Essays on The Credit Market and Macroeconomic Policy

Youel Rojas Zea

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THESIS SUPERVISOR
Julian di Giovanni i Luca Fornaro
Department Department d'Economia i Empresa

Universitat Pompeu Fabra
Barcelona

To Otilia and Severiano, my parents

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Abstract

This dissertation consists of three essays. In the first chapter, using a series of identified monetary policy shocks for Peru, I show robust evidence of supply side mechanisms of monetary policy for the credit market equilibrium determination. Using micro-data at the branch level, and an empirical strategy that focuses on local credit markets, I show that the sensitivity of lending supply to monetary policy shocks is increasing in the riskiness of borrowers: the risk-taking channel of monetary policy. In the second chapter, we develop a DSGE model with both supply and demand frictions to investigate the implications of an unconventional credit policy via central bank facilities for firms at the risk-free interest rate cost. This policy intervention reduces frictions while increasing credit supply and demand. Being more important during times of uncertainty. The third chapter extends the analysis to the ZLB constraint. Credit frictions increase the likelihood of a ZLB equilibrium, but the presence of unconventional credit policy keeps the economy from reaching it. Once the ZLB binds, the economy's power is limited.

Resumen

Esta tesis consta de tres ensayos. En el primer capítulo, Usando una serie de choques de política monetaria identificados para Perú, muestro evidencia robusta de los mecanismos del lado de la oferta de la política monetaria para la determinación del equilibrio del mercado de crédito. Usando microdatos a nivel de sucursal y una estrategia empírica que se enfoca en mercados de créditos locales, muestro que la sensibilidad de la oferta de crédito ante choques de política monetaria es creciente en el nivel riesgo de los prestatarios: el canal de toma de riesgos de la política monetaria. En el segundo capítulo, desarrollamos un modelo DSGE con fricciones tanto de oferta como de demanda para investigar las implicaciones de una política crediticia no convencional, a través de facilidades de préstamos del banco central para firmas y un costo de la tasa de interés libre de riesgo. Esta intervención política reduce las fricciones crediticias, y aumenta la oferta y la demanda de crédito. Siendo más importante en tiempos de incertidumbre. El tercer capítulo amplía el análisis a la restricción que impone el ZLB. Las fricciones crediticias aumentan la probabilidad de un equilibrio ZLB, pero la presencia de una política crediticia no convencional impide que la economía lo alcance. Sin embargo, una vez en el ZLB, su efectividad es limitada.

Preface

Since the Great International Financial Crisis, two trends have emerged around the world: i) Central banks and governments have adopted more expansionary policy measures, whether through conventional monetary policy or unconventional policies, resulting in an unprecedented period of low international interest rates; and ii) the role of the financial system and credit markets as mechanisms for shock transmission and amplification has gained prominence among policymakers and the macro literature. These trend were exacerbated more after the Covid-19 global shock. Policymakers and academics were forced even more to confront about the the limits of traditional policy tools for stimulating the economy. In particular, more central banks around the world faced the zero lower bound (ZLB) constraint. Although, a lot of research has been done to explain these phenomenon, the purpose of this dissertation is to contribute to a better understanding of the role of conventional monetary policy and unconventional credit policies in influencing lending markets and real variables in the presence of credit frictions. The dissertation consist of three essays. The first essay, from the perspective of Peru, an emerging market economy, shows empirically that the risk taking channel is important and works mainly as a credit supply side mechanism of monetary policy transmission. The second and third essays were written in collaboration with Jorge Pozo, and they demonstrate theoretically, using a general equilibrium model, that unconventional credit policies aim to reduce credit supply and credit demand frictions, thereby increasing the allocation of credit and capital in the economy.

In the first chapter, I take a different view on the risk-taking behavior of banks, and focus on how a bank can allocate loans differently across risky markets after a monetary policy shock in Peru. Based on identified monetary policy shocks, first, I show robust evidence at the aggregate level that the credit market equilibrium is mainly determined by supply forces. Second, using micro data at the branch level, a econometric strategy that focuses on local credit markets, and the geographic distribution of risk, I document further that the risk taking channel is a important credit supply side mechanism of monetary policy transmission. The branch-level estimates confirm that the sensitivity of lending to MP changes is increasing in the riskiness of borrowers. At higher levels of aggregation, the results maintain it economically and statistically significance. Further robustness on the estimates show, that the risk-taking channel of monetary policy has a sizable impact on the total lending issued by all financial firms, both large or small. A closer examination reveals, however, that a large portion of the dynamics responses of credit to monetary policy shocks occur primarily at markets below the median of the risk distribution.

In the second chapter, we develop a DSGE model where we reconcile both credit demand and credit supply frictions and evaluate the effects of an unconventional credit policy. The credit policy consists on central bank loans guaranteed by the government, which are provided directly provided to firms or through commercial banks intermediation. The credit policy we study differs from the conventional credit policies studied in Cúrdia and Woodford (2011) and Gertler and Karadi (2011a), in two reasons: 1) the required return on loans originated by the credit policy is not the market lending rate but the monetary policy rate; 2) loans are originated by a government-guaranteed credit policy. First, our results show that to mimic realistic dynamic of credit after a monetary policy shock, credit supply frictions are enough. Second, the analysis of an unconventional credit policy necessitates the consideration of both credit supply and credit demand frictions. The unconventional credit policy diminishes the impact of a negative shock in the economy by diminishing the impact of both frictions. On one side, since central bank loans are not subject to the moral hazard problem between bankers and depositors, credit market interventions raise aggregate credit supply. On the other side, the government guarantees reduce entrepreneurs' default probability and hence increase aggregate credit demand. Our results show that In periods of high uncertainty government guarantees' effects become very significant. Also, when bank loans have a higher seniority than central bank loans, the effectiveness of the credit policy on reducing real fluctuations increases. Finally, we find that an endogenous credit policy rule should be flexible enough so it responds appropriately to relative sources of frictions.

In the third chapter, we extend the analysis to ZLB constraint, as an important ingredient for the limits of both expansionary conventional monetary policy and unconventional credit policy, as well as their interactions However, we recur to simple two-period model. In this stylized but realistic model, credit and deposit markets are interlinked and credit demand and credit supply frictions amplify each other in such a way that produces in equilibrium inefficiently low levels of credit and stronger reductions of the real and nominal interest rates, so an economy is much closer to the ZLB. Firs, unconventional credit policy has a positive impact on capital and credit by partially undoing the effects of credit frictions in the resource allocation of the economy. Second, and more interestingly, the presence of the unconventional credit policy reduces the likelihood of reaching the ZLB. Furthermore, if the economy begins in an equilibrium near the ZLB and experiences a contractionary change, a strong enough policy intervention may be sufficient to lift the economy out of the ZLB. Finally, unconventional credit policy also has its limits. When the economy starts from an equilibrium in which the ZLB binds and a contractionary change occurs, the effectiveness of credit policy is reduced because its mechanism to stimulate credit via low borrowing costs may also be constrained.

Contents

List of Figures

List of Tables

Chapter 1

DISSECTING THE RISK-TAKING CHANNEL OF MONETARY POLICY: A NEW APPROACH AND EVIDENCE FROM PERU

1.1 Introduction

Since the Great International Financial Crisis, two changes have emerged: i) central banks have adopted expansionary monetary policy positions more frequently, setting rates at historically very low levels[1]; and ii) the role of the financial system and the credit markets as mechanisms for the transmission and amplification of shocks has been a focus of greater importance among policy makers and the macro literature. Together, these have called for the macro literature to investigate more on the transmission mechanisms of monetary policy operating via changes on banks' decisions. In particular, the effects of very low monetary policy rates on the risk-taking behavior of banks has been given great attention. The risk-taking behavior of banks is key to understand the role of the credit exuberance and business cycles (Adrian and Song Shin, 2010; Borio and Zhu, 2012; Jorda, Schularick and Taylor, 2013; Jiménez, Ongena, Peydró and Saurina, 2014; Maddaloni and Peydró, 2015; Acharya, Eisert, Eufinger and Hirsch, 2019).

In this chapter, I seek to answer the following question: How does the risk exposure of financial-firms change with monetary policy movements? Relative to the existing literature I take a different view on the risk-taking behavior of banks, and rather than focusing on large versus small banks, I focus on how each bank can allocate loans differently across risky locations after a monetary policy (MP) shock. In this interpretation, I see the credit allocation by banks as a portfolio problem, which must be operative across all financial institutions, either highly or poorly capitalized. Thus, monetary policy shocks alter the opportunity cost and profitability of lending (Adrian and Song Shin, 2010), and have differential effects across pools of borrowers to which a bank lends, by altering a bank's preference for issuing loans to high-risk or low-risk borrowers. In general, this chapter shows empirical estimates about the role of risk on the

[1] For example, after 2009 the number of countries at the Zero Lower Bound have increased overtime, and with the Covid-19 global shock, it not only include Advanced Economies but also Emerging market economies.

transmission of MP shocks: a bank's risk-taking mechanism.

I argue that Peru is a good setting to investigate the risk-taking behavior of financial firms and its interaction with monetary policy. Peru is an emerging market with limited developed capital markets, so credit markets are critical for monetary policy transmission. Credit-to-GDP ratio is of around 40 percent, which is very low relative to advanced economies[2]. During the last 20 years, credit in Peru has grown by around 11 percent per year, above the average growth rate of nominal GDP of 7 percent. Between 2000 and 2019 credit to GDP ratio almost doubled from 24.8 to 43.1 percent. Both the extensive and intensive margin contributed to the growth of credit (SBS, 2020). Thus, risk-taking channel is expected to be important and sizable.

However, for the risk-taking channel of monetary policy to be meaningful, one must demonstrate that credit supply factors are more important for determining equilibrium after a monetary policy shock. As a result, I divide the analysis of credit markets into two steps. First, at the aggregate level, I present strong evidence that supply factors are relatively more important for credit market equilibrium following a monetary policy shock. Once this is established, I demonstrate in a second step, using micro data at the branch level, that the risk-taking channel is a meaningful and statistically significant supply side mechanism of monetary policy.

Monetary policy is endogenous to the business cycle and, by extension, to the credit markets that I study. To overcome monetary policy endogeneity and provide a causal relationship between monetary policy power and credit markets, I first construct novel time series of monetary policy shocks for Peru using the same approach as Romer and Romer (2004). I use annual forecasts for GDP growth and inflation released by the Central Bank of Peru, supplemented with forecasts from professional forecasters, as in Holm, Pascal and Tischbirek (2021), when Central Bank forecasts are not available. Provided the identified monetary policy shocks, I use Peruvian aggregate and micro data on lending outcomes to show evidence that supply factors are important to explain the effect of MP changes on the credit markets. More importantly, these supply decisions are reflected in the overall risk of the banks' asset side.

First, I use the following intuition to interpret the empirical findings at the aggregate level: the response of lending rates to monetary policy shocks provides a signal about leading forces in equilibrium. Thus, for a supply side leading mechanism, one must observe that after a MP shock, the contraction in credit supply caused by banks is greater than a proportional fall in credit demand, resulting in a credit market adjustment that necessitates a rise in lending rates. This is precisely what the results show. At the aggregate level, using Local Projections, an empirical model that imposes few constraints in the data, I show that after a contractionary monetary policy shock there is a persistent and economically significant negative response of aggregate credit and an increment in lending rates after a monetary policy shock. Also, the results show, by using a market measure of overall risk, that a monetary policy impacts the risk-taking behavior of banks. Further analysis using a VAR for robustness confirm these findings. This robust fact, to several specifications, suggests that supply side changes and risk-taking behavior are relevant for the credit market equilibrium. With this in mind, further, I investigate the significance of the risk-taking channel of monetary policy that arises from changes in the banks' preferences to extend credit to high-risk or low-risk borrowers using micro-data.

Second, using microdata and an empirical strategy, I show that monetary policy shocks act as a supply side mechanism in the credit market via the risk taking channel. In particular, I use branch-level and bank-province level data, as well as a within-bank comparison, to control

[2] Data from the Bank of International Settlements show that the credit-to-GDP ratios in Advanced Economies are above 100 percent.

for omitted variables like lending opportunities and credit demand conditions. I define local markets at the province level.

In particular, after an expansionary MP shock, banks can take advantage of a better outlook of the economy and lower funding costs, which, in turn, increase banks' appetite for risk and allocate more loans to riskier markets. This differential response is given by credit frictions on the credit supply side that create a bias in the way banks assess risk, and as a result value markets differently and take advantage of lending in risky but profitable markets. This intuition is consistent with the positive general equilibrium effects of low policy rates on bank's default probability, and expected profits with it, which drives bank's incentives to take excessive risk (Adrian and Song Shin, 2010; Agur and Demertzis, 2012; Altunbas, Gambacorta and Marques-Ibanez, 2014).

I exploit two observations about credit markets. First, lending is an informational intensive activity, and banks need to screen among potential set of borrowers due to informational asymmetries. Geographic proximity reduces the costs of transmitting and processing that information. i.e., credit markets are still local (Nguyen, 2019). Second, risk varies across markets. In particular, as heterogeneous inherent characteristics across markets persist, risk varies geographically. Thus, I consider credit markets at the province level, and obtain measures of risk by computing non-performing loans (NPL) ratio at the province level.

A key idea in the identification strategy is that NPL signals banks to rebalance their lending portfolio taking advantage of profitable but riskier local markets, capturing the risk-taking channel mechanism. For the identification strategy to work, it is important to have variation in riskiness that is independent of a bank's lending opportunities or demand factors influencing bank's decisions. I use a within-bank identification, and by comparing across branches of the same bank, I am able to control for a bank's lending opportunities and identify the effects of the risk-taking channel on the lending sensitivity to monetary policy shocks.

The branch-level estimation confirms that the sensitivity of lending to MP changes is increasing in the riskiness of borrowers, even within a financial firm. After 100 bps expansionary monetary policy shock, a branch operating in an average high NPL market increases lending growth by 228.8 bps relative to a branch operating in an average low NPL market.[3] This result shows statistical and economical significance of the main prediction of the model, that is robust to several sample definitions and sample periods. I shows that the effects of monetary policy on lending are similar if I consider in the sample all financial firms and not only those financial firms serving more than two province markets. Also, the risk-taking channel at the branch level is similar for banks and non-banks. The results do not change if I exclude from the sample the metropolitan area, that accounts a lion's share of total credit. In fact, by focusing on riskier markets, estimates of the risk-taking channel are larger, and of similar magnitude for all types financial institutions: banks, non-banks and the 4 largest banks in the country. These findings contradict empirical evidence suggesting that undercapitalized banks are more likely to extend credit to risky borrowers (Jiménez, Ongena, Peydró and Saurina, 2014; Acharya, Eisert, Eufinger and Hirsch, 2019; Andrews and Petroulakis, 2019; Faria e Castro, Pascal and Sánchez, 2021).

Also, the results remain statistically significant if I control for sample selection or omitted variables such as bank concentration that may bias the estimates. The risk-taking channel estimate barely changes after I control for standard Herfindahl index, which shows the results do

[3]The average high (low) NPL corresponds to the average of markets with NPL above (below) the median.

not pick up bank concentration effects.

The results at the branch level are partial equilibrium estimates, and the risk-taking channel at the branch level may not be economically significant at higher levels of aggregation. First, I demonstrate that micro data at the branch level can generate credit dynamics that are similar to those observed with aggregate data. After estimating credit dynamics responses at the branch level across the risk distribution of credit local markets, I show that monetary policy has meaningful responses in local markets with risk distributions below the percentile 80. I also observe that the risk-taking channel is led by the dynamics of branches operating in markets below the median of the risk distribution in the overall periods following the monetary policy shock.

In addition, to show that the risk-taking channel estimates at the branch level captures overall bank behavior I aggregate lending at the province level, and use a within-province estimator. The idea is that at the bank level, the average risk that a bank faces across all markets in which it operates must be more important. In other words, the impact of the risk-taking channel of MP must be determined by the average riskiness of the local markets in which a financial firm operates. To explore this argument, I compute a financial firm-level measure of borrower riskiness NPL-Bank, by averaging the local market riskiness of all financial firm's branches, NPL-Branch, weighted by each branch share of the financial firm's total lending. To reach identification I compare the lending growth rate of different banks in the same province. The results of this within-province estimator show that after an expansionary monetary policy shock, banks that operate in riskier markets increase lending much more, relative to those banks serving less risky markets. A one standard deviation increase in NPL-Bank raises lending by 233.1 bps per 100 bps expansionary monetary policy shock.

Further, I aggregate the data to the province level to examine the overall effects of the risk-taking channel on lending and employment. I find that provinces whose banks lend in risky markets after an expansionary MP shock see larger increases in lending relative to other provinces. I also find that the risk-taking channel has the predicted direction effects on province employment. The effects are meaningful and statistically significant.

Finally, I verify that the results hold at the bank level and, after an expansionary MP shock, financial firms operating in riskier markets generate larger profits and issue higher foreign currency loans.

The remainder of this chapter is partitioned as follows. Section 1.2 presents the literature review. Section 1.3 constructs the time series of identified monetary policy shocks for the Peruvian economy. Section 1.4 examines the validity of the identified monetary policy shocks and presents aggregate empirical evidence pointing to a supply side mechanism of adjustment in credit markets following a monetary policy shock, as well as bank risk-taking behavior consistent with it. Section 1.5 presents the sources and summary statistics of the micro data I use for the empirical estimations of the risk-taking channel of monetary policy at the branch level. Section 1.6 presents the main estimates of the risk-taking channel under the branch-level identification strategy. Section 1.7 shows estimates of the effects of the risk-taking channel under different levels of data aggregation. Finally, section 1.8 concludes.

1.2 Literature Review

There has been a large amount of research into the impact of domestic policy rates on the degree of bank risk-taking, known as the "risk-taking channel" (term coined by Borio and Zhu

(2012)). The literature on risk-taking commonly suggests that a lower domestic interest rate increases bank risk-taking (see, e.g., Jiménez, Ongena, Peydró and Saurina (2014)). And I find the same results. In that sense, the contribution of this work is the approach used at both the aggregate and micro levels using loan information from Peruvian bank branches. Next, I examine the literature that is closely related to this chapter.

This chapter is related to the literature that study the different channels through which monetary policy might affect bank risk-taking decisions (see, e.g., Adrian and Song Shin (2010); Agur and Demertzis (2012, 2015); Dell'Ariccia, Laeven and Marquez (2014); Dell'Ariccia, Laeven and Suarez (2016)). It mainly highlights two channels: the *profit* and the *leverage* channel. According to the *profit* channel, a lower rate reduces funding costs of banks and hence increases banks' profits at good times. This in turn increases banks' incentives to take risk. According to the *leverage* channel, the lower rate makes leverage less expensive. Then, banks have less of their own money (bank net worth) to fund risky loans. This means that the bank internalizes less risk and increases risk-taking incentives. Dell'Ariccia, Laeven and Marquez (2014) conclude that when leverage is endogenous, low interest rates lead to higher bank risk-taking.[4]

Also, this chapter is related to the empirical literature that studies the risk-taking channel of monetary policy. This typically finds excess bank risk-taking increases after a reduction in the policy rate. Altunbas, Gambacorta and Marques-Ibanez (2014) find that in the European Union the low interest rates over an extended period of time contributed to an increase of market perceptions of banks' risk. Maddaloni and Peydró (2015) show that lending standards deteriorate after a reduction in the short-term interest rate. Ioannidou, Ongeda and Peydró (2015) by using Bolivian data show that when interest rates are low, banks take on higher risk and reduce the loan rates of risky borrowers. In addition, Chen, Wu, Nam-Jeon and Wang (2017), using a panel-data from more than 1000 banks in 29 emerging economies during 2000-2012, find that bank's riskiness increases when the monetary policy is eased. Paligorova and Santos (2019) find that banks require relative lower risk credit premium in periods of monetary policy easing relative to tightening. Angeloni, Faia and Lo Duca (2015) take a different approach, and by examining US aggregate data trough a VAR model, shows that the leverage channel of bank risk-taking is more significant after a monetary policy shock.

This chapter is also related to the literature of the practice of zombie lending. Andrews and Petroulakis (2019) and Faria e Castro, Pascal and Sánchez (2021) show empirical evidence that poorly capitalized banks are more likely to extend credit to risky and inefficient borrowers. Giannetti and Simonov (2013) observed a more relaxed lending behavior for capitalized banks during the Japanese banking crisis of the 1990s. Schivardi, Sette and Tabellini (2021) documented similar lending standards relaxation for Italy during the financial crisis, as did Acharya, Eisert, Eufinger and Hirsch (2019) during the aftermath of the European sovereign crisis following the ECB Outright Monetary Transactions program.

In particular, this chapter is closely related to Jiménez, Ongena, Peydró and Saurina (2014) that using credit register data from Spain find robust evidence that a lower policy rate induces lowly capitalized banks to grant more loan applications to ex ante risky firms (than highly capitalized banks). As they state, this is the first paper to empirically study the impact of the monetary policy rate on the composition of the supply of credit, in particular on banks' risk-taking. In that sense this chapter follows in spirit the same research question than Jiménez, Ongena, Peydró and Saurina (2014) facing several identification challenges as well. This chapter aims

[4] Dell'Ariccia, Laeven and Marquez (2014) assumes banks' limited liability and asymmetric information, depositors cannot observe ex-ante the bank's risk-taking level.

to contribute to this literature by following a different econometric approach. By using a series of identified monetary policy shocks and micro data at the branch level I aim to exploit the differences of risky investment opportunities across provinces. This is, while in Jiménez, Ongena, Peydró and Saurina (2014), they study the risk-taking channel across banks and see banks' risk-taking response conditional on banks' capital to asset ratio after a monetary policy change; in this chapter I study the risk-taking channel within banks and observe banks' decisions on the composition of low-risk and high-risk credit after a monetary policy change. I show evidence that the risk-taking channel behavior in is equally likely across all financial firms, highly or poorly capitalized.

1.3 Monetary policy shocks identification

The key policy rate of the Central Bank of Peru is the Reference Interest Rate, i_t. Although it is the main variable to measure the conventional monetary policy stance, in this chapter I do not consider changes in the policy rate, Δi_t, as monetary policy shocks. Monetary policy changes, Δi_t, are potentially endogenous to the business cycle and as a consequence to credit markets outcomes that I study in this chapter. To address this concern, and identify the causal effects of changes in the monetary policy stance I need to capture orthogonal movements to the systematic component of the monetary policy instrument.

To do so, I employ the Romer and Romer (2004) method to identify monetary policy shocks. The basic idea of this approach is to orthogonalize changes in the policy rate from the central bank's projections of the main target macroeconomic variables. Therefore, following Romer and Romer (2004) I regress the policy change between two meetings, Δi_m, on the central bank forecasts for GDP, $y^f_{m,t+k}$, and the inflation, $\pi^f_{m,t+k}$, for horizon $t+k$ and the corresponding forecast changes, denoted $\Delta\pi^f_{m,t+k}$ and $\Delta y^f_{m,t+k}$. Specifically, I estimate the following regression at a meeting-by-meeting frequency:

$$\begin{aligned}\Delta i_m =&\alpha_1 + \sum_{h=2}^{12} d_h + \alpha_2 i_{m,-1} + \sum_{k=0}^{1} \beta_k^{\pi} \pi^f_{m,t+k} + \sum_{k=0}^{1} \beta_k^{y} y^f_{m,t+k} \\ &+ \sum_{k=0}^{1} \beta_k^{\Delta\pi} \Delta\pi^f_{m,t+k} + \sum_{k=0}^{1} \beta_k^{\Delta y} \Delta y^f_{m,t+k} + \gamma_1 e_{m,-1} + \gamma_2 \mathbf{1}^{IT}_{m<2007m1} + \epsilon^{MP}_m \end{aligned} \tag{1.1}$$

where the dependent variable Δi_m is the change of the policy rate at meeting m and $i_{m,-1}$ is the level of the policy rate prior to meeting m. I estimate this regression for the period 2003m9 to 2019m12. Since 2003m9 the Central Bank of Peru sets the Reference Interest Rate, i_t as the benchmark rate for the interbank lending market each month, according to a previously announced schedule. Figure 1.8 in Appendix 1.A.2 shows that the policy rate in Peru during the sample period is not constrained by the zero lower bound limit, and therefore I can measure shocks associated to conventional monetary policy.

For all policy meetings, I rely on Central Bank of Peru's historical forecasts, which were created shortly before the meeting. When this is not the case, I follow Cloyne and Huertgen (2016); Holm, Pascal and Tischbirek (2021) by using market participants' forecasts as a proxy for the central bank's forecasts. Appendix 1.A.1 describes in detail the sources and procedure I use to assign the different forecasts to policy meetings.

Differently than Romer and Romer (2004) I do not use quarterly forecasts for inflation and GDP, but annual forecasts as in Holm, Pascal and Tischbirek (2021). Thus, the index k in the specification (1.1) denotes the year of the forecast relative to the meeting date m that takes a year t. Annual forecasts are available and consistently published during the sample period. I also do not include contemporaneous variables since real-time data is not consistently available for the sample period. However, I control for recent economic conditions by including $i_{m,-1}$, the level of the policy rate prior to meeting m. I also control for the regime change in inflation targeting by including the dummy $\mathbf{1}^{IT}_{m<2007m1}$. The Central Bank of Peru officially committed to a lower range of inflation targeting regime beginning in February 2007.[5] Furthermore, because Peru is a partially dollarized economy, the benchmark interest rate is supplemented by other instruments such as sterilization operations to reduce excessive volatility in the exchange rate. As a result, I add the exchange rate on the day before the meeting as an additional explanatory variable, $e_{m,-1}$.[6] Finally, to account for differences in information sets across the year for a fixed event of forecasting,[7] I include monthly dummies $d_h; , h = 2, 3, ..., 12$.

1.3.1 Estimation Results

I estimate the empirical equation (1.1) via OLS for the sample period 2003m9-2019m12, and for a total of 188 monetary meetings.[8] Table 1.1 shows the results of the estimation. The signs of all coefficients are as expected. Over the sample period, Peruvian monetary policy was conducted countercyclically. Thus, if projected inflation or output growth is high or has been rising in comparison to the prior forecasts, monetary policy tightens to counteract the business cycle. However, only current year changes in inflation forecasts, and next year GDP forecast are statistically significant. The constant and the coefficient associated with the lag of interest rates are both negative, reflecting the secular trend decline and mean reversion in interest rates. The coefficient associated with the foreign exchange rate is positive and statistically significant, implying that monetary policy tightens when the domestic currency falls in value. The coefficient associated with the regime change in the inflation target is negative, indicating that monetary policy became tighter after 2007, consistent with a lower inflation target regime. The R^2 of the regression is 0.37 which is of similar magnitude as the ones reported by Romer and Romer (2004); Cloyne and Huertgen (2016); Holm, Pascal and Tischbirek (2021) for United States, United Kingdom and Norway, respectively.

As in Romer and Romer (2004) I convert the series of residuals ϵ^{MP}_m from the estimated specification (1.1) from a meeting-by-meeting frequency into monthly and quarterly time series, by assigning each shock to the month or quarter in which it occurred. Because monetary policy meetings were held once a month for the sample period estimation, assigning meeting shocks to monthly series was simple. For the excluded monetary policy meeting I assign zero

[5]From February 2007, the inflation target was reduced from 2.5 to 2.0 percent, maintaining the tolerance of one percentage point up and down

[6]I must notice that the Central Bank of Peru does not have a commitment for a specific level of the exchange rate. However, by adding $e_{m,-1}$ I control for financial conditions that may impact on monetary policy decisions.

[7]The Expectation Survey is a type of survey conducted for "fixed events". For example, in each quarter panelists are asked to forecast output growth and inflation for the current calendar year and the next, implying that the forecast horizon changes with each survey round.

[8]Although for sample period there were 195 monetary policy meetings, I exclude 7 meetings on the basis of lack of information captured by released forecasts. Appendix 1.A.1 describes in detail the meetings and forecasts I consider in the estimation

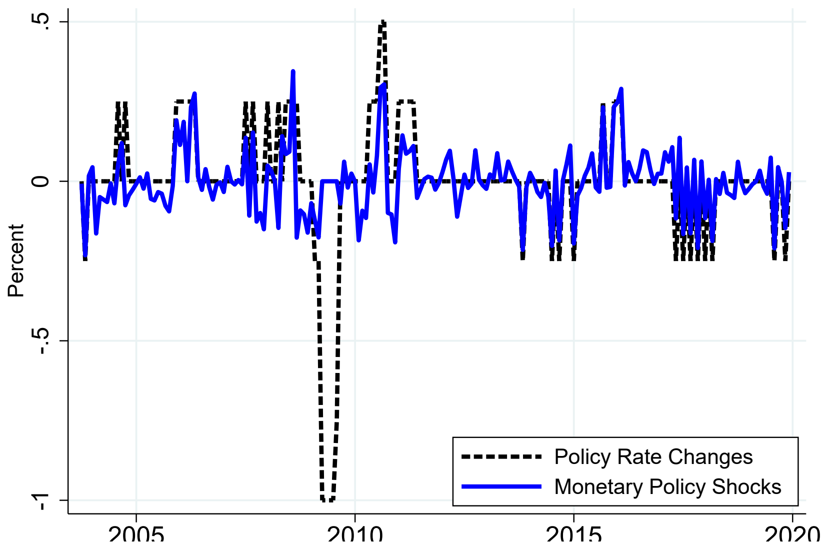
to the corresponding shock. Figure 1.1 shows the estimated monetary policy shocks and the corresponding monetary policy changes. Quarterly shocks are shown in figure 1.9 in Appendix 1.A.3.

Table 1.1: Determinants of the policy rate change

	Coef.	**S.D**	**P-val**
Constant	-0.648	0.292	0.028
$i_{m,-1}$	-0.067	0.014	0.000
$\pi^f_{m,t}$	0.018	0.023	0.429
$\pi^f_{m,t+1}$	0.057	0.036	0.112
$\Delta\pi^f_{m,t}$	0.025	0.014	0.079
$\Delta\pi^f_{m,t+1}$	0.046	0.030	0.125
$y^f_{m,t}$	0.001	0.030	0.969
$y^f_{m,t+1}$	0.095	0.054	0.082
$\Delta y^f_{m,t}$	0.005	0.022	0.833
$\Delta y^f_{m,t+1}$	0.059	0.041	0.148
$e_{m,-1}$	0.125	0.066	0.059
$\mathbf{1}^{IT}_{m<2007m1}$	-0.024	0.031	0.446
N =188			
R-sqrt = 0.37			

Note: Estimation for the determinants of policy changes, as in specification (1.1). Sample period 2003m9-2019m12. See Appendix 1.A.1.

Figure 1.1: Peru: Monthly Monetary policy shocks



Note: This figure shows the series of residuals ϵ^{MP}_m from the estimated specification (1.1), converted from a meeting-by-meeting frequency into monthly time series.

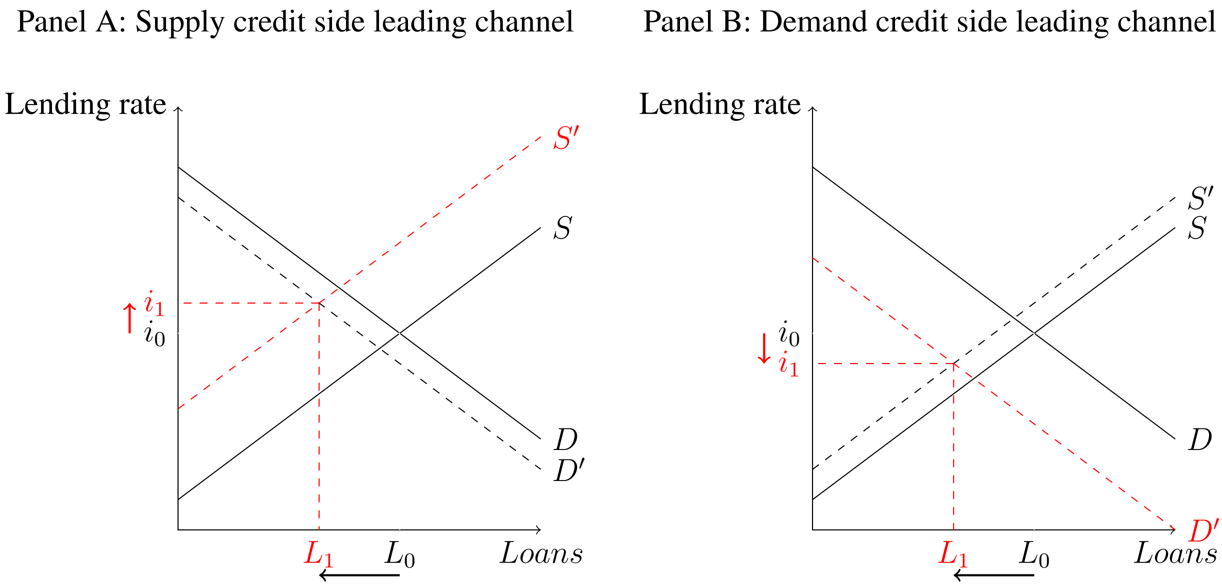
Some of the monetary policy shocks are large and reflect also large movements in policy rates. Contractionary shocks were particularly noticeable in 2008m8 and 2010m9, when current year inflation was above the target inflation range. It is also important to notice that although monetary policy shocks and policy rate changes commove they are significantly different. I can test the predictability of the monetary policy shocks. The F-statistic of a regression on 6 lags of inflation and an indicator of economic activity is 1.39 with a p-value of 0.17. When the number of lags is increased to 12, the F-statistic is 0.87, with a p-value of 0.71. As a result, there is no proof of predictability.

This series of shocks only reflect exogenous variation in monetary policy and not any endogenous feedback effects from the business cycle to policy. Thus, in the following sections I use them to study credit outcomes and mechanisms in response to monetary policy changes.

1.4 How does the credit market adjust to a MP shock? An aggregate time series view

First, the risk-taking mechanism of the monetary policy requires a market equilibrium determination led primarily by the supply side of the market made by banks, such that the quantity movements in banking lending are also accompanied by that risk-taking behavior. Although, the process of adjustment after a MP shock may be convoluted due to the different supply and demand forces contending at the same time, the equilibrium response of the credit market, in terms of total lending quantity and lending rates, still gives us a clear signal to disentangle which underlying force is driving the credit market adjustment after a MP shock.

Figure 1.2: Credit market adjustment to a contracionary MP shock



Note: The figures show the adjustment of the credit market after a MP shock. Panel Panel A: the credit supply side responds more aggressively, and credit spreads rise. Panel B: the credit demand side responds more aggressively, and credit spreads fall.

Figure 1.2 shows the intuition about the adjustment forces leading to a credit market equilibrium after a contracionary MP shock. On one side, the Panel A pictures a situation where the supply side response is higher relatively to demand side response. After a MP shock, the contraction in the credit supply by banks is bigger than a proportional fall in credit demand and it leads to an adjustment in the credit market that requires a raise in lending rates. On the other side, Panel B illustrates the scenario where the credit demand side response much more relatively the supply response, in which case, a fall in lending rates is needed to guarantee a new equilibrium. Notice, that the response of lending interest rates to a MP shock provides us a clear indication about which side of credit markets is determining a new equilibrium. One interpretation is that the risk-taking behavior of banks determines a supply side determination of credit market equilibrium. Thus, for a given fall in credit demand, banks take a lower risk and extend significantly less loans, so the credit supply curve shifts to the left, and the lending rate rises.

In this part, I use this intuition and document some facts about the equilibrium responses of credit markets (quantities and lending rate) after a monetary policy shock. I focus on a full dynamic model based on credit aggregate quantities and in the later sections I explore the heterogeneous effects of monetary policy shocks under the risk-taking mechanism.

To begin, I use a flexible model that imposes few constraints on the data to establish causal effects on aggregate variables. Specifically, I use the identified monetary policy shocks and run local projections to model the dynamic equilibrium response of economic activity and credit market variables after monetary policy shock. This section of the analysis also serves as a test of the monetary policy identification and its ability to capture what one knows about the responses of macroeconomic variables to monetary policy actions. Let y_t be the outcome variable at time t. Following Jordà (2005) I estimate the series of the following regressions:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h \epsilon_m^{MP} + \sum_{k=1}^{K} \gamma_k^h X_{t-k} + u_t^h \,, \tag{1.2}$$

where $h = 1, 2, ..16$. The coefficients β_h give the percentage change at horizon h in response to a 100-basis-point monetary policy shock. X_t denotes a vector of controls. Following the same specification as in Romer and Romer (2004), it includes three years of lagged values of the monetary policy shock and two years of lagged values of the dependent variable. Also, it adds a dummy variable for the period after 2009Q1. After the Global Financial Crisis the main macroeconomics variables started to show lower growth rates and more volatility. Importantly, the specification (1.2) leaves the contemporaneous response unrestricted, and it differs from a typical Cholesky identification usually used in VAR specifications. Later I compare these estimates with a VAR model that imposes more constraints on the aggregate data.[9]

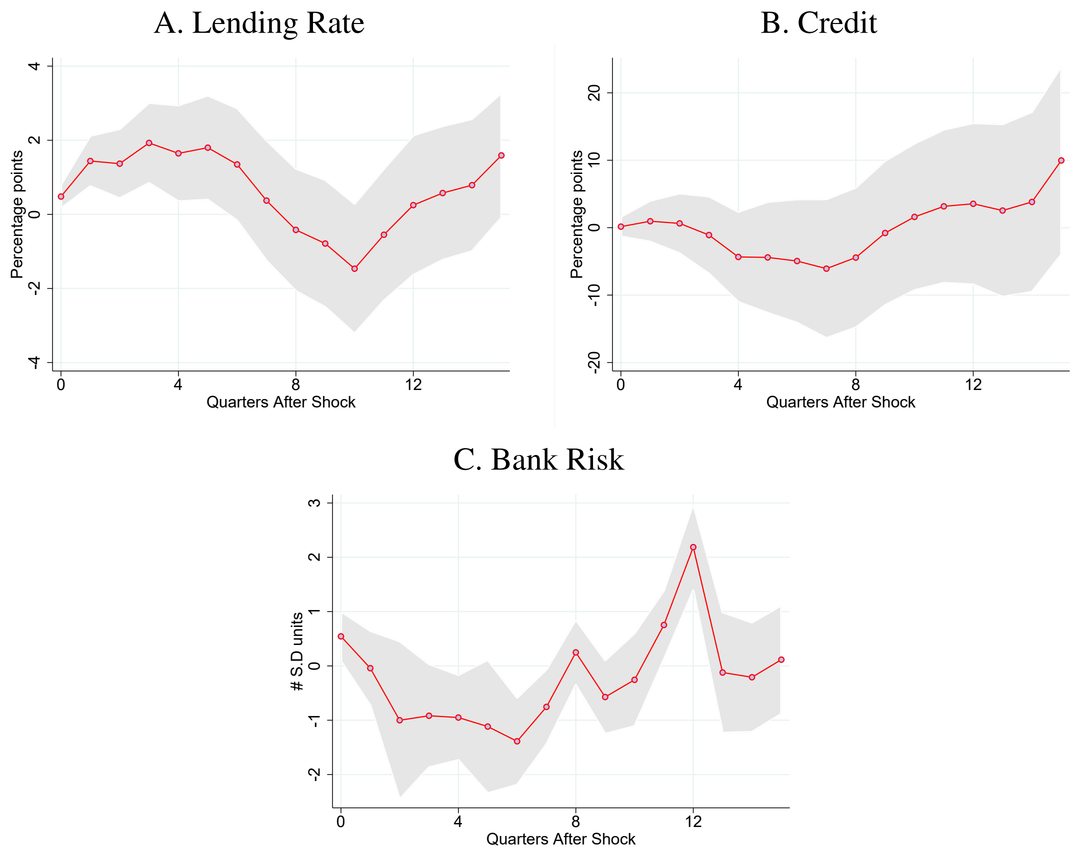
1.4.1 Estimation Results of Local Projections on Macro variables

The local projections, in specification (1.2), are estimated on a quarterly frequency for the sample period 2003Q4-2019Q4. I use the quarterly monetary policy shocks, as shown in figure 1.9 in Appendix 1.A.3. First, I consider the impact of a contractionary shock of 100 basis points on credit market outcome variables at the aggregate level: credit, average lending rate

[9]More specifically, In Appendix 1.D I estimate a VAR for the Peruvian aggregate data, under a Cholesky identification, to study monetary policy shocks.

and a measure of overall bank risk-taking. Following a similar strategy as in Angeloni, Faia and Lo Duca (2015), I measure total bank risk-taking as the quarterly realized volatility of the S&P/BVL Financials Index (PEN), calculated as the standard deviation of the index's daily returns over each quarter. The basic idea is that financial markets react to any information of bank default that is ultimately triggered by bad news on bank's investment returns. Due to data availability I estimate the specification (1.2) for bank risk for the shorter sample period 2011Q4-2019Q4 and with only 1 lag for the dependent variable.[10] A detail description of the other aggregate variables is provided in the appendix 1.C.

Figure 1.3: Local projections Results: Monetary Policy Shock, Credit Market and risk-taking



Note: This figure shows the impulse response functions to a 100 basis points contractionary monetary policy shock under the specification (1.2). 68 percent confidence bands are shown, using Newey and West (1987) standard errors. Sample period 2003q4 - 2019q4. Due to data availability I estimate the local projection for bank risk for the sample period 2011q4 - 2019q4.

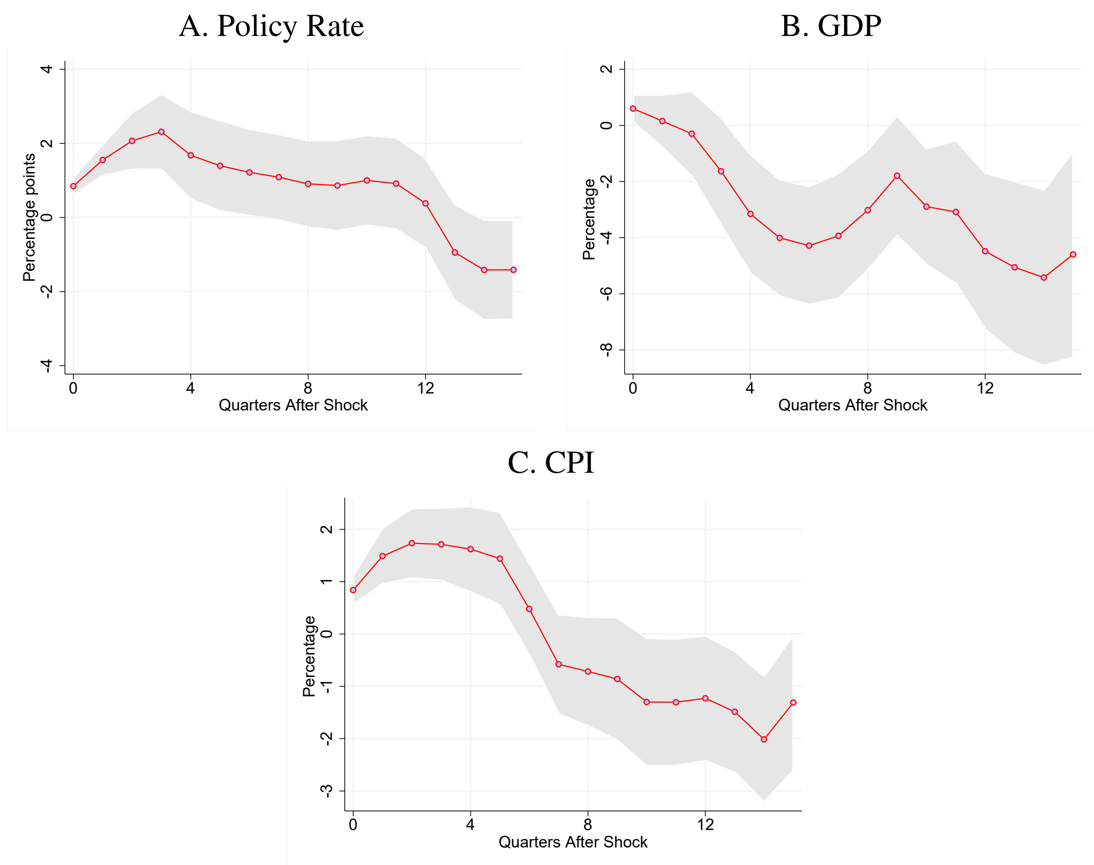
The impulse responses of credit market outcomes after the contractionary monetary policy shock are shown in Figure 1.3. The panel A of Figure 1.3 shows an increment in lending rates after a 100 basis point rise in the monetary policy rate: when the impact occurs the lending rate rises and reaches a maximum increment of 2% after two quarters and it is still up at around this

[10] Daily data on S&P/BVL Financials Index (PEN) in only available from 01/01/2011 onward. However, I also get a similar pattern for impulse response if I include 6 lags for the dependent variable, but the estimates are very imprecise after 8 quarters.

level one year later. The panel B of Figure 1.3 displays the persistent and economically significant negative response of aggregate credit after a monetary policy shock: credit declines by around 3% four quarters after the shock, and reaches a decline of around 5% in the subsequent year. More importantly, Panel C shows that after the MP shock the measure of overall risk of banks, perceived by investors, falls by around 1 standard deviation after 3 quarters. In Appendix 1.B I check and confirm that the results are robust to various baseline regression modifications.

Furthermore, in the Appendix 1.D I demonstrate that the equilibrium response of credit markets is qualitatively consistent with estimates from a model that imposes more constraints on the data: a VAR with a Cholesky identification for monetary policy shocks. Figure 1.13 shows that after a monetary policy shock one observes an increment of lending rates and a decline in credit. These findings are robust to several specifications, ordering of variables, detrending or scheme identification (see Figure 1.15 in Appendix 1.D.2).

Figure 1.4: Local projections Results: Monetary Policy Shock & The Business cycle



Note: This figure shows the impulse response functions to a 100 basis points contractionary monetary policy shock under the specification (1.2). 68 percent confidence bands are shown, using Newey and West (1987) standard errors. Sample period 2003q4 - 2019q4.

All these aggregate empirical evidence points out a supply side mechanism of adjustment in credit markets and it is consistent with the existence of a risk-taking channel after a MP shock[11].

[11]Quispe (2001) and Carrera (2011) also analyses the effects of monetary policy on credit markets in Peru, by using aggregate data. However, their analysis is limited to look the total impact on lending, independently of any

Motivated by this robust aggregate evidence in next sections I discuss the risk-taking channel as credit supply side of mechanism of monetary policy shocks. And in particular, how banks allocate loans and how risks are reflected in their asset side of the balance.

Finally, I also show the validity of the identified monetary policy shocks by testing its power to explain the main macroeconomic variables. I estimate local projection for GDP and the consumer price index. Figure 1.4 shows the estimated impulse responses to a contractionary shock of 100 basis points. Panel A shows that the policy rate increases consistently and subsequently reverses. Panel B shows that economic activity contracts persistently after 2 quarters and one year after GDP is around 4% below its initial level. Consumer prices also decline after 6 quarters, it persistently stays around 2% below its initial level after 2 years. These results are consistent with standard textbook responses of GDP and CPI to monetary policy tightening.

In Appendix 1.D.1 I also show that these results are consistent with impulse responses obtained from a standard VAR with a Cholesky identification for monetary policy shocks. The local projections method produces larger and more persistent impulse responses than the VAR method. Different sample periods do not explain these differences[12]. But, as shown by Cloyne and Huertgen (2016) these differences may mainly be explained by the different implied shock paths in the two methods[13]. The magnitude and persistence of the impulse responses obtained from the local projections, reported in 1.4, are consistent with those shown by Romer and Romer (2004); Holm, Pascal and Tischbirek (2021).

1.5 Micro Data

At the micro level, the analysis is based on Peruvian financial firm branch-level data and bank-province data. The Peruvian credit market is segmented locally, as there is heterogeneity in the number of institutions serving a given province. But also, there are large financial institutions with a extended geographical lending network that can overpass geographical market segmentation and serve more than one local market. The Peruvian financial system is composed by five main financial groups: banks, CAMCs, CRACs, EDPYMES and *empresas financieras*.[14] Banks engage in a wide range of financial activities and operate on a national scale. The latter four groups, non-bank financial institutions, provide limited financial services, intermediate small amounts of loans, and they are primarily focused on credit to small businesses and consumers, and reaching unbanked individuals.[15] The empirical analysis focuses on all financial institutions, bank and non-banks.

distinction between credit demand or supply side mechanisms or lending rates or risk-taking measures.

[12] **?** estimate a VAR for a larger sample, 2003Q1-2009Q4, but which does not feature bank risk, and the impulse responses for credit, lending rates, CPI and GDP show similar magnitudes and persistence than those from VAR I estimate here.

[13] The local Projections is specified in differences, thus a shock to the level of the policy rate is permanent. However, the VAR is specified in levels and a shock to the level of the policy rate is temporary.

