25 per cent of the pass through takes place in the following period and around 20 to 30 per cent of the pass through takes place in the third and fourth months. Overall, the pass through of interest rate for fixed term loans is incomplete as observed in the UK data.

For the floating interest rate loans, the on impact is also low. However,around 50 to 70 percent of the pass through takes place in the following month and there is a complete pass through by the end of four months.

On the whole, we find that interest rate pass through is fastest in France as compared to Germany where it is the slowest among the four Eurozone economies.

4 Model Overview

Our model is closely based on Clerc et al (2015). This model focuses on key real world features such as different types of defaults viz. firm/household data, bank default and deposit insurance default and their impact on the capital requirement for banks. They augment the baseline Bernanke, Gilchrist and Gertler (1999) framework with a banking sector and different layers of default to determine the optimal capital adequacy ratio for the banking sector, as well as to analyze the macroeconomic implications of bank capital structure under different shocks.

To discuss capital adequacy in a theoretical framework, it is essential to focus on the impact of borrower's default on the solvency of the banking system. The BGG framework assumes that interest rates charged by the banks are state contingent. This implies that higher interest rate charged on non defaulters are sufficient to meet the losses on account of defaulters ensuring that banks always makes a risk free return for its investors. This makes capital structure of the bank is irrelevant in the original BGG model and not modelled explicitly.

The Clerc et al (2015) makes an important departure from the BGG framework by assuming a non-contingent lending rate, which implies that in the event of defaults by borrowers, banks may also suffer losses. So, with costly state verification, defaults/bankruptcies are costly and entail a dead weight loss for the economy. This necessitates a role for bank capital. They also assume that investor wealth is scarce and hence cost of equity capital is higher than debt funding. This implies that although bank capital is necessary, it is expensive at the same time, thus creating a trade-off for the optimal bank capital requirement.

Key distortions in the model

As in the previous paper,following are the key distortions in our model

Limited Liability distortion

In the model, both the bank and its borrowers face limited liability. Limited liability of banks along with deposit insurance implies that banks over-borrow and thereby over-lend, as they may not fully internalize the full costs of default suffered by the deposit insurance agency and the economy as a whole. Regulatory capital is a means to restrict the use of excessive leverage by banks.

Costly state verification distortion (or Bankruptcy costs)

Costly state verification implies that defaults are costly. The CSV distortion can be viewed as similar to bankruptcy costs, which make the use of leverage more expensive. Equity capital is beneficial in that it reduces the leverage and thereby the associated verification costs.

On account of the following distortions/frictions, the model can be used to determine the optimal capital requirement as in Clerc et al (2015). However, in this paper,we focus on the positive analysis.

We build/modify upon the Clerc et al (2015) model, by adding the following ingredients:

Interest rate stickiness We incorporate interest rate stickiness to the model by assuming that only a fixed proportion of banks are allowed to change their interest rates as in Calvo (1983).

LTV limit A key feature of the mortgage lending market is the presence of a Loan to Value (LTV) limit. We assume that the LTV limit is set by the regulator. The LTV limit,in principle is similar to an exogenous collateral constraint as in Iacoviello (2005).

Penalty costs We introduce penalty costs for deviation from the minimum capital requirement, so as to create incentive (precautionary motive) for banks to have a capital adequacy ratio higher than the minimum prescribed.Also in reality, we find that banks maintain capital buffers so as not to breach the regulatory minimum.

Model set up

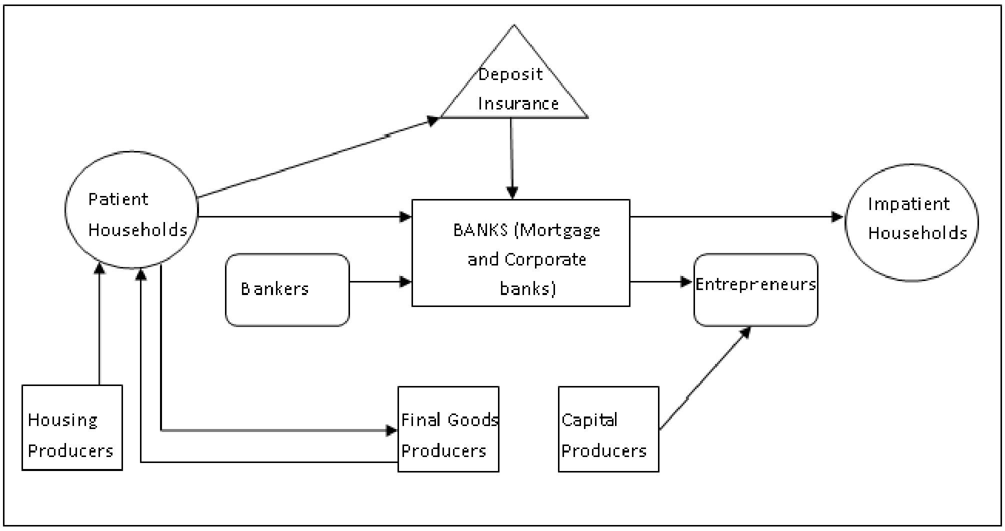
This is a infinite time horizon model with patient and impatient households.The other key agents in the model are entrepreneurs, banks,deposit insurance agency, final/investment/housing goods producers.A broad overview of the different agents in the model is depicted in the diagram above:

Households

There are two types of households, patient and impatient, with patient households having a higher discount factor as in Iacoviello (2015).Both patient and impatient households have concave utility functions and derive utility from consuming goods, housing and leisure. The individual households are a part of a representative dynasty,which provides perfect risk sharing within the group. Thus, all individual households within the type are identical.Even if the individuals face idiosyncratic shocks, they are perfectly insured within their dynasty and hence consume and save/borrow identically.Both households supply labour in a competitive labour market.

Patient households In equilibrium, patient households are savers who hold deposit with banks and buy houses with their own funds.

The objective function of the patient households (as is the case with impatient households) includes utility from consumption goods and housing and dis utility from



labour.

$$\max_{c_t^s, L_t^s, D_t, H_t^s} E_t \sum_{t=0}^{\infty} \beta_s^t [log(c_t^s) + vlog(H_t^s) - \frac{(L_t^s)^{1+\eta}}{1+\eta}] \tag{2}$$

This is subject to the following budget constraint:

$$c_t^s + q_t^H H_t^s + D_t = w_t L_t^s + q_t^H H_{t-1}^s (1-\delta) + D_{t-1} R_t^D + \pi_t \tag{3}$$

The term π_t includes profits of final goods producing firms and investment/housing production firms (which are owned by patient households), dividends from entrepreneurs and lumpsum transfers from deposit insurance agency.

Impatient households

Impatient households borrow from banks using their houses as collateral as in Bernanke, Gertler & Gilchrist (1999) . These mortgage loans are made on a limited liability non-recourse basis, implying that individual households default whenever the value of the house is lower than the outstanding mortgage loans.The value of the house depends both on aggregate shocks (which affect house prices) as well as an idiosyncratic shock which determines whether an individual borrower defaults. In equilibrium, borrowers with an idiosyncratic shock below a certain threshold default.In the case of default, the bank takes possession of the houses in which case it is subject to state verification costs.

The borrowing is subject to LTV (Loan to value) limit set by the regulator. It is similar to a borrowing/collateral constraint as in Kiyotaki & Moore (1997).

The objective function of the impatient households is the same as that of the patient households except for the discounting factor:

$$\max_{c_t^m, B_t^m, L_t, H_t^m} E_t \sum_{t=0}^{\infty} \beta_m^t [log(c_t^m) + vlog(H_t^m) - \frac{(L_t^m)^{1+\eta}}{1+\eta}] \tag{4}$$

The budget constraint of impatient households reflects their borrowings under limited liability:

$$c_t^m + q_t^H H_t^m - B_t^m = w_t L_t^m + \int_{\bar{\omega_t^m}}^{\infty} \left(\omega_t^m q_t^H H_{t-1}^m (1-\delta) B_{t-1}^m R_{t-1} \right) dF \omega_t^m + P_t \tag{5}$$

The term under the integral reflects the limited liability of the borrowers as they default on their loans when the idiosyncratic shock ω_t^m is below the threshold level of $\bar{\omega^m}_t$.