[14] The Peruvian financial regulator, *Superintendencia de Banca, Seguros y Administradoras de Fondos de Pensiones*, classifies the financial institutions into these five groups: i) Banking companies, ii) CAMCs, which are Municipal Savings Associations, iii) CRACs, which are Rural Savings and Loan entities, iv) EDPYME, that is an Entity for Small and Micro Business, and v) *empresas financieras*, that are financial or specialized companies

[15] CAMCs are mainly owned by regional governments; CRACs, privately-owned financial firms, originally focused on lending to the agriculture sector and rural areas, now offer commercial lending and personal loans in urban areas. EDPYMES are focused in lending to medium and small firms and *empresas financieras* mainly focused in consumer lending

1.5.1 Data Sources

Province Lending: The dataset comprises Peruvian branch-level data information from 2002m1 to 2018m12 about loans and deposits extended by banks across districts. The data on lending and number of financial institutions or branches operating in province is provided by the Peruvian financial regulator, *Superintendencia de Banca, Seguros y Administradoras de Fondos de Pensiones* (SBS).

Financial firms data: The financial firms data comes from balances reported to the Peruvian financial regulator. I access to data available from 2002m1 to 2017m09.

Non-Performing loans: The key variable for riskiness is Non-Performing Loans (NPL) at the province level. It was computed as the time average of yearly NPL ratios for each of 189 provinces in the country. To compute this NPL measures I make use of granular on credit data from the Credit Registry Data (RCC). This is a loan-level data that contains debt classification at client-level and at loan-level originated in the financial system.[16] The data is available at a quarterly frequency for the 2003Q1-2010Q3 period and at a monthly frequency for the 2010M10-2018M12 period. Debtors are identified by an SBS code, tax ID (RUC) and national ID (DNI). Thus, I compute NPL ratios at the province level or bank-province level at a quarterly basis from 2003Q1 to 2008Q4.

Thus, I first match the credit registry data with geographic location, in a province. Then, I use the geographic location of a debtor provided by the Peruvian tax administration (SUNAT) and finally I match this information to Location codes (UBIGEO).[17] The goal is to obtain a panel-data on credit and non-performing loans ratio at bank-province-time level. In this process, I identify a sample of all formal loans from the financial institutions.

Specifically, for the construction of any bank-province-time level variable, I proceed as follows:

1. Identify a sample of clients with RUC(Tax ID) in RCC.

2. Match clients with RUC in RCC with Locational data from SUNAT.

3. Select loans provided to private non-financial firms $\rightarrow$ Loans by RUC and Location

4. Construct credit information, risk-taking measures at bank-province-time level.

Note that I make two strong assumptions. First, I assume that loans go to the registered location of a borrower. It could be that the registered location is different to the one where the debtors' activities are performed. However, I assume this is an odd case. Second, I also assume that loans located in a certain region are issued by an agency from the same region. Appendix 1.E shows the results of this matching process. In general, the sample to compute NPL captures very well the dynamics of aggregate credit market in Peru.

In the analysis the risk-taking measure is captured by the non-performing loans ratio, which I calculate using the Peruvian financial regulator (SBS) criterion,

$$\frac{\text{loan arrears (Big firms(15d), small firms(30d) mortgage(30d), personal(90d))}}{\text{Total credits}}.$$

[16] This information is restricted. I thank to the Central Bank of Peru, BCRP, for giving us access to use the datasets.

[17] Once I have a UBIGEO, I use the Peruvian Bureau of statistics' information on location of a UBIGEO in a region.

Employment: I collect data on employment from administrative data provided by SUNAT.[18] The data cover all formal employment at monthly frequency from 2011m1 to 2018m12. I compute quarterly growth rate employment at the province level by matching the available firm's location information to Location codes (UBIGEO).

1.5.2 Summary Statistics

Table 1.2 presents the descriptive statistics for the main variables in the analysis. It shows the cross-section and time averages. The empirical analysis uses variation on lending at branch-level. There are 3682 branches located in 451 districts and 189 provinces. The identification

Table 1.2: Data: Statistics

	All		Low NPL		High NPL	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A. Province Characteristics						
Population (Thousand)	169.6	689.8	256.7	969.3	83.5	84.1
Area (sq. km.)	6,703.1	12,518	7,762	15,292	5,655.0	8,932.6
Formal Employment (share)	2.2	3.5	2.9	4.3	1.5	2.1
NPL-Branch (%)	15	18	6.1	3.1	24.7	21.0
Obs.(Provinces)	189		94		95	
Panel B. Branch Characteristics						
Loans (Thousand S/)	121.6	978.6	199.3	1,352.4	37.9	73.2
Loan growth (%)	4.5	19	4.9	22	3.9	15.9
Obs.(branch × Quarter))	68,969		35,773		33,196	
Panel C. financial firms Characteristics						
Assets (Mill. S/)	4,321.6	14,111.5	7,721.9	19,189.9	926.6	2,713.2
Loans (Mill. S/)	2,789.7	8,961.6	4,957.7	12,201.3	625.2	1,593.9
NPL-Bank (%)	5.1	5.3	2.3	.68	7.8	6.5
Obs.(Bank × Quarter))	2,490		1,245		1,245	

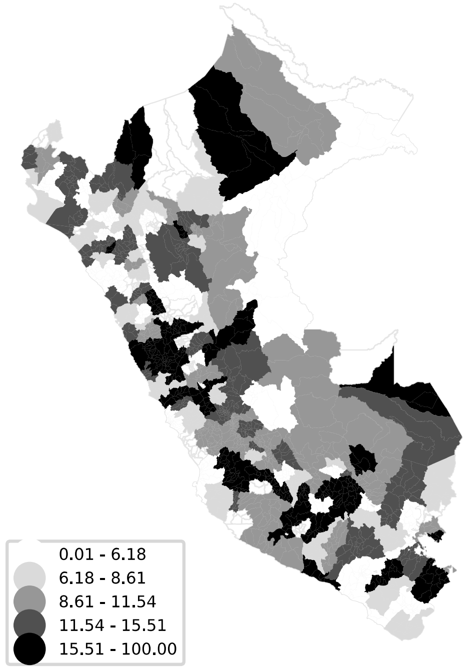
Note: This table provides summary statistics at the province, branch, bank level. All panels provide a breakdown by high and low non-performing loan (NPL), using below and above the median NPL for each respective sample. Panel A presents characteristics for all provinces with at least one financial firm branch. The underlying data are from the 2017 census. Data on employment comes from SUNAT. Panel B presents data on total credit and loan growth at the branch level. Panel C presents data about financial firms. Data from SBS. The underlying data are for NPL is based on RCC data, matched with locational data.

strategy uses variation in riskiness of local credit markets, which I measure using the Non-Performing Loans (NPL) at the given province, NPL-Branch. The NPL-Branch is calculated by adding all non-performing loans in a given province in a given year and then averaging the results over all years. I then assign to each financial firm branch in the data the NPL of the province in which it is located.

[18]This information is restricted. I thank to the Central Bank of Peru, for giving us access to use this dataset.

Figure 1.5 shows the map NPL-branch across Peru. A lower value indicates lower level of riskiness. There is heterogeneity across provinces, from a minimum NPL-Branch of 0.07 to a maximum of 1.

Figure 1.5: Province risk heterogeneity : $NPL - Branch$



Note: Given data on non-performing loans ratio at a province p and month t, it shows for each province p a time average computed as $\frac{\sum_t NPLf_{p,t}}{T}$, where T is the number periods in the sample. Sample: 2003m1-2017m12.

All panels in Table 1.2, for presentation purposes, provide a breakdown by high and low non-performing loan (NPL) using the median NPL as a threshold value to divide the respective samples. Panel A of Table 1.2 shows statistics of the data for all provinces with at least one financial firm branch. It is noticeable that low-risk local provinces (Low NPL-Branch) are larger and have higher formal employment than high-risk provinces. The average population in low-risk provinces is 256.7 thousand versus 83.5 in high-risk provinces. Formal employment share is almost double in low-risk markets: 2.9 versus 1.5.

Branch-level summary statistics is shown in Panel B of Table 1.2. Branches in low-risk provinces are larger (199.3 thousand Pen Soles versus 37.9 thousand Pen Soles). The average branch holds loans worth 121.6 thousand Pen Soles. However, branches in low-risk provinces show a higher credit growth rate on average relative to branches in high-risk provinces.

Panel C of Table 1.2 presents statistics at the financial level. For the financial firm-level analysis I compute a financial firm level measure of risk, NPL-bank, which is defined as the weighted average of NPL-Branch across all of the financial firm's branches, using branch lending shares as weights. Financial firms with low NPL-bank are larger, with assets worth 7721.9 million PEN soles versus 926.6 million PEN soles for high NPL-bank financial firms.

One key assumption of the empirical strategy is that the underlying riskiness of credit local markets is heterogeneous. Furthermore, differences in the underlying riskiness of local credit markets induce geographic variation in Non-Performing Loans (NPL). I regress the measure of

NPL on some regional structural characteristics that affect borrowers' riskiness to provide some evidence that this measure of NPL captures some fundamental riskiness. I collect annual data on a measure of capital stock available per worker as a proxy for firm investment, the share of the population with elementary education as a proxy for overall education, the average number of social conflicts as a proxy for business environment, and the number of mining operations in a region as a proxy for exposure to foreign shocks.[19].

Table 1.3: NPL and Regional Indicators

	Dependent variable: NPL				
	(1)	(2)	(3)	(4)	(5)
Capital per worker	0.214^{**}				0.164
	(0.101)				(0.139)
Share Basic Education		0.831			0.142
		(0.536)			(0.705)
Social Conflicts			4.359^{*}		3.428^{*}
			(2.154)		(1.947)
Mining Operations				0.170	0.0720
				(0.265)	(0.296)
R^2	0.176	0.128	0.126	0.00831	0.260
Observations	24	24	24	24	24

Note: This table estimates the relationship of regional indicators, as proxies for underlying province risk, and NPL, the measure of riskiness. NPL is aggregated to a regional level by taking averages across its provinces. Consistently, the regressors are also time averages over the annual sample 2010-2018. Capital per worker is a measure of the amount of capital available per worker. Share Basic Education is the percentage of the population who has received elementary education. Social Conflict is the average number of social conflicts in the regions. All these regional indicators were obtained from the Index of Regional Competitivity published by the Peruvian Institute of Economics. Mining Operations denotes the average number of mining operations in a region, reported by the Ministry of Mining and Oil Production. Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

NPL ratios are positively correlated with all previous measures of underlying riskiness, as shown in Table 1.3. In regions with higher levels of firm investment, NPL ratios are higher. Furthermore, regions with low educational levels and greater exposure to commodity prices fluctuations, due to the presence of mining operations in the region, have higher NPL ratios. Although these variables are not statistically significant. Finally, and most importantly, higher business environment volatility is associated to a higher NPL. Higher NPL ratios are found in regions with a higher number of social conflicts.

[19]Information of number of mining operations in each region was obtained from the Ministry of Mining and Oil Production. The rest of indicators were gathered from the Index of Regional Competitivity published by the Peruvian Institute of Economics

1.6 Monetary policy transmission at the bank-branch level: The Risk-Taking Channel

In this section, I attempt to establish direct causal effects of monetary policy on lending through the risk-taking channel mechanism. I investigate a causal link between credit market riskiness, as measured by the NPL ratio, and the power of monetary policy transmission, by exploiting the monetary policy shocks, I constructed in Section 1.3, and the bank-branch level Peruvian data, described in Section 1.5. This section first shows estimates of the aggregate effects of monetary policy implied by the bank-branch level data. To put it in another way, it displays macro estimates derived from micro data.

Second, the results are then disaggregated to investigate the risk-taking channel of monetary policy by utilizing geographic variation in Non-Performing Loans (NPL). I follow a similar strategy as in Drechsler, Savov and Schnabl (2017) to show a direct causal effect. In particular, I use bank branch-level and bank-province level data so I can control for omitted variables such as lending opportunities and credit demand conditions. Basically, through this identification I shed light on the risk-taking channel as a credit supply side mechanism of monetary policy. Under this approach, I conduct a cross-sectional analysis showing that the risk-taking channel is greater in exactly those pool of borrowers were theory would predict that banks' incentives to take risk are likely to be stronger.

1.6.1 Micro-Macro Responses of Credit to Monetary Policy Shocks

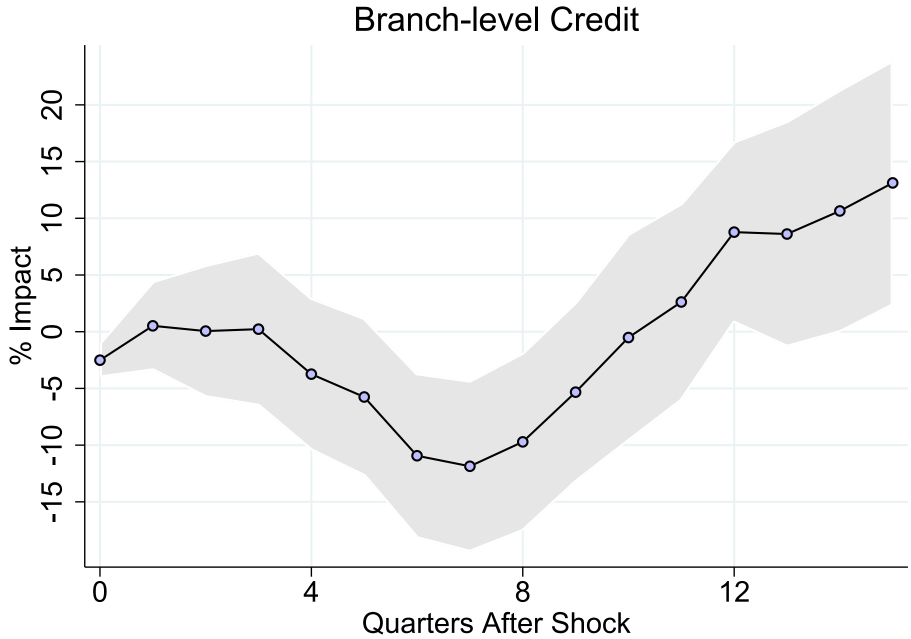
The validity of the branch-level data to capture the conditional response of credit to monetary policy shocks is a first step in the micro analysis. Thus, I first look for micro-macro impulse responses based on micro bank-branch level data on credit. Following similar strategy as Holm, Pascal and Tischbirek (2021), I estimate a series of the following local projection regressions as follows:

$$\frac{y_{j,t+h} - y_{j,t-1}}{\bar{y}_{t-1}} = \alpha_{j,h} + \beta_h \, \epsilon_t^{MP} + \sum_{k=1}^{K} \gamma_k^h X_{j,t-k} + u_{j,t}^h \,, \tag{1.3}$$

where $y_{j,t}$ is the amount of credit supplied by bank-branch j at time t. The dependent variable is the change in y_j from period $t-1$ to $t+h$, $h = 0, 1, ..16$. The key normalization variable is $\bar{y}_{t-1}$ which is the average value of credit across all branches in period $t-1$. Thus, under this normalization the β_h is comparable to the corresponding coefficient estimate on the aggregate data in specification (1.2) in Section 1.4.1. The coefficient β_h gives the percentage change of the average branch credit at horizon h in response to a 100-basis-point monetary policy shock. $\alpha_{j,h}$ is a branch specific fixed effect at horizon h. $X_{j,t}$ denotes a vector of controls. Following the specification (1.2), it includes three years of lagged values of the monetary policy shock and 2 years lagged values of the dependent variable.

The estimated impulse response for bank-branch credit is shown Figure 1.6. This result is comparable with the macro impulse response of aggregate credit shown in Figure 1.3. Surprisingly, both the micro-macro response of credit at the branch level and the macro response of aggregate credit, shown in Figure 1.3, to monetary policy shocks exhibit similar dynamics overtime. However, the micro-macro response is more severe, and credit falls by around 13 percent seven quarters after the shock, which is significantly higher than the aggregate macro response fall of around 8 percent.

Figure 1.6: Micro-Macro Impulse Response of Credit to a contractionary monetary Policy Shock



Note: This figure shows the Micro-Macro impulse response function of credit to a 100 basis points contractionary monetary policy shock under the local projection specification (1.3). 68 percent confidence bands are shown, using Driscoll and Kraay (1998) standard errors. Sample period 2003q4 - 2019q4.

Overall, this response demonstrates that monetary policy influences credit at the branch level, and it follows the expected direction, it is comparable to the aggregate level response and it is statistically significant. With this in hand, I examine the risk-taking channel as a credit supply side mechanism of monetary policy at the branch level in the following section.

1.6.2 The risk-taking channel mechanism: Micro evidence

Identification Strategy

This section investigates the connection between risk and the power of monetary policy transmission. I use the Non-Performing Loans (NPL) as a measure of the riskiness of a local credit market. As developed in Section 1.5.2, I assume that the geographic variation in Non-Performing Loans (NPL) is induced by differences in structural riskiness of local credit markets. This closely reproduce the idea of local credit markets (Nguyen, 2019). Geographic proximity reduces the costs of transmitting and processing that information of borrowers. Thus, branches specialize in asses the riskiness of pool of borrowers they face in local market.

A key idea in the identification strategy is that NPL, capturing the risk taking channel mechanism, signals financial firms to rebalance their lending portfolio and take advantage of profitable but riskier local markets. Financial firms internally can allocate funds across branches, but there are some administrative costs to reallocate resources across markets due to geographic segmentation. An expansionary monetary policy shock introduces additional incentives for financial firms to pay cost for portfolio rebalancing. In particular, additional cheaper funding leads to rebalance lending in such a way that a bank-branch facing a risky market expand lending much more relative to a bank-branch facing a less risky market, since excess of deposits is not costly but profitable. Under the risk-taking channel, lending supply should be more sensitive in riskier local lending markets.

For the identification strategy to work, it is important to have variation in riskiness that is independent of a financial firm's lending opportunities or demand factors influencing financial firm's decisions. To obtain such variation I compare lending across branches of the same financial firm located in different provinces at the same time. This is a within-financial firm identification, and I refer to it as branch-bank estimation. By comparing across branches of the same financial firm, one can control for the financial firm's lending opportunities and identify the effects of the risk-taking channel on the sensitivity of lending to monetary policy.

Branch-Bank estimation

Equation 1.4 implements the identification strategy and it is the main specification at the branch-level in a given province. The dependent variable, $\Delta y_{b(j)pt}$, is the growth rate of all loans granted by a branch j of a financial firm b in the province p at time t. NPL-Branch$_p$ is the indicator of riskiness of the local credit market in province p. ϵ_t^{MP} is the monetary policy shock constructed in Section 1.3. I include bank-time fixed effects, α_{bt}, for bank b that owns a branch j; and α_j , $\alpha_{p(j)}$, $\alpha_{r(j)t}$ are branch , province and region-time fixed effects, respectively.

$$\Delta y_{b(j)pt} = \alpha_j + \alpha_{p(j)} + \alpha_{r(j)t} + \alpha_{bt} + \beta \, \text{NPL-Branch}_p \times \epsilon_t^{MP} + \gamma_X X_{b(j)p,t} + \epsilon_{b(j)pt} \tag{1.4}$$

The key set of fixed effects are the bank-time fixed effects, α_{bt}, which absorbs all time differences across banks, to control for a bank's lending opportunities. So, I compare across branches of the same bank. NPL-Branch$_p \times \epsilon_t^{MP}$ captures the MP risk-taking channel. Basically, with $\beta < 0$, after a expansionary MP shock, branches operating in riskier provinces extend more loans relative to its branches in less risky locations.

Branch, province and region-time fixed effects are additional controls. Branch fixed effects control for branch-specific characteristics such as invariant managerial quality. Province fixed effects control for province specific differences, and region-time fixed effects control for economic or financial trends at a specific region level. If I omit bank-time fixed effects, I add time fixed effect to control for country level trends.

I also include $X_{b(j)p,t-k}$, a vector of controls. To control for initial credit conditions or specific variance of observation I add one lag of all loans granted by a branch j, $logy_{b(j)p,t-1}$. I also try different sets of controls, such as lags of dependent variables and lags of monetary policy shock interacted with the average NPL, to control for the mean reversion property of endogenous variable at the branch level and shock diffusion, respectively. Adding these controls is consistent with previous Local Projections specifications, in equations (1.2) and (1.3). I cluster errors at time and bank-level.

Results

Table 1.4 shows the results of the estimation of equation (1.4). The sample include all branches from all financial firms, banks and non-banks. The quarterly sample covers the period from 2004Q1 to 2018Q12. Lending data was winsorized at the 2% to control bias results due to outliers. From columns (1) to (4), I add or take out regressors. The preferred specification is in Column (2). Overall, I intend to control for variables that might influence the lender decision and that may be also correlated with a financial firm ownership, firm size, regional economic conditions, managerial decisions or initial branch trends.

Table 1.4: Branch-level estimation: Results

	Dependent variable: Δy_{bdt}			
	(1)	(2)	(3)	(4)
NPL-Branch $\times$ ϵ_t^{MP}	-0.0714***	-0.123***	-0.0908	-0.177*
	(0.0252)	(0.0431)	(0.0825)	(0.100)
y_{t-1}	-0.115***	-0.120***	-0.120***	-0.109***
	(0.0134)	(0.0160)	(0.0154)	(0.0179)
Controls Lag Dep.		✓	✓	✓
Bank-Time FE	✓	✓	✓	
Region-Time FE	✓	✓		
Branch FE	✓	✓	✓	✓
Province FE	✓	✓	✓	✓
Time FE				✓
R^2	0.346	0.348	0.329	0.179
Observations	68969	65321	65321	65724

Note: This table estimates the effect of the Peruvian monetary policy shocks on lending growth, $\Delta y_{b(j)pt}$. Quarterly Sample: 2004Q1 to 2018Q12 at the branch-level. The sample includes only banks with branches in two or more provinces. Lending growth is the log change in credit at the branch level. NPL-Branch measures market riskiness in the province where a branch is located. ϵ_t^{MP} is the monetary policy shock. Fixed effects are described at the bottom of the table. Standard errors clustered at time and bank-level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Columns (1) and (2) show that allowing for lags of branch lending growth rates makes no very significant difference in the risk-taking channel. Column (2) shows the operative and statistically significant risk taking MP channel. It confirms that the sensitivity of lending to MP changes is increasing in riskiness of borrowers, even within a financial firm. After 100 bps expansionary monetary policy shock, financial firms raise lending growth rates by 12.3 bps more at their branches in a high risky locations relative to their branches operating in low risky locations, per unit of NPL change. In particular, after 100 bps expansionary monetary policy shock, a branch operating in an average high NPL market (24.7) raises lending growth by 228.8 bps relative to a branch operating in an average low NPL market (6.1).[20] This result presents

[20]The average high (low) NPL corrresponds to the average of markets with NPL above (below) the median.

evidence of the main prediction of the model: higher lending inflows into riskier regions relative to less risky regions after an expansionary monetary policy shock.

Column (3) omits region-time fixed effects while column (4) also omits bank-time fixed effects. The risk-taking channel coefficients is similar as the one in column (2). All of these results confirms that the sensitivity of lending to monetary policy rate changes is increasing in the riskiness of the pool of borrowers, even within financial firms.

Robustness

Results from robustness tests are shown in Appendix 1.F. First, Table 1.10 in the Appendix 1.F.1 shows that the effects of monetary policy on lending are bit larger in the sample that includes all financial firms and not only those financial firms serving more than two province markets. i.e a specification without bank-time fixed effects. Table 1.11 in the Appendix 1.F.2 shows additional robustness to the main specification. It shows that even after controlling for sample selection and omitted variables such as bank concentration, the risk-taking channel of monetary policy at the branch level remains statistically significant. First, excluding observations from the initial years, 2002-2004, with some measurement issues and low representation of aggregate credit, has no effect on the significance and only slightly changes the magnitude of the main estimate. Second, restricting the sample before and after the Great Financial Crisis (GFC) to control for monetary stance, international liquidity availability, and international rate levels does not change the direction of the risk-taking channel, and they are very similar in magnitude between periods. Third, controlling for a measure of bank competition has little effect on the risk-taking channel estimate, demonstrating the robustness of the results and that it is not picking up the bank concentration effects.[21] Risky but profitable markets would also be those in which large banks or banks with greater market power prefer to operate. These type of banks obtain funding more easily, weakening the risk-taking channel of monetary policy. This robustness test, however, demonstrates that the risk-taking channel is independent of the degree of bank concentration in local markets.

Further, Table 1.5 shows robustness to the main specification in equation (1.4) for different samples of financial institutions and geographic areas. These robustness tests also show some evidence of risk taking channel heterogeneity across different types of financial institutions and local credit markets. Column (1) considers all branches for all financial institutions, column (2) restricts the sample to branches of banks, column (3) considers branches of Peru's four largest banks, and column (4) considers branches of non-bank financial institutions. Panel A considers the entire sample of branches from all Peruvian local markets. Panel B, on the other hand, show results from a sample that excludes branches operating in the metropolitan area, which accounts for the lion's share of credit in the country.[22]

Table 1.5 shows that the direction of the risk-taking channel of monetary policy on branch lending is consistent across all samples.

Panel A in Table 1.5 shows that the direction of the risk-taking channel of monetary policy on branch lending is consistent across banks, non-banks, and they are identical in magnitude

[21]It includes HH-Branch as measure of bank competition. It is computed by summing up the squared credit-market shares of all banks participating in a given province in a given year, and then averaging over all years.

[22]Pozo and Rojas (2021) show that branches in the metropolitan area (regions of Lima and Callao) account for around 75 percent of total credit, and it is mainly concentrated in the credit to corporate and large firms.

for these two groups. However, for the sample of large banks this sensitivity on lending is in the opposite direction, although smaller and not statistically significant.[23]

Table 1.5: Branch-level estimation: Robustness I

	Dependent variable: Δy_{bdt}			
	(1) All	(2) Banks	(3) Large Banks	(4) Non-Banks
Panel A: Full Sample				
NPL-Branch × ϵ_t^{MP}	-0.0714***	-0.110	0.0419	-0.110*
	(0.025)	(0.19)	(0.15)	(0.056)
y_{t-1}	-0.115***	-0.136***	-0.144***	-0.0833***
	(0.013)	(0.016)	(0.012)	(0.011)
Observations	68969	30965	17703	34244
R^2	0.346	0.342	0.311	0.427
Panel B: No Metropolitan Area Sample				
NPL-Branch × ϵ_t^{MP}	-0.152**	-0.184*	-0.175*	-0.190**
	(0.064)	(0.092)	(0.057)	(0.092)
y_{t-1}	-0.112***	-0.117***	-0.116***	-0.0724***
	(0.014)	(0.0099)	(0.0080)	(0.010)
Observations	44056	19849	11649	32703
R^2	0.416	0.392	0.345	0.427
Controls Lag Dep.	✓	✓	✓	✓
Bank-Time FE	✓	✓	✓	✓
Region-Time FE	✓	✓	✓	✓
Branch FE	✓	✓	✓	✓
Province FE	✓	✓	✓	✓

Note: This table estimates the effect of the Peruvian monetary policy shocks on lending growth. Lending growth is the log change in credit at the branch level, $\Delta y_{b(j)pt}$. Quarterly Sample: 2004Q1 to 2018Q12. The sample includes only banks with branches in two or more provinces. NPL-Branch measures market riskiness in the province where a branch is located. ϵ_t^{MP} is the monetary policy shock. Fixed effects are described at the bottom of the table. Large Banks sample considers only the large four banks in Peru. Non-Banks includes CAMCs, CRACs, EDPYMES and *empresas financieras*. Non Metropolitan Area sample: excludes Lima and Callao, which form the largest metropolitan area in the Peru. Standard errors clustered at time and bank-level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[23]The four largest banks in Peru have more branches and are present in almost all of the country's provinces. They are more cautious, and their decision not to take excessive risks may work against them. Furthermore, because they have more alternative funding options, large banks are less sensitive to monetary policy shocks.

Panel B takes a closer look, and examine the geographic area that does not include the metropolitan area, where the risk-taking channel may be weaker. The metropolitan area accounts for roughly 75 percent of credit in the sample, and it is primarily concentrated in credit for safer borrowers, such as corporations and large businesses (Pozo and Rojas, 2021). First, estimates of the risk-taking channel are larger and statistically significant across different financial institution samples. Second, the risk-taking channel is quantitatively greater in the non-bank sample than in the bank sample. Third, the risk-taking channel is quantitatively similar in both the sample of the largest banks and the sample of non-banks.

These findings support the robustness of the risk-taking channel and demonstrate that it operates across all types of financial institutions. It demonstrates that the effects of monetary policy are precisely stronger and more significant in markets with a riskier pool of borrowers. Furthermore, it demonstrates that both banks and non-banks have an incentive to take on more risk following an expansionary policy shock. During an expansionary monetary policy stance, even highly capitalized banks, such as Peru's four largest banks, are equally likely to engage in this risk-taking behavior. The findings contradict empirical evidence suggesting that undercapitalized banks are more likely to extend credit to risky borrowers Jiménez, Ongena, Peydró and Saurina (2014); Acharya, Eisert, Eufinger and Hirsch (2019); Andrews and Petroulakis (2019); Faria e Castro, Pascal and Sánchez (2021).

All these results show that the risk-taking channel is economically and statistically significant, and it operates as a credit supply side mechanism of monetary policy and it is present at the branch level.

Impulse Responses along the risk distribution

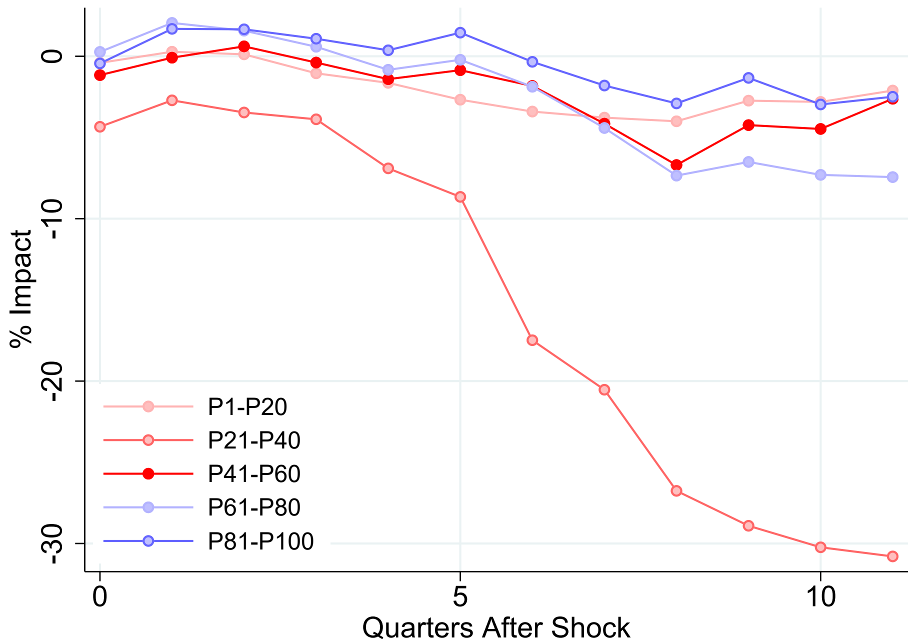
This part investigates further the role of the risk-taking channel in monetary policy transmission, by exploring the dynamic responses of branch credit across the risk distribution of local credit markets. I divide bank branches into groups of equal size indexed by g = 1,2,...,5 and estimate separate impulse responses for each group. A branch j is allocated to group g in period t if it operates in region with a NPL $t-1$ that fell between the $(g-1)$-th and $g-$th quantile of the distribution. Ordering branches according to lagged NPL values guarantees that the group allocation is not influenced by the shock occurring in period t. For each group g I run the local projections as follows:

$$\frac{y_{j,t+h} - y_{j,t-1}}{\bar{y}^g_{j,t-1}} = \alpha_{j,h} + \beta^g_h \, \epsilon^{MP}_t + \sum_{k=1}^{K} \gamma^{g,h}_k X_{j,t-k} + u^h_{j,t} \, , \tag{1.5}$$

with similar notation as in specification (1.3), with $h = 0, 1.., 11$. Changes of y_j from $t-1$ to $t+h$ are expressed in $t-1$ units of average of group g at time $t-1$. In this specification the key normalization variable is $\bar{y}^g_{j,t-1}$ which is the average value of credit across all branches in period $t-1$ in group g. Thus, under this normalization the β_h gives the percentage change of the average branch credit of group g at horizon h in response to a 100-basis-point monetary policy shock. $X_{j,t}$ includes three years of lagged values of the monetary policy shock and two years of lagged growth rates of the dependent variable, as in $X_{j,t}$ includes three years of lagged values of the monetary policy shock and two years of lagged growth rates of the dependent variable specifications (1.2) and (1.3).

Figure 1.7 shows micro impulse response of credit to a 100 basis points contractionary monetary policy shock across the five groups of the distribution of lagged NPL. To allow for a clear presentation, the figure only shows the point estimates, not the corresponding confidence intervals, because they display the impulse responses across the entire distribution.

Figure 1.7: Impulse Responses of branch credit: Across the distribution of risk



Note: This figure shows the micro impulse response function of branch credit to a 100 basis points contractionary monetary policy shock under the local projection specification (1.5) across 5 groups of the distribution of lagged NPL. 68 percent confidence bands are shown, using Driscoll and Kraay (1998) standard errors. Sample period 2003q4 - 2018q4.

Consistent with the results shown in Section 1.6.2, the responses to a monetary policy shock vary systematically depending on the level of local credit market risk that the bank-branch is exposed to. From the previous results, one should expect a higher lending contraction of credit in riskier regions relative to less risky regions after an expansionary monetary policy shock. Figure 1.7 shows that branches operating in credit markets below the median of the risk distribution determine a large portion of the credit dynamics response in the overall periods following the monetary policy shock. In particular, credit is contracted more frequently by branches operating at quantile 40 when compared to quantile 20. After two years, all branches operating in markets below the percentile 80 contract credit more than those operating in markets below the percentile 20. Another significant finding is that the response of those branches operating in markets at the top of the risk distribution shows very slight credit contraction across all time periods following the shock.

1.7 Aggregation of the Risk-Taking Channel

To identify the impact of the risk-taking channel on real activity one needs to revisit the estimates at higher levels of aggregation.

Previous results are at the branch-level, and they are partial equilibrium estimates. In general, the risk-taking channel at the branch level may not be economically significant at higher levels of aggregation, as financial firms can allocate lending across branches. At the bank level, the average risk that a bank faces across all markets in which it operates must be more important. In other words, the impact of the risk-taking channel of MP must be determined by the average riskiness of the local markets in which a financial firm operates. To explore this argument, I compute, a financial firm-level measure of borrower riskiness NPL-Bank, by averaging the local market riskiness of a financial firm's branches, NPL-Branch, weighted by each branch share of the financial firm's total lending.

An implication of the previous results at a more aggregate level must be that after an expansionary monetary policy shock, banks operating in risky markets (high NPL-Bank) expand lending much more relative to banks operating in less risky markets. However, testing this prediction is not easy, because one needs to control for differences in lending opportunities and credit demand conditions.

1.7.1 Within-province estimation

To overcome this challenge and ensure that financial firms face similar local lending opportunities I compare the lending growth rate of different banks in the same province. Thus, I estimate the following OLS regression:

$$\Delta y_{bpt} = \alpha_{bp} + \delta_{pt} + \gamma \,\text{NPL} - \text{Bank}_{bt-1} + \beta \textbf{NPL} - \text{Bank}_{bt-1} \times \epsilon_t^{MP}$$
$$\gamma_X X_{bpt} + \epsilon_{bpt}\,, \tag{1.6}$$

where the dependent variable, Δy_{bpt}, is the change in log of all loans granted by a financial firm b in the province p at time t. NPL-Bank$_{b,t}$ is the indicator of riskiness of markets that a bank faces from $t-4$ to t. ϵ_t^{MP} is the monetary policy shock. I include bank-province fixed effects, α_{bp}, to control for specific constant bank-branch specializations or bank regional interaction characteristics. The key set of controls are province-time fixed effects, δ_{pt}, which absorb changes in local lending opportunities or local market demand conditions. Thus, identification of β, the effect of monetary policy shocks in bank lending supply, comes from comparing loans extended by banks located in the same province p at quartet t.

X_{bpt} is a vector of controls. Similar to the specification (1.4), it includes the initial level of credit, $logy_{bp,t-1}$, two years of lags of the dependent variables and three years of lags of the monetary policy shock interacted with lag of NPL conditions. Standard errors clustered at time and bank-level.

Table 1.6 shows the results. Column (1) includes all the set of fixed effects and controls. It shows that after an expansionary monetary policy banks that operate in riskier markets increase lending more aggressively relative to banks serving less risky markets. After 100 bps expansionary monetary policy shock, a one standard deviation increment in NPL-Bank (5.1) increases the positive effect on lending growth by 233.1 bps. In other words, financial firms operating in a market with an NPL-Bank that is one standard deviation above the mean raise lending by 233.1 basis points more than the average financial firm per 100 pbs expansionary monetary policy shock. This risk-taking channel estimate at the province level is quantitatively similar to the one estimated at the branch level, in Section 1.6.2. It adds to the evidence that monetary policy rates affect lending in a given province via changes in lending incentives of financial firms that take more risk. i.e the risk-taking channel as a credit supply mechanisms of monetary policy transmission.

Table 1.6: Bank-Province estimation: Results

	Dependent variable: Δy_{bdt}		
	(1)	(2)	(3)
NPL-Bank $\times$ ϵ_t^{MP}	-0.457**	-0.560*	-0.509*
	(0.211)	(0.286)	(0.305)
NPL-Branch $\times$ ϵ_t^{MP}		-0.0858	-0.0546
		(0.0740)	(0.0696)
NPL-Bank	-0.276***	-0.254	-0.0967
	(0.0880)	(0.156)	(0.127)
y_{t-1}	-0.0600***	-0.0622***	-0.00993***
	(0.00159)	(0.00941)	(0.00146)
Controls	✓	✓	✓
Province-Time FE	✓		
Bank FE	✓	✓	✓
Bank-Province FE	✓	✓	
Province FE	✓	✓	✓
Time FE	✓	✓	✓
R^2	0.296	0.193	0.0942
Observations	32010	33138	33164

Note: This table show estimates of the effect of the risk-taking channel on lending. The data are at the financial firm-province-quarter level from 2004Q1 to 2018Q4. Δy_{bpt} is the log change of the total amount of lending by a given financial firm in a given province and quarter. NPL-Bank is the last four quarters average of NPL-Bank measures from a given financial firm in a given quarter. NPL-Bank is the average NPL-branch using lending shares across branches as weights. Fixed effects are denoted at the bottom. Standard errors clustered at time and bank-level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In column (2) includes the measure of local riskiness (NPL-Branch) interacting with the monetary policy shock.[24] Local riskiness has similar magnitude as those obtained in branch-level estimation, but is no longer statically significant. In contrast, the bank-level measure of risk-taking (NPL-bank) is similar to the one from column (1) and remains statistically significant. This result validate the assumption in Section 1.6.2 because it implies that portfolio lending decisions are made at the bank level, and banks allocate lending across branches.

Column (3) omits both the province-time and the bank-province fixed effects, and the main result remains similar in magnitude and statistically significant.

[24] To accomplish this, the province-time fixed effect is removed.

These findings suggest that the impact of financial firm risk-taking on the sensitivity of local lending to monetary policy is robust and substantial. Further, the Table 1.12 in Appendix 1.F.3 shows that the financial-firm level risk-taking channel operates through banks and non-banks. For the sample of large banks and banks, this sensitivity is even larger.

1.7.2 Province-level estimation

In this section I aggregate data and look for effects of the risk taking channel on lending and employment at the province level. One implication of the previous findings is that after an expansionary monetary policy, provinces, or local markets, served by banks that lend in riskier markets should experience larger lending expansions relative to provinces served banks operating in less risky markets.

To test this implication, I develop NPL-Province, a measure of province exposure to banks that take more risk at the provincial level. It is calculated by taking the weighted average of NPL-Bank across all financial firms operating in a given province and multiplying it by their lending shares one year earlier, $t-4$. I estimate the following OLS regression:

$$\Delta y_{pt} = \alpha_p + \delta_t + \beta \text{ NPL-Province}_{p,t-1} + \gamma \text{ NPL-Province}_{p,t-1} \times \epsilon_t^{MP} + \gamma_X X_{pt}\, , + \varepsilon_{pt} \quad (1.7)$$

where Δy_{pt} is quarterly rate change of lending or year-over-year rate change of employment in province p at time t[25]. ϵ_t^{MP} is the monetary policy shock. NPL-Province is the weighted average of NPL-Bank for all financial institutions in province p weighted by their lending shares. α_p are province fixed effects and δ_t are time fixed effects. Similar to previous specifications, X_{pt} is a vector of controls. It includes the initial log level of endogenous variable, $y_{p,t-1}$, two years of lags of the dependent variable and three years of lags of the monetary policy shock interacted with lag of NPL conditions. Standard errors are clustered at time level.

Column (1) in Table 1.7 shows the results of the benchmark specification using total lending growth as the dependent variable. It shows that provinces whose banks lend in risky markets after an expansionary MP shock see a larger increase in lending relative to other provinces. After 100 bps fall in the monetary policy shock, a one standard deviation increment in NPL-Province (4.57) increases the positive effect on total lending growth by 356.5 bps. This result is statistically significant and its magnitude is high. Column (2) adds local riskiness as a control (NPL-Branch) and the main estimate remains very similar and statistically significant. These results support the proposition that the risk-taking channel affects bank lending. Columns (3) and (4) in Table 1.7 present the results for the year-over-year employment growth. Columns (3) shows that the risk-taking channel has the predicted direction effects on province employment. Monetary policy is more expansionary in riskier provinces. A one standard deviation increase in NPL-Province (4.57) annual employment growth by 877 bps per expansionary monetary policy shock of 100 bps. The result is statistically significant. Column (4) adds local riskiness as a control (NPL-Branch) and results does not change. All of these findings provide compelling evidence that the risk-taking channel boosts credit and real activity following an expansionary monetary policy shock.

[25] Data on employment shows seasonality. Thus, to control for it, the analysis is done on the year-over-year rate change of employment.

Table 1.7: Province-Level estimation: Results

	$\Delta Loans$		$\Delta Employment$	
	(1)	(2)	(3)	(4)
NPL-Province $\times$ ϵ_t^{MP}	-0.780*	-0.800*	-1.918*	-1.915*
	(0.458)	(0.469)	(0.981)	(1.036)
NPL-Branch $\times$ ϵ_t^{MP}		-0.108		-0.432
		(0.111)		(0.252)
NPL-Province	-0.348	-0.337	-0.0416	-0.176
	(0.214)	(0.213)	(0.392)	(0.417)
$Loans_{t-1}$	-0.0589***	-0.0586***		
	(0.00847)	(0.00844)		
$Employment_{t-1}$			-0.438***	-0.439***
			(0.0346)	(0.0349)
Province FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
R^2	0.314	0.315	0.674	0.676
Observations	4878	4878	2164	2164

Note: This table show estimates of the risk-taking channel effect on Δy_{pt}: quarterly rate change of lending or year-over-year rate change of employment in province p at time t. The data are at the province-quarter level, and it corresponds to period 2004Q1-2018Q4 for lending and 2011Q1-2018Q4 for employment. NPL-Province is the last four quarters average of NPL-Province measures from a given province in a given quarter. NPL-Province is the average NPL-Bank using $t-4$ lending shares across provinces as weights. Fixed effects are denoted at the bottom. Standard errors clustered at time level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

1.7.3 Bank-level estimation

This section shows how banks change total lending after monetary policy shocks, and seek for evidence of the risk taking channel effects reflected on loans and profits at the financial firm-level. The unit of observation is a financial firm-quarter.

In particular, an implication of the previous results are that after an expansionary monetary policy shock, banks operating in riskier markets increase lending more aggressively and obtain more profits relative to banks operating in less risky markets. I test this implication by running the following OLS regression:

$$\Delta y_{bt} = \alpha_b + \delta_t + \gamma \text{ NPL-bank }_{b,t-1} + \beta_1 \text{ NPL-bank }_{b,t-1} \times \epsilon_t^{MP} + \gamma_X X_{bt} + \varepsilon_{bt} \quad (1.8)$$

where Δy_{bt} is the change in log of total loans, log of domestic currency loans or log of foreign currency loans or the financial margin to asset ratio. The financial margin is a profitability measure that reflects the percentage of profit that a financial firm earns from lending operations. It is defined as the ratio of the financial income net of financial expenses to total assets. ϵ_t^{MP} is the monetary policy shock. NPL-Bank is the weighted average of NPL-Branch for all financial institution's branches weighted by their lending shares. As a result, it captures the average risk that a bank faces across lending markets. α_b are financial firm fixed effects and δ_t are time fixed effects. X_{bt} is a vector of controls and previous specifications, it includes lags of the dependent variable, the log level of the dependent variable lagged one period, and lags of the MP shocks interacted with NPL-Bank.

Column (1) in Table 1.8 shows that in response to an expansionary monetary policy shock, financial firms that operate in riskier markets increase lending. The magnitude of the estimated coefficient is comparable to the previous estimates using bank-province data, show in Table 1.7. Column (2) and Column (3) show that the risk-taking channel operates mainly through foreign currency lending, which is statistically significant and larger in magnitude that domestic currency lending. These result may not be surprising, as lending in foreign currency tend to be riskier than domestic currency lending[26].

Finally, column (4) in Table 1.8 shows that after an expansionary monetary policy shock, financial firms operating in riskier markets tend to have more than proportionally profits, measured by the financial margin, relative to financial firms operating in more less risky markets. Following a 100 bps expansionary monetary policy shock, a one standard deviation increase in NPL-Bank (5.1) increases the positive effect on profits by 863.4 bps. This implies that changes in monetary policy introduce additional incentives, via higher profits, for banks to rebalance their lending portfolio by expanding more credit into riskier markets.

Table 1.8: Bank-Level estimation: Results

	Total loans	Domestic currency loans	Foreign currency loans	Financial margin
NPL-Bank $\times$ ϵ_t^{MP}	-1.047**	-0.1241	-3.888**	-1.693**
	(0.541)	(1.140)	(2.102)	(0.809)
Bank FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
R^2	0.477	0.461	0.404	0.96
Observations	1666	1666	1525	1673

Note: This table shows estimates of the risk-taking channel effects on bank-level lending and profits. The data are at the bank-quarter level and cover all financial firms from 2004Q1 to 2018Q12. It considers the change of log on total lending, log on domestic currency lending, log on foreign currency lending. The profit variable is the financial margin to assets ratio. Fixed effects are denoted at the bottom. Standard errors clustered by time in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

1.8 Conclusions

This chapter, using Peruvian data, shows that monetary policy shocks operate in the credit markets as a supply side mechanism via the risk taking channel. To obtain causal effects of monetary policy, I analyze data on credit market outcomes at the aggregate level and at the bank-branch level, together with a novel time series of identified monetary policy shocks for Peru. First, at the aggregate level, monetary policy shocks operate as a supply factor leading force for credit market equilibrium, and introduce incentives for financial firms to rebalance their lending portfolio across different local markets that varies

[26]For example, loans in foreign currency involve exchange rate risk.

in levels of riskiness. Using micro-data I test the following hypothesis: after an expansionary monetary policy shock, financial firms operating in riskier markets tend to expand lending much more relative to banks operating in less risky markets. Using branch-level data I show causal evidence that the risk-taking channel works even within financial firms. The incentives to rebalance lending portfolio to riskier loans does not disappear at higher levels of aggregation, and across the different types of financial institutions. I show that the impact of monetary policy on total credit via the risk-taking channel is important, and there is evidence of its effects on real variables, as employment. This finding of an operative risk-taking channel in Peru is robust to different specifications and sample definitions underlying the estimations.

As far as policy implications are concerned, the risk-taking channel may also work on the extensive margin by including riskier borrowers that otherwise may not have access to the credit market. However, I also show that the credit response dynamics via the risk taking channel operate for those credit markets below the 80 percentile of the risk distribution. Thus, the perils on financial stability from a risk-taking channel may be compensated by the financial inclusion of riskier borrowers with limited access to formal credit markets. It also demonstrates the limitations of monetary policy as a tool for attracting new riskier borrowers from the top of the risk distribution.

On the other hand, the mechanism I show in this chapter brings the concept of financial fragility due to excessive risk-taking. The estimates show that expansionary MP shocks tend to generate more than proportionally profits to banks operating in riskier markets. A regulator should be mindful about the excessive profit obtained by banks. Also, under the risk-taking channel, financial firms tend to prefer to loans in foreign currency, which may pose a sort of balance sheet fragility for a partially dollarized economy as Peru.

Appendices

1.A Monetary Policy Shocks Identification

1.A.1 Macroeconomic forecasts

This appendix describes the set of macroeconomics forecast I use in the estimation of regression (1.1). The Central Bank of Peru's monetary policy is based on an inflation targeting scheme that has been adopted since 2003. From September 2003 the Central Bank of Peru sets a benchmark rate, the Reference Rate, for the interbank lending market each month, according to a previously announced schedule. Accordingly, from 2003m1 until 2019m12 I obtain the Central Bank's forecast from the Inflation Reports. These forecasts are publicly available.[27] I collect annual GDP and inflation forecasts because they are consistently published over the sample period.

From 2003 to 2008, the Central Bank of Peru issued forecasts three times a year; beginning in 2009, forecasts were issued four times a year. The release of these forecasts sometimes coincided with a policy meeting. However, if the release of forecasts do not coincide with a date of policy decision, I assign forecast iteratively. I use forecasts published in the same month as the meeting or, if available, the previous month. For all remaining meetings, I follow Cloyne and Huertgen (2016); Holm, Pascal and Tischbirek (2021) in using forecasts by professional forecasters to proxy for the forecasts of the central bank. I specifically use data from the Expectations Survey of analysts and financial entities, which is conducted during the last two weeks of each month.[28] I resort to the mean of those projections. These forecasts are released at the end of each month, and monetary policy meetings are usually held before the middle of the following month.

Data from the Expectations Survey is a good proxy for Central Bank of Peru's forecast. Both sets of forecasts, Profesional forecasters forecasts and Central Bank forecasts show a high level of correlation. Monthly projections of current and next year GDP forecasts have a correlation coefficient of 0.99 and 0.91, and of 0.93 and 0.68 for inflation, respectively.

Table 1.9: Forecasts Assignment available for monetary policy meetings

Central Bank Forecasts from the Inflation Report	
Prepared for a policy meeting	11
Same month before the meeting	1
One month before the meeting	48
Professional Forecasts from the Expectation Survey	
Month before the meeting	135
Total number of monetary policy meetings	195

Note: This table shows all forecasts available for the monetary policy meetings held between 2003m9 and 2019m12.

Table 1.9 shows that for a 195 monetary policy meetings held between 2003m9 and 2019m12 in the sample I assign Central Bank of Peru forecast to 60 meetings and the remaining 135 are filled in

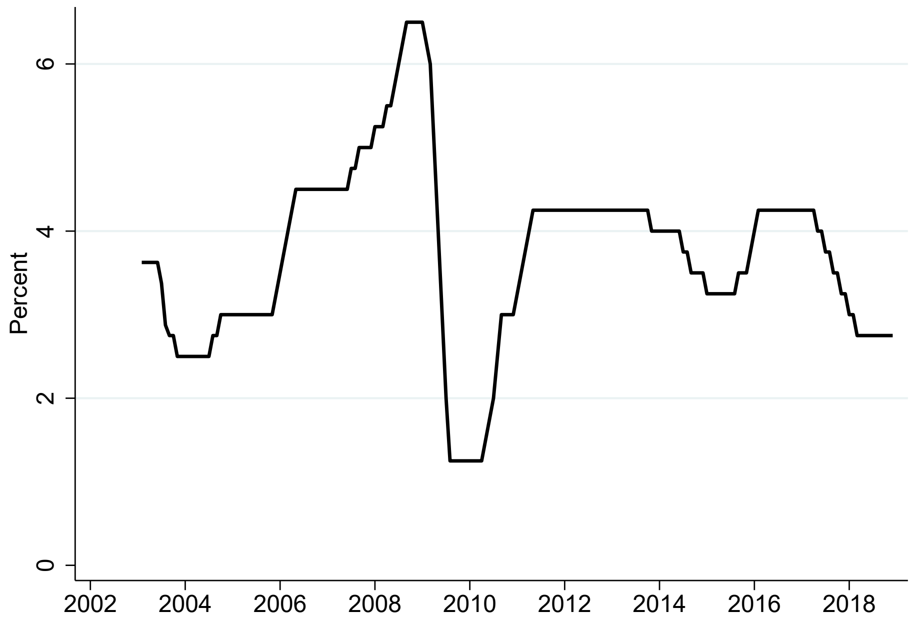
[27] The historical reports are available at the Central Bank of Peru Web Page.

[28] The Central Reserve Bank of Peru conducts the Expectation Survey to economic analysts and executives of financial and non-financial companies. The historical surveys are available at the Central Bank of Peru Web Page.

using professional forecasters form the Expectations Survey. Finally, I exclude the policy meetings that occurred between 2009m4 and 2009m8 from the estimation. The consequences of Global Financial Crisis was unfolding rapidly during this period, and the available forecasts may not capture the evolution of these rapid changes in the expectations about the future path of the economy. Thus, I may incorrectly assign a larger proportion of policy rate changes to a monetary policy shock if I include this period in the analysis. Also I exclude meetings on February 2005 and February 2007 due to lack of next year forecasts releases. At the end, the sample estimation is restricted to 188 meetings during the period 2003m9 and 2019m12.

1.A.2 Policy Rate

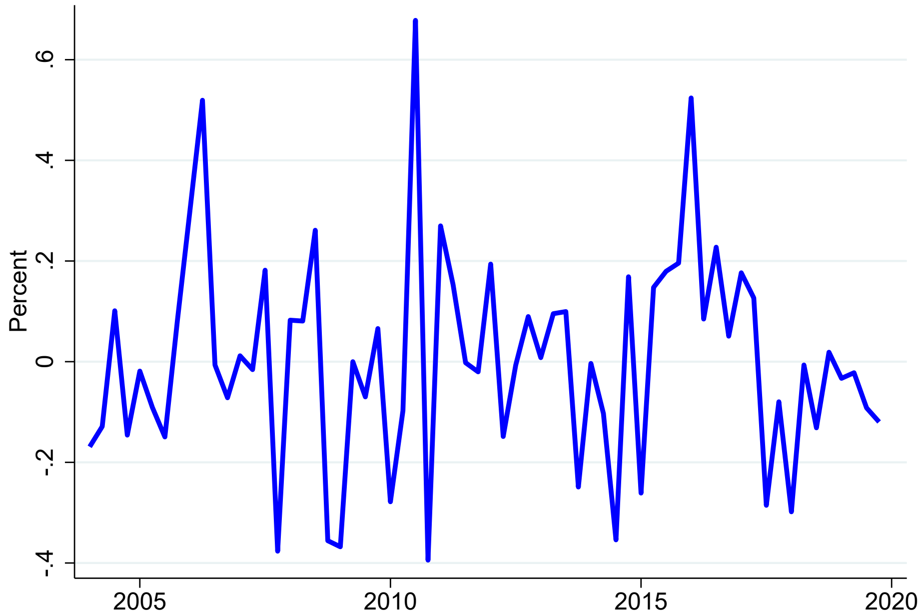
Figure 1.8: Central Bank of Peru's Policy Rate (Reference Rate)



Note: This figure shows the Central Bank of Peru's Policy Rate for the period 2003m9-2018m12.

1.A.3 Quarterly Monetary policy shocks

Figure 1.9: Peru: Quarterly Monetary policy shocks

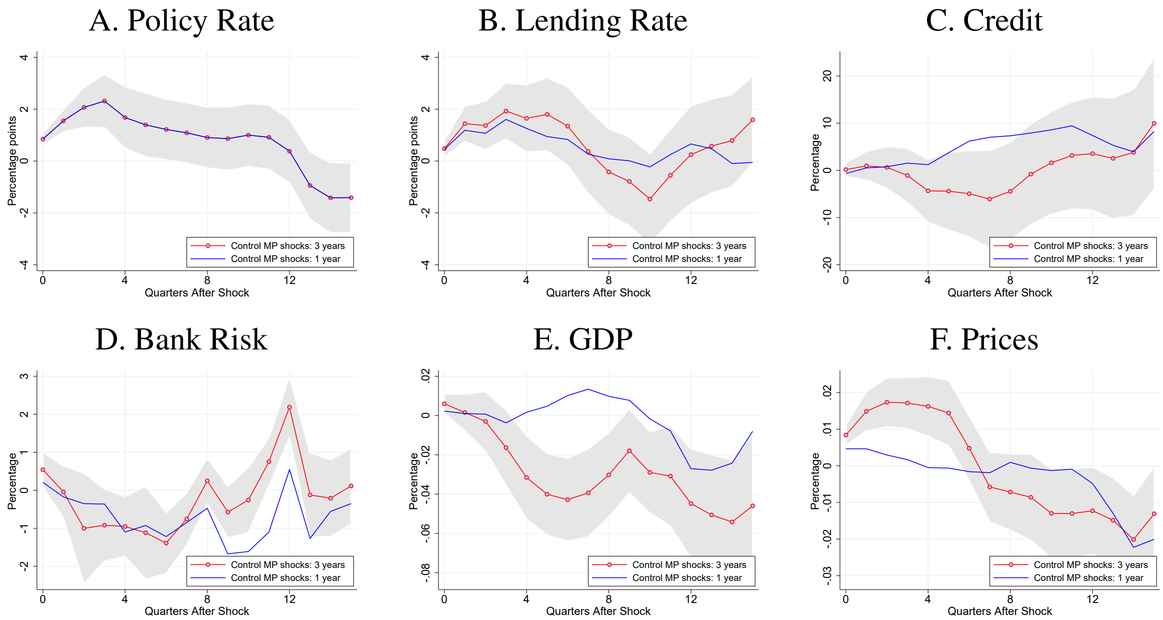


Note: This figure shows quarterly monetary policy shocks, by summing up monthly monetary policy shocks shows in figure 1.1.

1.B Robustness: Local Projections on Macro Variables

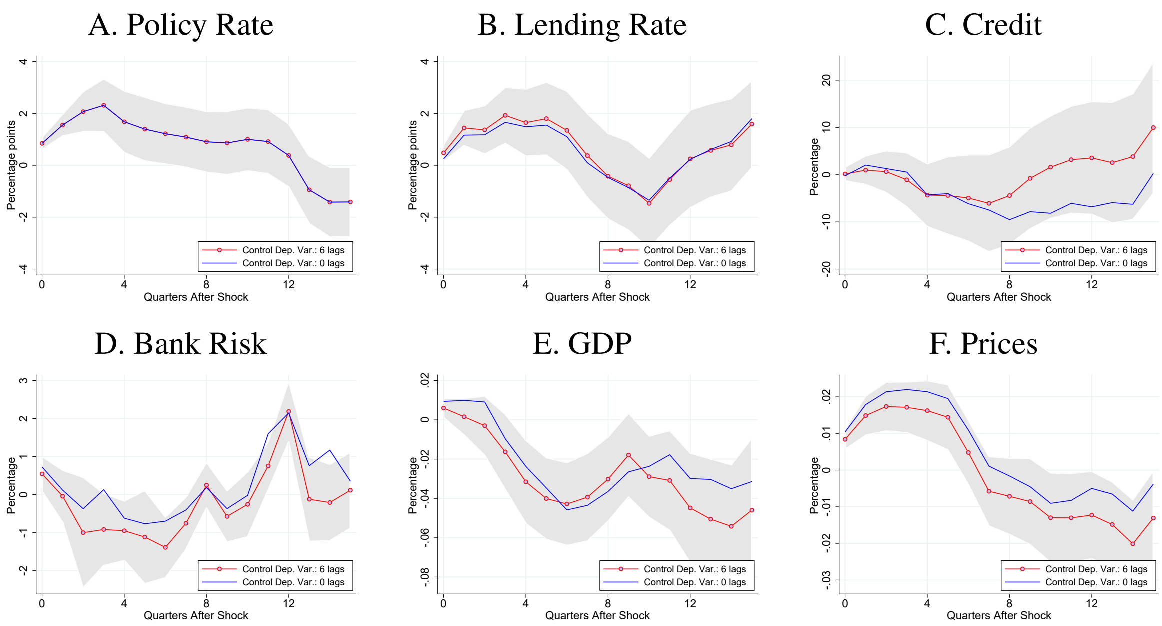
In this section I conduct some of robustness checks to the results shown in Section 1.4.1. Figure 1.10 shows that the impulse responses for credit and GDP and CPI prices are sensible to including only one year of lagged values of the monetary policy shock. However, the response of the lending rate and bank risk are not sensitive. From the intuition developed in Section 1.4 evidence for the monetary policy transmission via the credit supply side requires that the lending rate rises after a contractionary monetary policy shock, and evidence for the bank risk-taking channel requires a fall in bank risk. As a result, evidence for the findings of a supply side via a risk-taking mechanism remains robust to changes in the lag length of monetary policy shocks. Also Figure 1.11 shows that the results are robust to changes in the controls of the dependent variable's lagged growth rate. Finally, 1.12 shows that excluding Central Bank of Peru's forecasts from the process of identification described in Section 1.3 has little effects on the impulse responses.

Figure 1.10: Local Projections on Macro variables: Robustness to lag length of Monetary Policy shocks



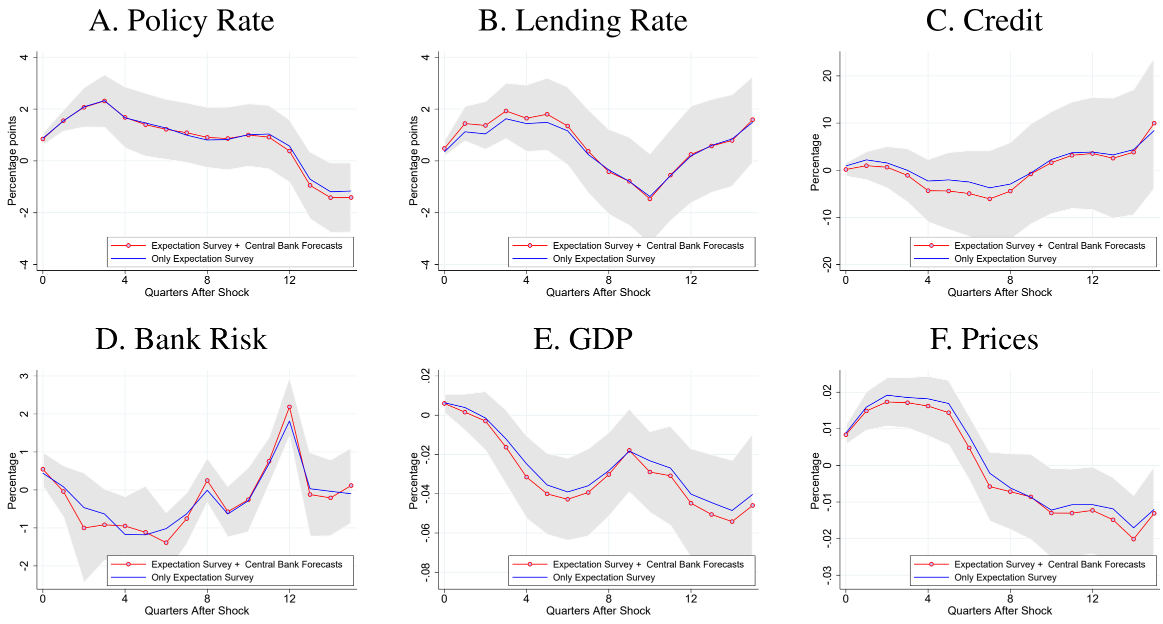
Note: This figure shows the impulse response functions to a contractionary monetary policy shocks of 100 basis points. Sample period 2003q4 - 2019q4. Light gray bands are 68% confidence bands using Newey and West (1987) standard errors. "Control MP shocks: 3 years"indicates the baseline model with three years of lagged monetary policy shocks as controls. "Control MP shocks: 1 year" add only shocks from the previous year as controls.

Figure 1.11: Local Projections on Macro variables: Robustness to lag length of depend variable as controls



Note: This figure shows the impulse response functions to a contractionary monetary policy shocks of 100 basis points. Sample period 2003q4 - 2019q4. Light gray bands are 68% confidence bands using Newey and West (1987) standard errors. "Control Dep. Var.: 6 lags"indicates the baseline model with 6 quarters of lagged dependent variable as controls. "Control Dep. Var.: 0 lags" add no lags as controls.

Figure 1.12: Local Projections on Macro variables: Robustness to forecast sets - Only Expectations Surveys forecasts



Note: This figure shows the impulse response functions to a contractionary monetary policy shocks of 100 basis points. Sample period 2003q4 - 2019q4. Light gray bands are 68% confidence bands using Newey and West (1987) standard errors. “Expectation Survey + Central Bank Forecasts”indicates the baseline approach I use in the analysis in section 1.3. “Only Expectation Survey ” excludes Central Bank of Peru’s forecasts from the process of identification in the baseline approach.

1.C Aggregate Data Sources

In this appendix I describe the aggregate data I use in the aggregate analysis in Section 1.4 and Appendix 1.D. The Peruvian data was obtained from Peruvian Central Bank of Peru’s macroeconomic data repository, BCRPData.

- Peruvian GDP (PN02538AQ): Real gross domestic output, millions of 2007 PEN soles. Data seasonally adjusted by using X13.
- Peruvian CPI: (PN01270PM): Consumer price index, 2009=100. Quarterly average from monthly data.
- Total Credit (PN00505MM): Total credit to private sector from depository institutions, in millions of PEN soles. End of quarter.
- Domestic interbank interest rate (PN07819NM): Quarterly average from monthly data.
- M1 (PN00181MM): Money, in millions of PEN soles. End of period. Data seasonally adjusted by using X13.
- Nominal exchange rates(PN01206PM): Nominal Foreign Exchange rate PEN soles per US dollar, interbank market, Bid.
- Stock Exchange price index, Índice General Bursátil BVL Bursátil BVL (PD04694MD).

- Lending rates, computed as a credit-weighted average of financial institutions' 1-year outstanding loan contracts, or 30-days outstanding loan contracts. Interest rates by currency (local and foreign) are weighted by the last year stock of credit. Interest rates in dollars are expressed in dollars by using the 12-ahead data on expected depreciation (BCRP Expectations Survey).
  - Stock local currency interest rates (PN07807NM): Bank average lending rates from the 1-year outstanding loan contracts, PEN soles denominated contracts.
  - Stock Foreign currency interest rates (PN07827NM): Bank average lending rates from the 1-year outstanding loan contracts, US dollars denominated contracts.
  - Flow local currency interest rates (PN07808NM): Bank average lending rates from the last 30-days outstanding loan contracts,PEN soles denominated contracts.
  - Flow Foreign currency interest rates (PN07828NM): Bank average lending rates from the last 30-days outstanding loan contracts, US dollars denominated contracts.
- Bank risk is computed as a quarterly realized volatility of the S&P/BVL Financials Index (PEN).
- Global commodity prices correspond to the Global Price Index of All Commodities from FRED Data (PALLFNFINDEXM).

1.D VAR Aggregate Analysis:

This appendix provides more details about the aggregate analysis shown in Section 1.4. In particular, it complements the estimation of local projections in specification 1.2 by estimating a VAR to identify impulse responses to monetary policy shocks. In particular I specify a recursive VAR with impulse responses from a Cholesky identification scheme. The main purpose of this exercise is to describe and show the robustness of the relationship between credit markets and monetary policy and document risk-taking behavior. I want to be clear that from this VAR analysis I do not pretend to go after a strong causal identification, as I do in Section 1.4.1, but it shows additional evidence for the arguments in section 1.4

I estimate a VAR for the Peruvian economy with and exogenous foreign external sector. The variables in the VAR model includes the log of Global commodity prices, log of US CPI, log of domestic GDP, log of domestic GDP, log of domestic CPI, log of total credit, the domestic interbank interest rate as the MP policy variable, log of Money (M1), a measure of lending rates, a measure of overall bank risk and log of nominal exchange rates. The measure for for bank risk-taking as explained in Section 1.4 is given by the quarterly realized volatility of the S&P/BVL Financials Index (PEN), calculated as standard deviation of daily returns of the index over each quarter. Since daily data on S&P/BVL Financials Index (PEN) in only available from 01/01/2011 onward, I estimate the VAR for the sample period 2011Q1-2019Q4. Appendix 1.C shows a detail description of the variables I use.

Given the sample period 2011Q1-2019Q4, the specification assumes the Peruvian economy is a small open economy prone commodity and US spillovers shocks. In particular, during this period several global shocks (for example terms of trade shocks and the *taper tantrum*) had impact on the peruvian economy. So, Consistently, I estimate a VARX with exogenous variables: log US GDP, Fed Funds Rate and Commodity prices. I restrict these variables to follow a VAR(1) process independent of domestic variables.

All previous selection of domestic variables follows in part Castillo, Pérez and Tuesta (2011), who developed a VAR to study monetary policy in Peru, but I extended it to include variables for determination of credit market as in Pozo and Rojas (2022) and a variable for risk-taking behavior of banks.

Thus, the structural VAR in levels is given by

$$A_0 Y_t = a + \sum_{i=1}^{p} A_i Y_{t-i} + \epsilon_t$$

where c is a matrix with a constant, a linear trend and exogenous variables, A_i's are the structural coefficients of the dynamic system, ϵ_t is the vector of structural shocks with $E(\epsilon_t \epsilon_t') = I$, and I is an identity matrix. The reduced form representation can be written as:

$$Y_t = c + \sum_{i=1}^{p} B_i Y_{t-i} + u_t$$

where $c = A_0^{-1} a$, $B_i = A_0^{-1} A_i$ and $u_t = A_0^{-1} \epsilon_t$ is the vector of reduced form residuals. Based on BIC information criterion I set $p = 1.$ that includes a constant and a linear trend. The identification assumption, by imposing a Cholesky decomposition on A_0, set the foreign variables ordered first, followed by the most exogenous and slow-moving domestic variables, with the foreign exchange rate ordered last, as the most endogenous variable. The monetary policy proxy is ordered after such that GDP, prices and credit respond with one lag to a MP shock. This estimation strategy follows similar ordering as in Christiano, Eichenbaum and Evans (1999). Robustness to the variable ordering, the inclusion or omission of variables or identification assumptions are shown in the appendix 1.D.2

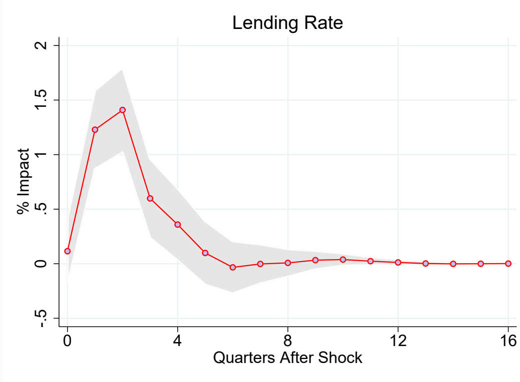
The impact of a contractionary monetary policy shock of 100 basis points on credit variables outcomes are show in Figure 1.13. Panel A shows an increment in lending rates after of a 100 basis point rise in the monetary policy rate: at impact the lending rate rises and reaches a maximum increment of 1.45% after two quarters and it is still up at around 0.25% one year later. Panel B displays the persistent and economically significant negative response of aggregate credit after a monetary policy shock: credit declines by around 3% two quarters after the shock, and reaches a decline of around 1.6% after a year. As I show in the appendix 1.D.2 the increment of lending rates and the decline in credit after a MP shock is robust to several specifications, ordering of variables, detrending or scheme identification (Figure 1.15). More importantly, Panel C shows that after the MP shock the measure of overall risk of bank, perceived by investors, falls by around 40 pbs after a 4 quarters. In particular, investor perceive that banks allocate loans to less risky borrowers during monetary policy tightening.

This aggregate empirical evidence add to the finding in Section 1.4 and also points out to a supply side mechanism of adjustment in credit markets that is consistent with the existence of a risk-taking channel after a MP shock.

The full set of results from the estimated VAR is shown in Appendix 1.D.1.

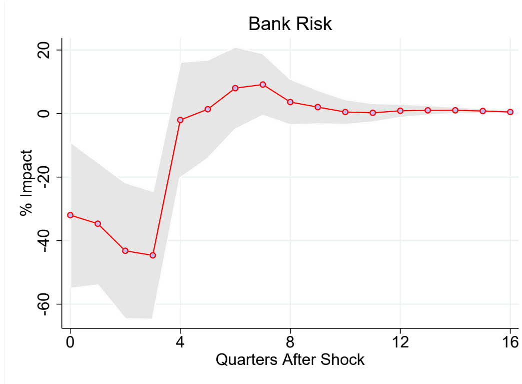
Figure 1.13: VAR Results: Monetary Policy Shock, Credit Market and risk-taking

A. Lending Rate



B. Credit

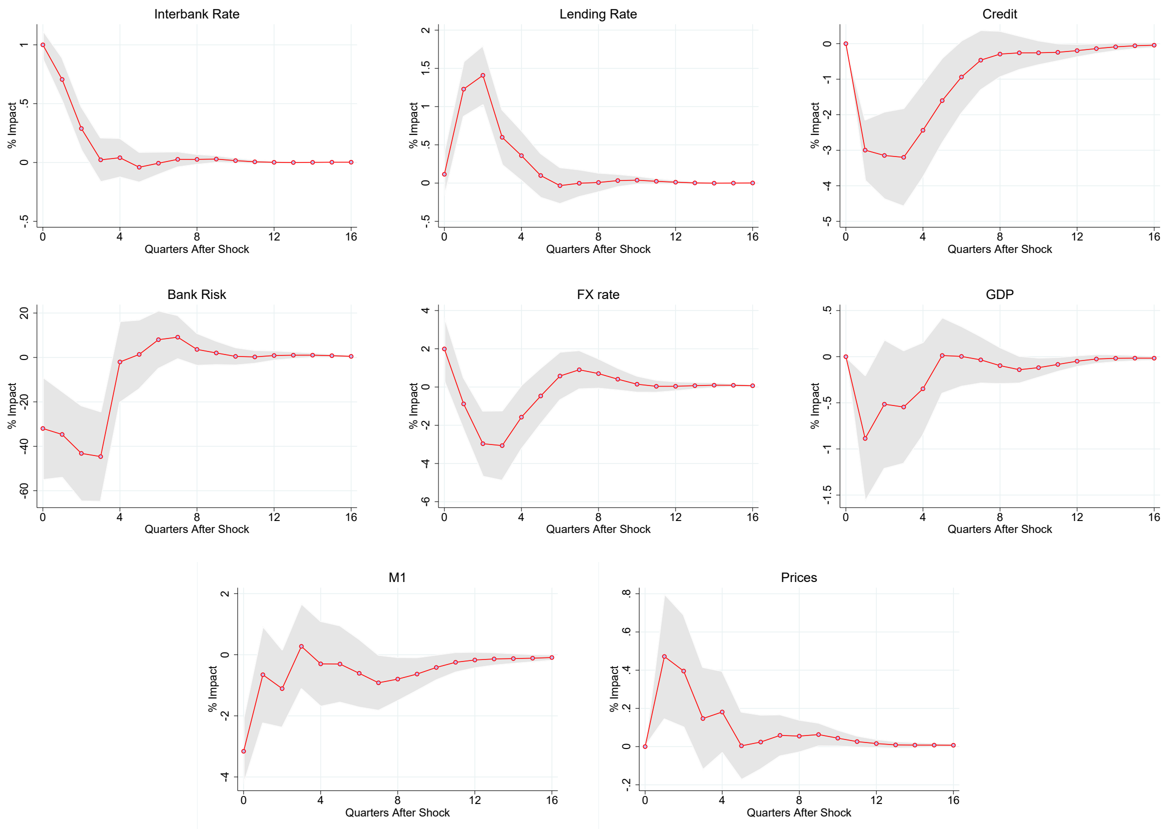
C. Bank Risk



Note: This figure shows the impulse response functions to a 1 percent increment in the domestic MP policy rate (RR). VAR identified under the recursive assumption, with the following ordering: log of Global commodity prices, log of US GDP, log of US CPI, log of domestic GDP, log of domestic CPI, log of total credit, the domestic interbank interest rate as the MP policy variable, log of Money (M1), a measure of overall bank risk, a measure of lending rates, and log of nominal exchange rates. log US GDP, Fed Funds Rate and Commodity prices are restricted to follow a VAR(1) process independent of domestic variables. VAR(1) includes a constant and a linear trend. Sample period 2011q4 - 2019q4.

1.D.1 Baseline VAR: Full set of results

Figure 1.14: Real, nominal and credit markets after a Monetary Policy Shock



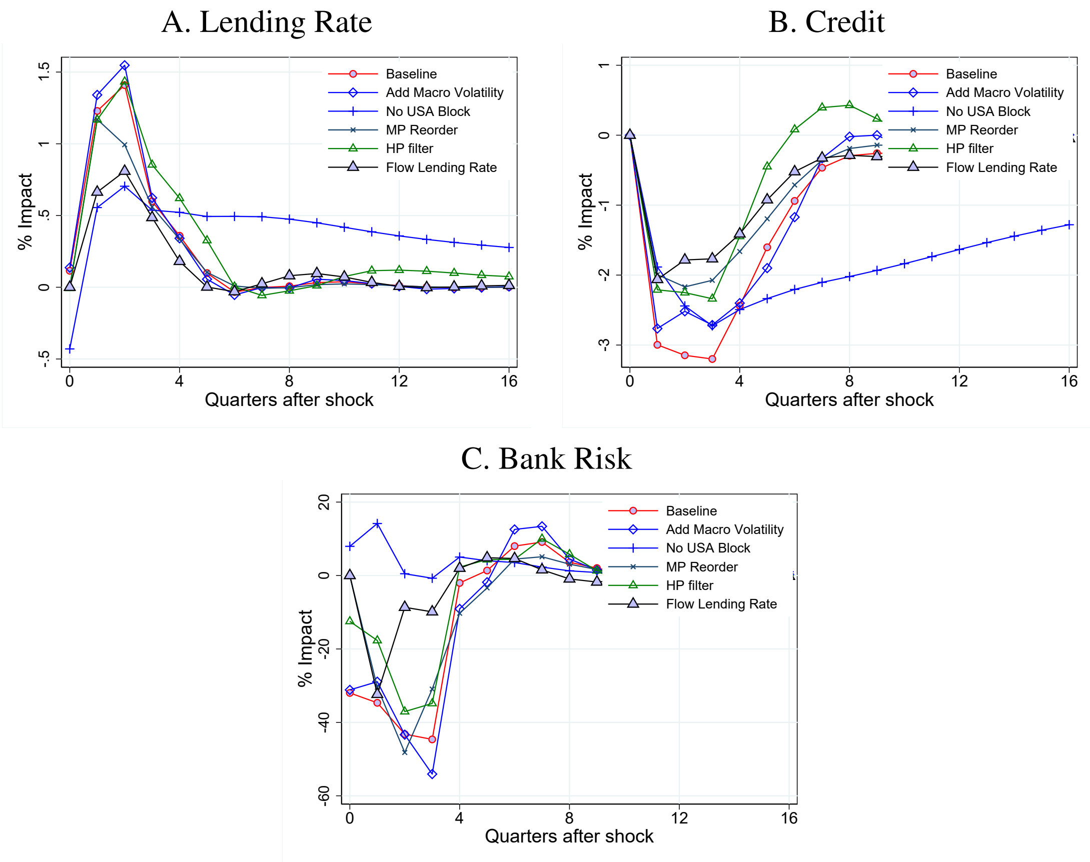
Note: This figure shows the impulse response functions to a 1 percent increment in the domestic MP policy rate (RR). VAR identified under the recursive assumption, with the following ordering: log of Global commodity prices, log of US GDP, log of US CPI, log of domestic GDP, log of domestic CPI, log of total credit, the domestic interbank interest rate as the MP policy variable, log of Money (M1), a measure of overall bank risk, a measure of lending rates, and log of nominal exchange rates. log US GDP, Fed Funds Rate and Commodity prices are restricted to follow a VAR(1) process independent of domestic variables. VAR(1) includes a constant and a linear trend. Sample period 2011q4 - 2019q4. Light gray bands are 95% confidence bands.

This section presents the full set of impulse responses after a MP shock, from estimating the VAR described in Section 1.D. Figure 1.14 shows both the credit market adjustment and real response of the economy after of a monetary shock. The responses are not persistent as the monetary policy shock is transitory and start to die out after the fourth quarter. The GDP negative response is more persistent than the monetary policy shock and economically significant; after 1 quarters GDP drops by around 0.8% and reaches -0.45% after 1 year. There is a price puzzle, which points to an incomplete empirical model provided by the VAR. Rather than being a problem of misspecification, I attribute this to the specific sample period of estimation. In the first part of the period 2011q4 - 2019q4 the peruvian economy was hit by supply shocks such that the core inflation was above the upper level of the target range for inflation of 3 per cent. Only after the end of 2017 inflation was starting to fall and be closer to 2 percent (see Rojas (2019) for a more detailed description of inflation in Peru during this period). Although initially the nominal exchange rate depreciates, after 1 quarter of the MP shock it is appreciated by around 3 percent.

1.D.2 VAR Robustness

Figure 1.15 displays a list of robustness results to the VAR analysis. It shows the impulse responses of the lending rate, credit and bank risk to a 1% rise in the policy rate.

Figure 1.15: Monetary Policy Shock, Credit Market and risk-taking: VAR Robustness



Note: This figure shows the impulse response functions to a 1 percent increment in the domestic MP policy rate (RR). VAR identified under the recursive assumption. VAR(1) includes a constant and a linear trend. Sample period 2011q4 - 2019q4. Baseline impulse responses (filled circle symbol) with the following ordering: log of Global commodity prices, log of US GDP, log of US CPI, log of domestic GDP, log of domestic CPI, log of total credit, the domestic interbank interest rate as the MP policy variable, log of Money (M1), a measure of overall bank risk, a measure of lending rates, and log of nominal exchange rates. log US GDP, Fed Funds Rate and Commodity prices are restricted to follow a VAR(1) process independent of domestic variables. Also, it present a specification including realized volatility of the Peruvian Stock Exchange price index (diamond symbols); a specification were I drop the influence of the US economy (+ symbols); a specification in which the MP variable is ordered last (x symbols); a specification in which all variables but the interest rates and the bank risk measure are HP filtered (hollow triangle symbols); and a specification in which lending rates are computed from loan contracts signed by financial institutions in the last 30 days (filled triangle symbols).

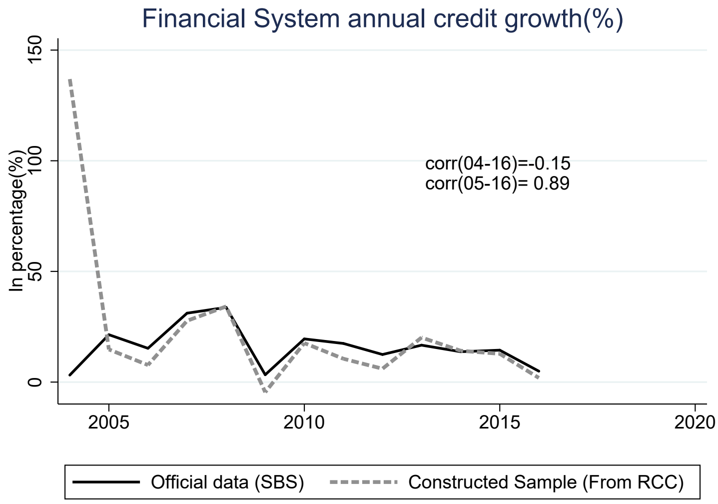
In particular, it shows the baseline impulse responses (filled circle symbol), a specification that includes realized volatility of the Peruvian Stock Exchange price index to control for overall economy risk and uncertainty (diamond symbols); a specification were I drop the influence of the US economy (+ symbols); a specification in which the MP variable is ordered last (x symbols); a specification in which all variables but the interest rates and the bank risk measure are HP filtered (hollow triangle symbols); and a specification in which lending rates are computed from loan contracts signed by financial institutions in the last 30 days (filled triangle symbols). The effects of the monetary policy shock in the credit market and risk-taking are robust to the different specifications. Bank risk is not robust to the omission of the US block, which in the sample period is a problem of misspecification, as during the 2011-2018 US economy spillovers in the peruvian economy were important. In general, the robustness results shows that there is a compelling evidence that MP shocks are transmitted via the supply side of the credit market and there is a risk-taking channel under operation.

1.E Appendix: Sample Data

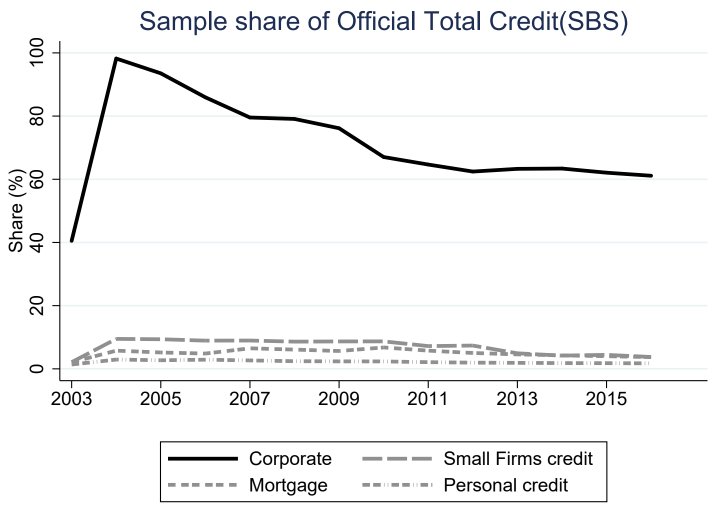
In this section I show results from the matching process. Figure 1.16 shows that the sample mimics very well the dynamics of the total bank credit. When the micro data sample is aggregated at the financial system level, its correlation with the official data shows a high level of correlation, 0.89, after excluding observations from 2004, where the data quality is not very good. Panel B of Figure 1.16 shows, in average, that the sample represents around 48 percent of the official total credit. Despite this low share, I can say that the sample is representative of the aggregate credit dynamics.

Figure 1.16: Representativeness of the sample - Aggregate credit

Panel A: Annual Credit Growth



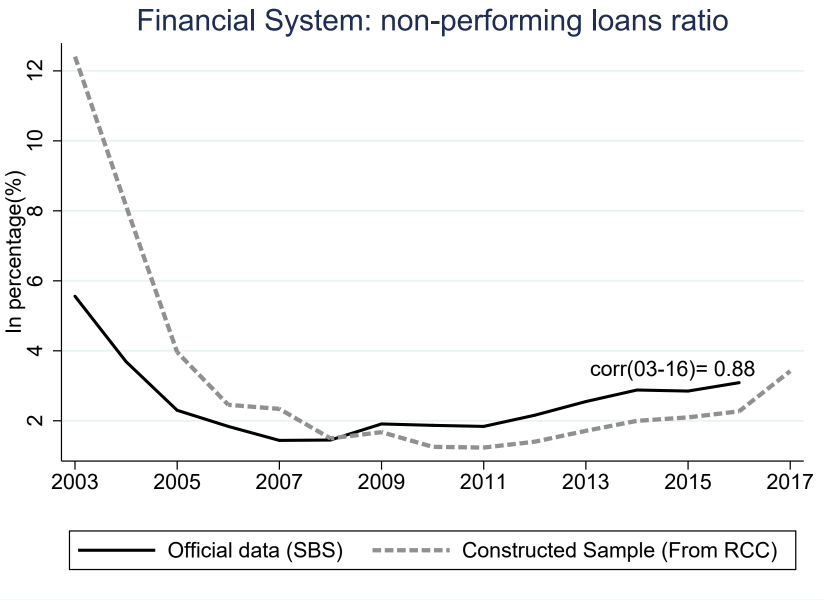
Panel B: Sample shares by credit types



Note: Annual Sample 2004-2016. SBS Official Data available for period 2002-2016.

Figure 1.17 also show that in aggregate, the sample follows similar dynamics of the NPL ratio published in official statistics.

Figure 1.17: Representativeness of the sample - Non Performing Loans ratio



Note: Annual Sample 2004-2016. SBS Official Data available for period 2002-2016.

1.F Appendix: Additional regressions and Robustness

1.F.1 Branch-bank estimation: All banks sample

This section presents robustness of the regression specification (1.4) by using the sample all banks, not only those serving more than one local province market. In specific, I estimate the following specification:

$$\Delta y_{b(j)pt} = \alpha_j + \alpha_{p(j)} + \alpha_{r(j)t} + \beta \, \text{NPL-Branch}_p \times \epsilon_t^{MP} + \sum_{k=1}^{K} \gamma_k^h X_{b(j)p,t-k} + \epsilon_{b(j)pt} \tag{1.9}$$

Table 1.10 shows that the effect of monetary policy on lending via the risk-taking channel is slightly larger when I do not include bank-time fixed effects.

Table 1.10: Branch-level estimation: All banks sample

	Dependent variable: Δy_{bdt}			
	(1)	(2)	(3)	(4)
NPL-Branch × ϵ_t^{MP}	-0.104*	-0.181**	-0.177**	-0.162*
	(0.0591)	(0.0767)	(0.0812)	(0.0826)
y_{t-1}	-0.106***	-0.109***	-0.109***	-0.0147***
	(0.00465)	(0.00511)	(0.00496)	(0.00144)
Controls Lag Dep.		✓	✓	✓
Region-Time FE	✓	✓		
Branch FE	✓	✓	✓	✓
Province FE	✓	✓	✓	✓
Time FE				✓
R^2	0.201	0.198	0.179	0.0522
Observations	69373	65724	65724	65802

Note: This table estimates the effect of the Peruvian monetary policy shocks on lending growth, $\Delta y_{b(j)pt}$. Quarterly Sample: 2004Q1 to 2018Q12 at the branch-level. The sample includes all financial firms with branches in one or more provinces. Lending growth is the log change in credit at the branch level. NPL-Branch measures market riskiness in the province where a branch is located. ϵ_t^{MP} is the monetary policy shock. Fixed effects are described at the bottom of the table. Standard errors clustered at time and bank-level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

1.F.2 Branch-Bank estimation: Robustness

Table 1.11 shows additional robustness to the main specifications due to sample selection or due to omitted variables such as bank concentration that may bias the results. The effect of risk-taking channel remains statistically significant in all specifications.

Table 1.11: Branch-level estimation: Robustness II

	Dependent variable: Δy_{bdt}			
	(1) After 2005m1	(2) Before GFC	(3) After GFC	(4) Control HH
NPL-Branch $\times\ \epsilon_t^{MP}$	-0.112*	-0.170	-0.150*	-0.111**
	(0.0588)	(0.102)	(0.0870)	(0.0551)
HH-Branch $\times\ \epsilon_t^{MP}$				-0.341
				(4.096)
y_{t-1}	-0.118***	-0.178***	-0.112***	-0.118***
	(0.0154)	(0.00851)	(0.0176)	(0.0154)
Bank-Time FE	✓	✓	✓	✓
Region-Time FE	✓	✓	✓	✓
Branch FE	✓	✓	✓	✓
province FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
R^2	0.336	0.362	0.343	0.336
Observations	64325	16614	53851	64325

Note: This table estimates the effect of the Peruvian monetary policy shocks on lending growth, $\Delta y_{b(j)pt}$. Quarterly Sample: 2004Q1 to 2018Q12 at the branch-level. The sample includes only banks with branches in two or more provinces. Lending growth is the log change in credit at the branch level. NPL-Branch measures market riskiness in the province where a branch is located. ϵ_t^{MP} is the monetary policy shock. Fixed effects are described at the bottom of the table. After 2005Q1 sample drops observations from 2002 to 2004. Before GFC sample corresponds to 2004Q1-2008Q4 period, but because the sample spam is only four years long, as controls it considers four quarters of lags for the monetary policy shock and two quarters of lags for the dependent variable. After GFC sample corresponds to 2009Q4-2018Q4 period. HH-Branch is calculated in a similar way to NPL-Branch. Control HH adds the standard Herfindahl index and it is referred as HH-Branch. HH-Branch and is computed by summing up the squared credit-market shares of all banks participating in a given province in a given year, and then averaging over all years. Standard errors clustered at time and bank-level in parentheses. * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Column(1) drops observations from 2002 to 2004. The initial years in our sample have measurement problems and have a low representation of the aggregate credit dynamics. This columns shows not a big difference with respect to the main estimates.

In columns (2) and (3) I try to control for the availability of international liquidity, and low international interest rates and expansionary monetary policy stance. In particular, before the Great Financial Crisis (GFC) monetary policy rates and economic growth rates were higher in Peru, and international interest rates were not low. After the GFC, with expansionary monetary policy stance from almost all major central banks in the world, international liquidity has been high and interest rates have been lower. Also, The monetary policy rates in Peru, in average, are lower during this period. In this context, the risk-taking behavior of banks can be a result of high liquidity and lower interest rates, than from changes in monetary policy rates. In column (2) I only consider the sample period before the Great Financial Crisis (GFC). In column (3) I only consider the sample period during and after the GFC. The results show that the direction of the risk-taking channel of monetary policy on branch lending is consistent across sample periods, but it is much stronger after-GFC. After GFC, the same expansionary monetary policy rate change, a branch rise lending growth rates by 15.6 bps more in a high risky location relative to a branch operating in a low risky location, per unit of NPL.

In column (4) I control for bank concentration or competition in the credit market by adding the standard Herfindahl index, which I refer as HH-Branch. HH-Branch and is computed by summing up the squared credit-market shares of all banks participating in a given province in a given year, and then averaging over all years. Bank competition may confounding the result, as risky but profitable markets would be also those markets were large banks operate or market power is higher. The results in Column(4) show that the risk-taking behavior of banks is still present and very similar in magnitude as the main specification after I control for bank concentration.

1.F.3 Bank-Province estimation: Robustness

Table 1.12: Bank-Province estimation: Robustness

	Dependent variable: Δy_{bdt}			
	(1) Banks	(2) Large Banks	(3) Non-Banks	(4) No Metropolitan
NPL-Bank $\times\ \epsilon_t^{MP}$	-3.483***	-17.96*	-1.026*	-0.487*
	(1.290)	(7.134)	(0.560)	(0.242)
NPL-Bank	-1.457	-0.576	-0.552***	-0.315*
	(1.367)	(3.973)	(0.162)	(0.169)
y_{t-1}	-0.0563***	-0.0922***	-0.0593***	-0.0634***
	(0.0131)	(0.00502)	(0.00929)	(0.0104)
Province-Time FE	✓	✓	✓	✓
Bank FE	✓	✓	✓	✓
Bank-Province FE	✓	✓	✓	✓
Province FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
R^2	0.362	0.499	0.392	0.302
Observations	12535	7133	18526	29695

Note: This table estimates the effect of the risk-taking channel on total lending. The data are at the financial firm-province-quarter level from 2004Q1 to 2018Q3. Δy_{bpt} is the log change of the total amount of lending by a given financial firm in a given province and quarter. NPL-Bank is the last four quarters average of NPL-Bank measures from a given financial firm in a given quarter. NPL-Bank is the average NPL-branch using lending shares across branches as weights. Fixed effects are denoted at the bottom. Large Banks sample considers only the large four banks in Peru. Non-Banks includes CAMCs, CRACs, EDPYMES and *empresas financieras*. Non Metropolitan Area sample: excludes Lima and Callao, which form the largest metropolitan areas in the Peru. Standard errors clustered by time and bank in parentheses. * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Chapter 2

UNCONVENTIONAL CREDIT POLICY IN AN ECONOMY WITH SUPPLY AND DEMAND CREDIT FRICTIONS

(Joint with Jorge Pozo)

2.1 Introduction

The Covid-19 global shock has confronted policy makers with the limits of standard policy tools to stimulate the economy. Standard monetary and fiscal policies are not quick enough to provide liquidity to firms experiencing a sudden fall in cash flows. Given the magnitude of the shock and its complex interaction with credit frictions and firms, medium and small ones mainly, additionally, facing credit rationing could turn the liquidity shock into a solvency shock. To alleviate the firms' liquidity shortage problem, governments have promptly adopted unconventional credit policies such as public guarantees for corporate loans or central bank liquidity facilities to fund loans backed up with government guarantees. In our view, these credit policies are named unconventional, and classified as different to conventional credit policies studied in Cúrdia and Woodford (2011); Gertler and Karadi (2011a), for two reasons: 1) loans are originated by a government-guaranteed credit policy; 2) the required return on loans originated by the credit policy is the monetary policy rate itself, not the market-determined required return on banks loans, which is free of firm default risk premium but contains a premium due to the credit supply frictions. The second reason opens the door to monetary policy considerations regarding the role of central bank intermediation for accessing credit.

These unconventional credit policies have grown in importance around the world. Following the Covid-19 shock, 41 out of the 113 economies that adopted debt finance policies, have used similar unconventional credit policies to reduce the cost of credit.[1] How should one think about the role of this type of credit programs? What mechanisms are behind? How does public credit interact with private credit? Which kind of credit policy rules are more effective? In this chapter we seek to answer these questions.

We develop a DSGE model to reconcile credit demand and supply frictions and assess the effect of an unconventional credit policy. The model includes households, banks, firms (entrepreneurs), and retailers. Risk-averse households own banks and retail businesses, while entrepreneurs are risk-neutral. Households make bank deposits and banks give loans to entrepreneurs, who in turn purchase capital (which, in

[1] Information on policies implemented around to world to face the Covid-19 shock is compiled by the World Bank and reported in the "Map of SME-Support Measures in Response to COVID-19".

combination with labor, is used to produce wholesale goods). Retail firms differentiate these goods and sell them. Price stickiness faced by retail firms allows to model central bank conventional monetary interventions. In this framework, unconventional credit policy plays an important role due to credit frictions that impede saving flows from financing investment opportunities and prevent banks from adequately monitoring projects. However, we are not claiming that the effectiveness of any unconventional credit policy is conditional on the existence of frictions or on a socially inefficient allocation of resources. In this line, it is worth to mention that the purpose of this chapter is not to look for the optimal policy that restores the socially efficient allocation, but rather to assess the implications of unconventional credit policies already implemented by several central banks.