The default decision by the borrowers is given by:

$$\omega_t^m q_t^H H_{t-1}^m (1-\delta) <= B_{t-1}^m R_{t-1}^m \tag{6}$$

The threshold level of $\bar{\omega^m}_t$ satisfies:

$$\bar{\omega^m}_t q_t^H H_{t-1}^m (1-\delta) = B_{t-1}^m R_{t-1}^m \tag{7}$$

The LTV limit (or the borrowing constraint) is given by:

$$[B_t^m - (1-rp) B_{t-1}^m] R_t <= \epsilon_t E_t [q_{t+1}^H [H_t^m - H_{t-1}^m (1-\delta)]] \tag{8}$$

where rp is the loan repayment rate and ϵ_t is the LTV limit.

The limit always binds in the steady state and it's neighborhood.

Entrepreneurs

Entrepreneurs are risk neutral agents who own and maintain the stock of physical capital. They rent capital to the final goods producing firms. Entrepreneurs derive utility from transferring part of their wealth to the saving dynasty (paying dividends) and retaining the rest for the next period (retained earnings). Entrepreneurs invest in capital goods and finance their investment by means of their own funds (net worth) and borrowings from banks. Similar to mortgage loans, these are limited liability non-recourse loans and hence subject to default by individual entrepreneurs in the event of value of assets falling below the outstanding loans.The value of the capital depends both on aggregate shocks (which affect house prices) as well as an idiosyncratic shock which determines whether an individual entrepreneur defaults. In equilibrium, borrowers with an idiosyncratic shock below a certain threshold default. As in the case of households, assets are seized by banks and subject to costly state verification costs.

$$\max_{K_t, B_t^e} E_t(W_{t+1}^e) \tag{9}$$

$$W_{t+1}^e = max[\omega_{t+1}^e (r_{t+1}^k + (1-\delta) q_{t+1}^K K_t) - R_t^F b_t^e, 0] \tag{10}$$

The default decision of the entrepreneurs is given by:

$$\omega_t^e q_t^H K_{t-1} (1-\delta) <= K_{t-1} R_{t-1}^f \tag{11}$$

The threshold level of $\bar{\omega^m}_t$ satisfies:

$$\bar{\omega^e}_t q_t^K K_{t-1}^m (1-\delta) = B_{t-1}^e R_{t-1}^f \tag{12}$$

As borrowing is subject to LTV limit as follows:

$$[B^e_t - B^e_{t-1}(1-rp)]R^f_t = \epsilon_t E_t[q^F_{t+1}[K_t - K_{t-1}(1-\delta)]] \tag{13}$$

Dividend rule:

A fixed proportion of wealth χ^e is paid out as dividends. This simple dividend paying rule for the entrepreneurs is given by:

$$c^e_t = \chi^e W^e_t \tag{14}$$

As a result the retained earnings by the entrepreneurs is given by:

$$n^e_t = (1-\chi^e)W^e_t \tag{15}$$

The balance sheet identity of the entrepreneurs is :

$$n^e_t + B^e_t = q^K_t K_t \tag{16}$$

Banks

Banks are financial intermediaries who channel savings from the savers to the borrowers.On the asset side of the banks, there are loans to households (mortgage lending) and entrepreneurs (business lending) respectively. As described earlier, these loans may default depending on aggregate state shocks and idiosyncratic borrower shocks in which case the banks seize the assets subject to state verification costs (these can also be viewed as bankruptcy costs).

On the liability side, there are deposits held by the patient households and equity capital held by the bankers. Deposits are insured by the Deposit Insurance agency. There is a capital adequacy requirement set by the regulator which along with a penalty cost function, which determines the amount of equity capital held by the bankers.

The key feature of the model is that banks may also default depending upon the performance of their loan portfolios (aggregate shocks) and idiosyncratic shocks (on similar lines as the borrowers). The banks face an idiosyncratic shock to their returns on loans.Thus, in equilibrium, a fraction of banks below a certain threshold of the idiosyncratic shock level default. In case of default, the bank loan assets are also subject to possession by the deposit insurance agency and costly state verification.

The banks' balance sheet identity is as follows:

$$n^b_t + D_t = B^m_t + B^e_t \tag{17}$$

The maximization problem of the bank is given by:

$$\max_{R^{mi}_t, R^{fi}_t} E_t \sum_{t=0}^{\infty} \xi^t \beta^t_s [\{(1-G^H_{t+1})(\widetilde{R^{mi}_t})(B^{mi}_t) + (1-G^F_{t+1})\widetilde{R^{fi}_t} B^{ei}_t\} - (1-bankdef.prob)R^D_t D_t + Penaltycost] \tag{18}$$

$$\widetilde{R^{mi}_t} = (1-def.prob^m)R^{mi}_t + G^m_{t+1}(1-\mu^m)(R^{mi}_t/\bar{\omega}^m_{t+1}) \tag{19}$$

$$\widetilde{R_t^{fi}} = (1 - def.prob^e)R_t^{fi} + G_{t+1}^e(1-\mu^e)(R_t^{fi}/\bar{\omega}_{t+1}^e) \tag{20}$$

The demand for Loans is given by:

$$B_t^{mi} = (\frac{R_t^{mi}}{R_t^m})^{-\tau} B_t^m \tag{21}$$

$$B_t^{ei} = (\frac{R_t^{fi}}{R_t^f})^{-\tau} B_t^e \tag{22}$$

Rmi/Rfi is the rate if interest charged by individual bank,τ is the elasticity of substitution between banks and determines their market power. μ is the proportion of state verification/bankruptcy costs.

Penalty cost function

Penalty costs are modeled as a non pecuniary gain in utility if the capital adequacy ratio is higher than the minimum capital requirement and a non pecuniary cost if the capital adequacy ratio is lower than the minimum capital requirement.

$$Penaltycost_t = \nu^b \frac{[\frac{\phi_t^b}{\bar{\varphi}_t}]^{1-\sigma} - 1}{1-\sigma} \tag{23}$$

The above functional form,based on Nukhwoon & Tsomocos (2018) builds in a non-linearity in the penalty costs.The marginal gains of having excess capital are decreasing whereas the marginal costs of having a shortfall in capital are increasing, whenever σ is greater than 1. This creates an incentive for banks to maintain capital at a higher level as compared to the minimum regulatory requirement. In reality, we find that banks do maintain capital buffer over what is the minimum required.The parameter ν^b determines the weight attached to this penalty costs.

Interest rate stickiness

Although, interest rate stickiness can be attributed to various reasons such as switching costs,menu costs, market structure, regulation etc.,we find the one of the main sources of interest rate sluggishness is the existence of fixed interest loans.

We introduce interest rate stickiness in a broader sense by modeling it as in Calvo (1983). This approach also has the benefit that it includes all possible sources of interest rate sluggishness in a reduced form (including the effect of long term fixed interest loans).It is assumed that only a 1-ξ proportion of banks are able to change their interest rates in a given period, whereas the remaining ξ proportion of banks are not able to change their interest rate. This staggered interest rate setting implies that the composite interest rate in the economy is an average of the current interest rate charged by the fraction of banks who can change the interest rate and the previous period interest rate. To micro-found the staggered interest rate setting, we assume that there is imperfect competition in the banking sector. Banks offer differentiated loan products as in Gerali et al (2010) and are able to set their interest rate in the monopolistically competitive loan market.The borrowers takes a composite loan product comprising of all the aforesaid differentiated banking services.The composite interest rate paid by the borrowers is thus staggered on account of the Calco friction.In short,we extend the New Keynesian approach to goods market to the loan markets so as to generate interest rate stickiness.

The FOCs for the interest rates are as follows.The FOC is similar to the FOC for price in a standard New Keynesian model with goods price stickiness:

$$R_t^{mi} = \frac{\tau}{\tau - 1} \frac{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t MC_t}{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t rm_t} \tag{24}$$

$$R_t^{fi} = \frac{\tau}{\tau - 1} \frac{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t MC_t}{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t rf_t} \tag{25}$$

$$MC_t = \lambda_{st+1}[(1 - bankdef.prob)((1 - \phi_t))R_{Dt} + \frac{\nu^b(\phi_t/\varphi_t)^{(1-\sigma)}}{(B_t^{mi} + B_t^{ei})}](R_t^m)^\tau B_t^m \tag{26}$$

As in the New Keynesian model with price stickiness, the interest rate charged by banks is a function of present discounted value (with the stickiness parameter) of present and future marginal cost times the mark up. The marginal cost includes the interest rate paid on deposits (in a competitive deposit market) and the penalty cost associated with the deviation from the regulatory capital requirement. The only difference from the standard New Keynesian version is the presence of borrower and bank defaults in the interest FOC for interest rate equation

Deposit Insurance Agency

The deposit insurance agency insures the deposits. The assets of the defaulting banks are taken over by the agency and is subject to bankruptcy costs.The difference between the amount of deposits and the value of assets realized assets is recovered by the charging a lumpsum tax on households.

Final goods producing Firms

There is a unit mass of perfectly competitive firms which combine capital and labour to produce the consumption good which is the numeraire.The firms rent capital from entrepreneurs. The firms are owned by patient households. They produce the final goods using a standard Cobb Douglas technology.

$$Y_t = A_t K_{t-1}^{\alpha} L_t^{1-\alpha} \tag{27}$$

Capital goods and Housing production

These are competitive firms which buy finished goods and produce capital goods /housing subject to quadratic adjustment costs.These firms produce new units of capital and housing using consumption goods which are then sold to entrepreneurs and households,respectively, at prices qK and qH. They represent the supply side of the capital goods/housing and pin down the equilibrium asset prices.These firms are also owned by the patient households.

Macro Prudential Policy

The Macro Prudential policy pursued by the regulator includes a minimum capital requirement (also known as capital adequacy ratio) for the banks and a maximum loan to value ratio (LTV) for the borrowers. The regulator also sets a countercyclical capital rule which responds to the credit growth in the economy.

$$CR_t = \bar{CR} + \psi^{cr} log(B_t/\bar{B}) \tag{28}$$

The first part of the rule is the static minimum capital requirement which the banks are supposed to hold at any point of time. The second part is the counter cyclical component,which tracks the credit growth in the economy.

On similar lines,following is the rule for the LTV limit:

$$LTV_t = L\bar{T}V - \psi^{LTV} log(B_t/\bar{B}) \tag{29}$$

4.1 Baseline parameterization

As of now,we have not calibrated the model to any specific economy. We assume parameter values based on the previous literature:

Description	Parameter	Value
Patient discounting factor	β_s	0.995
Impatient discounting factor	β_m	0.97
Home utility weight	v	0.25
Inverse of Frisch elasticity of labour	η	1
Mortgage bank bankruptcy costs	μ_H	0.25
Corporate bank bankruptcy costs	μ_F	0.25
Capital share in production	α	0.2
Depreciation rate	δ	0.035
Capital cost adjustment parameter	ψ	2
Shocks persistence	ρ	0.9
Interest rate stickiness	ξ	0.5
Penalty cost parameter	ν	0.3
Penalty cost shape parameter	σ	10
Elasticity of substitution for banks	τ	50
Loan repayment rate	rp	0.035
Capital adequacy ratio	ϕ	0.2
LTV limit	ϵ	0.8

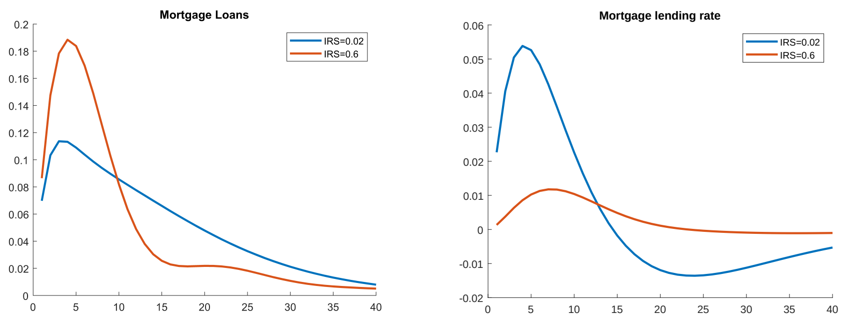
5 Results

In this section, we analyze the results of different policy experiments. We solve for the steady state of the model in matlab and use dynare to obtain our results.

5.1 Response to different shocks

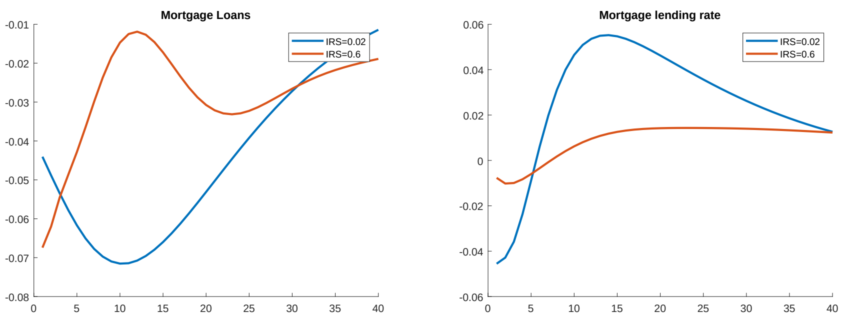
In this section, we study how the economy responds to the key shocks in the model (housing demand, default risk and productivity shocks) under flexible interest rates as against sticky interest rates.

Figure 4: Response of Mortgage Loans to Housing Demand shock



In response to a housing demand shock,we find that there is an increase in the demand for mortgage loans under both scenarios. However, the credit boom is much bigger when interest rates are sticky. The intuition for this is as follows. With an increase in housing demand, there is an increase in the demand for mortgage loans which under flexible interest rates also causes an increase in the lending rates, which regulates the demand for loans. However, when lending rates are sluggish to adjust, the demand for loans is higher leading to a higher credit boom.

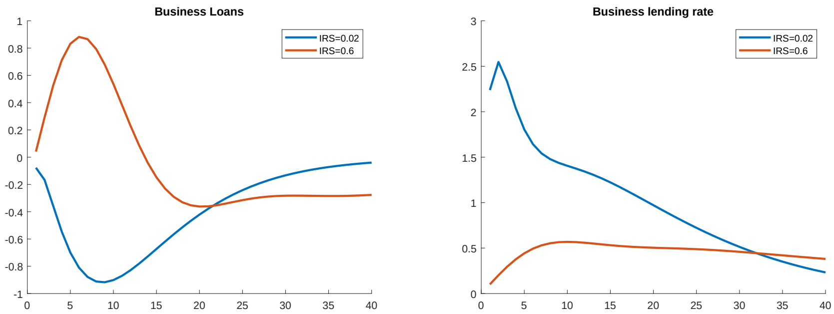
Figure 5: Response of Mortgage Loans to Risk shock



An increase in the default risk increases the default risk premium and hence the lending rates and a fall in lending in the economy.However, when lending rates do not adjust freely, the impact of the risk shock is considerably lower as the fall in lending is of a smaller magnitude.

A negative productivity shock translates into lower output,prices investment,an increase in the lending rates and hence lower business loans.However, when interest rates

Figure 6: Response of Business Loans to Productivity shock



are sticky, the lending rates increase very slowly and the contraction of business loans is delayed and is much lower after the initial rise.

5.2 Change in minimum capital requirement

In this section, we look at the impact of a permanent change in minimum capital requirement on key macro economic variables such as Loans (mortgage and business), interest rate, Capital and asset prices, with and without interest rate stickiness.

The economy is at the initial steady state, when the capital requirement is increased (the increase is fully anticipated) by a total of 1 percentage point, distribute equally over a period of 5 quarters i.e there is 0.2 percentage per quarter. We use the perfect foresight solver (in dynare) to study the transition of the economy to the new steady state with the increased capital requirement.

The same experiment is repeated for the case when interest rate stickiness parameter is low (ξ is 0.02) and when it is high (ξ is 0.5).

We find that, as expected an increase in the capital requirement leads to an increase in the interest rate and a fall in the mortgage loans and housing stock. The transmission can be understood with reference to the impact on penalty cost function (equation 27). With an increase in capital requirement, the existing capital buffer decreases (or capital deficit increases).This reduces the marginal benefit (or increases the marginal cost) associated with the holding capital buffer. As can be been from the first order condition for lending rate (equation 23 and 24), this increases the marginal cost of lending and as a result interest rates increase. This further leads to fall in mortgage and housing stock.

As such the economy moves to a new steady state with a lower level of loans and housing and a higher level of interest rate. The same is observed for the business loans and capital stock.

When interest rates are sticky, the increase in the interest rates from one steady state to the other is more gradual/slower as expected. As the increase in interest rates is smaller, the decrease of Loans and Capital/Housing stock during the transition is also lower as compared to the case when interest rates are flexible.