The novelty of our framework lies in the modeling of frictions on both the credit demand and supply sides. Credit demand frictions are modeled à la Bernanke, Gertler and Gilchrist (1999), henceforth BGG 1999. This arises by an asymmetric information problem between entrepreneurs and banks. Ex-ante identical firms face an idiosyncratic shock, which is not observable by banks, and for which a risk-premium is charged. Entrepreneurs might prefer to hold enough equity as collateral to ensure a not very high risk-premium. Credit supply frictions are modeled à la Gertler and Karadi (2011a), henceforth GKa 2011. A leverage constraint arises due to a moral hazard problem between banks and depositors. In particular, the endogenous leverage constraint ensures that banks do not divert banks assets and hence can operate. As a result, firms' equity and banks' equity are crucial to determine aggregate credit demand and credit supply, respectively.

The credit policy consists of government-guaranteed loans to firms, which are provided directly by the central bank or indirectly through commercial banks. The goal of this policy is to lessen the impact of a temporal negative shock in the economy, in particular on real variables; hence, the credit policy intervention is temporal as well. Under reasonable assumptions, the indirect central bank loans are equivalent to the direct central bank loans. We mainly discuss the indirect central bank loans in order to assess the relevance of government credibility in guaranteeing them. Since (direct or indirect) central bank loans are insured by the government, their required return is smaller than the required return on bank loans. As a result, firms exhaust central bank loans first and then resort to bank loans.

We find that, relative to frictionless economy, adding credit supply frictions allows us to mimic a more realistic dynamics of credit after a monetary policy shock. After a contractionary policy, we find that the bank credit increases if we do not let banks bear some aggregate risk. However, if we allow for credit supply frictions and let banks bear some risk, banks' net worth absorbs some losses, which in turn, constraints the supply of credit. In other words, given credit supply frictions, we might observe that after a contractionary monetary policy shock, there is a credit reduction.

We find that the unconventional credit policy diminishes the impact of a negative shock on the real economy. We highlight three channels. First, as in GKa 2011, central bank loans cannot be diverted, so the credit policy increases aggregate credit supply. This occurs since less bank equity is required per unit of aggregate credit. Second, cheap central bank loans, in the sense that central bank loans have a smaller required return than traditional bank loans, reduce entrepreneurs' obligations and hence their default probability. Third, government guarantees reduce the funding costs of entrepreneurs and hence reduces their default probability helping firms to accumulate more equity overtime. A lower default probability reduces the expected monitoring costs and hence increases entrepreneurs' incentives to purchase capital and to demand credit. In normal times the first channel is more relevant; however, in high-uncertainty periods that yields to periods of high default probability of entrepreneurs, government guarantees become also an important driver on reducing the impact of the negative shock. In other words, the positive effects of government guarantees are quantitatively significant in periods of high uncertainty.

Another important result that we find is that when bank loans have a higher seniority than central bank loans, the effectiveness of the credit policy on reducing fluctuations of real variables increases. When bank loans have higher seniority, these are paid first. Since bank loans are paid first, more resources are available to pay bank loans, which allows banks to reduce the (non-default) lending rate, and this pushes the default probability down. A lower default probability reduces expected monitoring costs and hence incentives entrepreneurs' incentives to demand capital and hence credit.

The credibility of government guarantees is also very important. We find that if commercial banks believe that government guarantees on central bank loans have low credibility, the credit policy effectiveness goes down. If banks believe that the government is not going to guarantee the loans, then banks will have to put their own money to ensure central bank loans are repaid in full. In order to compensate those future losses associated with the central bank loans, banks need to claim a higher a interest rate on their bank loans. As a result, a sign of no government credibility are higher lending rates on bank loans. However, this lower effectiveness is not quantitatively significant, unless we are in a period of high uncertainty where the impact of the government guarantees are quantitatively significant.

In addition, we find that an endogenous credit policy rule should not be automatic. This is, the rule should be flexible enough, so it can properly respond to indicators that capture the source and size of the economic deterioration. In that sense, the regulator should be capable to identify if the shock is affecting the credit supply and/or the credit demand conditions. A wrong endogenous rule might amplify the negative shock. We also find that ex-ante announcing the endogenous credit policy rule (i.e., letting entrepreneurs know that per one unit of demanded credit for sure they might get some cheap central bank loans), the one that reduces the marginal cost of external funding from entrepreneurs' perspective and increases entrepreneurs' incentives to demand credit, does not lead to significant benefits when the credit spread is small.

The remainder of this chapter is partitioned as follows. Section 2.2 presents the literature review. Section 2.3 develops the baseline model. Section 2.4 discusses the baseline parametrization and simulations. Section 2.5 presents the unconventional credit policy. Section 2.6 reports the simulations of the credit policy. Finally, section 2.7 concludes.

2.2 Literature Review

This work is related to the literature of demand side credit frictions as in Kiyotaki and Moore (1997) and, Bernanke, Gertler and Gilchrist (1999), or henceforth BGG 1999. In this literature, a collateral constraint limits borrowing. In particular, we follow BGG 1999 that features frictions on the credit demand side, known in the literature as the financial accelerator. It studies the implications of the monetary policy in an economy with financial frictions. Our contribution is to complement this setup with frictions on the credit supply side to get a better picture of real and financial shocks on real and financial variables.

This chapter is also related with the literature that incorporates financial intermediaries in DGSE models and develops a moral hazard problem between banks and depositors (see Gertler and Kiyotaki (2011); Gertler and Karadi (2011a); Gertler and Kiyotaki (2015); Gertler, Kiyotaki and Queralto (2012)). The moral hazard problem consists in the fact that bankers can divert a fraction of bank assets and hence depositors might want bankers put some of their money (as equity) to fund bank assets to the point that the bank charter value is higher that the value of diverting bank assets. This results in a marked based capital requirement constraint or in an endogenous leverage constraint. Our contribution to this literature is that we model credit supply frictions together with credit demand frictions which provide more realism in characterizing responses to real or financial shocks.

This chapter is also related to the literature that models the interaction of both demand and supply credit constraints to study the dynamics of credit markets to allocate resources as in Elenev, Landvoigt, and Van Nieuwerburgh (2017); Justiniano, Primiceri and Tambalotti (2019). Our contribution to this literature is studying the dynamics of supply and demand frictions in a relevant model to understand monetary policy. In fact, to some extent introducing lending and borrowing frictions is important so our unconventional credit policy is not trivial.

The credit policy developed in this chapter is related with the previous literature on credit policy as in Cúrdia and Woodford (2011); Gertler and Karadi (2011a). In general, in this literature credit policy is developed by a central bank issuing debt to households and paying the risk-free rate to fund loans that then are issued at the market lending rate, which captures the premium due to the moral hazard problem between bankers and depositors. It is assumed that central bank intermediation involves efficiency costs. Since the assets intermediated by the central bank do not require any collateral of bank equity, the credit policy increases the leverage ratio of total intermediated funds and hence raises aggregate credit. The key differences with this previous literature are the following: (i) we assume for simplicity that central bank intermediation does not involve any efficiency costs; (ii) central bank loans are insured by the government; and (iii) the required return on central bank loans is the risk-free interest rate and not the required return on bank loans which is determined in the market and free of entrepreneurs' default risk premium but captures the risk premium due to the moral hazard problem between bankers and depositors. A necessary condition for (iii) is the fact that central bank loans cannot be diverted as traditional bank loans. Indeed, in this chapter, we called the credit policy "unconventional" because (ii) and (iii).

Our work is also part of the current Covid-19 literature on policy interventions through credit markets as in Bigio, Zhang and Zilberman (2020); Chodorow-Reich, Darmouni, Luck and Plosser (2020); Drechsel and Kalemli-Ozcan (2020); Segura and Villacorta (2020); Céspedes, Chang and Velasco (2020). We seek to contribute with an additional dimension to this literature regarding the interaction of monetary policy constraints and credit policy, the former being the new element in the analysis.

2.3 Model

We develop a closed economy DSGE model with households, banks, firms (entrepreneurs) and retailers. Risk-averse households own banks and retail businesses, while entrepreneurs are risk-neutral. Households save only through bank deposits and supply labor. Banks issue loans to entrepreneurs. They fund loans through bank equity and deposits they issue to households. Entrepreneurs make capital purchases (which, in combination with labor, is used to produce wholesale goods) funded by entrepreneurs' equity and loans from banks. Price stickiness faced by retail firms allows to model central bank monetary interventions.

The novelty of our framework is that we add credit demand and credit supply frictions. In the credit demand side, the frictions are modeled à la BGG 1999. A credit demand friction arises from a costly state verification of entrepreneurs performance and banks have to pay a monitoring cost. Ex-ante identical firms face an idiosyncratic shock, which is not observable by banks. As a result, banks charge a risk-premium, and entrepreneurs prefer to hold enough equity as collateral to ensure a lower risk-premium. Thus, entrepreneurs' equity is a crucial factor in determining the demand of bank credit. Credit supply side frictions are modeled à la GKa 2011. In particular, an endogenous bank leverage constraint arises due to a moral hazard problem between banks and depositors. The endogenous leverage constraint prevents banks from diverting banks assets and also limits the amount of loans it can issue. As is the case of firms equity, bank equity is a crucial factor in determining bank credit supply.

The framework developed in this section is going to be used to study the effects of unconventional credit policies discussed in sections 2.5 and 2.6.

In the following subsections, we start describing the problem of households. Then, we describe the maximization problems of banks and entrepreneurs and present in detail the fundaments behind the credit supply and demand frictions, respectively. We continue with the problem of the capital producer firms, the entrepreneurial sector, retail sector, the market clearing conditions and finally the long-term equilibrium (or deterministic steady state).

2.3.1 Households

We formulate the household sector in a way that permits maintaining the tractability of the representative agent approach. In particular, there is a representative household with a continuum of members of mass unity. Within the household, there are $1-f$ "workers" and f "bankers". Workers supply labor, H_t, and return their wages, W_t, to the household. Each banker manages a financial intermediary (bank) and transfers nonnegative dividends back to the household. There is perfect consumption insurance within the family. Households do not acquire capital and they do not provide funds directly to nonfinancial firms. Rather, they supply funds to banks. It may be best to think of them as providing funds to banks that do not belong to them. Banks offer non-contingent riskless short-term real debt (one-period real deposits, D_t) to households. These deposits pay a gross real return R_t from t to $t+1$. The representative household preferences are given by,

$$\mathbb{E}_t \sum_{m=0}^{\infty} \beta^m \left[ln(C_{t+m} - hC_{t+m-1}) - \frac{\chi}{1+\varphi} H_{t+m}^{1+\varphi} \right], \tag{2.1}$$

where $\mathbb{E}_t$ is the expectation operator conditional on information at date t, $0 < \beta < 1$ is the households' discount factor, $0 < h < 1$ is the habit parameter, and $\varphi, \chi > 0$, φ is the inverse Frisch elasticity and χ is the utility weight of labor and C_t is real consumption. The household chooses consumption, labor supply and riskless real debt (or real bank deposits) (C_t, H_t, D_t) to maximize expected discounted utility, equation (2.1), subject to the flow of funds constraint,

$$C_t + D_t = W_t H_t + \Pi_t - T_t + R_{t-1} D_{t-1}\,, \quad \forall t.$$

Here, Π_t are the net funds from ownership of banks, capital producing firms, and retailers, and T_t are lump sum taxes. A household's first-order conditions for labor supply and consumption/saving are given respectively by,

$$u_{Ct} W_t = \chi H_t^{\varphi}, \tag{2.2}$$

$$\mathbb{E}_t(\Lambda_{t,t+1}) R_{t+1} = 1, \tag{2.3}$$

with,

$$u_{Ct} = (C_t - hC_{t-1})^{-1} - \beta h (C_{t+1} - hC_t)^{-1},$$

$$\Lambda_{t,\tau} = \beta^{\tau - t} \frac{u_{C\tau}}{u_{Ct}}, \qquad \tau \geq t,$$

where u_{Ct} denotes the marginal utility of consumption and $\Lambda_{t,t+r}$ the household's stochastic discount factor.

2.3.2 Banks: Credit Supply Frictions

Bankers transfer funds from households (deposits) to entrepreneurs (loans). Each banker does not run more than one bank. A Bank indexed by i gives B_t^i loans to entrepreneurs. Loans are funded by bank equity N_{bt}^j and household deposits D_t^i. A bank's balance sheet is given by,

$$B_t^i = D_t^i + N_{bt}^i, \tag{2.4}$$

A bank holds loans (bank assets) from t to $t+1$ to earn a gross return of R_{t+1}^l, which is going to be the required return per unit of bank loans, and pays the non-contingent real return of R_t to households deposits. In equilibrium both rates are determined endogenously.

Banks raise equity only through retained earnings. As a result, bank equity evolves as,

$$N_{bt+1}^i = R_{t+1}^l B_t^i - R_t D_t^i, \tag{2.5}$$

Because banks may be financially constrained, bankers will retain earnings to accumulate assets. In the absence of motivation to pay dividends, they may find it optimal to accumulate to the point where any leverage constraint is no longer binding. To limit bankers' ability to save and overcome the leverage constraint, a turnover between bankers and workers is introduced. In particular, there is an i.i.d. probability $1-\sigma$ that a banker exits next period, (i.e., an average survival time = $1/(1-\sigma)$). Upon exiting, a banker transfers retained earnings to the household and becomes a worker. Note that the expected survival time may be quite long (in our baseline calibration it is eight years). Each period, $(1-\sigma)f$ workers randomly become bankers, keeping the number in each occupation constant. Finally, because in equilibrium bankers will not be able to operate without any financial resources, each new banker receives a "startup" transfer from the family, as we describe in this section. Thus, Π_t are net funds transferred to the household; that is, funds transferred from exiting bankers minus the funds transferred to new bankers (aside from profits of capital producers and retailers).

Banks, at the end of period t, maximize the present value of future terminal dividends,

$$V_t^i = \mathbb{E}_t\left[\sum_{m=0}^{\infty}(1-\sigma)\sigma^m\Lambda_{t,t+1+m}N^i_{bt+1+m}\right], \tag{2.6}$$

where $\Lambda_{t,t+m}$ is the households stochastic discount factor that applies to earnings at $t+m$ since banks are owned by households.

To motivate a limit on banks ability to expand their assets indefinitely by borrowing additional funds from households, we introduce a moral hazard problem. As in GKa (2011) at the beginning of the period the banker can choose to divert some fraction λ of available funds and transfer them back to the household of which the banker is a member. The cost to the banker is that the depositors can force the bank into bankruptcy and recover only the remaining fraction $1-\lambda$ of assets. As a result, to ensure the existence of bank loans, the following incentive constraint must be satisfied,

$$V_t^i \geq \lambda B_t^i. \tag{2.7}$$

One can show that the value function is linear. i.e one can express V_t^i as follows,

$$V_t^i = \nu_t B_t^i + \eta_t N_{bt}^i,$$

with

$$\nu_t^i = \mathbb{E}_t\{(1-\sigma)\Lambda_{t,t+1}(R^l_{t+1}-R_t) + \Lambda_{t,t+1}\sigma x_{t,t+1}\nu^i_{t+1}\},$$
$$\eta_t^i = \mathbb{E}_t\{1-\sigma + \Lambda_{t,t+1}\sigma z^i_{t,t+1}\eta^i_{t+1}\},$$

where $x^i_{t,t+m} = B^i_{t+m}/B^i_t$ is the gross growth rate in assess between t and $t+m$ and $z^i_{t,t+m} = N^i_{bt+m}/N^i_{bt}$ is the gross growth rate of net worth. Then, the incentive constraint (2.7) becomes,

$$\nu_t^i B_t^i + \eta_t^i N_t^i, \geq \lambda B_t^i.$$

Under reasonable parameter values the constraint always binds within a local region of the steady state. In fact, we parameterize the model so the constraint is always binding. Then,

$$B_t^i = \frac{\eta_t^i}{\lambda - \nu_t^i} N_{bt}^i = \phi_t^i N_{bt}^i, \tag{2.8}$$

where ϕ_t^i is the ratio of bank loans to equity (or bank leverage). This constraint in equation (2.8) limits bank leverage ratio to the point where bank's incentives to divert funds is balanced by its cost. As a result, the moral hazard problem leads to an endogenous credit constraint on bank ability to issue loans. We rewrite the evolution of bank's net worth (2.5) as,

$$N_{bt+1}^i = \left[(R^l_{t+1} - R_t)\phi_t^i + R_t\right] N_{bt}^i.$$

We then rewrite $z^i_{t,t+1}$ and $x^i_{t,t+1}$ as, respectively,

$$z^i_{t,t+1} = N^i_{bt+1}/N^i_{bt} = (R^l_{t+1} - R_t)\phi^i_t + R_t,$$

$$x^i_{t,t+1} = B^i_{t+1}/B^i_t = (\phi^i_{t+1}/\phi^i_t)z^i_{t,t+1}.$$

Since ϕ^i_t does not depend on bank-specific factors, we can aggregate equation (2.8) to obtain a relationship between aggregate supply of bank credit B_t and aggregate bank net worth,

$$B_t = \frac{\eta_t}{\lambda - \nu_t} N_{bt} = \phi_t N_{bt}. \tag{2.9}$$

Equation (2.9) is the aggregate credit supply curve. According to this, due to the moral hazard problem, banks need to accumulate equity to be able to supply bank loans (or, equivalently, to be able to capture household deposits). In particular, the higher the spread $R^l_{t+1} - R_t$, the higher bank net worth accumulation. Ceteris paribus, from equation (2.9) there are two ways that aggregate credit supply increases. First, that a smaller fraction of bank assets (or aggregate credit) can be diverted, i.e., a smaller λ. As we will see later this happens with the credit policy in this chapter and also in GKa 2011. And second, increments in bank equity.

Total net worth in the banking sector, N_{bt}, equal the sum of the net worth of existing banks N_{ot} (o for old) and the net worth of entering (or "new") banks N_{nt} (n for new),

$$N_{bt} = N_{ot} + N_{nt}.$$

Since a fraction σ of banks at $t-1$ will survive until t, N_{ot} is given by,

$$N_{ot} = \sigma \left[(R^l_t - R_{t-1})\phi_{t-1} + R_{t-1} \right] N_{bt-1}, \tag{2.10}$$

As stated before, newly entering bankers receive "startup" funds from their respective households. We suppose the household gives its new banker a transfer equal to a small fraction of the value of assets that exiting bankers had intermediated in their final operating period. Given that the exit probability is i.i.d., the total final period assets of exiting bankers at t is $(1-\sigma)B_{t-1}$. We assume that each period the household transfers the fraction $\zeta/(1-\sigma)$ of this value to its entering bankers. As a result,

$$N_{nt} = \zeta B_{t-1}. \tag{2.11}$$

Combining equations (2.10) and (2.11) yields the aggregate motion of bank net worth,

$$N_{bt} = \sigma \left[(R^l_t - R_{t-1})\phi_{t-1} + R_{t-1} \right] N_{bt-1} + \zeta B_{t-1}. \tag{2.12}$$

2.3.3 Entrepreneurs: Credit Demand Frictions

Entrepreneurs are modeled as in BGG 1999. Entrepreneurs are risk-neutral and ex-ante identical. Yet, they face an idiosyncratic and an aggregate shock and supply one unit of labor inelastically to the labor market. Entrepreneurs produce wholesale goods in competitive markets.

Capital acquisitions are financed with wealth (entrepreneur's equity) and borrowing (bank loans). Net worth accumulation comes from profits from previous capital investments and income from labor supply.

To avoid accumulation of equity, we assume entrepreneurs have a finite life. This is, with a constant probability γ they survive to the next period, implying an expected lifetime of $1/(1-\gamma)$. Birth rate is such that the number of entrepreneurs is constant across time.

We assume there is an asymmetric information problem between entrepreneurs and banks. Banks cannot observe idiosyncratic shock faced by each entrepreneur. Hence, banks have to pay a monitoring cost to observe the realized value of entrepreneurs' payoffs. Banks are repaid in full if entrepreneurs do not default, so banks do not have any incentive to pay a monitoring cost to verify the entrepreneurs' performance; however, when an entrepreneur defaults, banks do have incentives to pay the monitoring cost to observe the realized payoffs. Then, a higher default probability of entrepreneurs raises the agency cost of monitoring projects. Given that these costs are internalized by entrepreneurs, the higher default probability reduces entrepreneurs' incentives to demand credit. We assume only one-period loans contracts between bankers and entrepreneurs. The optimal contract is designed to minimize the expected agency costs.

In this environment, high net worth allows for increasing self-financing (or equivalently, collateralized external finance), mitigating the agency problems associated with external finance and reducing external finance premium faced by entrepreneurs in equilibrium. Hence, as will be seen later, net worth position is a key determinant for the cost of external finance. As we will see, fluctuations in net worth amplify and propagate exogenous shocks to the system.

The capital investment decisions are at entrepreneur level. Entrepreneur take the price of capital and expected return of capital as given. Firms are indexed by $j \in [0, 1]$. At time t, an entrepreneur who manages firm j purchases capital, K_t^j, for use at $t + 1$, and pays price Q_t per unit of capital. The return of capital is sensitive to both aggregate and idiosyncratic risk. The ex-post return of capital is $\omega^j R_{t+1}^k$, where ω^j is the idiosyncratic disturbance to firm j's return and R_{t+1}^k is the ex-post aggregate return of capital (i.e., gross return averaged across firms).[2] We set that ω^j is i.i.d. across time and firms and $\mathbb{E}\{\omega^j\} = 1$. In particular, we assume ω follows a lognormal distribution.

At the end of t (going into period $t + 1$), entrepreneur j has available net worth N_t^j, and borrows B_t^j from banks,

$$B_t^j = Q_t K_t^j - N_{et}^j. \tag{2.13}$$

to purchase capital K_t^j. Banks pay a monitoring cost to observe entrepreneur's realized return, $\mu\omega^j R_{t+1}^k Q_t K_t^j$, with $\mu > 0$.

Assume first R_{t+1}^k is known in advance. Entrepreneur chooses, K_t^j and B_t^j, prior the realization of ω^j. The optimal contract (risky debt) is given by the gross non-default bank loan rate Z_{t+1}^j and a threshold value of the idiosyncratic shock, $\bar{\omega}^j$, defined as,

$$\bar{\omega}^j R_{t+1}^k Q_t K_t^j = Z_{t+1}^j B_t^j. \tag{2.14}$$

If $\omega^j \geq \bar{\omega}^j$, the entrepreneur fully repays a bank loan, otherwise it defaults. In latter case, banks pay the auditing cost, seize the entrepreneur's project and obtain $(1-\mu)\omega^j R_{t+1}^k Q_t K_t^j$. A defaulting entrepreneur receives nothing.

Let say the opportunity cost of banks is R_{t+1}^l. Hence, the required return on banks loans is R_{t+1}^l. Banks can perfectly diversify the idiosyncratic risk involved in lending and they do indeed that and hence in the optimal contract, banks receive a certain gross return of R_{t+1}^l per unit of bank loans. In other words, since lending risk is perfectly diversifiable, banks can ensure a certain return R_{t+1}^l for their loans. As a result, banks holds a perfectly safe portfolio (it perfectly diversifies the idiosyncratic risk involved in lending). The bank loan contract ($\bar{\omega}^j$, Z_{t+1}^j) must satisfy:

$$[1 - F(\bar{\omega}^j)] Z_{t+1}^j B_t^j + (1 - \mu) \int_0^{\bar{\omega}^j} \omega R_{t+1}^k Q_t K_t^j dF(\omega) = R_{t+1}^l B_t^j, \tag{2.15}$$

where F is the CDF of the r.v. ω^j and hence $F(\bar{\omega}^j)$ is the default probability of a j firm or equivalently the fraction of entrepreneurs that default at $t + 1$ for a given R_{t+1}^k. The left-hand side of equation (2.15) is the expected return on the loan to the entrepreneurs and the right-hand side is the opportunity cost of lending. By definition, in equilibrium the bank lending rate, Z_{t+1}^j, is higher than R_{t+1}^l.

[2]Note that ω^j is indeed ω_{t+1}^j; however, we omit time dimension for a notation simplicity.

We assume again R^k_{t+1} is uncertain. Combining equations (2.13) and (2.14) with equation (2.15), we obtain,

$$\left[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right] R^k_{t+1} Q_t K^j_t = R^l_{t+1}(K^j_t - N^j_{et}), \tag{2.16}$$

where,

$$\Gamma(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega) + (1 - F(\bar{\omega}^j))\bar{\omega}^j, \qquad G(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega). \tag{2.17}$$

From equation (2.16), $\bar{\omega}^j$ depends on the ex post realization of R^k_{t+1}. With aggregate uncertainty, the fraction of defaulting entrepreneurs is uncertain. Then, the expected default probability of an entrepreneur is given by,

$$\mathbb{E}_t\{F(\bar{\omega}^j)\},$$

where recall $F(\bar{\omega}^j)$ is the default probability given a realization of aggregate shock. The expected return (expected profits) to the entrepreneur may be expressed as:

$$\mathbb{E}_t \left\{ \int_{\bar{\omega}^j}^{\infty} (\omega R^k_{t+1} Q_t K^j_t - Z^j_{t+1} B^j_t) dF(\omega) \right\}.$$

Using (2.14), this is rewritten as,

$$\mathbb{E}_t \left\{ \left[1 - \Gamma(\bar{\omega}^j\right] R^k_{t+1} Q_t K^j_{t+1} \right\}. \tag{2.18}$$

An entrepreneur aims to maximize (2.18) optimally choosing K^j_t and $\bar{\omega}^j$ schedules (as a function of the realized values of R^k_{t+1}) subject to the set of state-contingent constrains implied by the bank loan contract, equation (2.16), and where B^j_t is solved in bank balance sheet equation (2.13) taking as given R^k_{t+1}, R_{t+1} and R^l_{t+1}, which are endogenously determined in the general equilibrium. Formally, the optimal problem may be now written as:

$$\max_{K^j_t, \bar{\omega}^j} \mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t + \lambda^j_{t+1} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t - R_{t+1} B^j_t \right] \right\},$$

where λ_{t+1} is the Lagrange multiplier associated with the loan contract that requires that equation (2.16) holds for any realization of R^k_{t+1}. The first order conditions for $\bar{\omega}^j$:

$$-\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} + \lambda^j_{t+1} \left(\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} - \mu \frac{G(\bar{\omega}^j)}{\partial \bar{\omega}^j} \right) = 0. \tag{2.19}$$

The first order conditions for K^j_t:

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \lambda_{t+1} \left[\, \left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} - R^l_{t+1} \, \right] \right\} = 0. \tag{2.20}$$

The first order conditions for λ_{t+1} yield the set of state-contingent constrains implied by equation (2.16), where,[3]

$$\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^j), \qquad \frac{\partial G(\bar{\omega}^j)}{\partial \bar{\omega}^j} = \bar{\omega}^j f(\bar{\omega}^j).$$

Combining equations (2.19) and (2.20) yields,

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \frac{1 - F(\bar{\omega}^j)}{1 - F(\bar{\omega}^j) - \mu \bar{\omega}^j f(\bar{\omega}^j)} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} - R^l_{t+1} \right] \right\} = 0, \tag{2.21}$$

[3] We assume $ln(\omega) \sim \mathcal{N}\left(-0.5\sigma^2_\omega, \sigma^2_\omega\right)$ so we have $\mathbb{E}(\omega) = 1$ and then $\Gamma(\bar{\omega}) = \Phi(z - \sigma_\omega) + \bar{\omega}[1 - \Phi(z)]$, $G(\bar{\omega}) = \Phi(z - \sigma_\omega)$, $\partial\Gamma(\bar{\omega})/\partial\bar{\omega} = 1 - \Phi(z)$ and $\partial G(\bar{\omega})/\partial\bar{\omega} = \bar{\omega}\Phi'(z)$, where $\Phi(.)$ and $\Phi'(.)$ are the c.d.f. and the p.d.f., respectively, of the standard normal and z is related to $\bar{\omega}$ through $z = (ln(\bar{\omega}) + 0.5\sigma^2_\omega)/\sigma_\omega$.

Note first that by construction $F(\bar{\omega}^j)$ is positive. If we assume that there is not any asymmetric problem, then $\mu = 0$, and hence equilibrium condition becomes,

$$\mathbb{E}_t \left\{ R^k_{t+1} - R^l_{t+1} \right\} = 0.$$

which is the typical equilibrium condition, where the expected marginal productivity of capital equates the expected marginal cost of capital. As a result, the asymmetric information problem distorts entrepreneur's incentives to demand capital.

To provide more intuition of how the frictions affect the decision process of entrepreneurs, we insert equation (2.16) into equation (2.18),

$$\mathbb{E}_t \left\{ \left[1 - \mu G(\bar{\omega}^j)\right] R^k_{t+1} Q_t K^j_t - R^l_{t+1} B^j_t \right\}. \tag{2.22}$$

where $\mu G(\bar{\omega}^j) R^k_{t+1} Q_t K^j_t$ represents the cost of entrepreneur defaulting. As a result, if the monitoring cost is $\mu = 0$ or equivalently if the asymmetric information is overcome costlessly, we are back to a model without frictions on the credit demand. From equation (2.22), the interaction of the entrepreneur's default probability (captured by $\bar{\omega}^j$) and the monitoring cost (μ) leads to a reduction of the net marginal benefit of demanding a unit of bank loans from entrepreneur perspective. This is, ceteris paribus a higher default probability or a higher μ reduces demand of credit. And hence in that sense equation (2.22) shows how the distortions in the market affects entrepreneur decisions on their demand of credit (B^j_t) or equivalently their purchases of capital (K^j_t). In other words, the asymmetric information problem reduces entrepreneur capacity to demand loans and hence to invest.

Regarding the required return on bank loans, R^l_{t+1}, we assess two alternative cases. First, we can assume that R^l_{t+1} is not contingent to the aggregate risk as it is done in BGG 1999. Second, one of the contribution of this framework that also features frictions on the credit supply is that we can also study the case when aggregate risk is also beared by banks by assuming that R^l_{t+1} is contingent to the aggregate risk. As explained later, the second one is more realistic and it is aligned with the literature that suggests that credit dynamics is essentially driven by credit supply shocks. For comparison reasons, we study the two cases and present the gains in terms of realism by introducing banks that also absorb some risk. Next, we discuss the reasoning behind these two cases and present their implications.

Non-State-Contingent Bank Loans Required Return

As stated in BGG 1999, since entrepreneurs are risk-neutral and households are risk-averse, entrepreneurs bear all aggregate risk in the loan contract and hence R^l_{t+1} is not contingent to the aggregate risk (or non-state-contingent). Thus, entrepreneurs are willing to guarantee banks a return on loans that is free of any systematic risk. In other words, conditional to the ex post realization of R^k_{t+1}, the entrepreneur offers a (state-contingent) non-default payment Z^j_{t+1} that guarantees the lender a return equal in expected value to R^l_{t+1}, as suggested by equation (2.15), that is agreed at t. This implies that equation (2.15) is a set of restrictions, one for each realization of R^k_{t+1}.

As a result, a low ex post realization of R^k_{t+1} is associated with a high Z^j_{t+1} in order to compensate for the high fraction of entrepreneurs that default due to low average return on capital. This in turn, implies an increase in the cutoff value of the idiosyncratic productivity shock, $\bar{\omega}^j$. In this case, as in BGG 1999, the model implies, reasonably, that default probabilities and default premia rise when the aggregate return to capital is lower than expected. As a result, the expected spread $\mathbb{E}_t\{Z^j_{t+1} - R^l_{t+1}\}$ captures both idiosyncratic and aggregate risk premium.

Notice that since R^l_{t+1} is not contingent to the aggregate risk, any technology shock or capital quality shock is mainly absorbed by entrepreneurs and not by banks. For example, in the case of a capital quality shock, a strong reduction in entrepreneurs' equity occurs but not necessarily on banks' equity. As a result, the shock is expected to mainly affect the aggregate credit demand and not the aggregate credit supply.

As a result, the model with non-state-contingent bank loans required return seems qualitatively similar to a model with only credit demand frictions as in BGG 1999.

State-Contingent Bank Loans Required Return

Here, we assume that R^l_{t+1} is contingent to the aggregate risk (or state-contingent). This means that R^l_{t+1} depends on the ex post realization of R^k_{t+1}. To our understanding this is a more realistic case. This assumption allows banks equity to absorb gains or losses that come from the aggregate return of capital (technology or capital quality shock) and hence the aggregate credit supply fluctuates more and bank-driven dynamics can explain better the dynamics of credit.

In this case the loan contract states that entrepreneurs are not going to bear all aggregate risk and hence R^l_{t+1} becomes contingent to aggregate risk. In other words, conditional to the ex post realization of R^k_{t+1}, the entrepreneur offers a state-contingent (non-default) payment Z^j_{t+1} that in this opportunity guarantees the lender a return equal in expected value to a state-contingent interest rate R^l_{t+1}.

In particular, we assume R^l_{t+1} is linear on R^k_{t+1}, i.e.,

$$R^l_{t+1} = \xi_t R^k_{t+1},$$

and hence ξ_t is endogenously determined in the general equilibrium. Then, equation (2.16) becomes,

$$\left[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right] Q_t K^j_t = \xi_t B^j_t. \tag{2.23}$$

where, $\bar{\omega}^j$ is independent of the aggregate risk. In this case, the fraction of defaulting entrepreneurs does not depend on the aggregate risk. In other words,

$$\mathbb{E}_t\{F(\bar{\omega}^j)\} = F(\bar{\omega}^j).$$

In this case from equation (2.14), a low ex post realization of R^k_{t+1} is associated with a lower (non-default) lending rate Z^j_{t+1}. This is because after a low R^k_{t+1}, ceteris paribus, we might expect that a higher fraction of entrepreneurs defaulting, then a lower (non-default) payment Z_{t+1} is required so $\bar{\omega}^j$ and the default probability keeps unchanged. So, in contrast to the non-state-contingent R^j_{t+1} case, here a low ex-post realization of R^k_{t+1} is associated with a low Z^l_{t+1}. Hence, in this case it is easy to verify that the expected spread $\mathbb{E}_t\{Z^j_{t+1} - R^l_{t+1}\}$ captures only the idiosyncratic risk premium. Finally, note that the rest of equilibrium conditions still holds.

2.3.4 Capital producers

Competitive capital producers make new capital I_t and are subject to adjustment costs. They sell new capital to entrepreneurs at the price Q_t. Given that households own capital producers, the objective of a capital producer is to choose new capital I_t to solve:

$$max\,, \mathbb{E}_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}, \tag{2.24}$$

where $f(\frac{I_\tau}{I_{\tau-1}})I_\tau$ reflects the physical adjustment costs, with $f(1) = f'(1) = 0$ and $f''(I_t/I_{t-1}) > 0$. From profit maximization, the price of the capital goods is equal to the marginal cost of investment goods as follows:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - \mathbb{E}_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{2.25}$$

Profits (which arise only outside the steady state) are redistributed to households as a lump sum. We assume that the cost of adjusting investment function is as follows,[4]

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\varphi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 .$$

2.3.5 Entrepreneurial Sector

Entrepreneurs purchase capital each period, which in combination with labor produces (wholesale) output. We assume that production has constant returns to scale. The aggregate production is given by,

$$Y_t = A_t(\psi_t K_{t-1})^{\alpha} L_t^{1-\alpha},$$

with $0 < \alpha < 1$, where Y_t is the aggregate output of wholesale goods, K_{t-1} is the aggregate of capital purchased at $t-1$, L_t is labor input, and A_t is the exogenous technology process, and ψ_t denotes the capital quality shock, so that $\psi_t K_{t-1}$ is the effective quantity of capital at time t. We assume the log of A_t and the log of ψ_t follow AR(1) processes. These are,

$$ln(\psi_t) = \rho_\psi ln(\psi_{t-1}) + \epsilon_{\psi,t}, \qquad ln(A_t) = \rho_A ln(A_{t-1}) + \epsilon_{a,t},$$

where $\rho_\psi, \rho_a \in (0,1)$, $\epsilon_\psi \sim \mathcal{N}(0, \sigma^2_{\epsilon_\psi})$ and $\epsilon_a \sim \mathcal{N}(0, \sigma^2_{\epsilon_a})$. We assume entrepreneurs sell their output to retailers. Let X_t be the relative price of wholesale goods. Equivalently, X_t is the gross markup of retail goods over wholesale goods. The production technology implies that holding a unit of capital from t to $t+1$ requires an ex-post gross return equal to,

$$R^k_{t+1} = \frac{\frac{1}{X_{t+1}}\frac{\alpha Y_{t+1}}{K_t} + \psi_t Q_{t+1}(1-\delta)}{Q_t}.$$

The demand curve of capital comes from aggregating the equation (2.21),

$$\mathbb{E}_t\left\{(1-\Gamma(\bar{\omega}))\, R^k_{t+1} + \frac{1-F(\bar{\omega})}{1-F(\bar{\omega})-\mu\bar{\omega}f(\bar{\omega})}\left[(\Gamma(\bar{\omega})-\mu G(\bar{\omega}))\, R^k_{t+1} - R^l_{t+1}\right]\right\} = 0\,, \tag{2.26}$$

which for given values of $R^k_{t+1}\,, R^l_{t+1}$ determines $\bar{\omega}$. The aggregation of the the bank loan contract, equation (2.16), yields,

$$(\Gamma(\bar{\omega}) - \mu G(\bar{\omega}))\, R^k_{t+1} Q_t K_t = R^l_{t+1}\,(Q_t K_t - N_{et})\ , \tag{2.27}$$

These two conditions, (2.26) and (2.27), help to determine the level of capital demand in the economy, K_t.

We assume entrepreneurs offer labor in the labor market. Total labor input L_t is obtained from the following composite of household labor and entrepreneurial labor,

$$L_t = (H_t)^{\Omega}(H^e_t)^{1-\Omega}.$$

We assume further that entrepreneurs supply their labor inelastically, and we normalize total entrepreneurial labor to unity. In the parameters' calibration below we set a small value to the entrepreneurial labor income share.

Let V^e_t be entrepreneurs equity, which is the accumulated wealth from operating firms, let W^e_t denote the entrepreneurial wage, and let $\bar{\omega}_t$ denote the state-contingent value of $\bar{\omega}$ set in period t. Then, aggregate entrepreneurial net worth at the end of period t, N_{et}, is given by,

$$N_{et} = \gamma V^e_t + W^e_t\,, \tag{2.28}$$

[4]This function form is also used in De Groot (2014) and Akinci and Queralto (2013).

where,

$$V_t^e = R_t^k Q_{t-1} K_{t-1} - \left(R_t^l + \frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_{t-1} dF(\omega)}{B_{t-1}} \right) B_{t-1}.$$

where γV_t^e is the equity held by entrepreneurs at $t-1$ who are still in business at t. Entrepreneurs who do not survive at t consume the residual equity $(1-\gamma)V_t^e$, This is $C_t^e = (1-\gamma)V_t^e$. Entrepreneurial equity equals gross earnings on holdings of capital from $t-1$ to t minus repayment of borrowings. The ratio $\frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_{t-1} dF(\omega)}{B_{t-1}}$ reflects the premium for external finance.

The demand curves for household and entrepreneurial labor are, respectively,

$$\frac{1}{X_t}(1-\alpha)\Omega \frac{Y_t}{H_t} = W_t,$$

$$\frac{1}{X_t}(1-\alpha)(1-\Omega) \frac{Y_t}{H_t^e} = W_t^e.$$

2.3.6 Retail Sector

Recall that entrepreneurs produce wholesale goods in competitive markets. Retailers, who are monopolistic competitors, buy wholesale goods from entrepreneurs, differentiate them (costlessly), and then re-sell them to households. To motivate sticky prices, we allow for monopolistic competition and (implicit) costs of adjusting nominal prices at the retail level. Retailers are indexed by $z \in [0, 1]$.

Let $Y_t(z)$ be the quantity of output sold by retailer z, in units of wholesale goods, and $P_t(z)$ the nominal price. The total final usable goods, Y_t^f, are the composite of individual retail goods:

$$Y_t^f = \left[\int_0^1 Y_t(z)^{(\epsilon-1)/\epsilon} dz \right]^{\epsilon/(\epsilon-1)},$$

with $\epsilon > 1$. The corresponding price index is given by,

$$P_t = \left[\int_0^1 P_t(z)^{1-\epsilon} dz \right]^{1/(1-\epsilon)}.$$

A retailer faces a demand curve given by:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} Y_t^f. \tag{2.29}$$

Retailers choose the sale price $P_t(z)$, taking the demand curve and the price of wholesale goods P_t^w as given. As it is standard in the literature, we also assume price inertia. Specifically, We assume that a retailer is free to change its price in a given period only with probability $1-\theta$. Let P_t^* be the price set by retailers who are able to change prices at t, and let $Y_t^*(z)$ the demand given this price. They choose P_t^* to maximize expected discounted profits,

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left[\Lambda_{t,k} \frac{P_t^* - P_{t+1}^w}{P_{t+k}} Y_{t+k}^*(z) \right], \tag{2.30}$$

where the discount rate $\Lambda_{t,k} = \beta^k \frac{u_{C_{t+k}}}{u_{C_t}}$ is the household stochastic discount factor, which retailers take as given and $P_t^w = P_t / X_t$ is the nominal price of wholesale goods. Before taking the partial derivative, we write (2.30) as,

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left[\Lambda_{t,k} \left(\frac{P_t^*}{P_{t+k}} \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon} Y^f - \frac{P_{t+k}^w}{P_{t+k}} \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon} Y^f, \right) \right]. \tag{2.31}$$

Taking the partial derivative with respect to P_t^*, we obtain,

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left[\Lambda_{t,k} \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon} Y_{t+k}^*(z) \left(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon - 1} \frac{P_{t+1}^w}{P_{t+k}} \right) \right] = 0. \tag{2.32}$$

The aggregate price evolves according to,

$$P_t = \left[\theta P_{t-1}^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon} \right]^{1/(1-\epsilon)}.$$

2.3.7 Market Clearing Condition and Monetary Policy

Final output may be either transformed into a single type of consumption good, invested, or used up in monitoring costs. In particular, the economy-wide resource constraint is given by

$$Y_t^f = C_t + C_t^e + \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] I_t + \mu \int_0^{\bar{\omega}_t} \omega R_t^k dF(\omega) Q_{t-1} K_{t-1}.$$

where the aggregate capital stock evolves according to:

$$K_t = I_t + (1-\delta)\psi_t K_{t-1}.$$

In equilibrium, the labor market is cleared, so labor demand equates labor supply,

$$\frac{1}{X_t}(1-\alpha)\Omega \frac{Y_t}{H_t} = \frac{1}{u_{Ct}} \chi H_t^{\varphi}.$$

The final goods market equilibrium requires,

$$\int_0^1 Y_t(z) dz = \int_0^1 Y_t^j dj = Y_t\,, \tag{2.33}$$

where from (2.29),

$$\int_0^1 Y_t(z) dz = \int_0^1 \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} d(z) Y_t^f = (\ddot{p}_t)^{-\epsilon} Y_t^f. \tag{2.34}$$

with $\ddot{p}_t$ being the price dispersion,[5]

$$\ddot{p}_t = \left[\int_0^1 \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} d(z) \right]^{-\frac{1}{\epsilon}}.$$

As a result, combining equations (2.33) and (2.34), yields,

$$Y_t = (\ddot{p}_t)^{-\epsilon} Y_t^f.$$

We suppose monetary policy is characterized by a simple Taylor rule with interest-rate smoothing. Let i_t be the net nominal interest rate, i the steady state nominal rate, and $Y_t^{f,*}$ the natural (flexible price equilibrium) level of output. Then,

$$i_t = \rho_i i_{t-1} + (1-\rho_i) \left[i_{ss} + \kappa_\pi \pi_t + \kappa_y (ln(Y_t^f) - ln(Y_t^{f,*})) \right] + \epsilon_{it},$$

where π_t is the inflation rate from $t-1$ to t, the smoothing parameter ρ lies between zero and unity, and where $\epsilon_{it} \sim \mathcal{N}(0, \sigma_{\epsilon_i}^2)$ is an exogenous shock to monetary policy and i_{ss} is the deterministic steady state value of i. The link between nominal and real interest rates is given by the following Fisher relation,

$$1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t}.$$

[5] This becomes irrelevant when solving the model using a first-order approximation.

2.4 Baseline Simulations

In this section we present the baseline parametrization. We also assess the two cases regarding the required return on bank loans: a non-state-contingent loan return and a state-contingent loan return. In addition, we describe and solve a credit puzzle observed after a contractionary monetary policy when there are not frictions on the credit supply side.

2.4.1 Parametrization

Table 2.1 summarizes the parameter values of the model. For the discount factor β, the depreciation rate δ, the capital share α, we choose conventional values. Other conventional parameters as the habit parameter h, the relative utility weight of labor χ, and the Frisch elasticity of labor supply ψ^{-1} are set to 0.815, 3.409, and 1/0.276, respectively, following Primiceri, Schaumburg and Tambalotti (2006).

Three parameters are specific to the financial intermediaries. The fraction of assets that can be diverted λ, the proportional transfer to entering banks ζ, and the bank survival probability σ. We set σ to 0.9687, so the average horizon of a banker is eight years. The other two parameters are set to hit the following two targets: an annualized steady state interest rate spread ($R^l - R$) of one hundred basis points and a steady state bank leverage of four.[6] This results in $\lambda = 0.363$ and $\zeta = 0.0029$.

[6]The steady state of the economy is presented in Appendix 2.A. Recall the deterministic steady state in the long-term equilibrium is one where the economy is not subject to aggregate shocks but only to idiosyncratic shocks.

Table 2.1: Parameter

Parameters		Values
Households, technology and capital producers		
Discount factor	β	0.990
Habit parameter	h	0.815
Capital share	α	0.330
Depreciation rate	δ	0.025
Utility weight of labor	χ	3.409
Inverse Frisch elast. of labor supply	ψ	0.276
Investment adjustment costs	φ_I	1.000
Banks		
Fraction of assets that can be diverted	λ	0.363
Survival rate of bankers	σ	0.969
Transfer to entering Banks	ζ	0.003
Entrepreneurs		
Households labor share	$(1-\alpha)\Omega$	0.660
Survival probability	γ	0.982
Volatility of the log of the idiosyncratic shock	σ_ω	0.269
Monitoring costs	μ	0.286
Retail firms		
Price rigidity parameter	θ	0.750
Elasticity of substitution between goods	ϵ	4.167
Taylor rule		
Monetary policy response to inflation	κ_π	1.500
Monetary policy response to output gap	κ_y	0.125
Monetary policy rate smoothing	ρ_i	0.800
Shock processes		
Persistence of capital quality shock	ρ_ψ	0.66
Persistence of productivity shock	ρ_a	0.66

Four parameters are specific to the entrepreneurial sector. We set Ω so the household labor share is $(1-\alpha)\Omega = 0.66$, and the share of income accruing to entrepreneurs' labor is equal to 0.01. This results in $\Omega = 0.985$. The other three parameters, the "death rate" of entrepreneurs $1-\gamma$, the variance of the ln(ω) and the fraction of realized payoffs lost in bankruptcy (or the monitoring costs) μ are chosen to obtain the following three conservative steady state outcomes: an annualized risk spread $R^k - R^l$ equal to one hundred basis points, an annualized business failure rate of three percent, and an entrepreneur leverage ratio of two. This results in $\gamma = 0.9822$, $\sigma_\omega = 0.2695$ and $\mu = 0.2862$.[7]

The price rigidity parameter θ is set to 0.75, implying that the average period between price adjustments is four quarters, and the elasticity of substitution between goods ϵ is set to 4.167. The investment adjustment parameter φ_I is set at 1 as in De Groot (2014).

For the Taylor rule, we use the conventional Taylor rule parameters of 1.5 for the κ_π and 0.125 for κ_y and 0.80 for ρ_i.[8] For simplicity, we use minus the price markup as a proxy for the output gap. We solve the model using a first order approximation with Dynare.[9]

[7] Regarding the monitoring cost, this is a bit higher than 0.12, used in BGG 1999, and than 0.20, used in Carlstrom and Fuerst (1997).

[8] Galí (2015); Gertler and Karadi (2011a); Gertler and Kiyotaki (2015) set $\kappa_\pi = 1.5$ and $\kappa_y = 0.125$, while GKa 2011 set $\rho_i = 0.80$.

[9] As detailed in Appendix 2.A we solve first for the parameters values associated with the banking sector and then for those associated with the entrepreneurial sector.

In the following subsections, we simulate the economy after a negative capital quality shock and evaluate the implications of assuming a non-state-contingent loan required return R^l_{t+1} or a state-contingent one. Later, we try to solve a puzzle that consists of a credit reduction observed after a contractionary monetary policy in an economy without credit supply frictions.