As can be seen from the figure, the fall in business loans is around 2.5% when the

Figure 7: Response to 1 % increase in Capital requirement

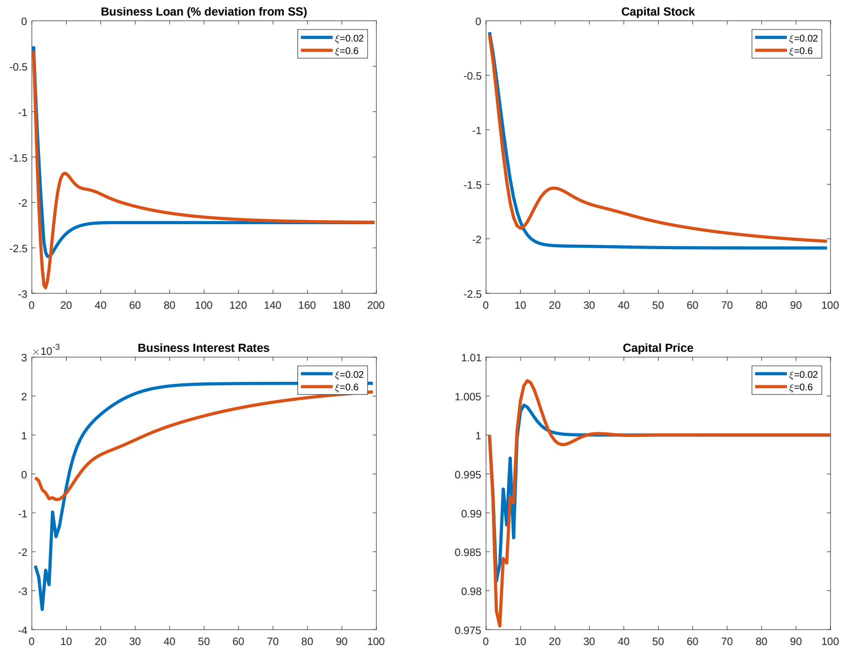
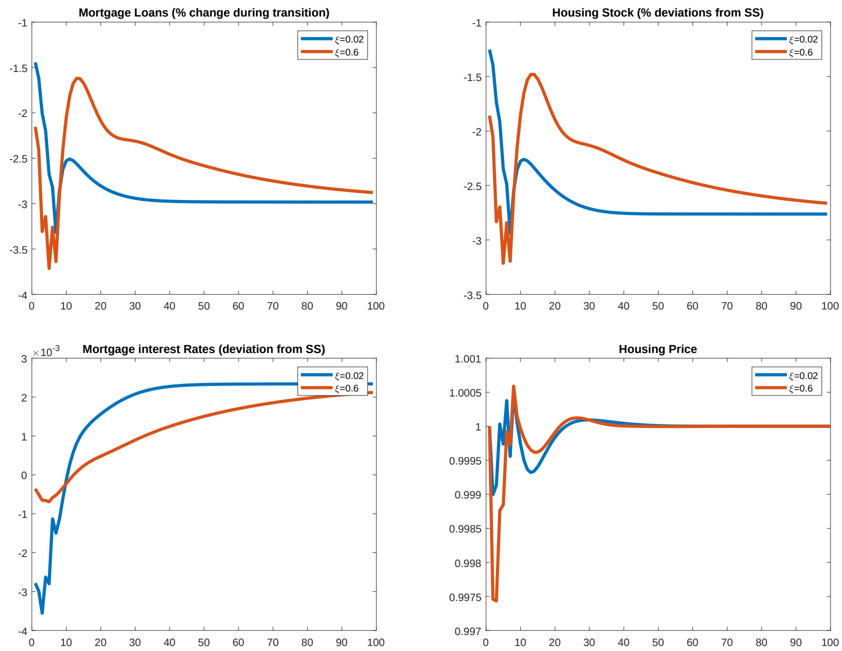


Figure 8: Response to 1 % increase in Capital requirement



interest rate is flexible, whereas the maximum fall is around 1.6% when the interest rates are sticky.A similar difference is observed for mortgage loans.

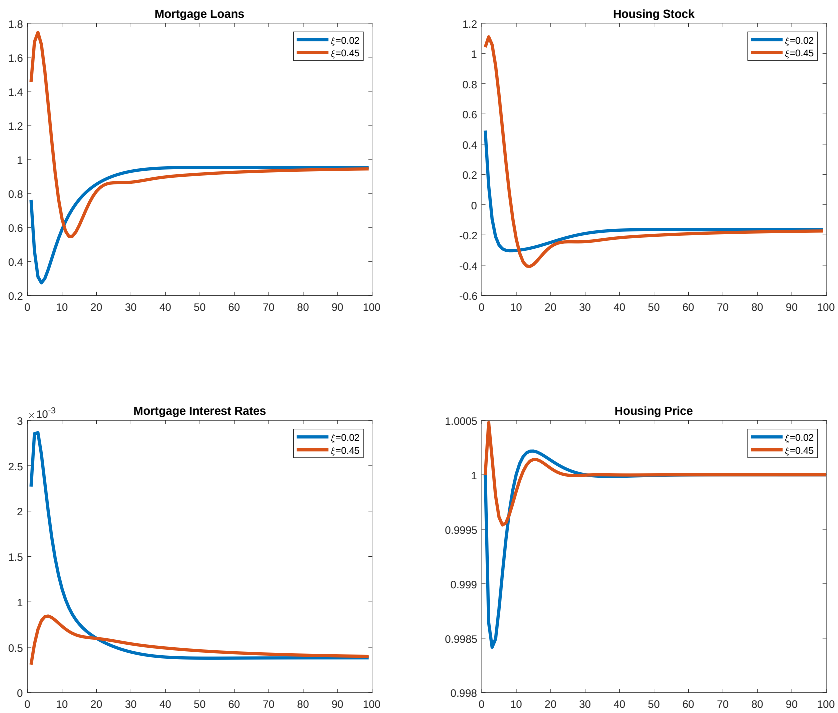
This suggests that the impact of the policy change (i.e.change in bank capital requirement) on the economy is comparatively smaller when interest rates are sticky. The effectiveness of prudential regulation could be subject to how freely the interest rates adjust.In the view of the empirical results in the previous section, the higher the proportion of fixed term contracts in the total loan portfolio and higher the term of the contract, lower would be the effect of a change in bank capital requirement.

5.3 Change in LTV limit

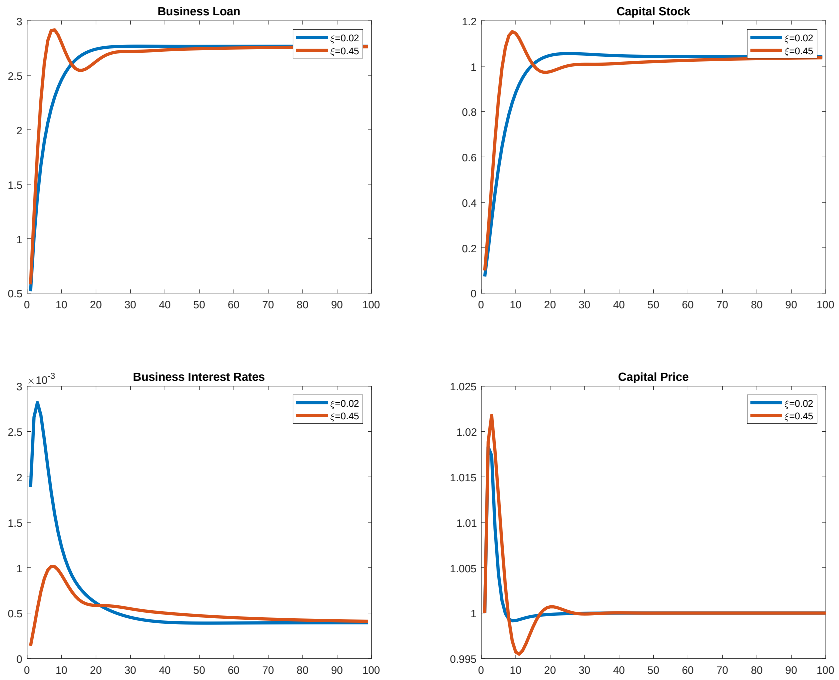
In this section, we look at the impact of a permanent change in LTV on key macro economic variables such as Loans (mortgage and business), interest rate, Capital and asset prices, with and without interest rate stickiness.

The economy is at the initial steady state, when the LTV limit is increased (the increase is fully anticipated) by a total of 5 percentage points, distribute equally over a period of 5 quarters. We use the perfect foresight solver (in dynare) to study the transition of the economy to the new steady state with the increased LTV limit.

The same experiment is repeated for the case when interest rate stickiness parameter is low (ξ is 0.02) and when it is high (ξ is 0.45).



On the whole, as expected, with an increase in the LTV limit, the economy moves to a new steady state with a higher level of mortgage loans and a higher level of interest



rate. The same is observed for the business loans. The transmission can be understood as follows. With a binding LTV limit, an increase in the limit increases the amount of new loans that can be borrowed against investment made. Higher demand for loans also spurs higher investment in houses and housing prices increase. With a higher loan demand and default rates, the lending rate also increase. This increase in lending rate limit the financial accelerator and the increase in loans, housing and prices.

When interest rates are sticky, the increase in the interest rates from one steady state to the other is more gradual/slower as expected. As the change in interest rates is smaller, the increase in the house prices is higher which leads to higher borrowing and a higher housing stock during the transition period. As compared to the flexible interest rate benchmark, the initial increase in asset prices, housing stock and loans is higher when the interest rates are sticky.

As can be seen from the figure, the maximum increase in in mortgage loans is around 0.8% when the interest rate is flexible, whereas the maximum increase is around 1.8% when the interest rates are sticky.

This suggests that the impact of the policy change (i.e.change in LTV) on the economy is comparatively larger when interest rates are sticky.

5.4 Countercyclical capital requirement and interest rate stickiness

In this section, we study how the interest rate stickiness affects the effectiveness of a counter cyclical capital policy. Under the counter cyclical capital rule, the capital requirement increases with the credit growth in the economy, with the aim of smoothing the financial cycle or 'leaning against the wind'. The countercyclical policy also works through the same interest rate channel as the earlier static capital requirement.

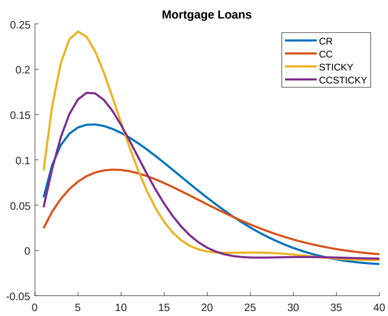
For example, in case of a housing demand shock, there is an increase in the mortgage loans. With the counter cyclical rule, for every percentage increase in the mortgage loans, there is an additional capital requirement based on the macro prudential rule give in equation 28. An increased capital requirement leads to an increase in interest rate and thus slows down the credit growth. However, with interest rate stickiness, the increase in interest rate is lower and thereby the credit growth is higher.This implies that the smoothing effect of counter cyclical policy is also weaker when interest rates are sluggish to adjust.

As can be seen in the figure, the response of mortgage loans to all the shocks is higher when interest rates are sticky. This implies that financial cycles are magnified or credit volatility is higher when interest rates do not adjust flexibly.When the prices are slow to adjust, quantities have to fluctuate more causing a higher volatility.

Housing Demand shock

Given below the response of mortgage loans to a shock to the housing preference of households by 1 percentage point.

Figure 9: Response of Mortgage loans to Housing demand shock



Technology shock Given below the response of mortgage loans to a shock to the productivity of the final goods.

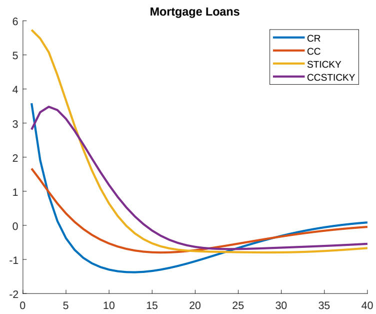
The following tables summarize the aforesaid results (depicted in the graphs) by comparing the reduction in volatilities brought about by the counter cyclical rule,under both flexible and sticky interest rates.

Demand shock

	Flexible interest rate	Sticky interest rates
Without Counter cyclical rule	0.029	0.049
With Counter cyclical rule	0.021	0.038
Reduction in volatility	26%	23%

Technology shock

Figure 10: Response of Mortgage loans to technology shocks



	Flexible interest rate	Sticky interest rates
Without Counter cyclical rule	0.45	1.18
With Counter cyclical rule	0.31	0.88
Reduction in volatility	30%	26%

As can be seen from the above tables, the counter cyclical capital rule was able to bring down the volatility due to housing demand shock by 26% under flexible interest rates. However, when interest rates are sticky the reduction in the volatility is only 23%. Similarly,the reduction in volatility due to technology shock is 30% under flexible interest rates and 26% when the interest rates are sticky. To sum up, the economic variables are more volatile when interest rates are sticky. So also, the counter cyclical rule is less effective in the face of interest rate stickiness.

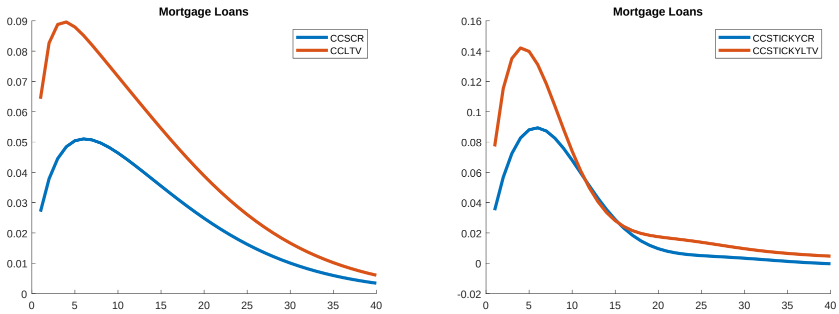
5.5 Countercyclical capital requirement v/s Countercyclical LTV

In the previous section, we saw that the countercyclical capital rule is less effective when interest rates are sticky. An alternative to this rule is the countercyclical LTV rule. Under the counter cyclical LTV rule, LTV is lowered in response to credit growth in the economy.Here we assume the countercyclical capital requirement coefficient (ψ^{cr}) and counter cyclical LTV rule coefficient (ψ^{LTV}) to be equal to 0.4 (equation 34 and 34). As earlier, we study the response of mortgage loans to housing demand and technology shock

Housing Demand shock

Given below the response of mortgage loans to a shock to the housing preference of households by 1 percentage point. The following tables summarize the aforesaid results (depicted in the graphs) by comparing the reduction in volatilities brought about by the counter cyclical rule,under both flexible and sticky interest rates.

Figure 11: Response of Mortgage loans to housing demand shock



	Flexible interest rate	Sticky interest rates
Countercyclical capital rule	0.016	0.031
Counter cyclical LTV rule	0.028	0.045
Difference	41%	30%

We see that the counter cyclical capital rule is more effective than the countercyclical LTV in reducing the volatility of the credit growth, both under flexible ad sticky interest rates.This is due to the differential impact of the two policies on interest rate and prices. In response to a housing boom, the countercyclical capital rule increases the capital requirement and thereby increases the interest rate, which limits the increase in housing prices,investment and mortgage loans. Whereas, the countercyclical LTV rule reduces the LTV limit to counteract the housing demand. The fall in LTV limit puts a downward pressure on interest rates (as default premium falls) whereas the impact LTV limit can be partly offset by lower fall in investment, thereby the smoothing effect on mortgage loans is lower. As seen in the previous section, the capital rule is more effective when the interest rates are flexible.

Next, to compare how the two policy rules perform individually and in combination with each other, we do the following exercise. We target a reduction in volatility of 10% in the mortgage loans.To achieve this we vary the counter cyclical response coefficient of each of the policy rules and compute the combination of the two policy coefficients so as to reduce the volatility of the mortgage loans by 10%. We obtain the following results.

ψ^{CR}	0.08	0.06	0.04	0.02	0
ψ^{LTV}	0	0.16	0.31	0.48	0.56

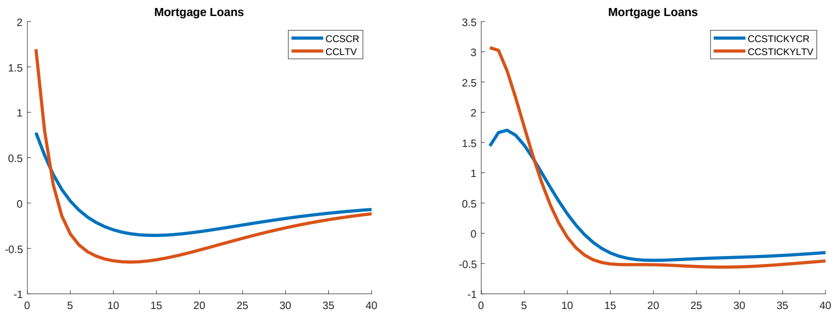
When the two policy rules are used separately to reduce the volatility of the credit boom by 10%, the countercyclical capital requirement should have a coefficient of 0.08 (i.e.a 0.08 per cent point increase in the capital requirement for a every 1% increase in the credit growth), whereas the the countercyclical LTV rule should have a coefficient of 0.56 (i.e.a 0.56 per cent point decrease in the LTV rule for a every 1% increase in the credit growth).The large difference in the coefficients highlights the previous result that a countercyclical capital rule is more effective than a counter cyclical LTV rule.