2.4.2 Who Bears The Aggregate Risk Matters

Recall that since households are risk-averse and entrepreneurs are risk-neutral, we might expect a contract with a non-state-contingent R^l_{t+1} and thus the entrepreneur absorbs the entire risk as in BGG 1999. However, in this framework that also features frictions on the credit supply we can also study the case where risk is also absorbed by banks, as observed in practice, by assuming that R^l_{t+1} is state-contingent. As a result, we compare the effects of a (aggregate) negative capital quality shock assuming a non-state-contingent R^l_{t+1} to the effects assuming a state-contingent R^l_{t+1} in this subsection.

In general, we would like to discuss how this negative capital quality shock might affect the credit demand and credit supply. On the demand side, a negative capital quality shock decreases marginal return of capital, reducing the incentives to purchase capital and demand for bank credit, as a result. The negative capital quality shock also reduces firm profits and hence firm equity, which raises the probability of default and increases the expected monitoring costs with it. Hence, through the credit demand frictions channel, the negative shock reduces firms' incentives to purchase capital and consequently demand for bank loans. On the supply side, the negative capital quality shock might reduce R^l_{t+1}, specially if this is state-contingent, and with it bank equity, which tighten the incentive constraint for banks to operate and hence reduces bank capacity to issue loans.

Figure 2.1 reports the impulse response function of a five percent negative capital quality shock. In general, the directions of the real variables are the expected, consumption, capital and output decrease. However, we observe a different quantitative impact when the aggregate shock (i.e., the aggregate risk) is absorbed only by firms (non-state-contingent R^l_{t+1}) relative to when this is also absorbed by banks (a state-contingent R^l_{t+1}), not only on the financial variables as bank loans, entrepreneur equity, firm equity and spreads, but also on real aggregate variables as consumption, capital and output. First, we explain the differential impact on financial variables and then on real variables.

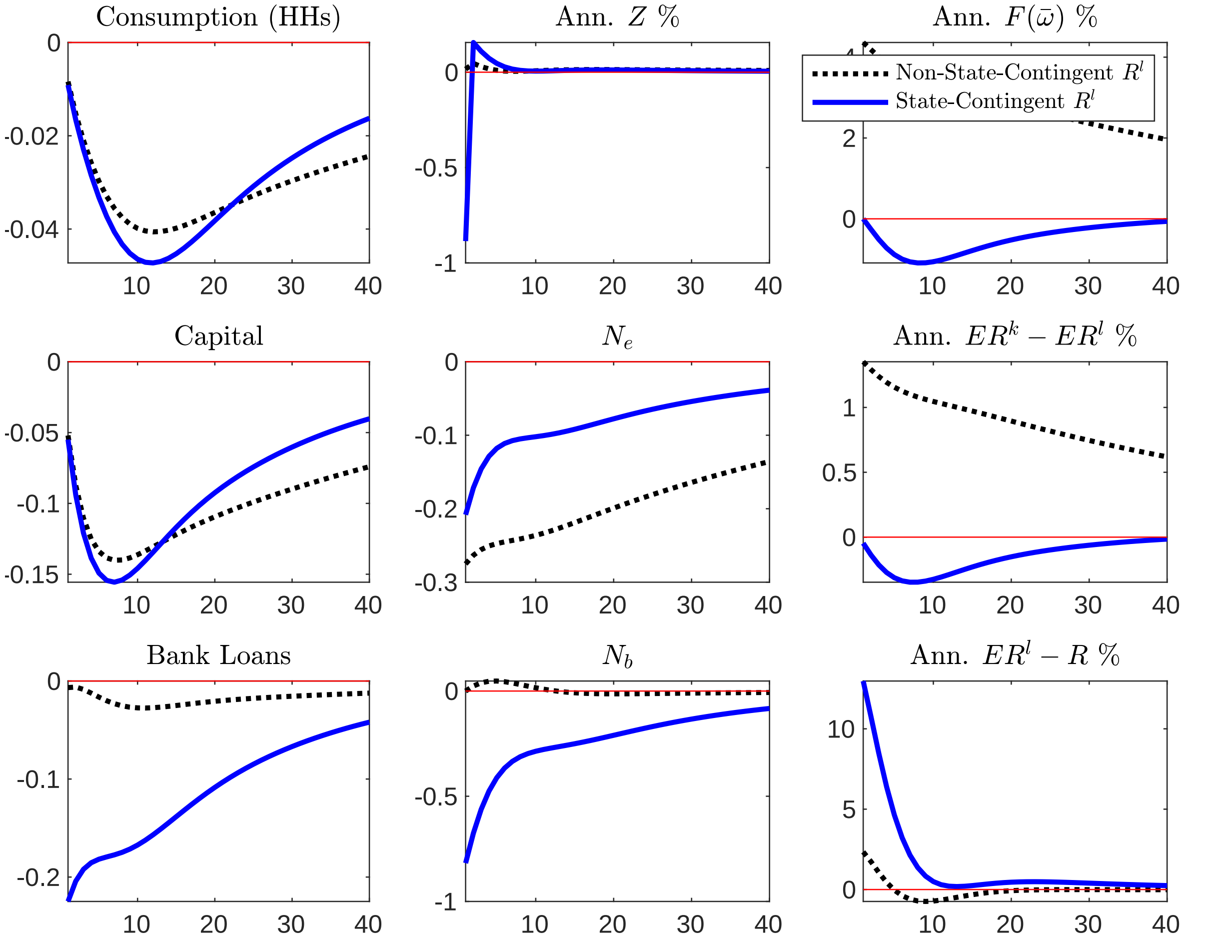
As expected with a non-state-contingent R^l_{t+1} since banks equity is not directly affected by the shock, the role of banks seems null. In other words, banks loans and bank equity are not visually affected. As a result, the drop on capital is associated by an immediate drop on entrepreneur equity. This is a consequence of entrepreneurs bearing the aggregate risk since R^l_{t+1} is not state-contingent. Note that since the entrepreneur equity takes time to recover, he faces higher and persistent spreads expected spreads, $E(R^k - R^l)$, which reduces his capacity to purchase capital.

When banks absorb some of the aggregate shock, i.e., with state-contingent R^l_{t+1}, we also observe an immediate reduction of bank's equity, and therefore there is a smaller reduction of entrepreneur's equity. Bank's equity reduction reduces bank loan supply. As a result, the drop in aggregate capital is explained by a reduction not only of the entrepreneur's equity but also by a reduction of the aggregate supply of bank loans. In addition, a higher spread $E(R^l - R)$ captures the smaller bank capacity to supply credit, and since the impact on entrepreneur's equity is smaller too, the expected spread $E(R^k - R^l)$ does not increases. Indeed, it goes down, which shows that entrepreneurs are now relatively facing higher credit supply.

In this economy the equity position of the agents that absorb the shock is crucial. In other words, the higher the leverage, the worse agents are able to handle a shock. When the shock is beared only by agents that hold a relatively low leverage, like the entrepreneurs, that corresponds to the case with a non-state-contingent R^l_{t+1}, we observe smaller fluctuations on real variables as consumption, output and capital. While if the impact of the shock is shared with agents that by definition have a higher leverage, like the financial intermediaries, that corresponds to the case with a state-contingent R^l_{t+1}, the economy suffers more and as a result we observe higher fluctuations on real variables.

These results suggest that modeling frictions on the demand and supply side allows us to have the whole story and hence to observe how the economy might respond if we consider the case where banks are bearing aggregate risk or they are not. As explained later, this characteristics of the model become very important when studying the effects of a conventional monetary policy and a unconventional credit policy.

Figure 2.1: A five percent negative capital quality shock: State vs non-state contingent contract



Note: All variables are in log deviations from steady-state except spreads, failure rate and (non-deafult) lending rate, shown in level deviation from steady-state.

2.4.3 Credit Contraction Puzzle

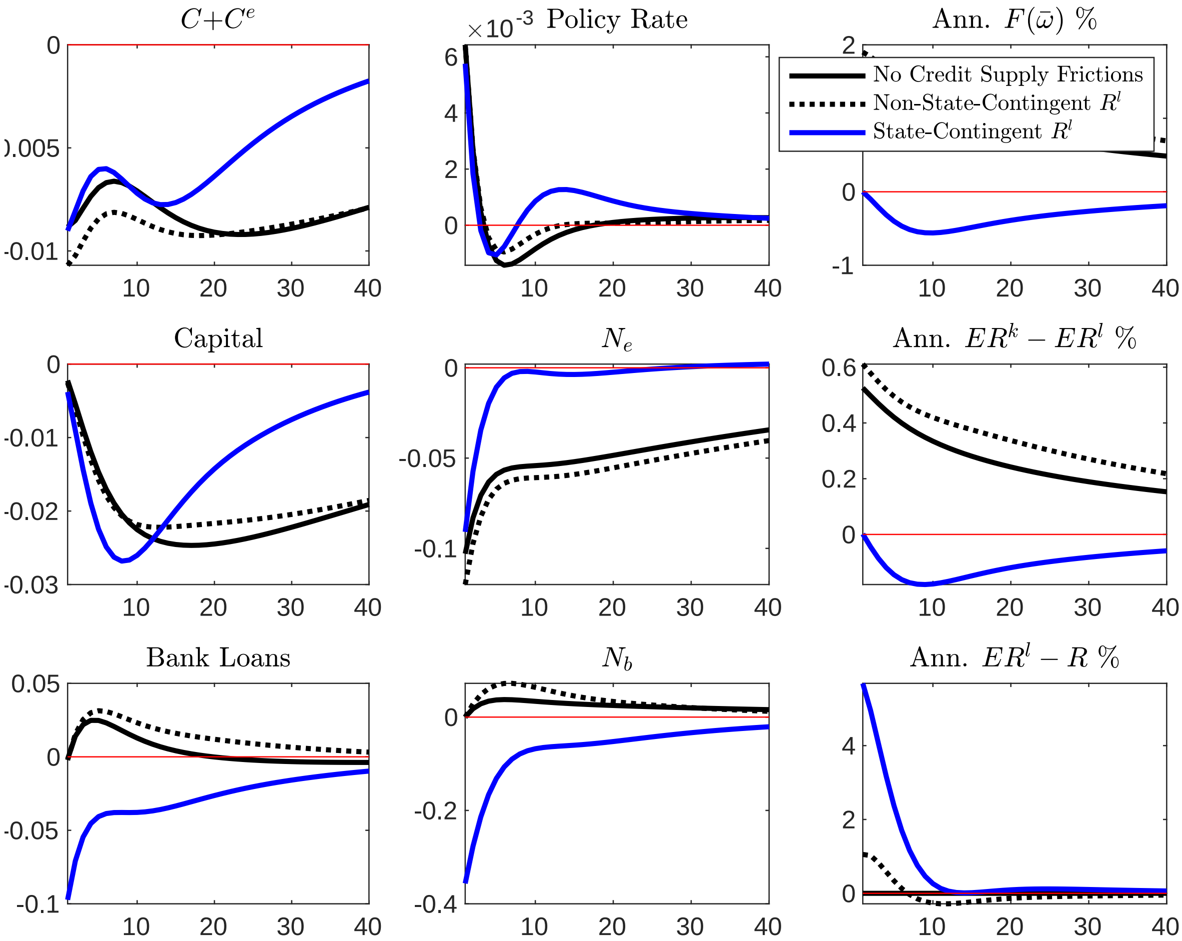
Here, we try to solve a puzzle that consists in observing a credit expansion after a contractionary monetary policy in an economy without credit supply frictions as BGG 1999.

Figure 2.2 shows the dynamics of the economy after a contractionary monetary policy shock of 25 basis points. In the dynamics of an economy without credit supply frictions, as in BGG 1999, we observe an increase of bank loans after the contractionary monetary policy. This is because the higher policy rate increases households' incentives to save and to hold more bank deposits, which in turn increases credit supply. Notice that the increased credit supply outweighs the lower entrepreneur capacity to demand credit due to the lower entrepreneur's equity. Hence, in equilibrium we observe an increase of bank loans after the contractionary monetary policy shock. In this chapter, this feature is named "the credit contraction puzzle". As expected, the same situation is observed in the model with credit supply frictions and with non-state-contingent R^l_{t+1}. As a result, it is not enough to model credit supply frictions to solve the model.

Figure 2.2 shows that the model with credit supply friction and with state-contingent R^l_{t+1} helps to the solve puzzle. Now the contractionary monetary policy shock in the economy affects also the banks' equity. The drop in the banks' equity diminishes the banks' capacity to supply credit, and in equilibrium its effects is higher than the household preference to make bank deposits.

Finally, incorporating credit supply frictions and contracts between entrepreneurs and banks, with state-contingent R^l_{t+1}, that is more realistic, helps us to capture what is observed after a contractionary monetary policy shock.

Figure 2.2: A contractionary monetary policy shock of 25 bps: Role of credit supply frictions



Note: All variables are in log deviations from steady-state except spreads, failure rate and (non-deafult) lending rate, shown in level deviation from steady-state.

2.5 Credit Policy

Here, we define the unconventional credit policy. This policy is characterized as the central bank (CB) lending facilities to entrepreneurs. We study two variations. In the first case, lending facilities are given to entrepreneurs (firms) directly by the central bank, while in a second case, these credit facilities are given to entrepreneurs indirectly through financial intermediaries (commercial banks).[10] So, in the former case we will have direct CB loans, while in the latter indirect CB loans. Notice that in both cases we consider these as CB loans, since these are funded by the central bank. As we explain in subsection 2.5.2, under reasonable assumptions these two variations are equivalent. Thus, we mainly discuss the indirect CB loans to study the importance of government credibility regarding the government guarantees.

Independently of whether the loans are given directly by the central bank or through banks, we assume these loans are guaranteed by the government. This is, if an entrepreneur is not able to fully pay the agreed gross return on central bank loans, government transfers are enough to ensure that the lender receives the agreed return for these CB loans. We assume government funds their activities with lump-sum taxes to households.

The required return on central bank loans set by the central bank is the risk-free interest rate, which is the opportunity cost of the central bank as well. A necessary condition for this is that the central bank loans cannot be diverted by banks. While this strictly holds with direct central bank lending, with indirect central bank lending as explained later it is still a realistic feature. Since the required return on central bank loans is the risk-free interest rate R_t and since the government bears the risk associated with these loans, the (non-default) lending interest rate of CB loans is R_t as well. Recall that since bank loans are not guaranteed by the government and are subject to the credit supply frictions, in equilibrium the bank loans (non-default) lending rate Z^j_{t+1} contains a firm default risk premium and another premium due to the moral hazard problem between bankers and depositors. Then, CB loans are cheaper than bank loans. In addition, due to the premium associated with the moral hazard problem, the required return on bank loans R^l_{t+1} is higher than the required return on CB loans R_t.

We assume that an entrepreneur does not internalize the effects of her capital and credit decisions on the CB loans injections. Hence, from the entrepreneur's perspective the marginal cost of external funding is still given by the required return on bank loans. We believe this is a reasonable assumption in a context of unconventional credit policy, in the sense that an entrepreneur cannot predict if the central bank will provide lending facilities.[11]

Then, entrepreneurs demand and deplete these CB loans first and then banks loans. So, entrepreneurs aim to substitute expensive bank loans for cheap CB loans. As a result, we cannot expect a one to one multiplier effect of the credit policy on aggregate lending. With this in mind, we can preliminary suggest how this credit policy might affect aggregate credit supply and credit demand. On the aggregate credit supply side:

- First, as in GKa 2011 CB loans cannot be diverted by banks[12], the credit policy is reducing the impact of the moral hazard problem between banks and depositors on this economy. In other words, banks required equity per unit of aggregate credit decreases, which allows for a smaller required return on bank loans for a given aggregate credit level. As a result, CB credit policy increases the aggregate supply of credit.

- Second, since the required return on central bank loans is smaller than those of the traditional bank loans, entrepreneurs now face a limited supply of cheap CB loans in addition to the supply curve

[10] For simplicity, we assume that the central bank obtains the funds from households through lump sum taxes.

[11] However, in section 2.6.5 we develop the context in which CB announces its credit policy rule. So in that case entrepreneur internalizes the effects of her decisions on CB loans.

[12] We assume it with indirect CB loans.

of bank loans, equation (2.9), which is not affected by the credit policy.

In the margin, the bank loan supply curve matters since the last external funding comes from bank loans. As a result, we can say that the aggregate credit supply curve changes, but the aggregate supply curve of banks loans that in the margin (together with the aggregate demand curve) determines the equilibrium level of credit is not affected. On the aggregate credit demand side:

- First, since the opportunity cost of the central bank is the risk-free interest rate R_t, banks or the central bank require a lower return per unit of these CB loans that the one required by bank loans, i.e., $\mathbb{E}_t\{\Lambda_{t,t+1}\}R_t < \mathbb{E}_t\{\Lambda_{t,t+1}R^l_{t+1}\}$.[13] This reduces the entrepreneur's default probability and hence reduces the default costs and pushes up the aggregate demand of capital increasing demand for credit as well.

- Second, the guarantee of the government avoids that the (non-default) lending interest rate associated with the CB loans reflects any risk-premium. In other words, while the (non-default) lending rate on banks loans is Z^j_{t+1}, the (non-default) lending rate on CB loans is R_t, where $Z^j_{t+1} > R_t$. Ceteris paribus for given capital and equity, CB loans reduce entrepreneur obligations, default probability and reliance on bank loans. This in turn reduces the default costs and pushes up the aggregate demand of capital and hence of credit.

Hence, the credit policy stimulates both the credit supply and the credit demand. In other words, the credit policy is expected to produce an increase of aggregate credit. Clearly, without frictions on the credit supply side, the credit policy does not increase aggregate credit supply and the first effect on aggregate demand is null.

While these arguments might be clear for direct CB loans, as we explain later, under reasonable assumptions these also hold even if CB loans are given through banks as explained in subsection 2.5.2.

Next, we assess how the credit policy affects the equilibrium conditions. For a better explanation, we first focus on direct CB loans to firms and then on indirect CB loans to firms. In addition, since entrepreneurs will have two sources of external funding (CB loans and bank loans), we discuss the implications of the seniority assumption of CB loans and bank loans.

2.5.1 Direct Credit to Firms

Here, we introduce to the model direct CB loans to firms. As we will see only the maximization problem of entrepreneurs is affected. In this case, the central bank facilitates direct lending B^g_t to firms. Since the opportunity cost of the central bank is the risk-free interest rate R_t and since CB loans are guarantee by the government, the central bank also claims R_t as the (non-default) lending rate of CB loans. As a result, at $t+1$, the central bank makes zero profits.

We assume central bank is willing to provide a fraction $\psi_{CB,t}$ of total external funding for entrepreneur j, i.e.,

$$B^{g,j}_t = \psi_{CB,t}(Q_t K^j_t - N^j_{et}). \tag{2.35}$$

However, we assume that entrepreneurs are not aware of this credit injection rule, equation (2.35), and, so, cannot internalize the effects of their decisions on $B^{g,j}_t$. At the end of t (going into period $t+1$), entrepreneur j with available net worth N^j_t, borrows B^j_t from banks and $B^{g,j}_t$ from central bank to buy capital K^j_t

$$B^{g,j}_t + B^j_t = Q_t K^j_t - N^j_{et}. \tag{2.36}$$

[13]Recall that the return required by bank loans is higher than the risk-free interest rate due to the moral hazard problem between banks and depositors and the asymmetric information problem between banks and firms.

Each time an entrepreneur j defaults, she needs to know the payment order to their creditors (central bank and banks). There are three alternative assumptions: (1) Both CB loans and bank loans have the same seniority, (2) bank loans have higher seniority and (3) CB loans have higher seniority. In (1) both loans are paid with the same priority and hence each time entrepreneurs default, they transfer the realized capital payoffs to their creditors proportionally. In (2) if an entrepreneur defaults it repays first bank loans, and then cares on repaying CB loans. In (3) the opposite occurs.

In this subsection, we solve the model assuming that bank loans and central bank loans have the same seniority. This is, when an entrepreneur defaults at $t+1$, realized revenues are use to repay CB loans and bank loans proportionally to their values at $t+1$. For example, if the debt with the central bank is one quarter of the debt with the banks, twenty percent of his realized revenues goes to repay CB loans and eighty percent to repay bank loans.

Banks and government pay monitoring costs to observe entrepreneur' realized return when she defaults. These payments are proportional to what bank and central bank obtain when entrepreneur defaults, respectively. Further, we assume these auditing costs are the same for both the banks and for the central bank. Hence, total monitoring costs must add up $\mu\omega^j R^k_{t+1} Q_t K^j_t$. This time the threshold value of the idiosyncratic productivity, $\bar{\omega}^j$, is defined as,

$$\bar{\omega}^j R^k_{t+1} Q_t K^j_t = Z^j_{t+1} B^j_t + R_t B^{g,j}_t. \tag{2.37}$$

Recall that if $\omega^j \geq \bar{\omega}^j$, an entrepreneur does not default and hence is able to fully repay both bank loans and CB loans, otherwise she defaults and repay partially both loans. So, if $\omega^j < \bar{\omega}^j$, government makes sure that CB loans are fully repaid by collecting lump sum taxes. A defaulting entrepreneur receives nothing.

Combining equations (2.35) and (2.37) yields

$$\bar{\omega}^j R^k_{t+1} Q_t K^j_t = Z^j_{t+1} B^j_t + R_t B^{g,j}_t \Rightarrow \bar{\omega}^j = \frac{Z^j_{t+1}(1-\psi_{CB,t}) + R_t \psi_{CB,t}}{R^k_{t+1}} \frac{\phi_{et}-1}{\phi_{et}} < \bar{\omega}^j \Big|_{\psi_{CB,t}=0}, \tag{2.38}$$

where $\phi^j_{et} = K^j_t / N^j_{et}$ is the leverage of entrepreneur j. According to equation (2.38), ceteris paribus, providing to entrepreneurs with a fraction $\psi_{CB,t}$ of cheap loans reduce $\bar{\omega}^j$ and hence the entrepreneur default's probability, which in turn it results in a lower expected monitoring cots. This increases the marginal benefit of capital and hence increases demand for bank loans. Clearly, the higher the $\psi_{CB,t}$, the stronger the increment of bank loan demand.

The bank loan contract ($\bar{\omega}^j$, Z^j_{t+1}), in equation (2.15), must satisfy that banks always receive a gross return R^l_{t+1} per unit of bank loans, and now becomes:

$$[1-F(\bar{\omega}^j)] Z^j_{t+1} B^j_t + (1-\mu) \int_0^{\bar{\omega}^j} \omega R^k_{t+1} Q_t K^j_t x^j_{t+1} dF(\omega) = R^l_{t+1} B^j_t, \tag{2.39}$$

where $x^j_{t+1} = Z^j_{t+1} B^j_t / (Z^j_{t+1} B^j_t + R_t B^{g,j}_t)$ is the proportion of the realized revenues that goes to repay bank loans when the entrepreneur defaults. For a given K^j_t the differences with respect to a bank loan contract without credit policy, equation (2.15), are two. i) Only a fraction $(1-\psi_{CB,t})$ of external funding comes from bank loans. In other words, without credit policy $B^j_t = Q_t K^j_t - N^j_{et}$, while with credit policy $B^j_t = (1-\psi_{CB,t})(Q_t K^j_t - N^j_{et})$. ii) Only a fraction x^j_{t+1} of $\omega R^k_{t+1} Q_t K^j_t$ goes to pay bank loans each time an entrepreneur defaults.

For convenience the bank loan contract is written as,[14]

$$\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t = R^l_{t+1} \left(Q_t K^j_t - B^{g,j}_t - N^j_t\right) + \Psi(\bar{\omega}^j) R_t B^{g,j}_t, \tag{2.40}$$

[14]Proof in Appendix 2.B.

where,

$$\Gamma(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega) + (1 - F(\bar{\omega}^j))\bar{\omega}^j, \qquad G(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega),$$

$$\Psi(\bar{\omega}^j) = (1-\mu)\frac{1}{\bar{\omega}^j}G(\bar{\omega}^j) + (1 - F(\bar{\omega}^j)).$$

In the left-hand side of equation (2.40) we have the resources available to repay loans. In the right-hand side we have uses for those resources. These resources are used to fully repay the gross return required on bank loans $R^l_{t+1}B^j_t$ and to partially pay the CB loans $\Psi(\bar{\omega}^j)R_tB^{g,j}_t$. So, $\Psi(\bar{\omega}^j)R_tB^{g,j}_t$ is the effective gross return repaid to CB loans by the entrepreneur. It is composed by the amount that non default entrepreneurs transfer to repay central bank loans $(1 - F(\bar{\omega}^j))R_tB^{g,j}_t$ and the value of seized projects from defaulting entrepreneurs $(1-\mu)\frac{1}{\bar{\omega}^j}G(\bar{\omega}^j)R_tB^{g,j}_t$, net of monitoring costs, to repay central bank loans. Note that each time an entrepreneur defaults, government honours the guarantee and hence transfers resources to ensure CB loans receive the agreed return. This implies that entrepreneurs' transfers are not enough to fully pay CB loans, i.e.,

$$\Psi(\bar{\omega}^j) < 1, \tag{2.41}$$

or equivalently the effective cost of CB loans from entrepreneur perspective is smaller than the risk-free interest rate, i.e.,

$$\Psi(\bar{\omega}^j)R_t < R_t.$$

This means that the amount of government transfers destined to repay CB loans are $(1 - \Psi(\bar{\omega}^j))R_tB^{g,j}_t$.

In this case the entrepreneur aims to maximize their expected profits,

$$\mathbb{E}_t \left\{ \int_{\bar{\omega}^j}^{+\infty} \left(\omega R^k_{t+1} Q_t K^j_{t+1} - Z^j_{t+1} B^j_t - R_t B^{g,j}_t \right) dF(\omega) \right\},$$

taking as given R^k_{t+1} and $B^{g,j}_t$. Using (2.37) it yields,

$$\mathbb{E}_t \left\{ \left[1 - \Gamma(\bar{\omega}^j)\right] R^k_{t+1} Q_t K^j_t \right\}, \tag{2.42}$$

We arrive to an expression identical to the one without credit policy which is independent of the loan seniority assumption. Entrepreneur chooses K^j_t and a schedule for $\bar{\omega}^j$ to maximize equation (2.42), subject to the state-contingent constraint implied by equation (2.40).[15] The aggregate credit demand curve, equation (2.26), becomes,[16]

$$\mathbb{E}_t \left\{ (1 - \Gamma(\bar{\omega}))\, R^k_{t+1} + \frac{1 - F(\bar{\omega})}{\Upsilon + 1 - F(\bar{\omega}) - \mu\bar{\omega}f(\bar{\omega})} \left[(\Gamma(\bar{\omega}) - \mu G(\bar{\omega}))\, R^k_{t+1} - R^l_{t+1} \right] \right\} = 0. \tag{2.43}$$

where,

$$\Upsilon = -\frac{\partial \Psi(\bar{\omega})}{\partial \bar{\omega}} \frac{R_t B^g_t}{R^k_{t+1} Q_t K_t} > 0. \tag{2.44}$$

Since $\Upsilon > 0$, and comparing (2.43) with (2.26), we observe that credit policy positively affects the net marginal benefit of capital and hence aggregate demand for bank loans. The intuition is that the credit policy reduces the amount of transfers from the entrepreneurs to partially repay CB loans (or equivalently, what is increasing is amount of transfers from government to repay CB loans), which reduces the entrepreneur's default probability and the expected defaulting costs, which as a consequence raises incentives to demand capital and bank loans.

[15]The first order conditions are found in Appendix 2.B.

[16]This is obtained from aggregating equation (2.21) in Appendix 2.B.

Inserting equation (2.40) into equation (2.42) yields,

$$\mathbb{E}_t \left\{ \left[1 - \mu G(\bar{\omega}^j\right] R^k_{t+1} Q_t K^j_{t+1} - R^l_{t+1}(K^j_t - B^{g,j}_t - N^j_t) - \Psi(\bar{\omega}^j) R_t B^{g,j}_t \right\}. \tag{2.45}$$

Equation (2.45) says that the marginal cost of capital is not affected directly by the credit policy and so it continues to be R^l_{t+1}. This is because entrepreneur is not internalizing the effects of their capital decision on B^j_t, as they are not aware of the credit policy rule, equation (2.35).[17] And, the equity held by entrepreneurs still operating in business at t, V^e_t, becomes,

$$\begin{aligned} V^e_t &= R^k_t Q_{t-1} K_{t-1} - R^l_t B_{t-1} - (1 - F(\bar{\omega}) + \frac{1}{\bar{\omega}} G(\bar{\omega})) R_{t-1} B^g_{t-1} \\ &- \mu \int_0^{\bar{\omega}_t} \left(\omega R^k_t Q_{t-1} K_{t-1} - \frac{\omega}{\bar{\omega}} R_{t-1} B^g_{t-1} \right) dF(\omega). \end{aligned}$$

where $(1 - F(\bar{\omega}) + \frac{1}{\bar{\omega}} G(\bar{\omega})) R_{t-1} B^g_{t-1}$ are the resources taken from entrepreneur's profits that goes to repay central bank loans, which by definition are not enough for a full repayment.

We can say that according to (2.38) for a given K_t credit policy reduces the entrepreneur's default probability and from (2.43) for a given $\bar{\omega}$ the net marginal benefit of capital increases. Both positively affect aggregate credit demand.

Next, we set an equation that allows us to understand the size of the government transfers (subsidies) due to the government guarantee on CB loans.[18] Recall these transfers are destined to make sure the central bank loans are fully repaid, which are funded with lump sum taxes. Since banks perfectly diversify the idiosyncratic risk, the following equation equates all the resources (from entrepreneur and government) available to fully repay both bank loans and central bank loans (left-hand side) with the total return required by both bank and central bank loans (right-hand side), for a given realization of the aggregate shock.

$$\begin{aligned} & [1 - F(\bar{\omega})] Z_{t+1} B_t + [1 - F(\bar{\omega})] R_t B^g_t + (1 - \mu) \int_0^{\bar{\omega}} \omega R^k_{t+1} Q_t K_t dF(\omega) x_{t+1} \\ + & \int_0^{\bar{\omega}} \omega R^k_{t+1} Q_t K_t dF(\omega)(1 - x_{t+1}) + S_{t+1} = R^l_{t+1} B_t + R_t B^g_t \\ + & \mu \int_0^{\bar{\omega}} \omega R^k_{t+1} Q_t K_t dF(\omega)(1 - x_{t+1}). \end{aligned} \tag{2.46}$$

In this equation (2.46), on the left hand side, the terms in black represent the entrepreneur' resources destined to fully repay bank loans, and the terms in red entrepreneur' resources destined to partially repay CB loans, and the term in blue is amount of government subsidies, S_{t+1}. So, S_{t+1} is computed as the difference between the gross return of CB loans (plus monitoring costs[19]) and entrepreneur's resources used to pay those, i.e.,

$$S_{t+1} = R_t B^g_t - [1 - F(\bar{\omega})] R_t B^g_t - (1 - \mu) \int_0^{\bar{\omega}} \omega R^k_{t+1} Q_t K_t dF(\omega)(1 - x_{t+1}), \tag{2.47}$$

[17] Otherwise, they are aware that, from an entrepreneur's perspective, one unit of external funding is funded with by both cheap CB loans and bank loans, reducing the marginal cost of capital. This case is studied in subsection 2.6.5.

[18] The same equation will also help us to study more the implications of government credibility, in subsection 2.5.2

[19] Recall the monitoring costs associated with entrepreneur revenues used to repay CB loans are paid by the government.

Notice that by definition, when inserting (2.47) into (2.46) we get the bank loan contract, equation (2.39). And that the right-hand side of equation (2.47) is a different way to write $(1-\Psi(\bar{\omega}))R_tB_t^g$. For illustrative purposes, we rewrite equation (2.46), as,

$$[1-F(\bar{\omega})](Z_{t+1}B_t+R_tB_t^g)+(1-\mu)\int_0^{\bar{\omega}}\omega R_{t+1}^k Q_t K_t dF(\omega)+S_{t+1}=R_{t+1}^l B_t+R_tB_t^g. \quad (2.48)$$

where S_{t+1} is rewritten as,

$$S_{t+1}=\int_0^{\bar{\omega}^j}\left[R_tB_t^g-(1-\mu)(1-x_{t+1})\omega R_{t+1}^k Q_t K_t\right]dF(\omega). \quad (2.49)$$

From this expression, we can clearly see that government subsidies complement the entrepreneurs' resources destined to repay central bank loans net of monitoring costs, $(1-\mu)(1-x_{t+1})\omega R_{t+1}^k Q_t K_t$, and make sure CB loans are fully paid and the central bank receives the agreed gross return, $R_tB_t^g$.

In this present analysis, it doesn't make sense assess the impact of no government credibility on the direct CB loans to firms. In other words, it is not realistic to say that ex-ante the central bank does not believe that the government ex-post will guarantee the CB loans, since they are part of the same organization. The implications of credibility make more sense when the CB loans are given through banks, since banks may believe that the government will not honor the guarantee on CB loans. We study the effects of no government credibility within the next subsection.

2.5.2 Indirect Credit to Firms Through Banks

Here, we study the implications of giving CB loans through banks. As it is showed next, under reasonable assumptions, this policy is equivalent to direct CB loans to firms.

In this case we assume that the central bank gives funding to banks with the commitment that (1) banks give at least the same amount of loans (CB loans) to entrepreneurs and (2) charge some agreed lending interest rate to entrepreneurs for these central bank loans. This is given in three steps. Step 1: The central bank offers the funds in an auction. Step 2: banks demand these funds and propose a (non-default) lending rate to be charged to entrepreneurs. Step 3: The central bank gives the funding to those banks that offer the lowest lending rate. Since all banks are identical and perfectly compete with other banks, at the end of the day they all offer the same lending rate, which, as explained later, is going to be the risk-free interest rate. We assume that the central bank can costlessly enforce banks to perform (1) and (2). Recall that since the opportunity cost of the central bank is the risk-free rate, then it also claims to banks the risk-free rate for funding CB loans.

We assume that there is not a moral hazard problem between banks and the central bank, as it exists between banks and depositors. In other words, we assume that bankers cannot divert the bank assets (CB loans) that are funded by the central bank. We believe this is a realistic assumption, since the central bank might have more monitoring and enforcement power over banks than depositors.

Furthermore, we assume that banks do not incur in any administrative cost (or these are negligible) for collecting the central bank funding and giving these to entrepreneurs as CB loans. Hence, the cost for banks of issuing CB loans is just the interest rate claimed by the central bank, which is the risk-free interest rate.

Also, since CB loans issued by banks are guaranteed by the government, the (no-default) lending interest rate on these loans asked by banks does not contain any risk premium. This means that the (non-default) lending rate for the CB loans is going to be equal to the required return for CB loans. Thus, we implicitly assume that there is government credibility. In other words, banks ex-ante believe that government will honour the guarantee for the CB loans. In this dynamic framework, are modeling in such a way that the ex-ante credibility responds to the observed behavior that the central bank has fulfilled its promise in the past. Thus, we can argue that even ex-post, the government always honor the guarantee.

Finally, given the previously discussed assumptions and that banks perfectly competing for CB loans, banks that obtain CB loans are those that commit to charging a (no-default) lending rate for CB loans equal to the risk-free interest rate R_t.[20]

In equilibrium, banks issue CB loans by exactly the same amount of funds received from the central bank.[21] Hence, banks balance sheet becomes,

$$B_t^g + B_t = B_t^g + D_t + N_{bt}, \tag{2.50}$$

where B_t^g is not only the amount of CB loans but also the amount of funds received from the central bank to finance these loans. As a result, equation (2.50) collapses to the balance sheet with direct CB loans, equation (2.4), and hence bank loans are funded by both households' deposits and bank equity.

We assume that the government pays the monitoring costs of observing the entrepreneur's realized revenues that goes to repay CB loans. Since CB loans are guaranteed, banks do not have any incentives to pay the monitoring costs associated to observe realized revenues that goes to pay CB loans. Similarly, the central bank does not have any incentive to do so due to the government guarantee. Hence, we believe it is a reasonable assumption to say that since the government take care of her budget, she is the more interested in recover as much as it can from entrepreneur revenues and hence pays the monitoring costs.

Thus, equilibrium conditions of the banking sector are not affected. This is because banks profits are not affected given that by definition the central bank revenues are perfectly cancelled out with their own funding costs.

In summary, under all these assumptions, direct CB loans are equivalent to indirect CB loans. Also, since this argument does not depend on CB loans seniority, it holds for any seniority assumption.

In the case of same seniority assumption, the bank loan contract becomes as in equation (2.46). Hence, since we assume that banks ex-ante believe that government will honour her guarantee, and S_{t+1} takes the same form in (2.47), the bank loan contract is indeed equivalent to the bank loans contract with direct CB loans.

Next, we discuss what happens if there is not government credibility. This is if banks ex-ante believe that government is not willing or able to guarantee CB loans.

No Government Credibility

Here, we study the case when banks ex-ante always banks believe that the government is not going to honor CB loans guarantees. This could be because in the past the government failed to pay the guarantees. In this dynamic framework, since the government observes that its guarantee announcement has not any (ex-ante) impact, the central bank has not ex-post incentives to claim CB loans and hence in equilibrium we assume that ex-post government does not honour the guarantee. We show that in this case of no government credibility, credit policy effectiveness is diminished.

We assume that the central bank charges a very high penalty to banks in case they do not fully repay the agreed return on the central bank funding. Thus, to make sure CB loans are fully repaid banks have to raise the (non-default) lending rate associated with bank loans. So, additional revenues are intended to compensate for resources that the bank believes will not be transferred from the government each time entrepreneurs default on CB loans. Then, a higher (non-default) lending rate on bank loans increases

[20]Notice that banks proposing a (non-default) lending rate bellow the risk-free interest rate is not incentive compatible.

[21]Clearly, banks are not willing to issue central bank loans funded with households deposits and/or bank equity, since the cost of collecting households deposits end up being higher than the risk-free interest rate, due to the moral hazard problem between banks and households, which is the return that they will obtain for issuing central bank loans.

the entrepreneur's default probability, which in turn increases the expected monitoring costs and reduces entrepreneurs' incentives to demand credit. As a result, the positive effect of credit policy on aggregate credit demand is diminished by no government credibility.

In other words, if there is zero government credibility, the credit policy should have a small effect in the economy. This is because the positive effects of having cheap CB loans in the economy are expected to be at least partially cancelled by the negative effects of having more expensive bank loans. Equivalently, the goal of the credit policy is to provide cheap credit to firms and absorb the riskiness of these loans but with zero credibility, banks do not believe government will absorb the risk and hence they have to bear the CB loans risk. So, banks have to charge a higher lending rate to compensate for the risk-taking on CB loans. Notice that government credibility does not affect aggregate credit supply, but aggregate demand.

Therefore, one policy recommendation is to monitor the lending interest rate of CB loans as an indicator of the government credibility and as an indicator of the effectiveness of central bank credit policy.

Under assumption that CB loans and bank loans have the same seniority, and with government credibility, the bank loan contract is given by equation (2.46) at its individual level, and government subsidies are defined in equation (2.47). Without government credibility, banks ex-ante believe that they will not receive any subsidy from the government, i.e., ex-ante banks believe $S^j_{t+1} = 0$, and hence the bank loan contract, in equation (2.46), at its individual level becomes,

$$[1 - F(\bar{\omega}^j)](Z^j_{t+1} B^j_t + R_t B^{g,j}_t) + (1 - \mu) \int_0^{\bar{\omega}^j} \omega R^k_{t+1} Q_t K^j_t dF(\omega) = R^l_{t+1} B^j_t + R_t B^{g,j}_t .$$

Using (2.37), it yields,

$$[\Gamma(\bar{\omega}^{g,j}) - \mu G(\bar{\omega}^{g,j})] R^k_{t+1} Q_t K^j_t = R^l_{t+1} B^j_t + R_t B^{g,j}_t . \tag{2.51}$$

Since in equilibrium, $B^{g,j}_t = \psi_{CB,t} B^j_t$, it finally becomes,

$$[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)] R^k_{t+1} Q_t K^j_t = \left(R^l_{t+1} - \frac{\psi_{CB,t}}{1 + \psi_{CB,t}} (R^l_{t+1} - R_t) \right) (B^j_t + B^{g,j}_t). \tag{2.52}$$

Comparing equation (2.52) with (2.16) or with (2.23), it no government credibility reduces the effectiveness of the central bank credit policy, but not the whole the effect. Intuition is as follows:

- Remember that the central bank credit policy has two direct benefits: first, it requires banks to require a lower return per unit of CB loans, and second, the government guarantee prevents the (non-default) bank lending rate associated with CB loans from reflecting any risk premium. These two advantages reduce the entrepreneur's default probability, which has a positive effect on aggregate credit demand.

- Without government credibility, the second benefits disappear, while the first do not. As suggested by equation (2.52) credit policy still benefits economy by affecting the aggregate supply of credit. In other words, the credit policy still allows entrepreneurs to get on average cheap loans. $\frac{\psi_{CB,t}}{1+\psi_{CB,t}} (R^l_{t+1} - R_t)$ captures the effects of cheap CB loans in terms of reduction on the risk premium that banks charge to the average loan to entrepreneurs.

- If we further assume that there are not credit supply frictions (i.e., $R^l_{t+1} = R_t$), the impact of the central bank credit policy is null. In this case, bank loan contract, equation (2.51), becomes,

$$[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)] R^k_{t+1} Q_t K^j_t = R_t (K^j_t - N^j_t), \tag{2.53}$$

which is the same loan contract under not credit policy, equation (2.16), with $R^l_{t+1} = R_t$. In this case, K^j_t and $\bar{\omega}^j$ are the same that under not credit policy.[22] Thus, from equation (2.37),

$$\bar{\omega}^j R^k_{t+1} Q_t K^j_t = Z^j_{t+1} B^j_t + R_t B^{g,j}_t, \tag{2.54}$$

it implies that, since the threshold value that separates the bankrupt and non-bankrupt entrepreneurs, the left hand in equation (2.54), does not change, in order to keep the total repayment value of loans, the right hand side in equation (2.54), unchanged, a bank needs to increase the (no-default) interest rate of bank loans, Z^j_{t+1}, so it compensates the lower return, R_t, of the CB loans. In order words, for a given K^j_t, banks need to increases Z^j_{t+1} so the entrepreneur's default probability is unchanged.

- With credit supply frictions, the loan contract in equation (2.52), the average required gross return per unit of loans is smaller (i.e., $R^l_{t+1} - \frac{\psi_{CB,t}}{1+\psi_{CB,t}}(R^l_{t+1} - R_t) < R^l_{t+1}$). This means that the entrepreneur's default probability could be higher, i.e., $\bar{\omega}^j$ increases. Then, from equation (2.54), it requires an increase of Z^j_{t+1}, which is even higher than the one without credit supply frictions. We conclude that if banks believe the government will not fully guarantee their CB loans, they will charge higher (non-default) lending rates for bank loans, Z^j_{t+1}, to compensate for the government subsidies not received at $t+1$. This in turn pushes up the entrepreneur's default probability and, as a result, reduces the effects of credit policy.

2.5.3 Seniority implications

Here, we assess how the assumption about the seniority of loans affects the impact of the credit policy.[23] As seen before, the effectiveness of the central bank credit policy depends also on the level of risk that is being absorbed by the government, and thus on the size of the guarantees (or subsidies) provided by the government to ensure CB loans are fully repaid. In other words, we may anticipate that the greater the government transfers, the greater the impact of credit policy.[24]

When both bank loans and CB loans have the same seniority, all loans are paid with the same priority. This is, each time an entrepreneur defaults, entrepreneur realized revenues are distributed proportionally to the size of both kinds of debts.

When bank loans have higher seniority, if an entrepreneur defaults, bank loans are paid first and hence by definition a greater fraction of realized revenues goes to repay bank loans.[25] This means that the amount recovered to repay banks loans increases and consequently the amount that goes to repay CB loans falls. Consequently, government guarantees are higher and hence government ends up giving more subsidies to repay CB loans. Since bank loans are paid first, the probability that entrepreneur defaults on bank loans decreases. It clearly pushes down the (non-default) interest rate rate Z^j_{t+1}, which in turn reduces the entrepreneur's default probability. This reduces expected monitoring costs and hence increases the net marginal benefits of capital, which in turn pushes up the aggregate credit demand.

When central bank loans have lower seniority, the opposite occurs. If an entrepreneur defaults, central bank loans are paid first. Since now the the amount recovered to payback CB loans are higher,

[22]Appendix 2.F reports the first order conditions the entrepreneurs that are identical to the case of no credit policy and no credit supply frictions.

[23]In Appendix 2.C we solve the maximization problem of entrepreneurs when CB loans have higher seniority and in Appendix 2.D when CB loans have the higher seniority. As suggested in subsection 2.5.2, the analysis holds independently if we are talking about direct CB loans or indirect CB loans.

[24]In Appendix 2.G we formally explore the government subsidies to repay central bank loans.

[25]There are some entrepreneurs (with very low ω^j) that only are able to partially repay bank loans and repay nothing to CB loans.

this implies that government subsidies are smaller. In this case a smaller fraction goes to repay bank loans. Since CB loans are paid first, the probability that entrepreneur defaults on bank loans increases, it pushed up the (non-default) interest rate rate Z_{t+1}^{j}, which in turn increases the entrepreneur's default probability. This pushes down the aggregate credit demand.

2.6 Credit Policy Simulations

In order to quantitatively compare the effects of the credit policy, we describe it first as an exogenous rule. By using an exogenous rule we can describe the effects of a credit policy shock (in subsection 2.6.1); compare the effects of the credit policy under different assumptions such as the seniority of loans (in subsection 2.6.2), the credibility of government guarantees (in subsection 2.6.3) and describe the dynamics comparison between conventional versus unconventional policy (in subsection 2.6.6). An endogenous rule that responds to different general equilibrium effects might lead to different size effects of the credit policy intervention and then it becomes not comparable. In particular, we assume that the fraction of external funding that comes from the central bank resources $\psi_{CB,t}$ follows an AR(1) process,

$$\psi_{CB,t} = \rho_{CB}\psi_{CB,t-1} + \epsilon_{CB,t}, \tag{2.55}$$

with $\rho_{CB} = 0.95$. In the baseline simulation we set $\epsilon_{CB,1} = 10\%$ and assume future values of ϵ_{CB} equal to zero. This means that immediately after a negative shock (e.g., a capital quality shock), CB loans intervention will account for 10% of the credit market and will gradually decline.

Later, in subsection 2.6.4 we make use of an endogenous credit policy rule, to study the effectiveness in the design of a policy rule. Further, in subsection 2.6.5, we study the effects of an ex-ante announcement of the credit policy rule. In particular, we assume that $\psi_{CB,t}$ follows,[26]

$$\psi_{CB,t} = \nu \mathbb{E}_t\{spread_{t+1} - spread_{ss}\}, \qquad \nu > 0, \tag{2.56}$$

where $spread_{t+1} \in \{R_{t+1}^{k} - R_{t+1}^{l}, R_{t+1}^{l} - R_t\}$. Equation (2.56) describes an endogenous credit policy rule of injecting central bank loans in the credit market. Hence, in this case credit injection depends on the deviation of some spread form its long-term value. $R_{t+1}^{k} - R_{t+1}^{l}$ captures entrepreneur's capacity to purchases capital and hence to demand credit (external funding), and $R_{t+1}^{l} - R_t$ captures banks' capacity to supply credit and hence to capture households' deposits. The latter is also known in the literature as the credit spread. In general, the higher spread the smaller capacity of lending. For example, higher credit spread implies that banks are facing problems to issue credit per unit of bank net worth and hence they need more equity to keep the same level of credit supply. A period where the credit spread rise sharply can be defined as a credit supply crisis. Similarly, a period where $R_{t+1}^{k} - R_{t+1}^{l}$ rises sharply can be defined as a credit demand crisis.

Note that it could be the case that $\psi_{CB,t} < 0$, in this case the credit policy rule will offer firms to hold some risk-free assets in the central bank (in the case of direct CB loans) or to hold bank safe deposits on banks (in the case of indirect CB loans). As a result, this rule is indeed a countercyclical. We set $\nu = 40$ as its baseline value.

Note that it is possible to assume different rules. For example, credit injection might depend on the deviations of the credit to GDP ratio from its long term, or from the percentage deviations of credit or output from its long-term value.[27] However, for illustrative purposes we set the rule described in equation (2.56), as it is a very well used rule in several papers that study the effects of more conventional credit

[26]This follows the spirit of Gertler and Karadi (2011a).

[27]A study of the effectiveness of different rules of countercyclical capital buffers on macroeconomic and financial stability is presented in Pozo (2020).

policies (see Gertler and Kiyotaki (2011); Gertler and Karadi (2011a); Gertler, Kiyotaki and Queralto (2012))

By definition, the unconventional credit policy rule does not affect the deterministic steady state. Next, we simulate the model to evaluate the effects of the unconventional credit policy and the implications of the seniority of loans, government credibility, credit policy design, ex-ante announcements of the credit rule and the unconventional feature of the policy.