Between these two cases (where only one of the counter cyclical policy is active), we also find the combination of the two policies acting together so as to reduce the volatility by 10%.The (almost)linear relation between the two sets of coefficients suggests that there are no interactions effects between the two rules. In other words, the two rules appear to be close substitutes.

Technology shock

We repeat the same exercise for a productivity shocks. Given below the response of mortgage loans to a shock to the productivity of the final goods.

Figure 12: Response of Mortgage loans to technology shock



	Flexible interest rate	Sticky interest rates
Countercyclical capital rule	0.23	1.01
Counter cyclical LTV rule	0.45	1.02
Difference	44%	0.01%

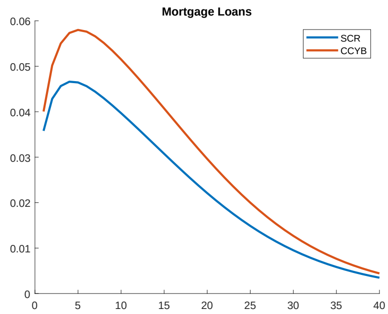
In case of the productivity shock, the same pattern emerges.The countercyclical capital rule is more effective than the counter cyclical LTV rule even when interest rates are not flexible. However, the effectiveness reduces with the increase in interest rate stickiness.

5.6 Countercyclical capital requirement v/s Sectoral capital requirement

In the previous section countercyclical capital requirement implied an economy wide countercyclical rule which tracked the aggregate credit growth. In this section we compare this rule with a countercyclical sectoral capital requirement which is a sector specific rule that targets the credit growth of the specific sector (viz. mortgage lending and corporate lending).For the purpose of comparison,we have kept the coefficient same for both rules.

	CCYB	SCR
Volatility reduction	38%	50%

Figure 13: Sectoral Capital v/s CCyB under Housing demand shock



As can be seen from the above table, the sectoral capital rule does a better job at smoothing the sector specific housing demand shock as it targets the credit growth of the respective sector. The housing demand shock is a sector specific shock. The use of a common counter cyclical capital requirement is less effective as it targets total credit growth in the economy (i.e for both the sectors). The sectoral capital requirement, however targets only the mortgage loan growth and is better as smoothing the shock.The reduction in volatility is 50% as compared to 38% in case of a common counter cyclical rule.

5.7 Interaction of CR and LTV

In this sub section, we attempt to analyze the interaction between the two macro prudential tools i.e. Capital requirement and LTV limit. To do this, we study the impact of a change in capital requirement at different levels of LTV limit and the impact of change in LTV limit for different levels of capital requirement.This would be helpful in understanding whether there are any level effects in the interaction between the policy tools.

In the figure 7 & 8, there is an increase in the capital requirement by 1 % point.We study the response of the key economic variables to this increased capital requirement under 2 scenarios, one where the LTV limit is 0.8 and the other case where the LTV limit is 0.7.

We see that the response of variables differs quantitatively under both scenarios. For the higher LTV limit, the impact of the increase in the capital requirement is higher,both in absolute as well as percentage deviations from the initial steady state values.

The permanent fall in mortgage loans is 3 % when the LTV limit is 0.8 as compared to a 2.1 % when the LTV limit is 0.7. Also during transition, the maximum fall in mortgage loans on impact is 3.4% when LTV is 0.8, whereas the fall on impact is 2.5% when the LTV is 0.7 Similarly, the fall in business loans is 2.3 % percentage when the LTV limit is 0.8 as compared to a 1.6 % when the LTV limit is 0.7.Also during transition, the peak fall in business loans is 2.5% when LTV is 0.8, whereas the peak fall is 1.8% when the LTV is 0.7.

Figure 14: Response to increase in Capital requirement

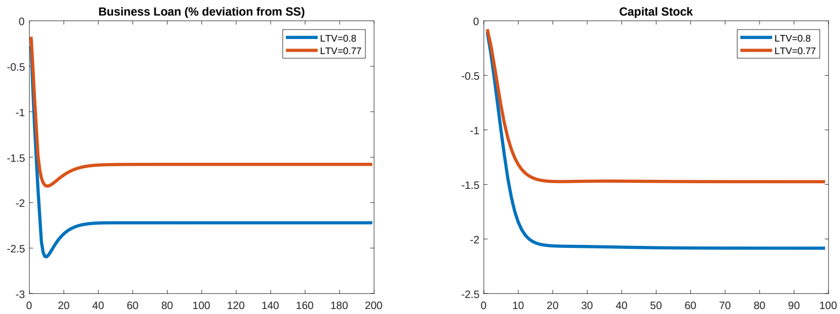
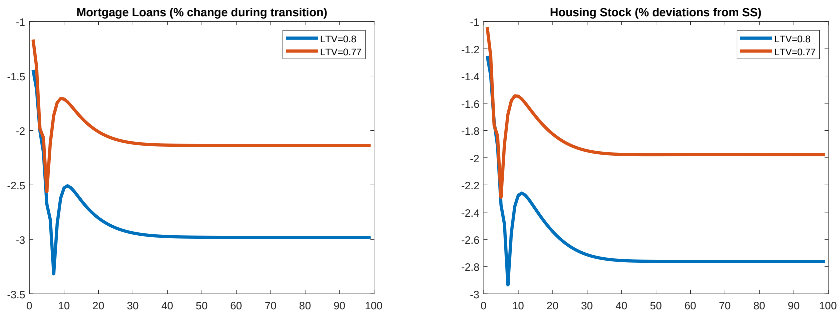


Figure 15: Response to increase in Capital requirement



The transmission of the increase in capital requirement is amplified by the presence of the binding LTV limit. The impact of the financial accelerator is high when the LTV limit (or the collateral constraint) is high. As discussed earlier, the increase in capital requirement leads to an increase in the interest rate, fall in the investment, asset prices and loans.This financial accelerator effect increases with the LTV limit.

This implies that the changes in the capital requirement have a higher effect on the economy, when the binding LTV limit is higher.

On similar lines,we study the impact of a permanent change in LTV limit by 5 % percentage under two scenarios, one where the capital requirement is 18 % and the other with capital requirement of 20 %.

The permanent increase in business loans is 3 % when the CR is 0.16 as compared to a 2.5 % when the CR is 0.2. Similarly, the permanant increase in mortgage loans is 1.1 % percentage when the CR is 0.16 as compared to a 0.9 % when the CR is 0.2.Similar change is observed for capital and housing stock, where the economy with lower capital requirement has a higher stock of assets in the long run. The reason for the difference is again due to the impact on lending rates. With a lower capital requirement, the lending rates in the economy are lower. So with an increase in the LTV limit, the demand for loans and investment is higher when interest rates are lower.As a result, impact of the change in LTV is higher when capital requirement is lower.

Figure 16: Response to increase in LTV limit

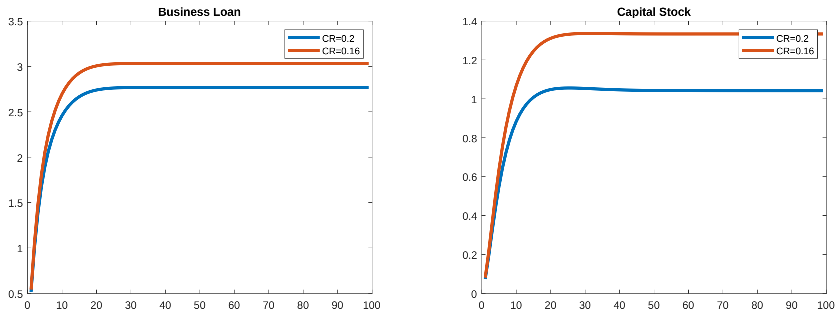
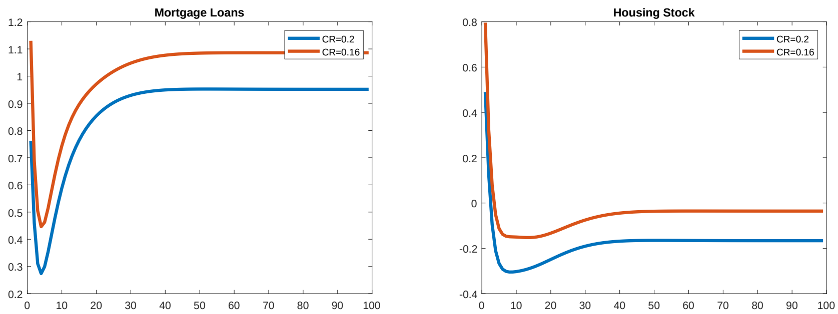


Figure 17: Response to increase in LTV limit



6 Conclusion

In this paper, we provide cross country evidence of interest rate sluggishness due to fixed interest rate loan contract. The response of fixed term interest rates is lower as compared to the floating interest rate term. Moreover,the immediate impact on lending rates is small even for floating interest loans. The interest rate pass through is complete for the floating rate loans and incomplete for fixed term interest loans, both for the UK as well as the four Euro zone economies.

We use a two sector DSGE model with a crucial role for the banking sector, to 1)evaluate the role of interest rate stickiness in the transmission of macro prudential policy and 2) study the interaction between capital requirement and the LTV limit. We find that sluggishness in the adjustment of interest rates lowers the impact of the capital regulation on the economy.At the same, interest rate stickiness makes the a change in LTV policy more effective. It also increases the volatility of macro economic variables to various shocks. We find that interest rate stickiness dampens the effectiveness of the countercyclical capital policy under different shocks. However countercyclical capital rule is still more effective than the LTV rule.As regards the interaction between the policy tools, we find that the impact of a change in capital requirement is higher when the LTV limit in the economy is high. On the other hand, the change in LTV limit has a higher impact when the capital requirement is lower.

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8 Appendix

Model set up

This is a infinite time horizon model with patient and impatient households.The other key agents in the model are entrepreneurs, banks,deposit insurance agency, final/investment/housing goods producers.

Households

There are two types of households, patient and impatient, with patient households having a higher discount factor as in Iacoviello (2015).Both patient and impatient households have concave utility functions and derive utility from consuming goods, housing and leisure. The individual households are a part of a representative dynasty,which provides perfect risk sharing within the group. Thus, all individual households within the type are identical.Even if the individuals face idiosyncratic shocks, they are perfectly insured within their dynasty and hence consume and save/borrow identically.Both households supply labour in a competitive labour market.

Patient households In equilibrium, patient households are savers who hold deposit with banks and buy houses with their own funds.

The objective function of the patient households (as is the case with impatient households) includes utility from consumption goods and housing and dis utility from labour.

$$\max_{c_t^s, L_t^s, D_t, H_t^s} E_t \sum_{t=0}^{\infty} \beta_s^t [log(c_t^s) + vlog(H_t^s) - \frac{(L_t^s)^{1+\eta}}{1+\eta}] \tag{30}$$

This is subject to the following budget constraint:

$$c_t^s + q_t^H H_t^s + D_t = w_t L_t^s + q_t^H H_{t-1}^s (1-\delta) + D_{t-1} R_t^D + \pi_t \tag{31}$$

The term π_t includes profits of final goods producing firms and investment/housing production firms (which are owned by patient households), dividends from entrepreneurs and lumpsum transfers from deposit insurance agency.

The FOCs for deposit and Housing stock is given by:

$$U'(c_t^s) = \beta_s E_t[U'(c_{t+1}^s) R_{Dt}] \tag{32}$$

$$U'(c_t^s) q^H = E_t[\beta_s U'(H_{t+1}^s) + \beta_s U'(c_{t+1}^s)(1-\delta) q_{t+1}^H]; \tag{33}$$

Impatient households

Impatient households borrow from banks using their houses as collateral as in Bernanke, Gertler & Gilchrist (1999) . These mortgage loans are made on a limited liability non-recourse basis, implying that individual households default whenever the value of the house is lower than the outstanding mortgage loans.The value of the house depends both on aggregate shocks (which affect house prices) as well as an idiosyncratic shock which determines whether an individual borrower defaults. In equilibrium, borrowers with an idiosyncratic shock below a certain threshold default.In the case of default, the bank takes possession of the houses in which case it is subject to state verification costs.

The borrowing is subject to LTV (Loan to value) limit set by the regulator. It is similar to a borrowing/collateral constraint as in Kiyotaki & Moore (1997).

The objective function of the impatient households is the same as that of the patient households except for the discounting factor:

$$\max_{c_t^m, B_t^m, L_t, H_t^m} E_t \sum_{t=0}^{\infty} \beta_m^t [log(c_t^m) + vlog(H_t^m) - \frac{(L_t^m)^{1+\eta}}{1+\eta}] \tag{34}$$

The budget constraint of impatient households reflects their borrowings under limited liability:

$$c_t^m + q_t^H H_t^m - B_t^m = w_t L_t^m + \int_{\bar{\omega_t^m}}^{\infty} \left(\omega_t^m q_t^H H_{t-1}^m (1-\delta) B_{t-1}^m R_{t-1} \right) dF \omega_t^m + P_t \tag{35}$$

The term under the integral reflects the limited liability of the borrowers as they default on their loans when the idiosyncratic shock ω_t^m is below the threshold level of $\bar{\omega^m}_t$.

The default decision by the borrowers is given by:

$$\omega_t^m q_t^H H_{t-1}^m (1-\delta) <= B_{t-1}^m R_{t-1}^m \tag{36}$$

The threshold level of $\bar{\omega^m}_t$ satisfies:

$$\bar{\omega^m}_t q_t^H H_{t-1}^m (1-\delta) = B_{t-1}^m R_{t-1}^m \tag{37}$$

The LTV limit (or the borrowing constraint) is given by:

$$[B_t^m - (1-rp) B_{t-1}^m] R_t <= \epsilon_t E_t [q_{t+1}^H [H_t^m - H_{t-1}^m (1-\delta)]] \tag{38}$$

where rp is the loan repayment rate and ϵ_t is the LTV limit.

The limit always binds in the steady state and it's neighborhood.

The FOCs for Mortgage loans and Housing stock is given by:

$$E_t U'(c_t^s) - \beta_m U'(c_{t+1}^s)(R_t^m (1 - def_{t+1})) - \lambda_t R_t^m + \lambda_{t+1}(1-rp)(1-def_{t+1}) R_{t+1}^m = 0 \tag{39}$$

$$E_t U'(c_t^s) q^H = \beta_m U'(H_{t+1}^s) + \beta_s U'(c_{t+1}^s)(1 - Gm_{t+1})(1-\delta) q_{t+1}^H + \lambda_t (\epsilon_t q_{t+1}^H) - \lambda_{t+1}(\epsilon_{t+1} q_{t+2}^H)(1-\delta) \tag{40}$$

where def is the probability of default and the function Gm() represents the proportion of housing stock taken over by the bank for defaulted loans.λ_t is the lagrange multiplier on the LTV constraint.

Entrepreneurs

Entrepreneurs are risk neutral agents who own and maintain the stock of physical capital. They rent capital to the final goods producing firms. Entrepreneurs derive utility from transferring part of their wealth to the saving dynasty (paying dividends) and retaining the rest for the next period (retained earnings). Entrepreneurs invest in capital goods and finance their investment by means of their own funds (net worth) and borrowings from banks. Similar to mortgage loans, these are limited liability non-recourse loans and hence subject to default by individual entrepreneurs in the event of value of assets falling below the outstanding loans.The value of the capital depends both on aggregate shocks (which affect house prices) as well as an idiosyncratic shock which determines whether an individual entrepreneur defaults. In equilibrium, borrowers with an idiosyncratic shock below a certain threshold default. As in the case of households, assets are seized by banks and subject to costly state verification costs.

$$\max_{K_t, B_t^e} E_t(W_{t+1}^e) \tag{41}$$

$$W_{t+1}^e = max[\omega_{t+1}^e(r_{t+1}^k + (1-\delta)q_{t+1}^K K_t) - R_t^F b_t^e, 0] \tag{42}$$

The default decision of the entrepreneurs is given by:

$$\omega_t^e q_t^H K_{t-1}(1-\delta) <= K_{t-1} R_{t-1}^f \tag{43}$$

The threshold level of $\bar{\omega^m}_t$ satisfies:

$$\bar{\omega^e}_t q_t^K K_{t-1}^m (1-\delta) = B_{t-1}^e R_{t-1}^f \tag{44}$$

As borrowing is subject to LTV limit as follows:

$$[B_t^e - B_{t-1}^e(1-rp)]R_t^f = \epsilon_t E_t[q_{t+1}^F[K_t - K_{t-1}(1-\delta)]] \tag{45}$$

Dividend rule:

A fixed proportion of wealth χ^e is paid out as dividends. This simple dividend paying rule for the entrepreneurs is given by:

$$c_t^e = \chi^e W_t^e \tag{46}$$

As a result the retained earnings by the entrepreneurs is given by:

$$n_t^e = (1-\chi^e) W_t^e \tag{47}$$

The balance sheet identity of the entrepreneurs is :

$$n_t^e + B_t^e = q_t^K K_t \tag{48}$$

Banks

Banks are financial intermediaries who channel savings from the savers to the borrowers.On the asset side of the banks, there are loans to households (mortgage lending) and entrepreneurs (business lending) respectively. As described earlier, these loans may default depending on aggregate state shocks and idiosyncratic borrower shocks in which case the banks seize the assets subject to state verification costs (these can also be viewed as bankruptcy costs).