Unless otherwise stated, the simulations respond to a five percent negative capital quality shock. And in our baseline model, banks bear the risk, i.e., R^l_{t+1} is state-contingent, CB loans are given through banks and all loans have the same seniority.

Note that our measure of effectiveness of the credit policy is related to how much it diminishes the impact of the negative capital quality shock on real variables. Hence, the focus on financial variable is to assess how these might affect the dynamics of real variables. For simplicity, we focus on only one variable, the aggregate capital, to measure the effectiveness of credit policy. This is, the larger the reduction of capital the smaller the effectiveness of the credit policy.

2.6.1 Credit Policy Effects

Figure 2.3 reports that (baseline) the credit policy, characterized by the exogenous rule, equation (2.55), reduces the effects of a negative capital quality shock. Since we have already discussed, in subsection 2.4.2, the effects of a negative capital quality shock, here we focus on how the credit policy reduces the negative effects of the shock. On the aggregate credit supply side, as explained before the fact that the required return on CB loans is smaller than on bank loans, and that CB loans cannot be diverted, the credit policy increases the aggregate supply of credit. Recall what happens on the aggregate demand credit side:

1. New cheap external funding reduces entrepreneurs' obligations and hence their default probability. This is because for a given K^j_t, entrepreneurs substitute bank loans with CB loans. A lower default probability decreases the costs of defaulting (total monitoring costs) which in turn pushes upward entrepreneurs' incentives to purchase capital and hence to demand credit.

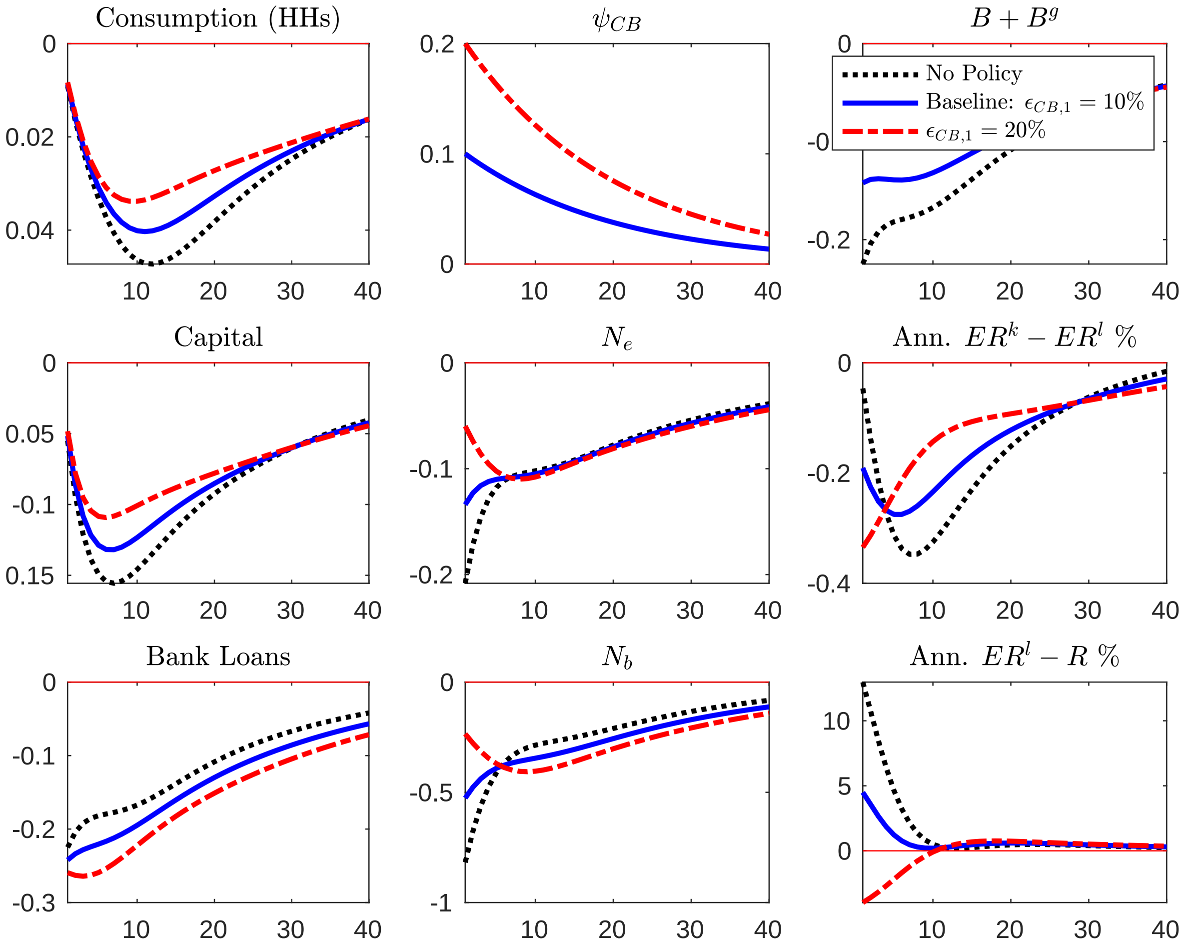
2. Government guarantees allow the central bank to extend CB loans with the (non-default) lending rate being the risk-free interest rate. This reduces the average (non-default) lending rate, which as before reduces further entrepreneur's default probability. As argued above, this increases also aggregate credit demand.

As a result, the effect of credit policy is not only that the entrepreneurs substitute expensive loans for cheap ones, but maybe more importantly, it reduces entrepreneur's default probability and creates incentives to purchases more capital and take more credit, and also it reduces the frictions on the credit supply and hence increases aggregate credit supply. In Appendix 2.E we assess the impact of the policy when there are only frictions on the credit demand side or credit supply side, respectively. In our baseline calibration we might say that the credit policy is more effective on reducing credit supply frictions than credit demand frictions. However, as we will see latter this is not necessarily true if we target a higher entrepreneur's default probability, i.e., if there is a higher uncertainty in the economy.

Quantitatively, Figure 2.3 shows that a persistent exogenous credit policy of 10% over total aggregate credit, diminished the reduction of capital in 200 basis points. This is essentially driven by a smaller reduction on aggregate credit of around 300 basis points. Note that bank loans decreases now more because these are being substituted with CB loans. However, the magnitude of this additional reduction is smaller than the increase of CB loans. This in turn drives the higher aggregate credit in equilibrium.

In addition, Figure 2.3 shows that if we double the intensity of credit policy, i.e. we double the CB loans participation from $\epsilon = 10\%$ to $\epsilon = 20\%$, we observe that the credit policy diminishes much more the negative effects of the negative capital quality shock. For example, with an initial CB loans participation of 10%, the relative maximum fall in capital is reduced by 200 basis points, whereas with a CB loans participation of 20%, this is reduced by 400 basis points.

Figure 2.3: A five percent negative capital quality shock: Baseline



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

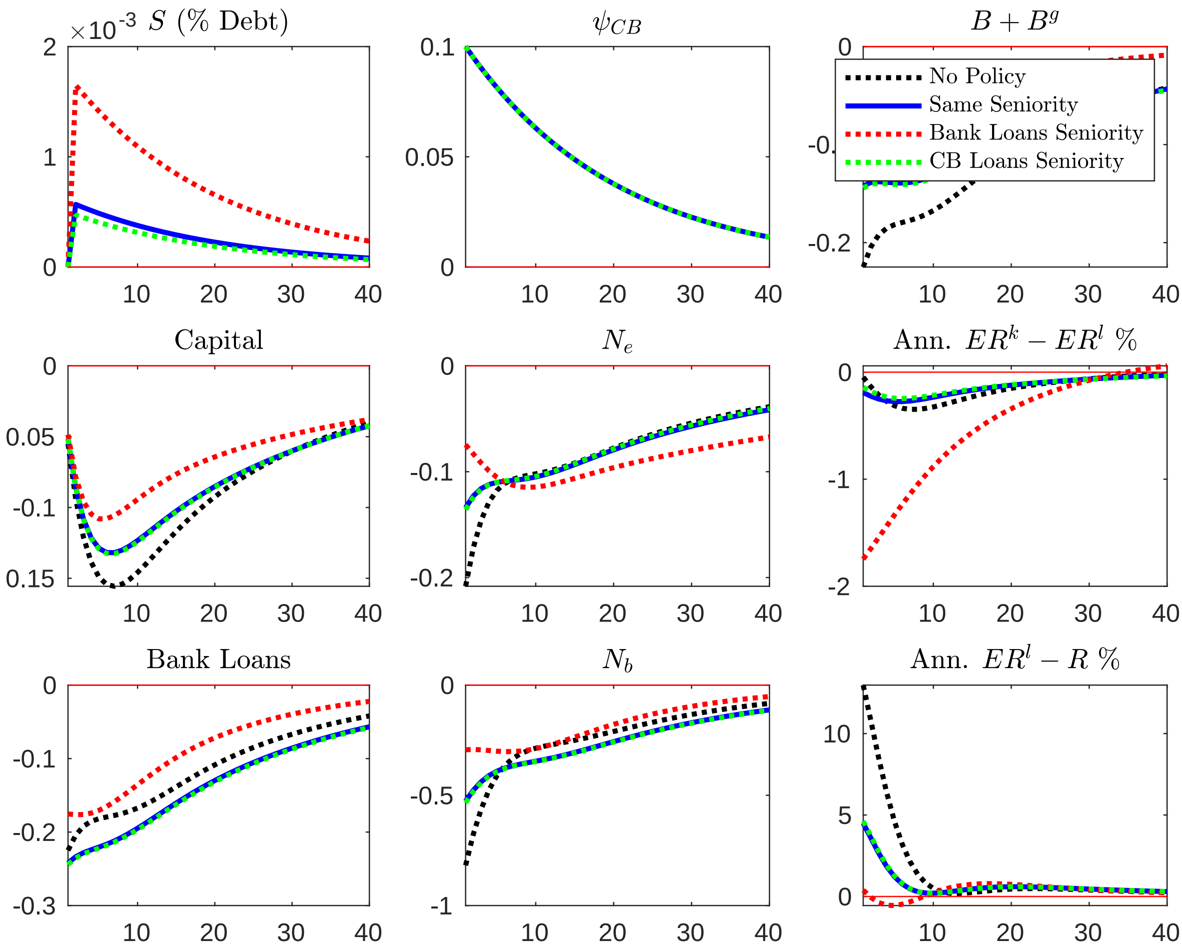
2.6.2 Seniority

We assess the effects of different seniority assumptions. To do so we consider the case of a state-contingent R^l_{t+1} and the exogenous credit policy rule, in equation (2.55).

Figure 2.4 suggests, by observing aggregate capital, that compared to the baseline case (same seniority), when bank loans have higher seniority, the impact of the credit policy is stronger. As discussed in subsection 2.5.3 this is because when bank loans have higher seniority it leads to lower default probability on bank loans, which in turn reduces the (non-default) lending rate, Z^j_{t+1}, and hence the entrepreneur's default probability. This reduces expected monitoring costs and hence pushes up entrepreneurs' incentives to purchase capital and hence expands the effectiveness of the credit policy.

However, when CB loans have higher seniority, the impact of the credit policy is similar to the same seniority case. This is because we assume the monitoring costs are paid by the government. So, on the one hand, due to higher central bank loans seniority, CB loans are paid first and it leaves less resources for bank loans, but on the other hand, more monitoring costs are being paid by the government as more entrepreneur's profits pay CB loans.[28]

Figure 2.4: A five percent negative capital quality shock: Different seniority assumptions



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

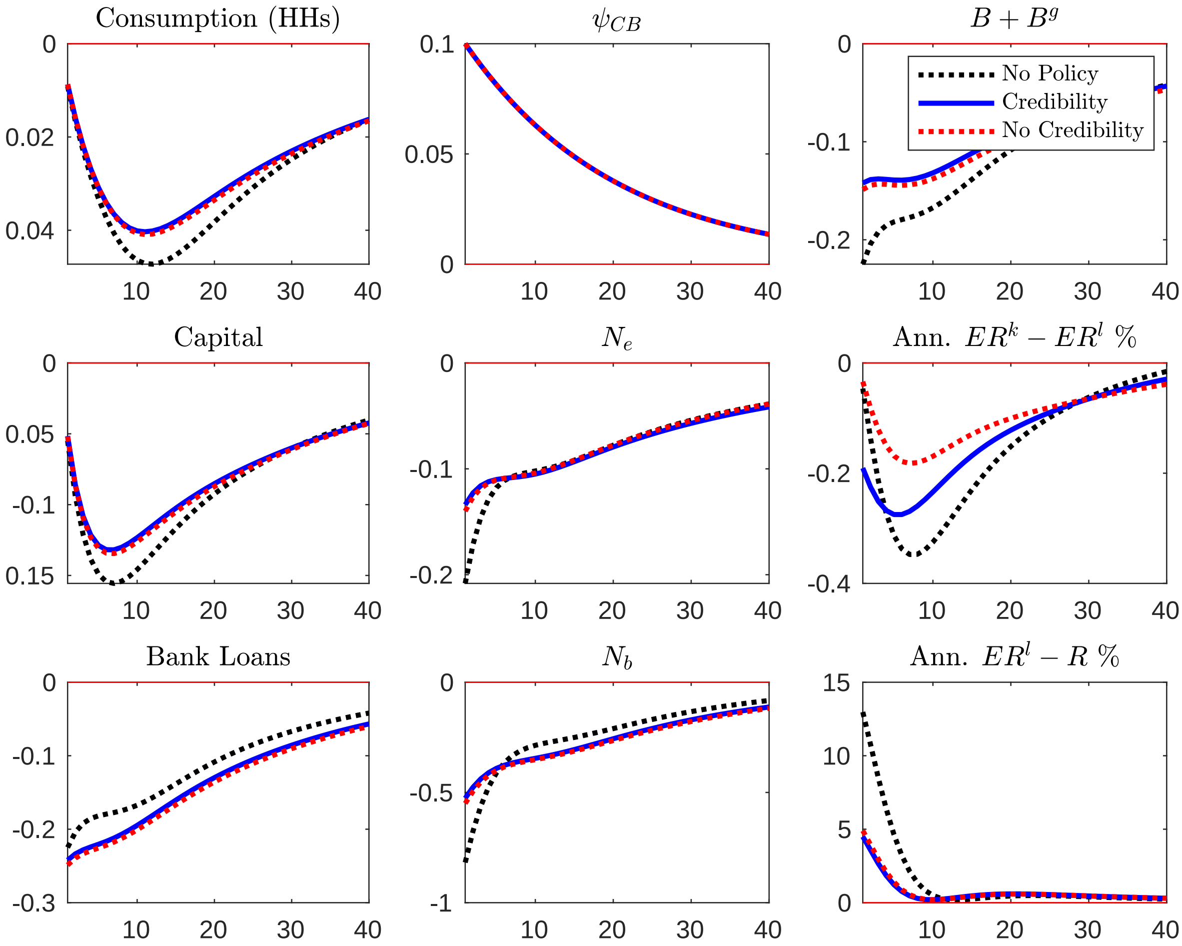
2.6.3 No Government Credibility

According to Figure 2.5, by observing aggregate capital, and with respect to the baseline calibration, no government credibility does not diminish significantly the effectiveness of the credit policy. In other words, in the baseline calibration, with state-contingent R^l_{t+1}, government guarantees do not seem to be crucial on reducing the impact of the shock. This could be because entrepreneurs are not absorbing too much risk since R^l_{t+1} is state-contingent and hence S_{t+1} is not very affected. However, according to Figure 2.14, in Appendix 2.I, where R^l_{t+1} is not state-contingent, this is not the main explanation and hence government guarantees do not seem so relevant. Hence, in the baseline calibration what essentially explain the reduction on the impact of the shock is the fact that central bank loans reduces aggregate credit supply frictions. In particular, CB loans cannot be diverted by bankers and/or the fact

[28]These arguments also hold for the case of non-state-contingent R^l_{t+1} see Figure 2.13 in Appendix 2.I.

that the required return on CB loans is smaller that the required return on bank loans. Hence, in a model with only credit demand frictions, the effect of the credit policy is very low, as suggested in Figure 2.15, in Appendix 2.I, under our baseline calibration. Notice also that in the case the credibility disappears completely, the impact of the credit policy is null, as suggested in subsection 2.5.2.

Figure 2.5: A five percent negative capital quality shock: Credibility during normal times



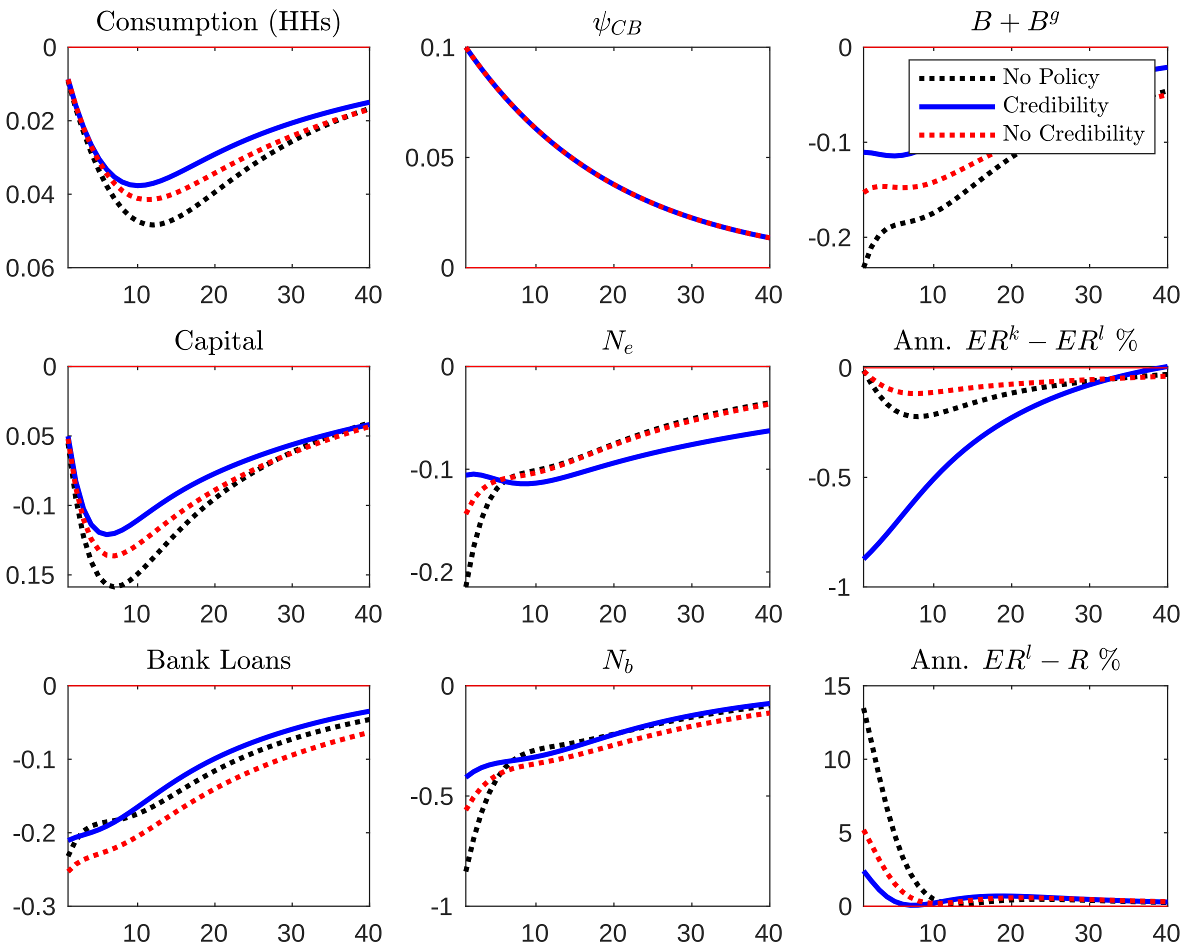
Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.6 shows the case when our target for the annualized the entrepreneur's default probability is 20% and keep the other targets unchanged.[29] It means that in the long-term a larger fraction of entrepreneurs is going to default. In this context of a lot of uncertainty, the effect of credibility seems relatively more significant. In other words, the impact of government guarantees is more significant, and then government subsidies or transfers becomes larger.[30]

[29]This results in $\gamma = 0.983$ (0.982), $\mu = 0.0533$ (0.286) and $\sigma_\omega = 0.3689$ (0.286). Baseline calibration in parenthesis.

[30]Figure 2.16 shows the results for the non-state-contingent R^l_{t+1}.

Figure 2.6: A five percent negative capital quality shock: Credibility during uncertain times



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

2.6.4 Endogenous Credit Policy Rule

In this section, we consider the endogenous credit policy rule, described in equation (2.56), and we study the effective design of an automatic rule. As we will see, a wrong endogenous rule might exacerbate the impact of the negative capital quality shock in the economy.

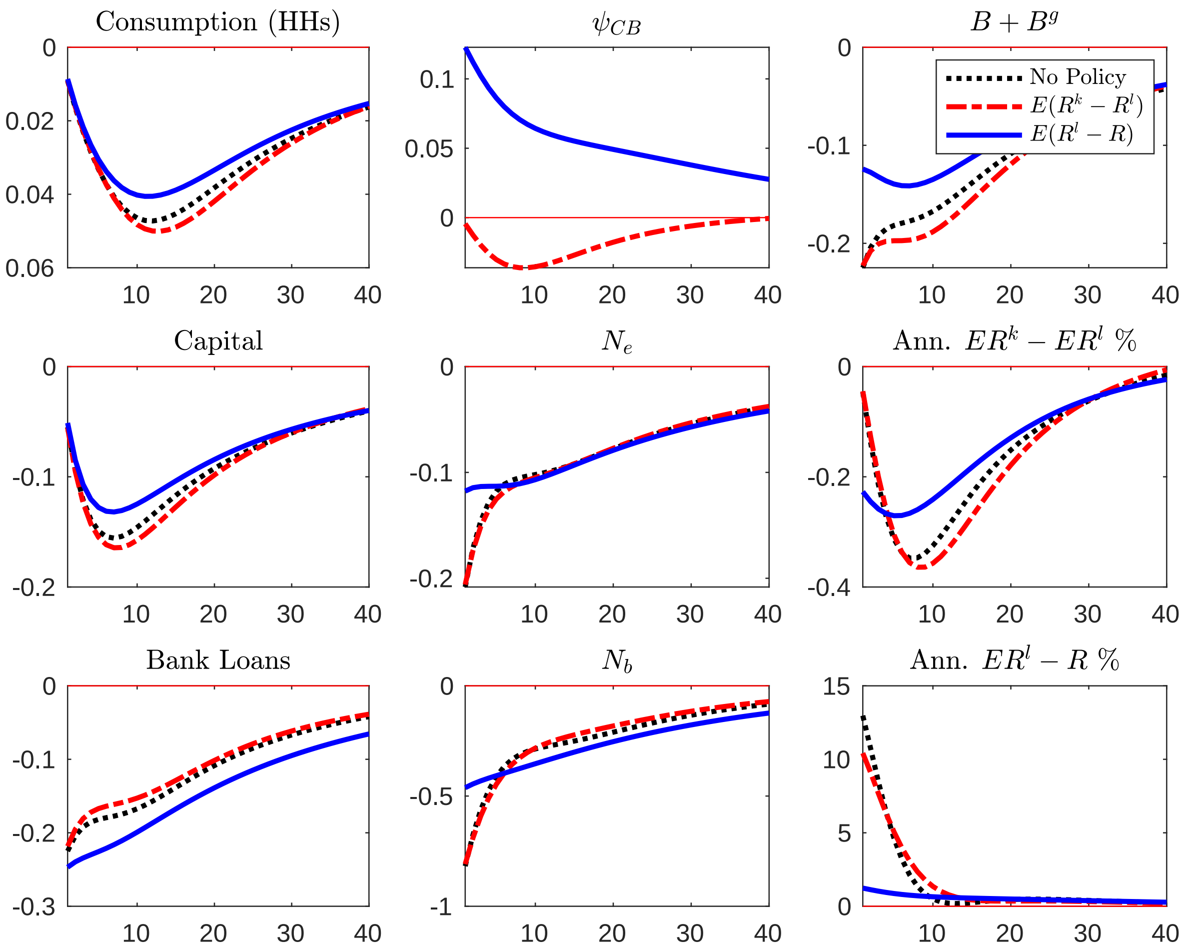
Figure 2.7 reports (assuming same seniority) the results for two different rules. In the first rule, credit injection responds on credit supply frictions (or credit supply conditions), i.e., $\mathbb{E}_t\{R^l_{t+1} - R_t\}$ while in the second rule, it responds on credit spread (or credit demand conditions), i.e., $\mathbb{E}_t\{R^k_{t+1} - R^l_{t+1}\}$.

With state-contingent R^l_{t+1} Figure 2.7 shows that, as explained in subsection 2.4.2, the negative capital quality shock reduces capital level and increases the credit spread, $E(R^l - R)$, and decreases $E(R^k - R^l)$. Then, as observed in Figure (2.7) a credit policy rule that positively responds to the credit spread $E(R^l - R)$ injects positive cheap guaranteed CB loans and hence reduces the impact of the shock. While a credit policy rule that positively responds to the problems of the credit demand side is going to inject negative CB loans, or equivalently CB requires entrepreneurs to hold deposits at the CB, and if anything it reduces entrepreneur resources to purchases capital.[31] Hence, we observe how this policy

[31]Notice that banks might not have the incentives to male CB deposits. Hence, we assume that entrepreneurs

rule reduces aggregate capital and exacerbates the shock in the economy.

Figure 2.7: A five percent negative capital quality shock: Endogenous credit rules



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

For completeness, Figure 2.17 in Appendix 2.I reports the case of non-state-contingent R^l_{t+1} and verifies that in that case a policy rule that responds to the credit demand frictions, i.e., $\mathbb{E}_t\{R^k_{t+1} - R^l_{t+1}\}$, is better in mitigating the negative impact of the capital quality shock since the aggregate risk is all absorbed by the entrepreneurs and consequently, as also commented in subsection 2.4.2, the $\mathbb{E}_t\{R^k_{t+1} - R^l_{t+1}\}$ rise is greater than the credit spread.

These results show that, as a policy recommendation, a credit policy should not be designed as a fixed automatic rule, but it should be flexible enough so it can properly detect the source of frictions in financial markets and hence responds accordingly. In other words, credit policy effectiveness depends on regulators ability to promptly detect the source and the size of the economic deterioration. In other words, credit policy effectiveness depends on regulators ability to identify if the shock is deteriorating credit demand or credit supply conditions.

do so otherwise they are charged a high penalty.

2.6.5 Announced Credit Policy Rule

We assume here that the central bank announces ex-ante the credit policy rule, equation (2.35). Hence, being aware of the injection rule, entrepreneur internalizes the effects of their decisions on the size of the credit policy injection, $B_t^{g,j}$. This is, entrepreneur internalizes that the cost of capital is a weighted average of the required return on bank loans and the effective cost of central bank loans, i.e., ex-ante the entrepreneur knows that for each unit of external funding a fraction $\phi_{CB,t}$ is funded with CB loans, while a fraction $1 - \phi_{CB,t}$ is funded with bank loans. The key question is to know if the credit policy becomes more effective.

Under the same seniority assumption, substituting the expression for amount fo CB loan, equation (2.35), into the bank loan contract of entrepreneur j, equation (2.40), it becomes,

$$\left[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right] R_{t+1}^k Q_t K_t^j = \bar{R}_{t+1}^l \left(Q_t K_t^j - N_t^j\right). \tag{2.57}$$

where $\bar{R}_{t+1}^l = R_{t+1}^l(1-\psi_{CB,t}) + \Psi(\bar{\omega}^j) R_t \psi_{CB,t}$ is the weighted average of the required return on bank loans, R_{t+1}^l, and the effective cost of CB loans $\Psi(\bar{\omega}^j)R_t$, were recall $\Psi(\bar{\omega}^j) < 1$.

With an announced credit policy rule as equation (2.35) from entrepreneur's perspective there are not two loan supply curves, but there is only one aggregate supply curve. In other words, entrepreneur is not going to exhaust first CB loans and then bank loans, but demand both simultaneously. This is, each unit of demanded external funding is composed by $\psi_{CB,t}$ units of CB loans and $1 - \psi_{CB,t}$ of bank loans. And the cost per unit of external funding at the margin is $\bar{R}_{t+1}^l$. Then, an announced credit policy rule has an effect on the aggregate credit supply curve, that together with the aggregate credit demand curve determines the aggregate credit in equilibrium.

Bank profits of entrepreneur, equation (2.45), becomes,

$$\mathbb{E}_t \left\{ \left[1 - \mu G(\bar{\omega}^j\right] R_{t+1}^k Q_t K_{t+1}^j - \bar{R}_{t+1}^l (Q_t K_t^j - N_t^j) \right\}.$$

Since $\bar{R}_{t+1}^l < R_{t+1}^l$ we see that an announced credit policy rule reduces the marginal cost of capital and hence of credit. The aggregate demand curve of credit, equation (2.43), becomes,[32]

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R_{t+1}^k + \frac{1 - F(\bar{\omega}^j)}{\Upsilon + 1 - F(\bar{\omega}^j) - \mu \bar{\omega}^j f(\bar{\omega}^j)} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R_{t+1}^k - \bar{R}_{t+1}^l \right] \right\} = 0.$$

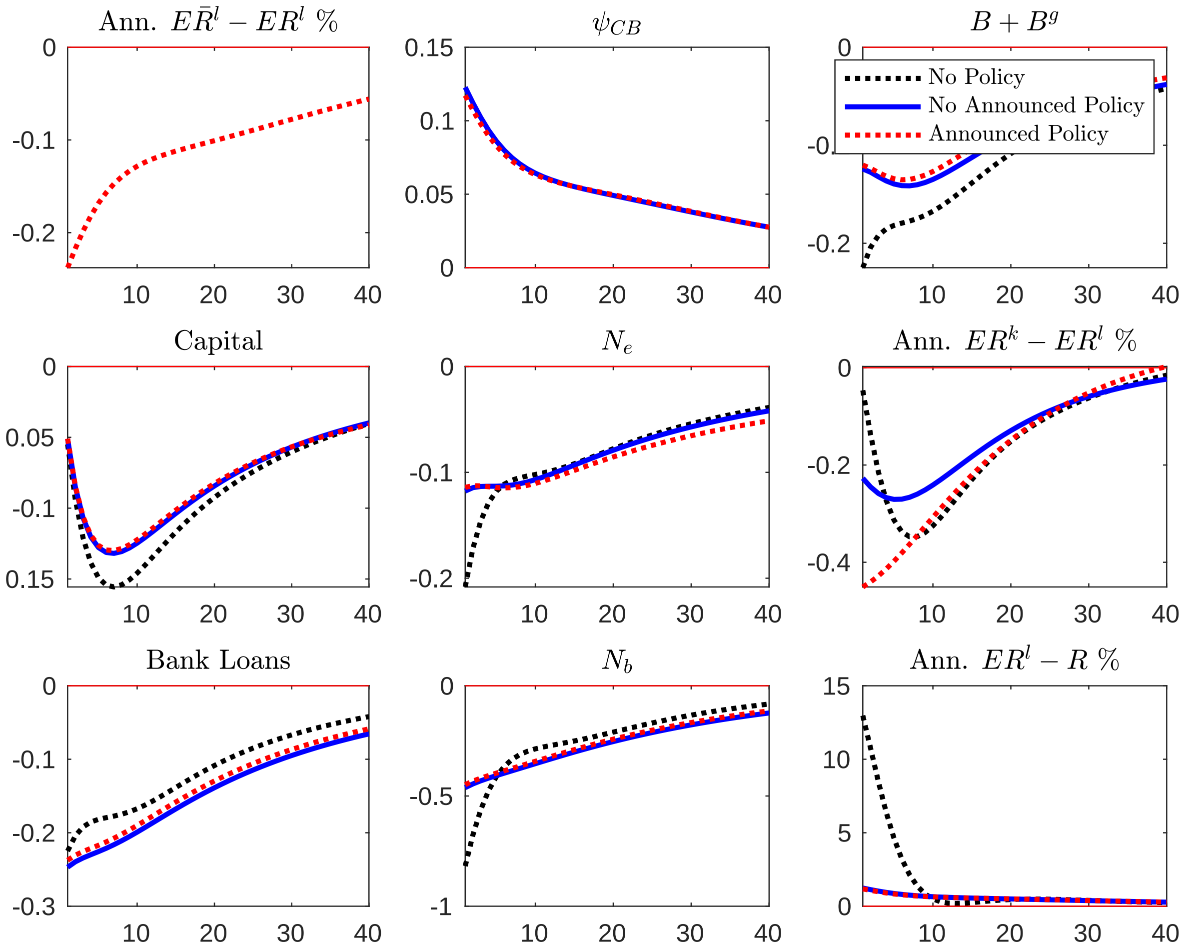
Contrasting it with equation (2.43), the announcement of the credit policy does not affect the aggregate demand of external funding (credit), but it positively affects the aggregate supply of credit by reducing the marginal cost of credit faced by entrepreneurs from R_{t+1}^l to $\bar{R}_{t+1}^l$.

Figure 2.8 reports that visually announcing a credit policy rule improves but not significantly effectiveness of the credit policy. In other words, letting the entrepreneurs to internalize the effects of their decisions on the central bank lending facilities does not significantly increase the effectiveness of the credit policy.

Figure 2.18 in Appendix 2.18 reports the results for a higher intensity of the central bank intervention. This is we set $\nu = 320$ (40 in baseline calibration). Since the proportion of cheap loans is now higher, this leads to a stronger reduction of the cost of a unit of external funding, $\bar{R}_{t+1}^l$, which in turns produces a more stronger recovery of capital. However, although we have a stronger central bank credit policy, the announcement does not significantly improve the recovery of capital and hence the announcement does not still improve significantly the effectiveness of the credit policy. The small power of ex-ante announcing the policy is because the spread between the required lending rate $E_t\{R_{t+1}^l\}$ and the risk-free interest rate is only 0.25%.

[32] Proof in Appendix 2.B.

Figure 2.8: A five percent negative capital quality shock: Ex-ante announcements



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

2.6.6 Unconventional vs. Conventional Credit Policy

So far we have discussed what we have defined as unconventional credit policy (see Section 2.5). In the case of a conventional credit policy as the one proposed in GKa 2011, there are two different assumptions that depart from the unconventional credit policy: 1) the required return on the central bank loans is the market lending rate R^l_{t+1} and 2) central bank loans are not guarantee by the government. Here, we study the qualitative and quantitative differences between unconventional and conventional credit policies. Recall that we already know the implications of 2), the government guarantees on CB loans.

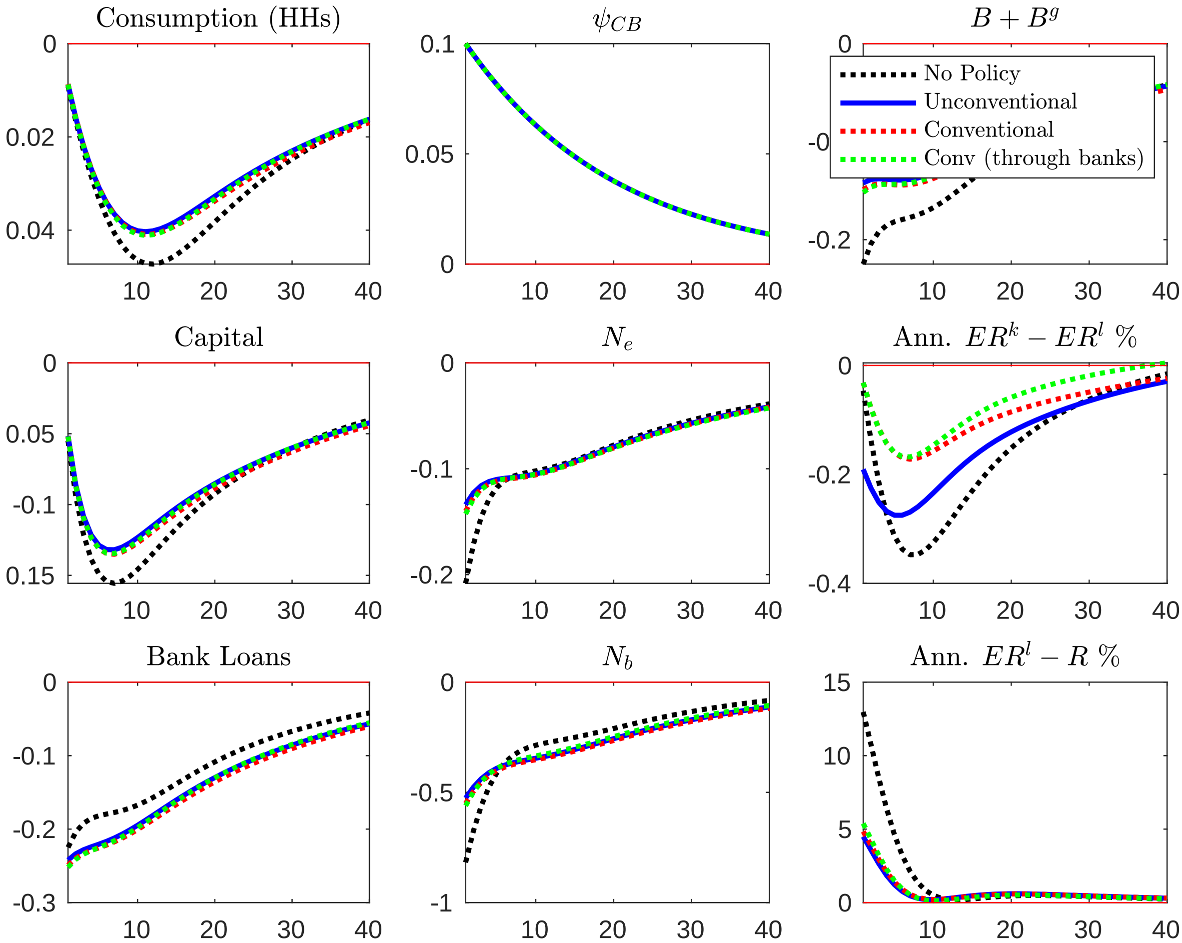
Let start assuming that CB loans are directly given by central bank. In the case of a conventional credit policy, as proved in Appendix 2.H, given CB loans and bank loans are identical from the entrepreneurs' perspective, the aggregate credit demand is not altered by the conventional credit policy.[33] Even though the required return on CB loans is the same as on bank loans, the fact that CB loans cannot be diverted increases the aggregate credit supply. In other words, because there is no moral hazard problem between depositors and the central bank, it reduces the extent of credit supply frictions. Indeed, this

[33]It is easy to verify that this holds for any seniority assumption.

is the only transmission of the conventional policy on the credit market. Figures 2.9 (state-contingent R^l_{t+1}) and 2.10 (non-state-contingent R^l_{t+1}) reports that the real effects (effects on aggregate capital) of the conventional credit policy are quantitatively similar to the unconventional credit policy. It suggests that neither the government guarantees nor the fact that CB loans have a required return lower than bank loans have an important effect on reducing the impact of the shock. Hence, the effectiveness of the unconventional credit policy is driven by the fact that credit policy reduces the credit supply frictions since CB loans cannot be diverted. As suggested in subsection 2.6.3 in an economy with a higher entrepreneur's default probability, the government guarantees become more important and hence the impact of unconventional credit policy becomes stronger that a conventional one.

Let assume that CB loans are given through banks and that for comparison reasons (with the unconventional credit policy) we say that banks cannot divert CB loans and hence clearly credit policy is going to affect aggregate credit supply. The main difference between the conventional policy given directly and indirectly by CB is that in the latter the gains or losses are absorbed by banks' net worth.[34] Figures 2.9 and 2.10 report that the impact of banks absorbing gains or losses from CB loans is negligible.

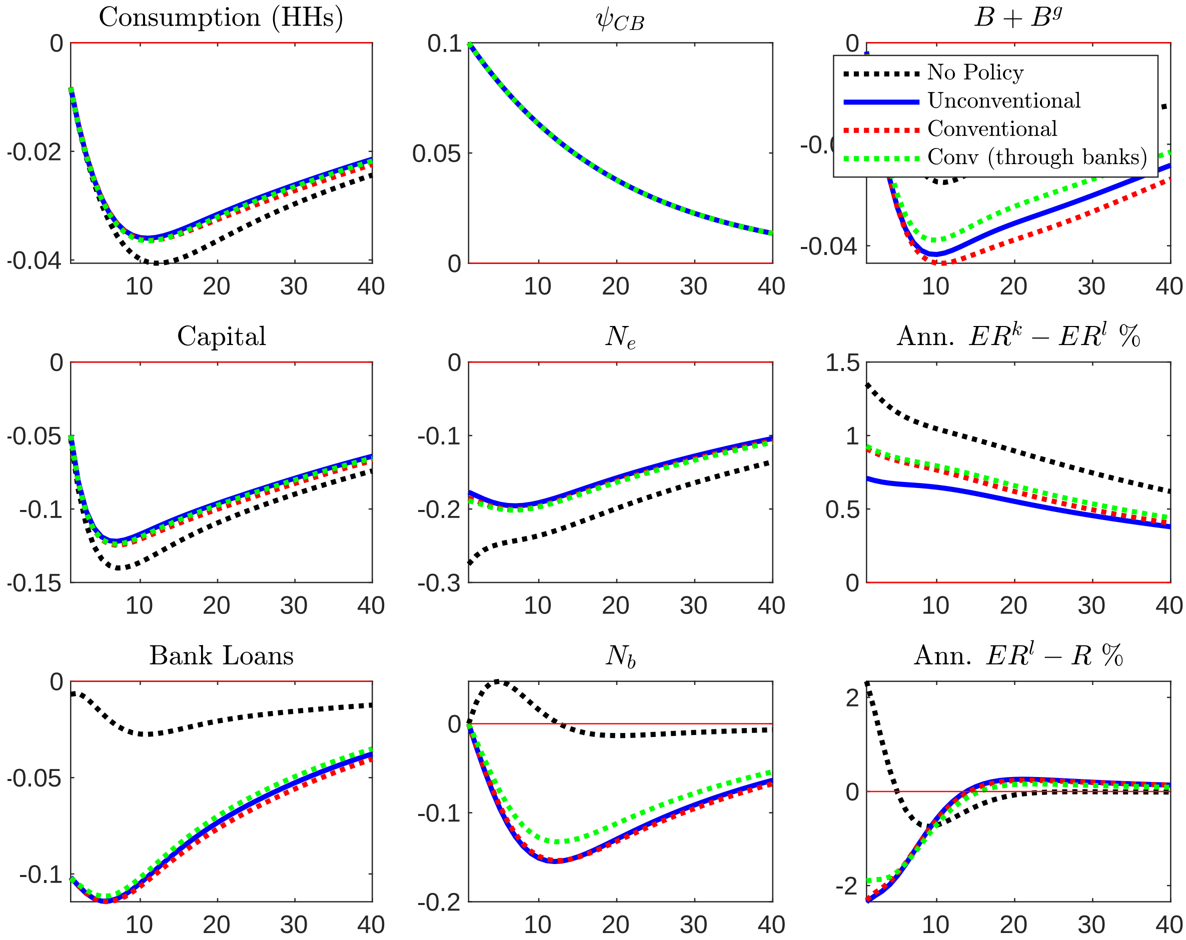
Figure 2.9: A five percent negative capital quality shock: Conventional vs unconventional credit policy - State-Contingent R^l_{t+1}



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

[34]Appendix 2.H reports how the equilibrium conditions of banks are affected.

Figure 2.10: A five percent negative capital quality shock: Conventional vs unconventional credit policy - No-State-Contingent R^l_{t+1}



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

2.7 Conclusions

We develop a DSGE model with frictions on the credit demand side and credit supply side. The presence of credit supply frictions allows us to obtain a more realistic dynamics of credit after a monetary policy shock. In particular, by letting banks to absorb a part of aggregate risk, bank lending capacity is constrained by their leverage position. As a result, aggregate credit falls after a contractionary monetary policy. On the contrary, when considering only demand side frictions we observe a puzzle: a contractionary monetary policy expands credit. Thus, having supply credit frictions will suffice to study credibly dynamics of credit after a monetary policy shock. Credit demand frictions, on the other hand, are required to better understand the various mechanisms underlying the implementation of credit policies. Credit demand frictions allow us to characterized how banks' assessment of profitable lending change in response to the riskiness of entrepreneurs. Also, firms' loan demand is constrained by their leverage, and influenced by the bank's monitoring costs that is reflected into the cost of credit.

Thus, with this more realistic framework we are able to address the question about the role of an "unconventional" credit policy that provides lending facilities to firms, at the cost of the risk-free rate and are guaranteed by the government.

We find that the unconventional credit policy diminishes the impact of a negative shock on the real economy since it increases both credit demand and credit supply: i) as central bank loans cannot be diverted, credit policy diminishes the bank equity requirement per unit of aggregate credit, which increases aggregate credit supply; ii) entrepreneurs face a limited supply of cheap CB loans, in the sense that CB loans have a required return smaller than traditional bank loans; and iii) CB loans are guaranteed by the government. In other words, unconventional credit policies reduces frictions on both sides of the credit market: demand and supply frictions. However, we find that the impact of this policy is different across states of the world. In normal times, the positive effects on credit supply are more relevant; however, in higher uncertainty periods, the government guarantees become also an important driver on reducing the impact of the negative shock.

Also, the rank seniority of loans is important for the effectiveness of the credit policy. In general, we find that the lower the seniority of the central bank loans, the higher the effectiveness of the credit policy. Since bank loans are paid first, banks can reduce the (non-default) lending rate, which pushes default probability down and increases credit demand.

Further, the credibility of the government guarantees matters for effectiveness of the credit policy to diminish credit demand frictions. Following the implementation of a credit policy, the interest rate paid by firms on bank loans offers an indicator of the credibility of the government guarantees and the effectiveness of central bank credit policy.

In addition, governments should be aware of automatic credit policy rules. This is, the rule should be flexible enough to respond appropriately to indicators that capture the source and magnitude of economic deterioration. Finally, ex-ante announcements to entrepreneurs about the credit rule might in turn reduce the marginal cost of external funding a bit more, but does not lead to significant benefits when credit spread is small.

2.8 Appendices

2.A Long-term Equilibrium: Deterministic Steady-State

In the deterministic steady state (SS) equilibrium $P_{ss} = P^*_{ss}$, then $X_{ss} = \frac{\epsilon}{\epsilon-1}$. From the intertemporal condition of households, $R_{ss} = 1/\beta$, and the first order condition form capital producing firms $Q_{ss} = 1$. The nominal interest rate $i_{ss} = 1/\beta$. Inflation $\pi_{ss} = 0$. The marginal utility of consumption at the steady state is $u_{Css} = (1 - \beta h)/(C_{ss}(1 - h))$. From the capital and labor markets,

$$R^k_{ss} = \frac{\alpha Y_{ss}}{K_{ss}} + (1 - \delta), \qquad Y_{ss} = K^{\alpha}_{ss} H^{(1-\alpha)\Omega}_{ss},$$

$$\frac{1}{X_{ss}}(1 - \alpha)\Omega \frac{Y_{ss}}{H_{ss}} = \frac{1}{u_{Css}} \chi H^{\varphi}_{ss},$$

From the banks side equilibrium conditions:

$$1 = \sigma \left[(R^l_{ss} - R_{ss})\phi_{ss} + R_{ss} \right] 1 + \zeta \phi_{ss},$$

$$\phi_{ss} = \frac{\eta_{ss}}{\lambda - \nu_{ss}},$$

$$\nu_{ss} = \frac{1}{1 - \beta\sigma x_{ss}}(1 - \sigma)\beta(R^l_{ss} - R_{ss}),$$

$$\eta_{ss} = \frac{1}{1 - \beta\sigma z_{ss}}(1 - \sigma),$$

$$z_{ss} = (R^l_{ss} - R_{ss})\phi_{ss} + R_{ss},$$

$$x_{ss} = z_{ss},$$

$$B_{ss} = D_{ss} + N_{bss}.$$

$$B_{ss} = \phi_{ss} N_{bss}.$$

From entrepreneurs side equilibrium conditions:

$$(1 - \Gamma(\bar{\omega}_{ss}))\, R^k_{ss} + \frac{1 - F(\bar{\omega}_{ss})}{1 - F(\bar{\omega}_{ss}) - \mu\bar{\omega}_{ss} f(\bar{\omega}_{ss})} \left[(\Gamma(\bar{\omega}_{ss}) - \mu G(\bar{\omega}_{ss}))\, R^k_{ss} - R^l_{ss} \right] = 0,$$

$$(\Gamma(\bar{\omega}_{ss}) - \mu G(\bar{\omega}_{ss}))\, R^k_{ss} K_{ss} = R^l_{ss} \left(K_{ss} - N_{ess} \right),$$

$$N_{ess} = \gamma V^e_{ss} + \frac{(1 - \alpha)(1 - \Omega)}{X_{ss}} K^{\alpha}_{ss} H^{(1-\alpha)\Omega}_{ss}.$$

$$V^e_{ss} = R^k_{ss} K_{ss} - \left(R^l_{ss} + \frac{\mu \int_0^{\bar{\omega}_{ss}} \omega dF(\omega) R^k_{ss} K_{ss}}{B_{ss}} \right) B_{ss},$$

$$K_{ss} = B_{ss} + N_{ess}, \quad C_{ess} = (1 - \gamma) V^e_{ss},$$

From market clearing of goods:

$$Y_{ss} = C_{ss} + C_{ess} + I_{ss} + \mu \int_0^{\bar{\omega}_{ss}} \omega dF(\omega) R^k_{ss} K_{ss}.$$

In the case of a state-contingent required return on bank loans, it also applies that,

$$R^l_{ss} = \xi_{ss} R^k_{ss}.$$

Procedure to find the parameter values: We first focus on the banking sector. In particular, we solve the system of equations of the first four equations from banks side. Our six variables that we want to know their values are ν_{ss} , η_{ss}, ζ and λ. In order to do so, we first set the parameter values for β and σ and set the targets $R^l_{ss} - R_{ss}$ (or R^l_{ss}) and ϕ_{ss} (and hence z_{ss} and x_{ss}). Then, with this information solve the rest of equations. Also we solve for the parameters γ, μ and σ_ω given the targets values for $R^k_{ss} - R^l_{ss}$, $F(\bar{\omega}_{ss})$ and ϕ_{ess}.