On the liability side, there are deposits held by the patient households and equity capital held by the bankers. Deposits are insured by the Deposit Insurance agency. There is a capital adequacy requirement set by the regulator which along with a penalty cost function, which determines the amount of equity capital held by the bankers.

The key feature of the model is that banks may also default depending upon the performance of their loan portfolios (aggregate shocks) and idiosyncratic shocks (on similar lines as the borrowers). The banks face an idiosyncratic shock to their returns on loans.Thus, in equilibrium, a fraction of banks below a certain threshold of the idiosyncratic shock level default. In case of default, the bank loan assets are also subject to possession by the deposit insurance agency and costly state verification.

The banks' balance sheet identity is as follows:

$$n_t^b + D_t = B_t^m + B_t^e \tag{49}$$

The maximization problem of the bank is given by:

$$\max_{R_t^{mi}, R_t^{fi}} E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t [\{(1 - G_{t+1}^H)(\widetilde{R_t^{mi}})(B_t^{mi}) + (1 - G_{t+1}^F)\widetilde{R_t^{fi}} B_t^{ei}\} - (1 - bankdef.prob) R_t^D D_t + Penaltycost] \tag{50}$$

$$\widetilde{R_t^{mi}} = (1 - def.prob^m) R_t^{mi} + G_{t+1}^m (1 - \mu^m)(R_t^{mi} / \bar{\omega}_{t+1}^m) \tag{51}$$

$$\widetilde{R_t^{fi}} = (1 - def.prob^e) R_t^{fi} + G_{t+1}^e (1 - \mu^e)(R_t^{fi} / \bar{\omega}_{t+1}^e) \tag{52}$$

The demand for Loans is given by:

$$B_t^{mi} = (\frac{R_t^{mi}}{R_t^m})^{-\tau} B_t^m \tag{53}$$

$$B_t^{ei} = (\frac{R_t^{fi}}{R_t^f})^{-\tau} B_t^e \tag{54}$$

Rmi/Rfi is the rate if interest charged by individual bank,τ is the elasticity of substitution between banks and determines their market power. μ is the proportion of state verification/bankruptcy costs.

Penalty cost function

Penalty costs are modeled as a non pecuniary gain in utility if the capital adequacy ratio is higher than the minimum capital requirement and a non pecuniary cost if the capital adequacy ratio is lower than the minimum capital requirement.

$$Penaltycost_t = \nu^b \frac{[\frac{\phi_t^b}{\bar{\varphi}_t}]^{1-\sigma} - 1}{1 - \sigma} \tag{55}$$

The above functional form,based on Nukhwoon & Tsomocos (2018) builds in a non-linearity in the penalty costs.The marginal gains of having excess capital are decreasing whereas the marginal costs of having a shortfall in capital are increasing, whenever σ is greater than 1. This creates an incentive for banks to maintain capital at a higher level as compared to the minimum regulatory requirement. In reality, we find that banks do maintain capital buffer over what is the minimum required.The parameter ν^b determines the weight attached to this penalty costs.

Interest rate stickiness

Although, interest rate stickiness can be attributed to various reasons such as switching costs,menu costs, market structure, regulation etc.,we find the one of the main sources of interest rate sluggishness is the existence of fixed interest loans.

We introduce interest rate stickiness in a broader sense by modeling it as in Calvo (1983). This approach also has the benefit that it includes all possible sources of interest rate sluggishness in a reduced form (including the effect of long term fixed interest loans).It is assumed that only a ξ proportion of banks are able to change their interest rates in a given period, whereas the remaining 1-ξ proportion of banks are not able to change their interest rate. This staggered interest rate setting implies that the composite interest rate in the economy is an average of the current interest rate charged by the fraction of banks who can change the interest rate and the previous period interest rate. To micro-found the staggered interest rate setting, we assume that there is imperfect competition in the banking sector. Banks offer differentiated loan products as in Gerali et al (2010) and are able to set their interest rate in the monopolistically competitive loan market.The borrowers takes a composite loan product comprising of all the aforesaid differentiated banking services.The composite interest rate paid by the borrowers is thus staggered on account of the Calco friction.In short,we extend the New Keynesian approach to goods market to the loan markets so as to generate interest rate stickiness.

The FOCs for the interest rates are as follows.The FOC is similar to the FOC for price in a standard New Keynesian model with goods price stickiness:

$$R_t^{mi} = \frac{\tau}{\tau - 1} \frac{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t MC_t}{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t rm_t} \tag{56}$$

$$R_t^{fi} = \frac{\tau}{\tau - 1} \frac{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t MC_t}{E_t \sum_{t=0}^{\infty} \xi^t \beta_s^t rf_t} \tag{57}$$

$$MC_t = \lambda_{st+1}[(1 - bankdef.prob)((1 - \phi_t))R_{Dt} + \frac{\nu^b(\phi_t/\varphi_t)^{(1-\sigma)}}{(B_t^{mi} + B_t^{ei})}](R_t^m)^\tau B_t^m \tag{58}$$

As in the New Keynesian model with price stickiness, the interest rate charged by banks is a function of present discounted value (with the stickiness parameter) of present and future marginal cost times the mark up. The marginal cost includes the interest rate paid on deposits (in a competitive deposit market) and the penalty cost associated with the deviation from the regulatory capital requirement. The only difference from the standard New Keynesian version is the presence of borrower and bank defaults in the interest FOC for interest rate equation

Deposit Insurance Agency

The deposit insurance agency insures the deposits. The assets of the defaulting banks are taken over by the agency and is subject to bankruptcy costs.The difference between the amount of deposits and the value of assets realized assets is recovered by the charging a lumpsum tax on households.

Final goods producing Firms

There is a unit mass of perfectly competitive firms which combine capital and labour to produce the consumption good which is the numeraire.The firms rent capital from entrepreneurs. The firms are owned by patient households. They produce the final goods using a standard Cobb Douglas technology.

$$Y_t = A_t K_{t-1}^{\alpha} L_t^{1-\alpha} \tag{59}$$

Capital goods and Housing production

These are competitive firms which buy finished goods and produce capital goods /housing subject to quadratic adjustment costs.These firms produce new units of capital and housing using consumption goods which are then sold to entrepreneurs and households,respectively, at prices qK and qH. They represent the supply side of the capital goods/housing and pin down the equilibrium asset prices.These firms are also owned by the patient households.

They maximize their profits as follows:

$$\max_{I_t} E_t \sum_{i=0}^{\infty} \beta_s^t \{ \frac{c_t^s}{c_{t+1}^s} \} [q_{t+i}^K I_{t+i} - \{1 + g[\frac{I_{t+i}}{I_{t+i-1}}]\}] \tag{60}$$

$$\max_{I_t^H} E_t \sum_{i=0}^{\infty} \beta_s^t \{ \frac{c_t^s}{c_{t+1}^s} \} [q_{t+i}^H I_{t+i} - \{1 + g[\frac{I_{t+i}^H}{I_{t+i-1}^H}]\}] \tag{61}$$

Macro Prudential Policy

The Macro Prudential policy pursued by the regulator includes a minimum capital requirement (also known as capital adequacy ratio) for the banks and a maximum loan to value ratio (LTV) for the borrowers. The regulator also sets a countercyclical capital rule which responds to the credit growth in the economy.

$$CR_t = \bar{CR} + \psi^{cr} log(B_t/\bar{B}) \tag{62}$$

The first part of the rule is the static minimum capital requirement which the banks are supposed to hold at any point of time. The second part is the counter cyclical component,which tracks the credit growth in the economy.

On similar lines,following is the rule for the LTV limit:

$$LTV_t = L\bar{T}V - \psi^{LTV} log(B_t/\bar{B}) \tag{63}$$