2.B Both central bank and bank loans have the same seniority

Recalling the bank loan contract, equation (2.39),

$$[1 - F(\bar{\omega}^j)]Z^j_{t+1}B^j_t + (1-\mu)\int_0^{\bar{\omega}^j} \omega R^k_{t+1}Q_tK^j_t x^j_{t+1} dF(\omega) = R^l_t B^j_t, \tag{2.58}$$

Recalling Z^j_{t+1} is obtained in equation (2.37). Then,

$$x^j_{t+1} = (\bar{\omega}^j R^k_{t+1}Q_tK^j_t - R_tB^{g,j}_t)/(\bar{\omega}^j R^k_{t+1}Q_tK^j_t) = 1 - \frac{R_tB^{g,j}_t}{\bar{\omega}^j R^k_{t+1}Q_tK^j_t}, \tag{2.59}$$

and so equation (2.58) becomes,

$$[1 - F(\bar{\omega}^j)](\bar{\omega}^j R^k_{t+1}Q_tK^j_t - R_tB^{g,j}_t) + (1-\mu)\int_0^{\bar{\omega}^j} \left(\omega R^k_{t+1}Q_tK^j_t - \frac{\omega}{\bar{\omega}^j}R_tB^{g,j}_t\right) dF(\omega) = R^l_{t+1}B^j_t.$$

For convenience, this is written as,

$$-\Psi(\bar{\omega}^j)R_tB^{g,j}_t + \left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1}Q_tK^j_t = R^l_{t+1}\left(Q_tK^j_t - B^{g,j}_t - N^j_{et}\right), \tag{2.60}$$

where,

$$\Gamma(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega) + (1 - F(\bar{\omega}^j))\bar{\omega}^j, \qquad G(\bar{\omega}^j) = \int_0^{\bar{\omega}^j} \omega dF(\omega).$$

$$\Psi(\bar{\omega}^j) = (1-\mu)\frac{1}{\bar{\omega}^j}G(\bar{\omega}^j) + (1 - F(\bar{\omega}^j)).$$

The optimal contracting problem may be now written as:

$$\max_{K^j_t,\bar{\omega}^j} \mathbb{E}_t\{\left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1}Q_tK^j_t$$
$$+\lambda_{t+1}\left[-\Psi(\bar{\omega}^j)R_tB^{g,j}_t + \left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1}Q_tK^j_t - R^l_{t+1}B^j_t\right]\},$$

where $B^j_t = Q_tK^j_t - B^{g,j}_t - N^j_{et}$. The first order condition for $\bar{\omega}^j$:

$$-\frac{\partial\Gamma(\bar{\omega}^j)}{\partial\bar{\omega}^j}R^k_{t+1}Q_tK^j_t + \lambda_{t+1}\left[-\frac{\partial\Psi(\bar{\omega}^j)}{\partial\bar{\omega}^j}R_tB^{g,j}_t + \left(\frac{\partial\Gamma(\bar{\omega}^j)}{\partial\bar{\omega}^j} - \mu\frac{G(\bar{\omega}^j)}{\partial\bar{\omega}^j}\right) R^k_{t+1}Q_tK^j_t\right] = 0. \tag{2.61}$$

The first order condition for K^j_t:

$$\mathbb{E}_t\left\{\left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \lambda_{t+1}\left[(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j))R^k_{t+1} - R^l_{t+1}\right]\right\} = 0. \tag{2.62}$$

The first order condition for λ_{t+1} yields equation (2.60), where,

$$\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^j), \quad \frac{\partial G(\bar{\omega}^j)}{\partial \bar{\omega}^j} = \bar{\omega}^j f(\bar{\omega}^j).$$

$$\frac{\partial \Psi(\bar{\omega}^j)}{\partial \bar{\omega}^j} = (1-\mu)\left(-\frac{G(\bar{\omega}^j)}{(\bar{\omega}^j)^2} + \frac{1}{\bar{\omega}^j}\frac{\partial G(\bar{\omega}^j)}{\partial \bar{\omega}^j}\right) - f(\bar{\omega}^j) = -(1-\mu)\frac{G(\bar{\omega}^j)}{(\bar{\omega}^j)^2} - \mu f(\bar{\omega}^j) < 0.$$

Combining equations (2.61) with (2.62) yields,

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \frac{1 - F(\bar{\omega}^j)}{\Upsilon + 1 - F(\bar{\omega}^j) - \mu \bar{\omega}^j f(\bar{\omega}^j)} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} - R^l_{t+1} \right] \right\} = 0.$$

where,

$$\Upsilon = -\frac{\partial \Psi(\bar{\omega}^j)}{\partial \bar{\omega}^j} \frac{R_t B^{g,j}_t}{R^k_{t+1} Q_t K^j_t} > 0.$$

The amount transferred back to the central bank from entrepreneur is,

$$M_{t+1} = [1 - F(\bar{\omega}^j)] R_t B^{g,j}_t + (1-\mu) \int_0^{\bar{\omega}^j} \omega R^k_{t+1} Q_t K^j_t (1 - x^j_{t+1}) dF(\omega).$$

Using (2.59), we obtain,

$$M_{t+1} = [1 - F(\bar{\omega}^j)] R_t B^{g,j}_t + (1-\mu) \int_0^{\bar{\omega}^j} \frac{\omega}{\bar{\omega}^j} R_t B^{g,j}_t dF(\omega).$$

$$M_{t+1} = \left([1 - F(\bar{\omega}^j)] + (1-\mu) \frac{G(\bar{\omega}^j)}{\bar{\omega}^j} \right) R_t B^{g,j}_t.$$

By construction, the entrepreneurs' revenues used to repay central bank loans (M_{t+1}) are not enough to fully repay central bank loans, and hence government collect lump sum taxes to ensure central bank loans are fully paid. In other words, It holds that $M_{t+1} < R_{t+1} B^g_t$. This implies that the government transfers $R_{t+1} B_{t+1} - M_{t+1}$ to central bank.

Announced Policy:

Here, we solve the model assuming that entrepreneur knows that $B^j_t = \psi_{CB,t}(Q_t K^j_t - N^j_t)$. Recall that the bank loan contract, equation (2.57), is

$$\left[\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right] R^k_{t+1} Q_t K^j_t = \bar{R}^l_{t+1} \left(Q_t K^j_t - N^j_{et} \right). \tag{2.63}$$

where $\bar{R}^l_{t+1} = R^l_{t+1}(1 - \psi_{CB,t}) + \Psi(\bar{\omega}^j) R_t \psi_{CB,t}$. The optimal contracting problem may be now written as:

$$\max_{K^j_t, \bar{\omega}^j} \mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t + \lambda_{t+1} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t - \bar{R}^l_{t+1}(Q^j_t K^j_t - N^j_{et}) \right] \right\}.$$

The first order condition for $\bar{\omega}^j$:

$$-\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} R^k_{t+1} Q_t K^j_t + \lambda_{t+1} \left[\left(\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} - \mu \frac{G(\bar{\omega}^j)}{\partial \bar{\omega}^j} \right) R^k_{t+1} Q_t K^j_t - \frac{\partial \bar{R}^l_{t+1}}{\partial \bar{\omega}^j} (Q^j_t K^j_t - N^j_{et}) \right] = 0. \tag{2.64}$$

The first order condition for K^j_t:

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \lambda_{t+1} \left[(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)) R^k_{t+1} - \bar{R}^l_{t+1} \right] \right\} = 0. \tag{2.65}$$

The first order condition for λ_{t+1} yields equation (2.63), where,

$$\frac{\partial \bar{R}^l_{t+1}}{\partial \bar{\omega}^j} = \frac{\partial \Psi(\bar{\omega}^j)}{\partial \bar{\omega}^j} R_t \psi_{CB,t}.$$

Combining equations (2.64) with (2.65) yields,

$$\mathbb{E}_t \left\{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \frac{1 - F(\bar{\omega}^j)}{\Upsilon + 1 - F(\bar{\omega}^j) - \mu \bar{\omega}^j f(\bar{\omega}^j)} \left[\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right) R^k_{t+1} - \bar{R}^l_{t+1} \right] \right\} = 0.$$

where,

$$\Upsilon = -\frac{\partial \Psi(\bar{\omega}^j)}{\partial \bar{\omega}^j} \frac{R_t B^{g,j}_t}{R^k_{t+1} Q_t K^j_t} > 0.$$

2.C Bank loans have higher seniority

When the two external funding of the entrepreneurs have not the same seniority, we can define another threshold value of the idiosyncratic shock, $\bar{\omega}^{g,j}$,

$$\bar{\omega}^{g,j} R^k_{t+1} Q_t K^j_t = Z^j_{t+1} B^j_t, \tag{2.66}$$

where clearly $\bar{\omega}^j > \bar{\omega}^{g,j}$, that is associated with the lowest value of ω^j so entrepreneurs can still fully pay the external funding with higher seniority. Hence, in this case, if $\bar{\omega}^j > \omega^j \geq \bar{\omega}^{g,j}$, entrepreneur is able to fully pay bank loans but cannot fully pay CB loans, so government must intervene to ensure CB fully receive the agreed gross return. If $\bar{\omega}^{g,j} > \omega^j$, entrepreneur is not able to pay anything to the central bank, while it partially pay to banks. In this case, the government will have to pay for the whole debt of firms to CB. By definition, a defaulting entrepreneur receives nothing.

The bank loan contract ($\bar{\omega}^j$, Z^j_{t+1}), equation (2.39), becomes,

$$[1 - F(\bar{\omega}^{g,j})] Z^j_{t+1} B^j_t + (1-\mu) \int_0^{\bar{\omega}^{g,j}} \omega R^k_{t+1} Q_t K^j_t dF(\omega) - \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} Z^j_{t+1} B^j_t dF(\omega) = R^l_{t+1} B^j_t, \tag{2.67}$$

where left-hand side of equation (2.67) is the expected return on the loan to the entrepreneur and the right-hand side is the opportunity cost of bank lending. Clearly, in equilibrium the bank lending rate, Z^j_{t+1}, is higher than R^l_{t+1}.

The amount transferred back to the central bank from entrepreneur is,

$$M_{t+1} = [1 - F(\bar{\omega}^j)] R_{t+1} B^{g,j}_t + (1-\mu) \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \left(\omega R^k_{t+1} Q_t K^j_t - Z^j_{t+1} B^j_t \right) dF(\omega).$$

It is true that $M^j_{t+1} < R_{t+1} B^{g,j}_t$. This implies that the government transfers $R_{t+1} B^j_{t+1} - M^j_{t+1}$ to the central bank are such it receives the agreed gross return of R_{t+1}.

Combining equations (2.36) and (**??**) with equation (2.67) we obtain,

$$\left([1 - F(\bar{\omega}^{g,j})] \bar{\omega}^{g,j} + (1-\mu) \int_0^{\bar{\omega}^{g,j}} \omega dF(\omega) - \mu (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j})) \bar{\omega}^{g,j} \right) R^k_{t+1} Q_t K^j_{t+1} = R^l_{t+1} B^j_t, \tag{2.68}$$

Note that $\bar{\omega}^j$ and $\bar{\omega}^{g,j}$ are contingent to the realization of R^k_{t+1}. Entrepreneurs aim to maximize (2.42). For convenience equation (2.68) is written as,

$$\left(\Gamma(\bar{\omega}^{g,j}) - \mu G(\bar{\omega}^{g,j}, \bar{\omega}^j) \right) R^k_{t+1} Q_t K^j_t = R^l_{t+1} B^j_t, \tag{2.69}$$

where,

$$\Gamma(\bar{\omega}^{g,j}) = \int_0^{\bar{\omega}^{g,j}} \omega dF(\omega) + (1 - F(\bar{\omega}^{g,j}))\bar{\omega}^{g,j},$$

$$G(\bar{\omega}^{g,j}, \bar{\omega}^j) = \int_0^{\bar{\omega}^{g,j}} \omega dF(\omega) + (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}))\bar{\omega}^{g,j}.$$

Combining (2.37) and (2.66), we obtain the following relationship or the expression for $\bar{\omega}^{g,j}$:

$$\bar{\omega}^j R^k_{t+1} Q_t K^j_t = \bar{\omega}^{g,j} R^k_{t+1} Q_t K^j_t + R_t B^{g,j}_t. \tag{2.70}$$

The optimal contracting problem may be now written as,

$$\max_{K^j_t, \bar{\omega}^j} \mathbb{E}_t\{\left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t + \lambda_{t+1} \left[\left(\Gamma(\bar{\omega}^{g,j}) - \mu G(\bar{\omega}^{g,j}, \bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t - R^l_{t+1} B^j_t\right]\},$$

where $\bar{\omega}^{g,j}(\bar{\omega}^j, K^j_t)$ is obtained from (2.70) and $B^j_t = Q_t K^j_t - B^{g,j}_t - N^j_{et}$. The first order condition for $\bar{\omega}^j$:

$$-\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} + \lambda_{t+1} \left(\frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial \bar{\omega}^j} - \mu \frac{G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} \right) = 0. \tag{2.71}$$

The first order condition for K^j_t:

$$\begin{aligned} &\mathbb{E}_t \{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \lambda_{t+1} [\left(\Gamma(\bar{\omega}^{g,j}) - \mu G(\bar{\omega}^{g,j}, \bar{\omega}^j)\right) R^k_{t+1} \\ + &\left(\frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial K^j_t} - \mu \frac{\partial G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K^j_t} \right) R^k_{t+1} K_t - R^l_{t+1}] \} = 0. \end{aligned} \tag{2.72}$$

The first order condition for λ_{t+1} yields equation (2.69), where,

$$\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^j), \qquad \frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial \bar{\omega}^{g,j}} = 1 - F(\bar{\omega}^{g,j}),$$

$$\frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial K^j_t} = \frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial \bar{\omega}^{g,j}} \frac{\partial \bar{\omega}^{g,j}}{\partial K^j_t} = (1 - F(\bar{\omega}^{g,j})) \frac{R_t}{R^k_{t+1} Q_t} \frac{B^g_t}{(K^j_t)^2}.$$

$$\frac{\partial G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^{g,j}} = F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}),$$

$$\frac{\partial G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K^j_t} = \frac{\partial G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^{g,j}} \frac{\partial \bar{\omega}^{g,j}}{\partial K^j_t} = (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j})) \frac{R_t}{R^k_{t+1} Q_t} \frac{B^g_t}{(K^j_t)^2}.$$

Since $\frac{\partial \bar{\omega}^{g,j}}{\partial \bar{\omega}^j} = 1$,

$$\frac{\partial \Gamma(\bar{\omega}^{g,j})}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^{g,j}),$$

$$\frac{\partial G(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} = f(\bar{\omega}^j)\bar{\omega}^{g,j} + F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}).$$

In this case V^e_t becomes,

$$\begin{aligned} V^e_t &= R^k_t Q_{t-1} K_{t-1} - R^l_t B_{t-1} - (1 - F(\bar{\omega})) R_{t-1} B^g_{t-1} - \int_{\bar{\omega}^g}^{\bar{\omega}} \left(\omega R^k_t Q_{t-1} K_{t-1} - Z_t B_{t-1}\right) dF(\omega) \\ &- \mu \int_0^{\bar{\omega}^g_t} \omega R^k_t Q_{t-1} K_{t-1} dF(\omega) - \mu \int_{\bar{\omega}^g_t}^{\bar{\omega}_t} Z_t B_{t-1} dF(\omega). \end{aligned}$$

where $(1 - F(\bar{\omega})) R_{t-1} B^g_{t-1} + \int_{\bar{\omega}^g}^{\bar{\omega}} \left(\omega R^k_t Q_{t-1} K_{t-1} - Z_t B_{t-1}\right) dF(\omega)$ are the resources taken from entrepreneur's profits that goes to repay central bank loans

2.D Central bank loans have higher seniority

When Central Bank loans have higher seniority, we redefine $\bar{\omega}^{g,j}$ as,

$$\bar{\omega}^{g,j} R^k_{t+1} Q_t K^j_t = R_t B^{g,j}_t. \tag{2.73}$$

If $\bar{\omega}^j > \omega \geq \bar{\omega}^{g,j}$, entrepreneur is able to fully payback central bank loans, while cannot fully pay bank loans, so government must intervene to ensure CB fully receive the agreed gross return. If $\bar{\omega}^{g,j} > \omega^j$, banks receive nothing from entrepreneurs and only pay partially to the Central Bank. In this case, the government will have to pay for the whole debt of firms to the central bank.

In this case the bank loan contract, equation (2.67), becomes,

$$[1 - F(\bar{\omega}^j)] Z^j_{t+1} B^j_t + (1-\mu) \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} (\omega R^k_{t+1} Q_t K^j_t - R_t B^{g,j}_t) dF(\omega) = R^l_{t+1} B^j_t, \tag{2.74}$$

Combining (2.37) and (2.73), yields,

$$(\bar{\omega}^j - \bar{\omega}^{g,j}) R^k_{t+1} Q_t K^j_t = Z^j_{t+1} B^j_t$$

Then, equation (2.74) yields,

$$\left([1 - F(\bar{\omega}^j)](\bar{\omega}^j - \bar{\omega}^{g,j}) + (1-\mu) \left(\int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \omega dF(\omega) - (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}))\bar{\omega}^{g,j} \right) \right) R^k_{t+1} Q_t K^j_t = R^l_{t+1} B^j_t.$$

For convenience this is written as,

$$\left(\Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j) - \mu G_b(\bar{\omega}^{g,j}, \bar{\omega}^j) \right) R^k_{t+1} Q_t K^j_t = R^l_{t+1} \left(Q_t K^j_t - B^{g,j}_t - N^j_{et} \right), \tag{2.75}$$

where,

$$\Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j) = \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \omega dF(\omega) + F(\bar{\omega}^{g,j})\bar{\omega}^{g,j} + (1 - F(\bar{\omega}^j))\bar{\omega}^j - \bar{\omega}^{g,j},$$

$$G_b(\bar{\omega}^{g,j}, \bar{\omega}^j) = \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \omega dF(\omega) - (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}))\bar{\omega}^{g,j}.$$

From (2.73), we obtain the expression for $\bar{\omega}^{g,j}$:

$$\bar{\omega}^{g,j} = R_t B^{g,j}_t / (R^k_{t+1} Q_t K^j_t). \tag{2.76}$$

Entrepreneurs aim to maximize equation (2.42), this time subject to equation (2.74). The optimal contracting problem may be now written as:

$$\max_{K_t, \bar{\omega}^j} \mathbb{E}_t \{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} Q_t K^j_t + \lambda_{t+1} \left[\left(\Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j) - \mu G_b(\bar{\omega}^{g,j}, \bar{\omega}^j) \right) R^k_{t+1} Q_t K^j_t - R^l_{t+1} B^j_t \right] \},$$

where $\bar{\omega}^{g,j}(K^j_t)$ is obtained from (2.76) and $B^j_t = Q_t K^j_t - B^{g,j}_t - N^j_{et}$. The first order condition for $\bar{\omega}^j$:

$$-\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} + \lambda_{t+1} \left(\frac{\partial \Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} - \mu \frac{G_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} \right) = 0.$$

The first order condition for K^j_t:

$$\begin{aligned} &\mathbb{E}_t \{ \left(1 - \Gamma(\bar{\omega}^j)\right) R^k_{t+1} + \lambda_{t+1} [\left(\Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j) - \mu G_b(\bar{\omega}^{g,j}, \bar{\omega}^j) \right) R^k_{t+1} \\ &+ \left(\frac{\partial \Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K^j_t} - \mu \frac{\partial G_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K^j_t} \right) R^k_{t+1} K^j_t - R^l_{t+1}] \} = 0. \end{aligned}$$

The first order condition for λ_{t+1} yields equation (2.75), where,

$$\frac{\partial \bar{\omega}^{g,j}}{\partial \bar{\omega}^j} = 0, \qquad \frac{\partial \bar{\omega}^{g,j}}{\partial K_t^j} = -R_t B_t^{g,j} / (R_{t+1}^k Q_t (K_t^j)^2).$$

$$\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^j),$$

$$\frac{\partial \Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} = \bar{\omega}^j f(\bar{\omega}^j) - F(\bar{\omega}^j)\bar{\omega}^j + (1 - F(\bar{\omega}^j)) = 1 - F(\bar{\omega}^j).$$

$$\frac{\partial G_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial \bar{\omega}^j} = \bar{\omega}^j f(\bar{\omega}^j) - \bar{\omega}^{g,j} f(\bar{\omega}^j) = f(\bar{\omega}^j)(\bar{\omega}^j - \bar{\omega}^{g,j})$$

$$\frac{\partial \Gamma_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K_t^j} = \left(-\bar{\omega}^{g,j} f(\bar{\omega}^{g,j}) + f(\bar{\omega}^{g,j})\bar{\omega}^{g,j} + F(\bar{\omega}^{g,j}) - 1\right) \frac{\partial \bar{\omega}^{g,j}}{\partial K_t^j} = (F(\bar{\omega}^{g,j}) - 1) \frac{\partial \bar{\omega}^{g,j}}{\partial K_t^j}$$

$$\frac{\partial G_b(\bar{\omega}^{g,j}, \bar{\omega}^j)}{\partial K_t^j} = \left[-\bar{\omega}^{g,j} f(\bar{\omega}^{g,j}) + f(\bar{\omega}^{g,j})\bar{\omega}^{g,j} - (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}))\right] \frac{\partial \bar{\omega}^{g,j}}{\partial K_t^j} = -(F(\bar{\omega}^j) - F(\bar{\omega}^{g,j})) \frac{\partial \bar{\omega}^{g,j}}{\partial K_t^j}$$

The amount transferred back to the central bank from entrepreneur is,

$$M_{t+1} = [1 - F(\bar{\omega}^{g,j})] R_t B_t^{g,j} + (1-\mu) \int_0^{\bar{\omega}^{g,j}} \omega R_{t+1}^k Q_t K_t^j dF(\omega) - \mu (F(\bar{\omega}^j) - F(\bar{\omega}^{g,j})) R_t B_t^{g,j}.$$

In this case V_t^e becomes,

$$\begin{aligned} V_t^e &= R_t^k Q_{t-1} K_{t-1} - R_t^l B_{t-1} - (1 - F(\bar{\omega}^g)) R_{t-1} B_{t-1}^g - \int_0^{\bar{\omega}^g} \omega R_t^k Q_{t-1} K_{t-1} dF(\omega) \\ &- \mu \int_{\bar{\omega}_t^g}^{\bar{\omega}_t} \left(\omega R_t^k Q_{t-1} K_{t-1} - R_t B_{t-1}^g \right) dF(\omega). \end{aligned}$$

where $(1 - F(\bar{\omega}^g)) R_{t-1} B_{t-1}^g + \int_0^{\bar{\omega}^g} \omega R_t^k Q_{t-1} K_{t-1} dF(\omega)$ are the resources taken from entrepreneur's profits that goes to repay central bank loans

2.E Credit Policy Effects and Frictions

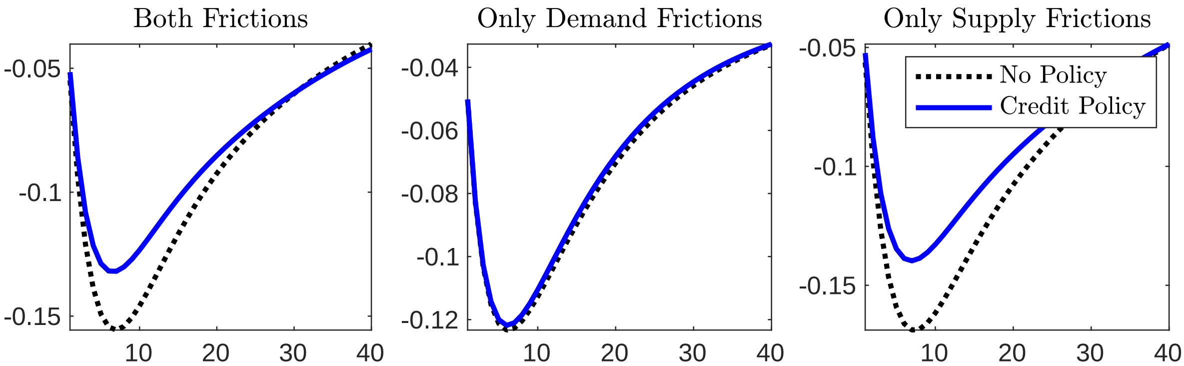
Figure 2.11 and Figure 2.12 reports the effects of the credit policy rule on the aggregate capital in an economy with either frictions only on the credit demand side or frictions only on the supply side, for both a state-contingent and non-state-contingent R_{t+1}^l, respectively.

When there are only frictions on the credit demand side, the only effect of credit policy effect is on the credit demand side due to the government guarantees. In the case of state-contingent R_{t+1}^l, according to Figure 2.11, in the baseline calibration the government guarantees do not have a significant impact on reducing the negative effects of the capital quality shock. With non-state-contingent R_{t+1}^l, Figure 2.12, the government guarantees should have a stronger effects since entrepreneurs are more exposed to aggregate shocks, however, this is still negligible.

When there are only frictions on the credit supply side (i.e. $\mu = 0$), the only effect of the credit policy is that it reduces the frictions of the credit supply side. In other words, since CB loans cannot be diverted, it increases the aggregate supply of credit per unit of bank net worth. According to Figure 2.11, in the baseline calibration the fact that a fraction of aggregate credit cannot be diverted, which reduces the credit supply frictions, have a more significant impact on reducing the negative effects of the capital quality shock. With non-state-contingent R_{t+1}^l, Figure 2.12, since shock is absorbed by entrepreneurs' net worth, which by definition does not affect credit demand, the effectiveness of the credit policy that essentially affects the credit supply is smaller.

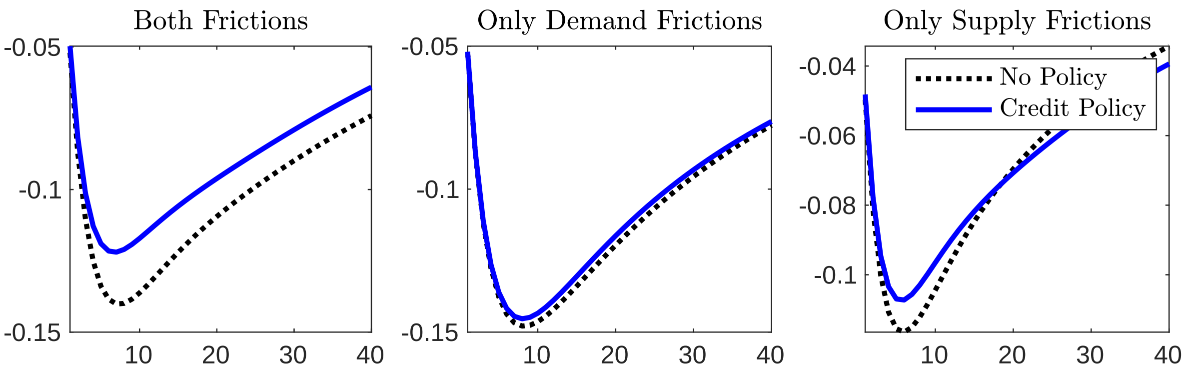
Finally, in our baseline calibration we might say that credit policy is more effective on reducing credit supply frictions than credit demand frictions. However, as we see in subsection 2.6.3 this is not necessarily true if we target a higher entrepreneur's default probability, i.e., if there is a higher uncertainty in the economy.

Figure 2.11: State-contingent R^l_{t+1}: A five percent negative capital quality shock. Capital



Note: Capital is in log deviations from steady-state.

Figure 2.12: Non-state-contingent R^l_{t+1}: A five percent negative capital quality shock. Capital



Note: Capital is in log deviations from steady-state.

2.F No government credibility without supply credit frictions

As in the case of government credibility, entrepreneurs aim to maximize their expected profits, given by equation (2.42), but this time subject to the state-contingent constraints implied by equation (2.53). The first order conditions for $\bar{\omega}^j$, K^j_t and λ_{t+1} are respectively,

$$-\frac{\partial\Gamma(\bar{\omega}^j)}{\partial\bar{\omega}^j} + \lambda^j_{t+1}\left(\frac{\partial\Gamma(\bar{\omega}^j)}{\partial\bar{\omega}^j} - \mu\frac{G(\bar{\omega}^j)}{\partial\bar{\omega}^j}\right) = 0.$$

$$\mathbb{E}_t\left\{\left(1-\Gamma(\bar{\omega}^j)\right)R^k_{t+1} + \lambda_{t+1}\left[\,\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right)R^k_{t+1} - R_t\,\right]\right\} = 0.$$

$$\left(\Gamma(\bar{\omega}^j) - \mu G(\bar{\omega}^j)\right)R^k_{t+1}Q_tK^j_t = R_t\left(Q_tK^j_t - N^j_{et}\right).$$

where,

$$\frac{\partial \Gamma(\bar{\omega}^j)}{\partial \bar{\omega}^j} = 1 - F(\bar{\omega}^j), \qquad \frac{\partial G(\bar{\omega}^j)}{\partial \bar{\omega}^j} = \bar{\omega}^j f(\bar{\omega}^j).$$

Clearly, these equilibrium conditions are the same than those under no credit policy. This implies that in equilibrium K_t^j and $\bar{\omega}^j$ are also identical to those under no credit policy.

2.G Government transfers due to guarantees of CB loans

When bank loans have higher seniority, equation (2.46) becomes,

$$\begin{aligned} & [1 - F(\bar{\omega}^{g,j})] Z_{t+1}^j B_t^j + [1 - F(\bar{\omega}^j)] R_t B_t^{g,j} + (1-\mu) \int_0^{\bar{\omega}^{g,j}} \omega R_{t+1}^k Q_t K_t^j dF(\omega) \\ - & \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} Z_{t+1}^j B_t^j dF(\omega) + \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \left(\omega R_{t+1}^k Q_t K_t^j - Z_{t+1}^j B_t^j \right) dF(\omega) + S_{t+1}^j \\ = & R_{t+1}^l B_t^j + R_t B_t^{g,j} + \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \left(\omega R_{t+1}^k Q_t K_t^j - Z_{t+1}^j B_t^j \right) dF(\omega), \end{aligned} \tag{2.77}$$

where,

$$S_{t+1}^j = R_t B_t^{g,j} - [1 - F(\bar{\omega}^j)] R_t B_t^{g,j} - (1-\mu) \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \left(\omega R_{t+1}^k Q_t K_t^j - Z_{t+1}^j B_t^j \right) dF(\omega).$$

It is easy to verify that equation (2.77) becomes as the equilibrium condition described in equation (2.48). However, the government subsidies, equation (2.49), become,

$$S_{t+1}^j = \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} \left[R_t B_t^{g,j} - (1-\mu) \left(\omega R_{t+1}^k Q_t K_t^j - Z_{t+1}^j B_t^j \right) \right] dF(\omega) + F(\bar{\omega}^{g,j}) R_t B_t^{g,j}.$$

It says that for a fraction $(F(\bar{\omega}^j) - F(\bar{\omega}^{g,j}))$ of entrepreneurs, the government has to complement the payment to CB loans, while for a fraction $F(\bar{\omega}^{g,j})$ of entrepreneurs, who already exhausted all their revenues repaying bank loans first and cannot repay anything of the CB loans, the government needs to fully pay the whole central bank loan debt. Thus, when both, bank loans and CB loans, have the same seniority, equation (2.49), the government (for a given K_t^j) have to spend more, since a larger share of revenues repay bank loans as these are paid first. For a given K_t, we conclude that when bank loans have higher seniority, government expends more.

Also, when central bank loans have higher seniority, equation (2.46) becomes,

$$\begin{aligned} & [1 - F(\bar{\omega}^j)] Z_{t+1}^j B_t^j + [1 - F(\bar{\omega}^{g,j})] R_t B_t^{g,j} + (1-\mu) \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} (\omega R_{t+1}^k Q_t K_t^j - R_t B_t^{g,j}) dF(\omega) \\ + & \int_0^{\bar{\omega}^{g,j}} \omega R_{t+1}^k Q_t K_t^j dF(\omega) + S_{t+1}^j = R_{t+1}^l B_t^j + R_t B_t^{g,j} \\ + & \mu \int_0^{\bar{\omega}^{g,j}} \omega R_{t+1}^k Q_t K_t^j dF(\omega) + \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} R_t B_t^j dF(\omega), \end{aligned} \tag{2.78}$$

where,

$$S_{t+1}^j = R_t B_t^{g,j} - [1 - F(\bar{\omega}^{g,j})] R_t B_t^{g,j} + \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^j} R_t B_t^j dF(\omega) - (1-\mu) \int_0^{\bar{\omega}^{g,j}} \omega R_{t+1}^k Q_t K_t^j dF(\omega),$$

It is easy to verify that equation (2.78) becomes as in equation (2.48). However, government subsidies, equation (2.49), become,

$$S_{t+1}^{j} = \int_{0}^{\bar{\omega}^{g,j}} \left[R_t B_t^{g,j} - (1-\mu)\omega R_{t+1}^{k} Q_t K_t^{j} \right] dF(\omega) + \mu \int_{\bar{\omega}^{g,j}}^{\bar{\omega}^{j}} R_t B_t^{j} dF(\omega),$$

This time, the government only complements payments for a fraction $F(\bar{\omega}^{g,j})$ and also pays for the monitoring costs when entrepreneur defaults, but can still fully pay central bank loans. Contrasting with (2.49), the fraction of entrepreneurs that default on CB loans is smaller, and consequently required transfers are smaller. For a given K_t we can conclude that when bank loans have lower seniority, government expends less.

Finally, we can immediately see that the arguments delivered regarding the effects of no government credibility in subsection 2.5.2 holds for any seniority assumption.

2.H Conventional Credit Policy

Equation (2.37) becomes,

$$\bar{\omega}^{j} R_{t+1}^{k} Q_t K_t^{j} = Z_{t+1}^{j} B_t^{j} + Z_{t+1}^{g,j} B_t^{g,j}, \tag{2.79}$$

where $Z_{t+1}^{g,j}$ is the (non-default) lending rate of CB loans since these are not longer guarantee by government. Let start assuming that CB loans are directly given by central bank. So, there is a contract for bank loans and another for CB loans. In this case, the bank loan contract, equation (2.39), becomes,

$$[1 - F(\bar{\omega}^{j})] Z_{t+1}^{j} B_t^{j} + (1-\mu) \int_{0}^{\bar{\omega}^{j}} \omega R_{t+1}^{k} Q_t K_t^{j} x_{t+1}^{j} dF(\omega) = R_{t+1}^{l} B_t^{j}, \tag{2.80}$$

and we have the CB loan contract,

$$[1 - F(\bar{\omega}^{j})] Z_{t+1}^{g,j} B_t^{g,j} + (1-\mu) \int_{0}^{\bar{\omega}^{j}} \omega R_{t+1}^{k} Q_t K_t^{j} (1 - x_{t+1}^{j}) dF(\omega) = R_{t+1}^{l} B_t^{g,j}. \tag{2.81}$$

where,

$$x_{t+1}^{j} = \frac{Z_{t+1}^{j} B_t^{j}}{Z_{t+1}^{g,j} B_t^{g,j} + Z_{t+1}^{j} B_t^{j}}. \tag{2.82}$$

From equations (2.80), (2.81) and (2.82),

$$Z_{t+1}^{j} = Z_{t+1}^{g,j}.$$

and hence CB loans and bank loans are identical from entrepreneur's perspective. Also,

$$x_{t+1}^{j} = \frac{B_t^{j}}{B_t^{g,j} + B_t^{j}}. \tag{2.83}$$

Combining the loan contracts equations (2.80) and (2.81) and using (2.79) yields,

$$\left(\Gamma(\bar{\omega}^{j}) - \mu G(\bar{\omega}^{j}) \right) R_{t+1}^{k} Q_t K_t^{j} = R_{t+1}^{l} \left(Q_t K_t^{j} - N_{et}^{j} \right),$$

As a result, the optimal contracting problem is identical to the maximization problem without credit policy. Hence, the first order conditions for $\bar{\omega}^{j}$, K_t^{j} and λ_{t+1} are as in the case without credit policy. Then, the aggregate demand is not altered by the credit policy.[35]

[35] It is easy to verify that this holds for any seniority assumption.

In terms of the composition of external funding, we state that in equilibrium entrepreneurs demand all CB loans available, and then $B_t^j = K_t^j - B_t^{g,j} - N_{et}^j$ in such a way that per unit of external funding a share $\psi_{CB,t}$ is demanded to the central bank while a share $1-\psi_{CB,t}$ is demanded to banks.

Now, let assume that CB loans are given through banks. In other words, central bank gives funds to bank and charge a risk-free rate for these funds, and ask banks to issue the same amount as central bank loans. Note that if we assume that banks can also divert a fraction λ of CB loans, we are back to the case of no credit policy. This is because in that scenario CB bank loans are identical to bank loans from banks' perspective. For realism and for comparison reasons we say that banks cannot divert CB loans as they do with bank loans and hence clearly credit policy is going to affect aggregate credit supply. Formally, equation (2.5) becomes,

$$N_{bt+1}^i = R_{t+1}^l (B_t^i + B_t^{g,i}) - R_t (D_t^i + B_t^{g,i}),$$

and banker's incentive constraint, equation (2.7), becomes,

$$V_t^i \geq \lambda B_t^i + \lambda^g B_t^{g,i}, \tag{2.84}$$

Note that since it is more difficult to divert CB loans that bank loans, $0 < \lambda^g < \lambda$. For comparison reasons, we assume the extreme case $\lambda^g = 0$. We can express V_t^i as follows,

$$V_t^i = \nu_t (B_t^i + B_t^{g,i}) + \eta_t N_{bt}^i,$$

with

$$\nu_t^i = \mathbb{E}_t\{(1-\sigma)\Lambda_{t,t+1}(R_{t+1}^l - R_t) + \Lambda_{t,t+1}\sigma x_{t,t+1}\nu_{t+1}^i\},$$
$$\eta_t^i = \mathbb{E}_t\{1-\sigma + \Lambda_{t,t+1}\sigma z_{t,t+1}^i \eta_{t+1}^i\},$$

where $x_{t,t+m}^i = (B_{t+m}^i + B_{t+m}^{g,i})/(B_t^i + B_t^{g,i})$. Then, the incentive constraint (2.84) becomes,

$$\nu_t^i (B_t^i + B_t^{g,i}) + \eta_t^i N_t^i, \geq \lambda B_t^i = \lambda(1-\psi_{CB,t})(B_t^i + B_t^{g,i}).$$

Under reasonable parameter values the constraint always binds within a local region of the steady state. Then,

$$B_t^i + B_t^{g,i} = \frac{\eta_t^i}{\lambda(1-\psi_{CB,t}) - \nu_t^i} N_{bt}^i = \phi_t^i N_{bt}^i,$$

where $\phi_t^i = (B_t^i + B_t^{g,i})/N_{bt}^i$. We rewrite the evolution of bank's net worth (2.5) as,

$$N_{bt+1}^i = \left[(R_{t+1}^l - R_t)\phi_t^i + R_t\right] N_{bt}^i.$$

We then rewrite $z_{t,t+1}^i$ and $x_{t,t+1}^i$ as, respectively,

$$z_{t,t+1}^i = N_{bt+1}^i / N_{bt}^i = (R_{t+1}^l - R_t)\phi_t^i + R_t,$$

$$x_{t,t+1}^i = (B_{t+1}^i + B_{t+1}^{g,i})/(B_t^i + B_t^{g,i}) = (\phi_{t+1}^i/\phi_t^i) z_{t,t+1}^i.$$

Then, equations (2.11) and (2.12) becomes respectively,

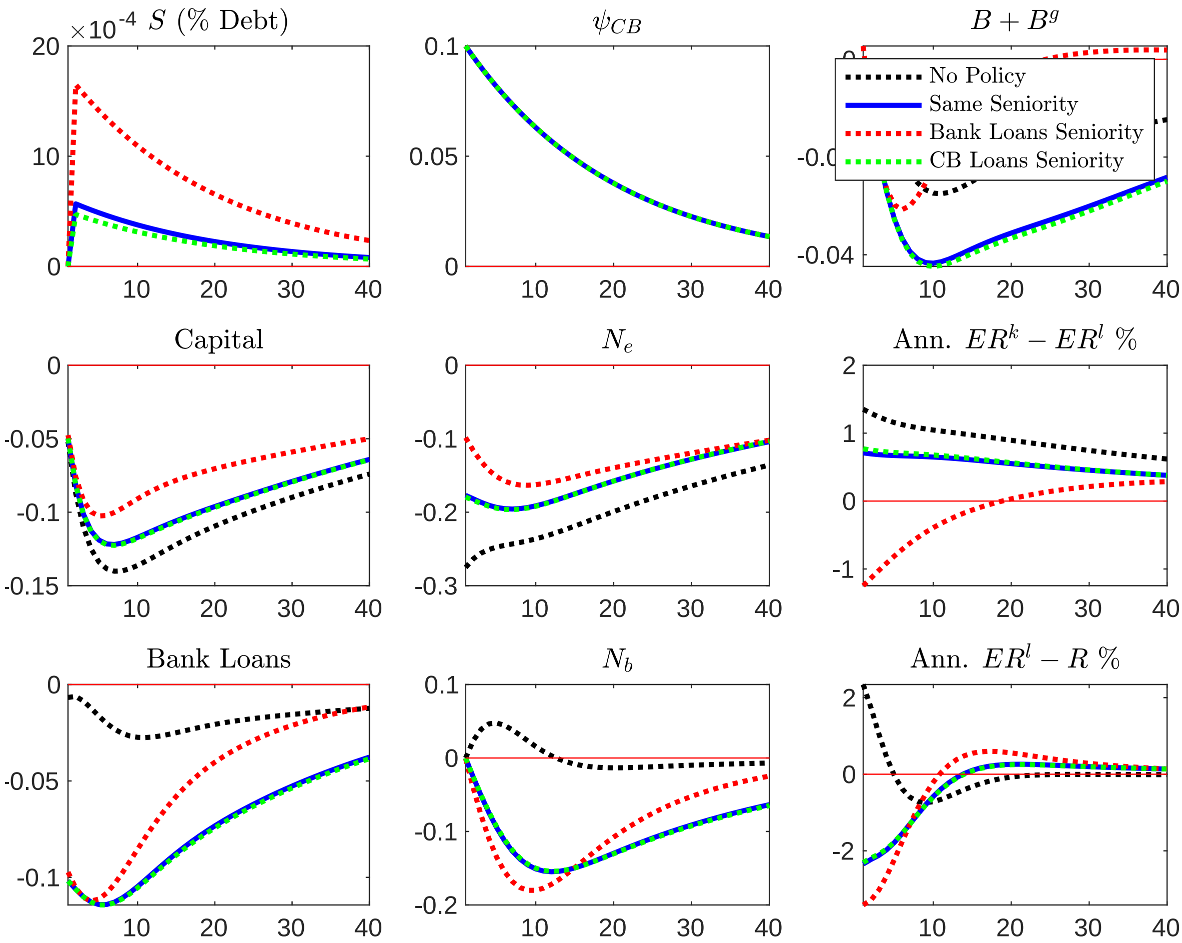
$$N_{nt} = \zeta(B_{t-1} + B_{t-1}^g).$$

Combining equations (2.10) and (2.11) yields the aggregate motion of bank net worth,

$$N_{bt} = \sigma\left[(R_t^l - R_{t-1})\phi_{t-1} + R_{t-1}\right] N_{bt-1} + \zeta(B_{t-1} + B_{t-1}^g).$$

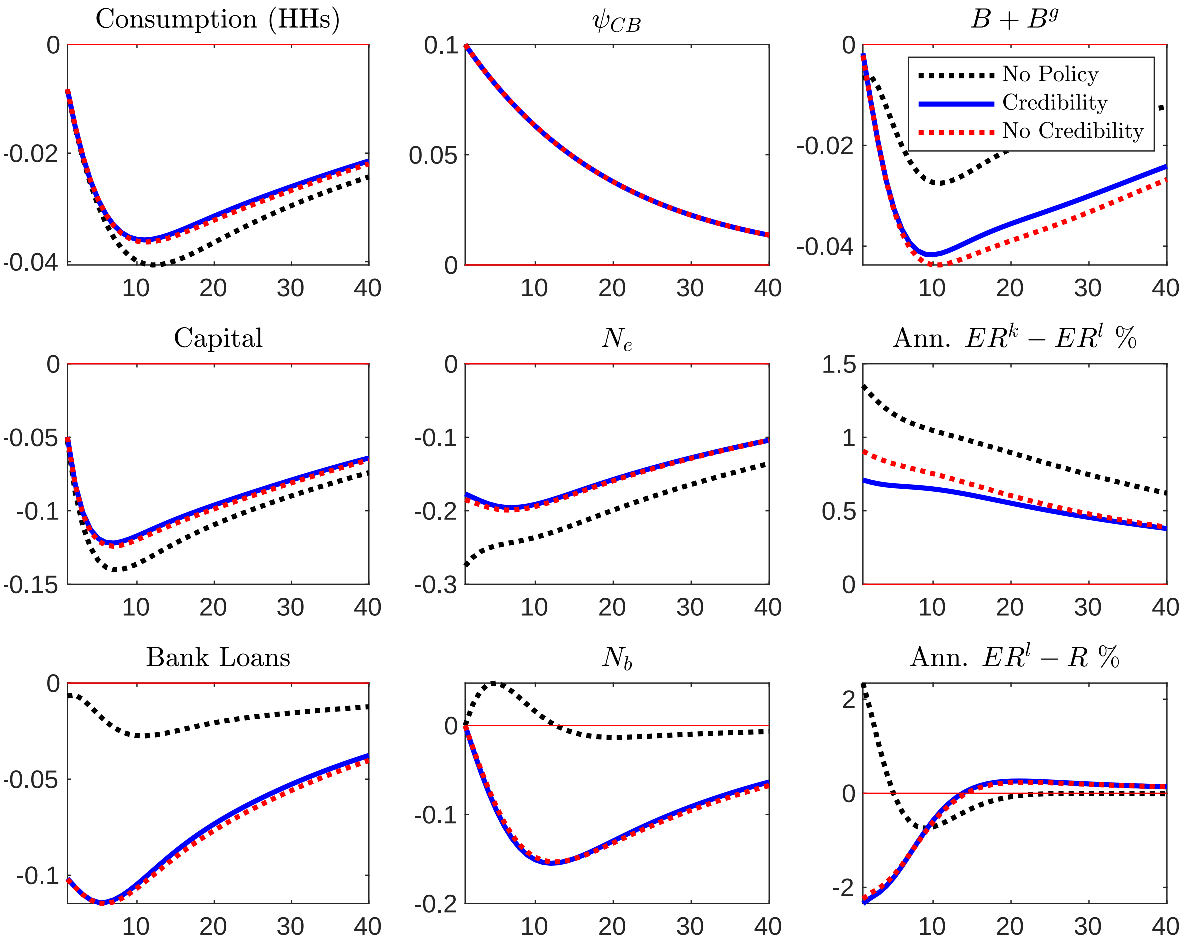
2.I Additional Figures

Figure 2.13: A five percent negative capital quality shock. Non-state-contingent R^l_{t+1}. Seniority assumptions



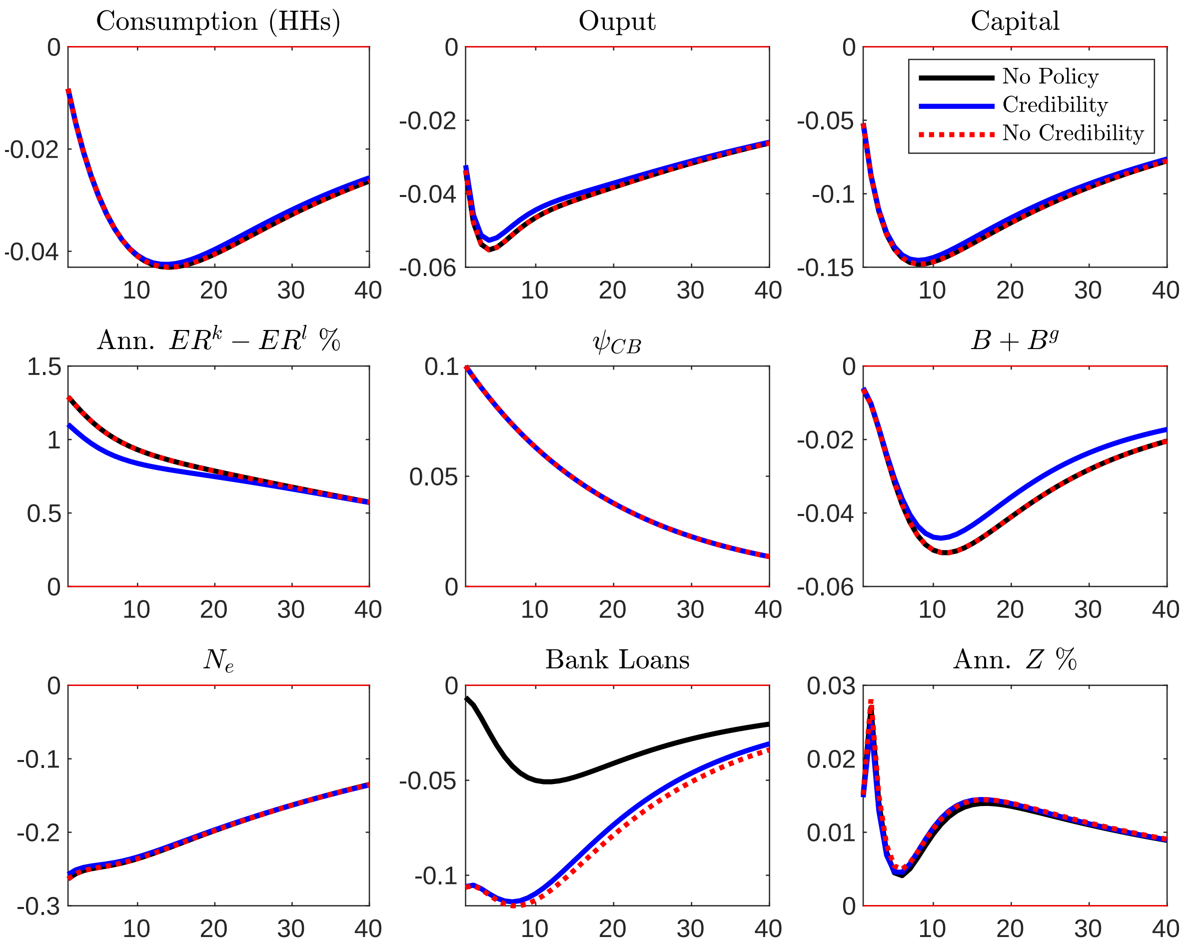
Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.14: Credibility: A five percent negative capital quality shock: Non-State-Contingent R^l_{t+1}



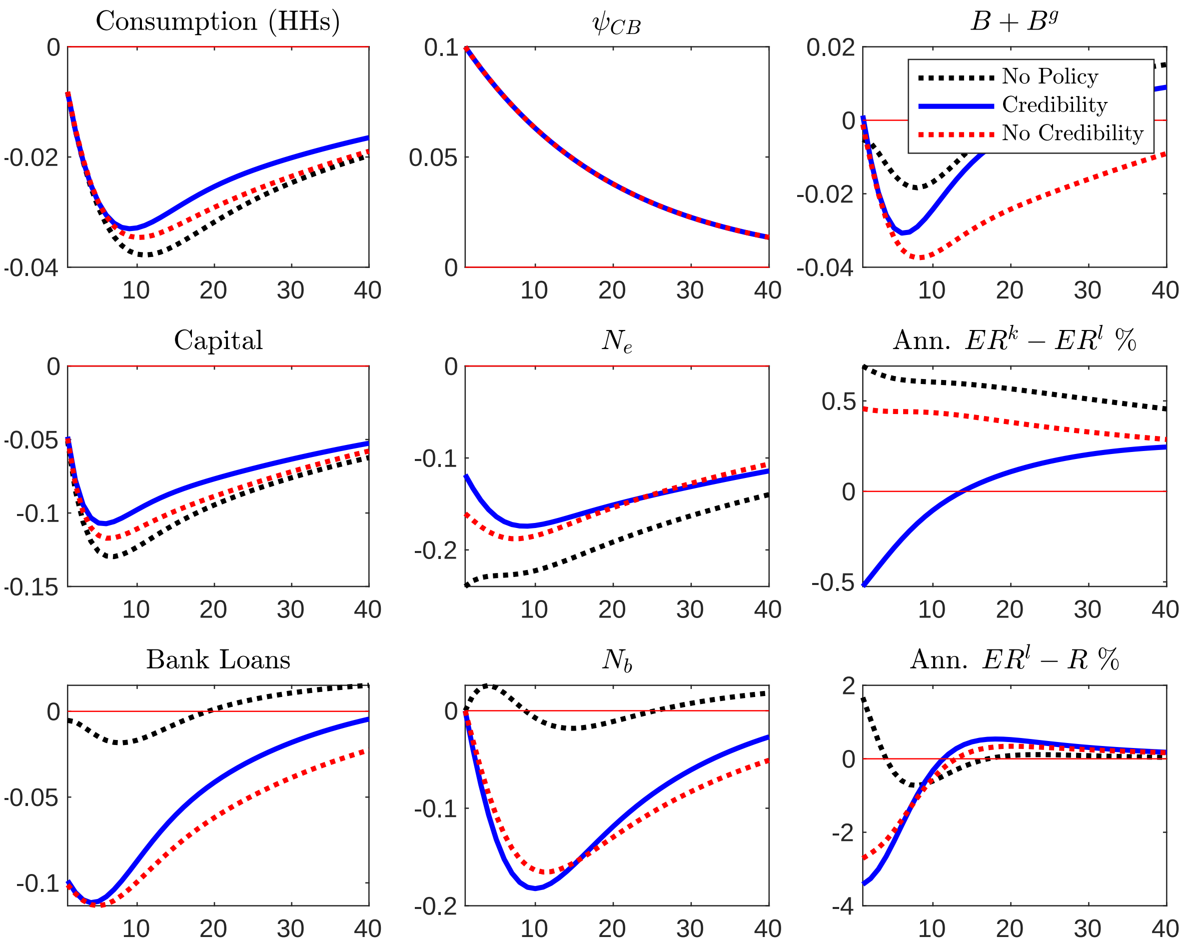
Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.15: Credibility: A five percent negative capital quality shock: No credit supply frictions



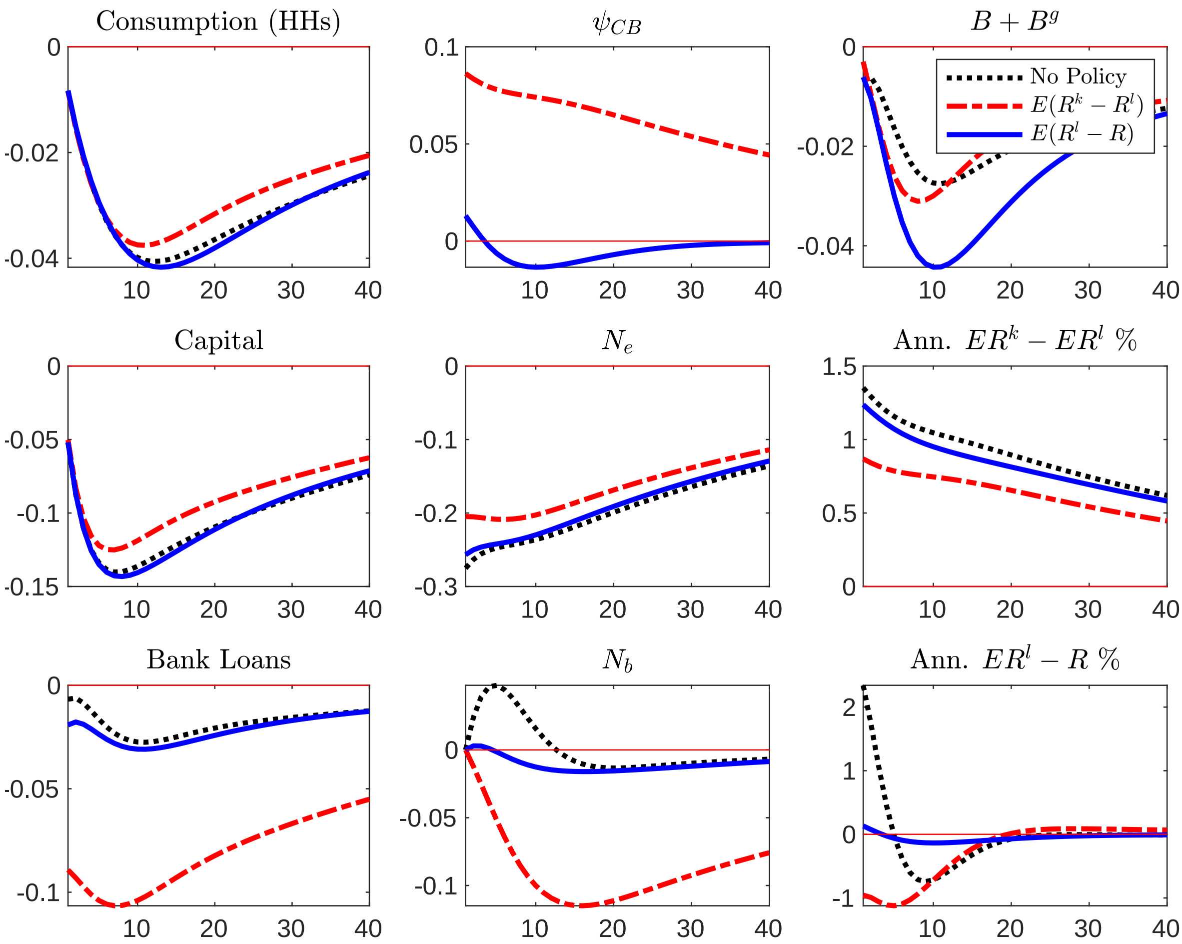
Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.16: Credibility: A five percent negative capital quality shock: Non-State-Contingent R^l_{t+1}



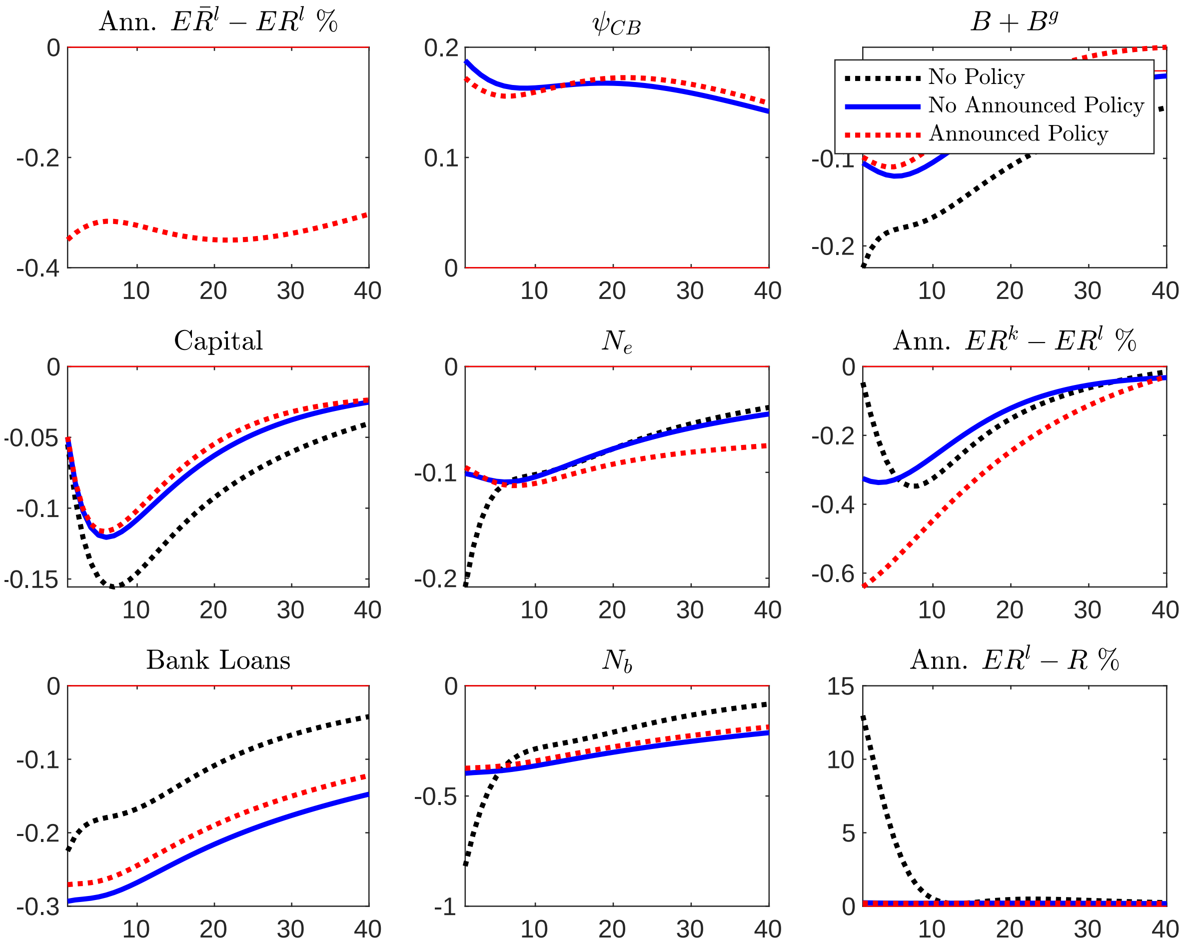
Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.17: Endogenous rules: A five percent negative capital quality shock. Non-state-contingent R^l_{t+1}



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Figure 2.18: Ex-ante Announcement: A five percent negative capital quality shock



Note: All variables are in log deviations from steady-state except spreads and CB loans share, shown in level deviation from steady-state.

Chapter 3

UNCONVENTIONAL CREDIT POLICY IN AN ECONOMY UNDER ZERO LOWER BOUND

(Joint with Jorge Pozo)

3.1 Introduction

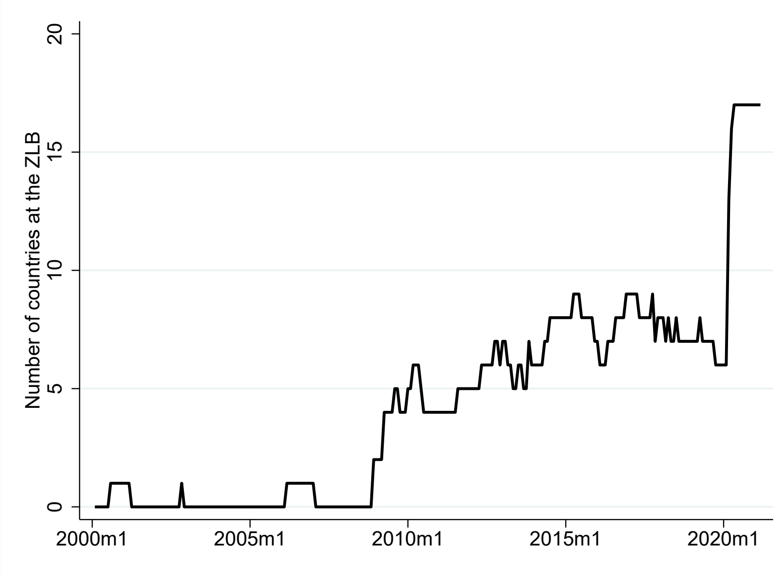
The Covid-19 global shock has forced policymakers to confront the limits of traditional policy tools for stimulating the economy. One important constraint faced by several central banks is the zero lower bound (ZLB) in the monetary policy rate. Figure 3.1 shows that during the Covid-19 pandemic the number of ZLB countries more than duplicated, from around 7 to 17. Other countries are also close to the ZLB. However, monetary policy has not stopped and now includes unconventional measures, such as Quantitative Easing (QE), to reduce the cost of financing and limit the types of moral hazard issues that could freeze the credit market. In addition, to avoid a deep recession, some central banks implemented unconventional credit policies such as additional liquidity facilities or government-guaranteed corporate lending at the policy rate. These unconventional credit policies are becoming increasingly important around the world. From the 113 economies that adopted debt finance policies, 41 countries have used these unconventional credit policies to reduce the cost of credit.[1] Governments promptly adopted these unconventional credit policies due to the firms' liquidity shortage shock.

This chapter extends the model developed in Chapter 2 to uncover the implications of the unconventional credit policy under a ZLB environment, but in a simple two-period framework with credit supply and credit demand frictions. As we described en Chapter 2, an unconventional credit policy differs from a conventional credit policy (Cúrdia and Woodford, 2011; Gertler and Karadi, 2011a) in two ways: 1) the required return on loans originated by the credit policy is not the market lending rate but the monetary policy rate; and 2) the loans are originated by a government-guaranteed credit policy. Thus, the unconventional credit policy in presence of the ZLB opens the door to policy considerations regarding the role of central bank (CB) intermediation for accessing credit in a zero-cost economy. Thus, our primary goal this chapter is to determine whether the ZLB improves or deteriorates the effectiveness of the unconventional credit policy intervention. In the same vein, we examine whether unconventional credit policy intervention allows central banks to exit the ZLB more quickly. The simplicity of the two-period

[1] Information on policies implemented around to world to face the Covid-19 shock is compiled by the World Bank and reported in the "Map of SME-Support Measures in Response to COVID-19".

model allows us to better understand the intuition of mechanisms and results of the implementation of the unconventional credit program in this context.

Figure 3.1: Number of countries at the ZLB



Note: Source: IMF, BIS. Own computations. Monthly data: 2000m1-2021m3. Indeed, this is the number of countries whose monetary policy rate becomes equal or lower than 0.25%.

Similar to Chapter 2, in this two-period framework the inefficiencies created by credit supply and credit demand frictions allow for the implementation of an unconventional credit policy. This is, conventional credit policy plays a role due to credit frictions that hamper savings flows in financing investment opportunities and prevent banks from adequately monitoring projects and assessing entrepreneurs' default probability. The model includes households, banks, entrepreneurs and firms. Households make bank deposits and banks give loans to entrepreneurs, who in turn create capital. Intermediate goods firms demand capital to produce. Price stickiness is introduced by assuming that a fraction of them cannot update prices and allows to model conventional central bank monetary interventions. Final goods firms demand intermediate goods to produce final goods. In addition, the monetary policy rate is subject to a ZLB constraint. We assume that the monetary authority successfully reaches its target inflation unless the economy has reached the ZLB.

When it comes to modeling credit frictions, we follow the same strategy as in Chapter 2, but this time the dynamics of net-worth are absent because we present a two-period model. Credit demand frictions are modeled à la Bernanke, Gertler and Gilchrist (1999). So, there is an asymmetric information problem between entrepreneurs and banks. Ex-ante identical entrepreneurs face an idiosyncratic shock, which is not observable by banks, and for which a risk premium is charged. Entrepreneurs might prefer to hold enough equity as collateral to ensure a not very high risk premium. Credit supply frictions are modeled à la Gertler and Karadi (2011a). This is, there is a moral hazard problem between banks and depositors. An endogenous leverage constraint arises in order to ensure that banks do not divert banks' assets and hence can operate. As a result, firms' and banks' equity is crucial to determine aggregate credit demand and supply, respectively.

We continue to use the modeling assumptions for the unconventional credit policy developed in Chapter 2. The unconventional credit policy entails central bank liquidity injections into banks in exchange for the latter's commitment to use these resources to make government-guaranteed loans. Given that loans are fully ensured we name these loans as indirect central bank loans, but from hereafter for simplicity, unless it is necessary for precision, we refer to these as CB loans to distinguish them from traditional bank loans funded by private deposits. The liquidity is provided in auctions where the winners offer the lower (non-default) lending interest rate. Since central bank has better enforcement power over banks than depositors and since indirect CB loans are government-guaranteed, the (non-default) lending interest rate is the risk-free interest rate and hence CB loans are cheaper than traditional bank loans. The goal of this policy is to lessen the impact of a negative shock on the economy. In this chapter a contractionary supply shock takes the economy to the ZLB (Fernández-Villaverde Gordon, Guerrón-Quintana and Rubio-Ramírez, 2015; Garín, Lester and Sims, 2019).

First, from our analysis, the interaction of the credit supply and demand frictions takes the economy closer to the ZLB. As expected the credit supply and demand frictions yield to an inefficiently low capital allocation and credit level. In particular, the credit supply frictions deteriorate the supply of lending made by banks and the credit demand frictions reduce entrepreneurs' incentives to demand loans. Furthermore, the interaction of these two frictions results in a greater reduction of the real interest rate, and thus of the nominal interest rate. This is because a low credit demand pushes the return on bank loans down, which in turn further deteriorates banks' profits and hence capacity to demand households' deposits. This pushes the real interest rate down.

Second, assuming the economy begins in an equilibrium near the ZLB and a contractionary shock occurs, unconventional credit policy can lift the economy out of the ZLB by increasing capital and credit. Because the policy intervention is funded by lump-sum taxes on households, the government is moving households' wealth across time with this policy, and as a result, in order to smooth consumption, households reduce their supply of deposits. This raises the real interest rate and the nominal interest rate as well. This means, a strong enough policy intervention might take the economy out of the ZLB. In the same line, the unconventional credit policy can reduce the likelihood of reaching the ZLB.

Finally, assuming the economy begins in an equilibrium where the ZLB binds, the effectiveness of the credit policy in increasing capital and hence total credit is reduced. This is because once the ZLB is reached, after an negative shock, the policy maker cannot reach the target inflation and it is observed (i) even a relatively stronger inflation reduction, which in turn reduces entrepreneurs' incentives to demand bank loans, and more importantly (ii) that the relative cost reduction from having access to cheaper central bank loans is smaller.

The remainder of this chapter is partitioned as follows. Section 3.2 presents the literature review. In section 3.3 we develop the simple two-period model. Section 3.4 studies how the credit and the deposit market are interlinked and how both credit frictions interact. In section 3.5 we study the implications of the unconventional credit policy. In section 3.6 we study the consequences of the ZLB. Finally, section 3.7 concludes.

3.2 Literature Review

This chapter extends the analysis described in Chapter 2 in a simple two-period model by discussing the implications of unconventional credit policy in the presence of the ZLB, which imposes limits on macroeconomic policy in order to stabilize the economy. As a result, this chapter is also related to the literature on demand side credit frictions and supply side credit frictions, which is discussed in the literature section of Chapter 2 (see Section 2.2).

This chapter is also related to the literature on the ZLB: Krugman (1998); Eggertsson and Krugman (2012); Eggertsson and Woodford (2003); Fernández-Villaverde Gordon, Guerrón-Quintana and Rubio-Ramírez (2015); Galí (2015), Eggertsson and Egiev (2019); and Eggertsson and Singh (2019), Garín, Lester and Sims (2019) among others. This literature focus on the troubles generated by the ZLB in order to implement conventional monetary policy and the risks of observing a deflationary spiral. We technically depart from this literature, since in the two-period framework that we develop inflation moves above its target when the ZLB binds. However, we claim this does not affect at least qualitatively our main results. Our contribution to the literature involves discussing the role of credit market interventions by a central bank under the ZLB constraint.

This work is also related to the literature that studies the effects of the credit policy under ZLB. Schenkelberg and Watzkab (2013) find that a quantitative easing shock leads to a significant increase in output and price level for the post-1995 Japanese data. Similarly, Wu and Xia (2016) find evidence that the unconventional monetary policy implemented by the Fed has succeeded in lowering unemployment. In addition, in a panel VAR for eight advanced countries for the 2008 global financial crisis, Gambacorta et al. (2014) find that the increase of central banks' balance sheet at the ZLB temporarily increases economic activity. Gertler and Kiyotaki (2011) in its DSGE model with financial intermediaries and with only credit supply frictions discuss the implications of the ZLB and the effects of a credit policy under a ZLB. They find that the credit policy diminishes the negative effects of the ZLB after a capital quality shock. We complement this literature by focusing on the effects of the ZLB on the effectiveness of the credit policy and by clearly illustrating the mechanisms behind our results using a simple two-period model.

Given the nature of the shock we study, this chapter is also part of the current Covid-19 literature on policy interventions through credit markets as in Segura and Villacorta (2020); Céspedes, Chang and Velasco (2020); and Drechsel and Kalemli-Ozcan (2020). Segura and Villacorta (2020) study optimal government support in a lockdown in a framework with firm-bank linkages. Without government intervention, output losses are amplified. In a minimalist framework Céspedes, Chang and Velasco (2020) also models a lockdown shock and amplification effects. They find that unconventional policies are more effective than conventional ones. And Drechsel and Kalemli-Ozcan (2020) recommend direct cash transfers to support small and medium-sized enterprises, implemented via a negative tax. We seek to contribute with an additional dimension to this literature regarding the interaction of monetary policy constraints and credit policy, the former being the new element in the analysis.

3.3 A two-period model

In this chapter we present a stylized model that incorporates the basic features of the New Keynesian model as well as demand and supply credit frictions. It is a two-period model where the only factor of production is capital. Capital enables the economy to transfer goods across time, so current and future conditions are inextricably linked.[2]

For simplicity, we assume no aggregate uncertainty, but only idiosyncratic risk faced by entrepreneurs investing in capital services. In this economy, we have 5 types of agents: households, entrepreneurs, banks, intermediate and final goods firms. Households own banks and all businesses.

The timeline and the role of each agent in the economy is as follows. At time $t = 1$, households are endowed with y_1 units of goods and decide how much to allocate to consumption, c_1, and savings via bank deposits, D_2. In addition, given that households own entrepreneurs' business and banks, they make exogenous transfers in a fixed amount to entrepreneurs, $N_{1,e}$, and to bankers, $N_{1,b}$. This assumption captures the idea that initial equity is needed by entrepreneurs and banks to operate. Bankers, endowed with $N_{1,b}$ goods, demand households' deposits D_2 and lend to entrepreneurs $B_2 = N_{1,b} + D_2$. Hence, banks screen entrepreneurs' projects and intermediate funds. At period $t = 2$, banks pay the gross

[2]This feature makes our model different from a standard New Keynesian (NK) model, as in Galí (2015), where labor is the only input for production and transfers of goods across periods is not possible. In the standard NK model, the labor market equilibrium depends on current economic conditions, and the real interest rate clears the goods market in such a way that there are no incentives for households to transfer goods across periods via savings/debt. These assumptions conveniently simplify the analysis. However, in our model savings are necessary to finance capital, and the capital market depends on current and future economic condition.

interest rate on deposits funds, R_2, and charge the gross interest on loans, R_2^l.

Entrepreneurs, endowed with $N_{1,e}$ goods, at period $t = 1$ take also a loan from a bank, B_2, and invest it into a risky project to produce capital, $K_2 = N_{1,e} + B_2$, to earn $\omega_2 R_2^k$ per unit of capital at period $t = 2$, where ω_2 is the idiosyncratic shock that has a lognormal distribution, and R_2^k is the gross rate of return on capital. At period $t = 2$, a competitive monopolistic firm buys capital, pays a given price R_2^k, and produces intermediate goods with a decreasing return to scale technology. This intermediate goods firm sets prices under pricing frictions: we assume that a share of firms can not set prices optimally but at a prior exogenous level. Perfect competitive final goods firms demand intermediate goods to produce final goods firms with a Dixit-Stiglitz technology. At the end of period $t = 2$, households consume all earnings from deposits and profits made by bankers, entrepreneurs and intermediate goods and final goods firms.

3.3.1 Households

Households make deposits, D_2, decide consumption allocation, $\{c_1, c_2\}$, and take dividends and profits as lump-sum transfers. A representative household solves the following problem:

$$\max_{c_1,c_2,D_2} u(c_1) + \beta u(c_2)$$

subject the budget constraints at period 1 and 2, respectively,

$$\begin{aligned} c_1 + D_2 &= y_1 - N_{1,b} - N_{1,e} \\ c_2 &= R_2 D_2 + \pi_2^T \end{aligned} \tag{3.1}$$

where $u(c)$ represents a standard utility function of consumption, with $u'(c) > 0$ and $u''(c) < 0$, β is the discount factor, y_1 is the exogenously given endowment, $-N_{1,b}$, $-N_{1,e}$ are fixed amount of dividends at period 1 and $\pi_2^T = \pi_2^e + \pi_2^b + \pi_2^f$ dividends at period 2 received from entrepreneurs, banks and intermediate firms. The economic justification of having $N_{1,b} + N_{1,e}$ as outflows at period 1 is that households own banks and entrepreneurs' business. Thus, they do not only receive dividends at period 2, but also are responsible for equity (capital) injections $N_{1,b}$ and $N_{1,e}$ to both banks and business, respectively. $R_2 = (1 + i_1)/(P_2/P_1)$ is the gross real interest rate, where i is the nominal interest rate and P_1 and P_2 are nominal prices.

The optimal consumption allocation across the two periods is given by the first order condition with respect to deposits, D_2, or the Euler equation,

$$u'(c_1) = \beta R_2 u'(c_2), \tag{3.2}$$

which establishes an equilibrium condition between the intertemporal marginal rate of substitution in consumption and the real interest rate. The real interest rate affects the allocation of consumption across periods, as it affects the relative valuation of consumption between periods. Other things equal, a rise in the interest rate stimulates a household to save more via bank deposits by discouraging consumption at period 1, i.e., incentivizing consumption at period 2.

We can further gain more insights by assuming an isoelastic utility function $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, where σ is the inverse of the intertemporal elasticity of substitution. As a result, equation (3.2) becomes $c_2 = c_1 (\beta R_2)^{1/\sigma}$, which after some algebra by substituting into (3.1) yields the households' supply curve of deposits,

$$D_2 = \frac{(y_1 - N_{1,b} - N_{1,e}) (\beta R_2)^{1/\sigma} - \pi_2^T}{(\beta R_2)^{1/\sigma} + R_2}, \tag{3.3}$$

which is a different way to write the Euler equation. The equation of supply of deposits (3.3) shows that due to intertemporal smoothness, other things being equal, a higher level of endowment at period 1, y_1, increases supply of deposits, D_2, but higher profits at period 2, π_2^T, reduce supply deposits, D_2.

3.3.2 Banks: Demand of deposits and credit supply frictions

Banks capture deposits from households, D_2, that together with their initial exogenous equity (cash) $N_{1,b}$, are used the fund the loans issued to firms, B_2, i.e., bank balance sheet is,

$$B_2 = D_2 + N_{1,b}. \tag{3.4}$$

The process of demand of deposits is not frictionless, and there is a moral hazard problem between banks and depositors. It creates a credit supply friction that prevents a free flow from deposits to loans. Since banks are identical in what follows we discuss the problem of the representative bank.

A bank receives a gross return R_2^l per unit of loans and pays R_2 per unit of deposits. We assume that there is no aggregate uncertainty and banks can perfectly diversify their loans across entrepreneurs, that face idiosyncratic risk, and as a result the lending rate R_2^l is agreed and known at $t = 1$.

We introduce a moral hazard problem, as in Gertler and Kiyotaki (2011), to motivate a limit on banks' ability to expand their assets indefinitely by borrowing additional funds from households. At period 2, a banker can choose to intermediate loans or to divert some fraction λ of available funds and transfer them back to the household of which she is a member. The cost to a banker that diverts is that the depositors can force the bank into bankruptcy and recover only the remaining fraction $1 - \lambda$ of all available funds. As a result, to ensure the existence of bank loans, the following incentive constraint (IC) must be satisfied,

$$V_1 \geq \lambda B_2 R_2^l. \tag{3.5}$$

where V_1 is the value of future bank profits,

$$V_1 = R_2^l B_2 - R_2 D_2. \tag{3.6}$$

Equation (3.5) says that the charter value of the bank, the benefits of continuing operating, should be greater than the benefits of diverting bank assets. Hence, banks optimally choose the size of deposits D_2 in order to maximize (3.6) subject to the incentive constraint (3.5), where $B_2 = D_2 + N_{1,b}$. Notice that the only difference with the frictionless case is the presence of this incentive constraint. The first order condition with respect to D_2 leads to:

$$R_2^l - R_2 = \frac{\nu\lambda}{(1+\nu)}\,, \tag{3.7}$$

where $\nu \geq 0$ is the Lagrange multiplier associate with the incentive constraint. We calibrate our model so that (3.5) binds, so $\nu > 0$ always[3].

According to equation (3.7), a positive spread arises between the funding costs of banks and the lending interest rate, which is zero without credit supply frictions, $R_2^l = R_2$. This positive spread captures the idea that banks need to generate enough profits, so V_1 is high enough that banks do not divert and prefer intermediate loans. This positive spread that bankers earn can be called, *credit spread* or *credit risk premium*.

From the binding incentive constraint (3.5) we obtain the demand curve of deposits D_2,

$$D_2 = N_{1,b}\left[\frac{(1-\lambda)R_2^l}{R_2 - (1-\lambda)R_2^l}\right]. \tag{3.8}$$

Equation (3.8) not only represents the demand curve of deposits but also determines the supply curve of loans, since $B_2 = D_2 + N_{1,b}$ and bank's equity, $N_{1,b}$ is exogenous. In fact, it can be expressed simply as:

$$B_2 = N_{1,b}\frac{R_2}{R_2 - (1-\lambda)R_2^l}. \tag{3.9}$$

[3]See Appendix 3.A for a proof.

Due to the moral hazard problem (financial friction) bank's capacity to fund supply of loans with deposits is constrained to a proportion of its equity level. This means that the higher the bank net worth, the higher the bank's capacity to demand deposits and issue loans. When banks put more of their skin, they have fewer incentives to perform this costly divertion, which in turn allows banks to capture more deposits and hence to issue more loans. Equation (3.9) also shows, other things equal, that the higher the lending rate R_2^l the higher bank loans supply, as a bank's incentives are lower.

Thus, equations (3.8) and (3.9) show how closely related bank's capacity to demand deposits and hence to supply credit are. In particular, ceteris paribus, the higher the deposit rate R_2, the lower bank's future profits and hence the higher the bank's incentives to divert which in turn leads to a tighter incentive constraint and less capacity to capture deposits. This describes the negative slope of the deposit demand curve by banks. Similarly, ceteris paribus the higher the lending rate R_2^l, the higher bank future profits and hence the lower the bank incentives to divert which in turn leads to a looser incentive constraint and more capacity to capture deposits and hence to issue loans. This describes the positive slope of the credit supply curve by banks.

Shifts on the deposits demand and credit supply curves: According to equation (3.8) the higher the bank ability to divert, i.e., the higher the λ, the lower the bank capacity to supply loans per unit of equity. The intuition is that a higher λ increases the ability of a bank to divert, so the depositors will require banks to hold more equity per unit of loans in order to diminish their incentives to divert via the IC; i.e., for a given level of bank equity, a higher λ decreases deposits demand and credit supply. Notices also that, ceteris paribus, a higher bank lending rate of funding R_2^l increases deposits demand and a higher banks' cost of funding R_2 decreases credit supply. The intuition is that a higher R_2^l (higher R_2) increases (decreases) bank profits, which in turn looser (tighten) the IC, and increases deposits demand (decreases credit supply). As a result, there is a movement to the right (left) of the deposits demand curve (credit supply curve).

3.3.3 Entrepreneurs: Lending diversification and credit demand frictions

In order to study credit demand frictions and demand for capital, we assume lending is also frictionless. We adopt the same modeling device as in Bernanke, Gertler and Gilchrist (1999): a Costly State Verification (CSV) problem. An entrepreneur has asymmetric information of the state of her firm and banks need to pay a monitoring cost to observe the entrepreneur's realized return.

At the end of period $t = 1$, entrepreneurs start a firm, indexed by $j \in [0, 1]$, that transforms, under a linear technology, funding, composed by an initial equity or net worth, N_2^j, and bank's loans, B_2^j, into capital, K_2^j. i.e entrepreneur j balance sheet is,

$$K_2 = B_2 + N_{1,e} \tag{3.10}$$

where we forget index j as entrepreneurs are ex-ante identical[4], so we solve the problem as of a representative entrepreneur.

Entrepreneurs are risk-neutral and ex-ante identical and face an idiosyncratic shock. Specifically, the ex-post gross return of each unit of capital is $\omega_2 R_2^k$, where ω_2 is a random idiosyncratic disturbance to entrepreneur j and R_2^k is the aggregate return of capital. We set that the random variable ω_2 is i.i.d. across entrepreneurs follows a c.d.f $F(\omega)$ equal to the lognormal distribution with $\mathbb{E}_1\{\omega_2\} = 1$.

The asymmetric information problem consists that banks cannot observe ω_2, the idiosyncratic shock faced by each entrepreneur. However, banks can pay a monitoring cost to observe the realized gross value

[4]Also, as we will see later, given that entrepreneurs use a constant return technology, even ex-post there is a factor of proportionality between the demand for capital and net worth that is independent of entrepreneurs' specific factors. Thus, aggregation is easier. Bernanke, Gertler and Gilchrist (1999) provide a more detailed discussion.

of entrepreneurs' payoffs. The monitoring cost is equal to a fixed proportion $\mu > 0$ of entrepreneurs realized return: $\mu\omega_2 R_2^k K_2$.

Entrepreneur chooses K_2, and hence the level of borrowing B_2 prior to the realization of ω_2 taken as given the aggregate return of capital R_2^k. The optimal lending contract offered by a bank is given by the gross non-default bank loan rate Z_2 and a threshold value of the idiosyncratic shock, ω_2, defined as,

$$\bar{\omega}_2 R_2^k K_2 = Z_2 B_2. \tag{3.11}$$

For values of the idiosyncratic shock higher than the threshold value, $\omega_2 \geq \bar{\omega}_2$, an entrepreneur fully repays bank loan, otherwise, it defaults. Banks are repaid in full if entrepreneurs do not default, so banks do not have any incentive to pay a monitoring cost to verify the entrepreneurs' performance. However, when an entrepreneur defaults, banks do have incentives to pay the monitoring cost to observe the realized payoffs. They pay the auditing cost, seize the entrepreneur's project and obtain $(1-\mu)\omega_2 R_2^k K_2$. i.e a defaulting entrepreneur receives nothing. Notice that $F(\bar{\omega}_2)$ is the probability of default. i.e It is the probability that entrepreneur j defaults at $t = 2$ (or the fraction of entrepreneurs that defaults at $t = 2$). Then, a higher default probability of entrepreneurs raises the agency cost of monitoring projects, but it also increases the repayment value, $Z_2 B_2$.

On one hand, the lending contract must reflect the opportunity cost of funding loans. Recall that the required return on bank loans, compatible with a no diverting deposits equilibrium, is R_2^l. Banks can perfectly diversify the idiosyncratic risk involved in lending across entrepreneurs, and as a result an optimal lending contract requires banks receiving a certain gross return of R_2^l per unit of bank loans. In other words, banks hold a perfectly safe portfolio (it perfectly diversifies the idiosyncratic risk involved in lending) that ensures a certain return R_2^l for their loans. Hence, the bank's loan contract ($\bar{\omega}_2$, Z_2) must satisfy:

$$[1 - F(\bar{\omega}_2)]Z_2 B_2 + (1-\mu)\int_0^{\bar{\omega}_2} \omega R_2^k K_2 dF(\omega) = R_2^l B_2. \tag{3.12}$$

The left-hand side of equation (3.12) is the expected return on the loan to the entrepreneurs and the right-hand side is the opportunity cost of lending. By definition, in equilibrium since a positive number of entrepreneurs default (i.e., since $\bar{\omega}_2 > 0$), the (non-default) bank lending rate, Z_2, is higher than R_2^l. Intuitively, the positive spread charged to the required return on bank loans aims to compensate bank revenues for that fraction of entrepreneurs that are not able to fully repay bank loans. As a result, the spread Z_2-R_2^l represents the idiosyncratic risk premium.

On the other hand, the lending contract offered by a bank must maximize the expected profits to the entrepreneur, which may be expressed as:

$$\int_{\bar{\omega}_2}^{\infty} (\omega R_2^k K_2 - Z_2 B_2) dF(\omega). \tag{3.13}$$

Entrepreneurs aim to maximize (3.13) optimally choosing K_2 and $\bar{\omega}_2$ subject to the constraint implied by the bank loan contract, equation (3.12), the repayment value, in equation (3.11) and where B_2 is solved in bank balance sheet equation (3.10) taking as given R_2^k, R_2 and R_2^l, which are endogenously determined in the general equilibrium. Formally, the solution the this problem yields the credit demand curve of the representative entrepreneurs[5], given by

$$\left[[1 - \Gamma(\bar{\omega}_2)]\frac{1 - F(\bar{\omega}_2) - \mu\bar{\omega}_2 f(\bar{\omega}_2)}{1 - F(\bar{\omega}_2)} + (\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2))\right] R_2^k - R_2^l = 0\,, \tag{3.14}$$

and equation (3.12), that determines the portfolio allocation from banks,

$$B_2 = N_2 \left[\frac{\left(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)\right)\frac{R_2^k}{R_2^l}}{1 - \left(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)\right)\frac{R_2^k}{R_2^l}}\right] \tag{3.15}$$

[5]See Appendix 3.B

where, $\Gamma(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega) + (1 - F(\bar{\omega}_2))\bar{\omega}_2$ is the gross share of entrepreneurs' profits going to pay banks and $\mu G(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega)$ are expected monitoring costs.

By construction $F(\bar{\omega}_2)$ is positive[6], and therefore the term that multiplies R_2^k in equation (3.14) is lower than one, which implies a (positive) spread between the marginal productivity of capital and the lending rate (bank loans return), i.e.,

$$R_2^k - R_2^l > 0.$$

This premium is also called external finance premium. The asymmetric information problem distorts entrepreneur's incentives to demand capital. Put it differently, the costly information problem between entrepreneurs and banks reduces net marginal benefits of capital, which produces a shift to the left of the credit demand curve (i.e., smaller demand of credit). If we assume that there is not any asymmetric information problem, then $\mu = 0$, and hence equilibrium condition becomes, $R_2^k - R_2^l = 0$, which is the typical equilibrium condition, where the expected marginal productivity of capital equates the expected marginal cost of capital.

In this environment, net worth position is a key determinant for the cost of external finance. From equation (3.15), a higher equity amplifies exogenous changes in the economy. First, there is a direct effect of higher net worth on lending. Secondly, From equation (3.11), ceteris paribus, the higher the entrepreneur equity, the lower the likelihood that it defaults (i.e., the lower $\bar{\omega}_2$) and hence the smaller the distortions (i.e., the smaller $R_2^k - R_2^l$) and increases demand for lending. i.e a higher net worth mitigates the agency problems and reduces external finance premium faced by entrepreneurs in equilibrium.

As a result, this new curve of demand for lending (and hence supply of capital) not only shifts to the left but is also steeper than the frictionless curve. This is because a higher credit (and hence supply of capital) increases entrepreneurs' default probability which in turn increases monitoring costs and reduces the effective return of capital and hence entrepreneurs are willing to borrow at a lower lending interest rate, R_2^l. As a result, we should observe a stronger reduction of the lending rate after a higher demand of credit.

To gain more intuition of how the frictions affect the decision process of entrepreneurs, we insert equation (3.12) into equation (3.13),

$$[1 - \mu G(\bar{\omega}_2)]\, R_2^k K_2 - R_2^l B_2, \tag{3.16}$$

where $\mu G(\bar{\omega}_2) R_2^k K_2$ represents the cost of entrepreneur's default. As a result, if the monitoring cost is $\mu = 0$ or equivalently if the asymmetric information is overcome costlessly, we are back to a model without frictions on the credit demand. One can see that the interaction of the entrepreneur's default probability (captured by $\bar{\omega}_2$) and the monitoring cost (μ) leads to a reduction of the net marginal benefit of demanding a unit of bank loans. This is, ceteris paribus, a higher default probability or a higher μ reduces demand of credit. And hence in that sense this equation shows how the costly state verification distortions affect entrepreneur decisions on their demand of credit (B_2) or equivalently their purchases of capital (K_2). In other words, the asymmetric information problem reduces entrepreneur capacity to demand loans and hence to invest. As stated before, a higher entrepreneur's equity reduces the likelihood of reduction of the net marginal effects of issue loans from bankers' perspective.

Notice that from the credit demand equations (3.14) and (3.15), the risk premium and the amount of borrowing relative to equity of the entrepreneur does not depend on idiosyncratic characteristics of financial position of the entrepreneur. These features of the model makes aggregation straightforward. And in fact, the aggregate credit demand curve is identical to the credit demand curve of the representative entrepreneur, (3.14), where the aggregate loan contract (which is also the aggregate bank's balance sheet .) is thus given by equation (3.15).

[6] We assume $ln(\omega) \sim \mathcal{N}\left(-0.5\sigma_\omega^2, \sigma_\omega^2\right)$ so we have $\mathbb{E}(\omega) = 1$ and then $\Gamma(\bar{\omega}) = \Phi(z - \sigma_\omega) + \bar{\omega}[1 - \Phi(z)]$, $G(\bar{\omega}) = \Phi(z - \sigma_\omega)$, $\partial\Gamma(\bar{\omega})/\partial\bar{\omega} = 1 - \Phi(z)$ and $\partial G(\bar{\omega})/\partial\bar{\omega} = \bar{\omega}\Phi'(z)$, where $\Phi(.)$ and $\Phi'(.)$ are the c.d.f. and the p.d.f., respectively, of the standard normal and z is related to $\bar{\omega}$ through $z = (ln(\bar{\omega}) + 0.5\sigma_\omega^2)/\sigma_\omega$.

3.3.4 Sticky prices: Final goods firms and intermediate goods firms

Next, we add sticky prices to the model as is tradition in a standard NK models[7]. Final goods are produced competitively by final firms that transform substitute intermediate domestic goods, $Y_{i,2}$, into a homogeneous good, Y_2, using the following constant elasticity of substitution (CES) production function,

$$Y_2 = \left[\int_0^1 Y_{i,2}^{\frac{\theta-1}{\theta}}\, di\right]^{\frac{\theta}{\theta-1}},$$

where θ is the elasticity of substitution between different intermediate inputs, with $\theta > 1$ to ensure input substitutability. As the final good is produced competitively, the demand schedule for a domestic intermediate i is:

$$Y_{i,2} = \left(\frac{P_{i,2}}{P_2}\right)^{-\theta} Y_2, \tag{3.17}$$

and the aggregate price index, P_2, is

$$P_2 = \left[\int_0^1 P_{i,2}^{1-\theta} di\right]^{\frac{1}{1-\theta}}, \tag{3.18}$$

where $P_{i,2}$ is the price of an domestic intermediate good i.

Firms: Intermediate good producers

Differentiated intermediate goods are produced by monopolistic competitive firms indexed by $i \in [0,1]$. These firms set price, $P_{i,2}$, and produce $Y_{i,2}$ using a decreasing return to scale technology:

$$Y_{i,2} = a\,(K_{i,2})^{\alpha}\ , \quad \text{with } \alpha < 1, \tag{3.19}$$

where $K_{i,2}$ is capital and a is technical innovation constant or a productivity level. The problem of a firm i is to choose $\{K_{i,2}\,, P_{i,2}\}$[8] such as to maximize profits, subject to a demand function, its production technology and the total cost function,

$$\max_{\{K_{i,2}\,,P_{i,2}\}} \left[\left(\frac{P_{i,2}}{P_2}\right) Y_{i,2} - \mathcal{C}(Y_{i,2})\right], \tag{3.20}$$

subject to demand curve, (3.17), and the production function, (3.19), and where $\mathcal{C}(Y_{i,2}) = R_2^k K_{i,2}$ is the total cost function.

To model price rigidities we assume a fraction γ of firms have sticky prices and their prices are set to a predetermined value equal to the aggregate price in period $t = 1$, i.e $P_{i,2} = P_1$. A fraction $1-\gamma$ of firms can update prices. In other words, a fraction γ does not internalize the decisions of $Y_{i,2}$ on prices $P_{i,2}$, the inverse demand curve, while a fraction $1-\gamma$ does.

[7]See Appendix 3.C for a more detailed derivation of this section.

[8]In this problem choosing $K_{i,2}$ is identical as choosing $Y_{i,2}$, as there is a one-to-one relationship between these two given the production function. In fact, as derived in the Appendix 3.C, this problem can be transformed in such a way that there is just one decision variable, $Y_{i,2}$.

A firm i that has the opportunity to change prices, solves the profits maximization problem, (3.20). The solution of this problem yields the optimal pricing, in which we undo price distortions:[9]

$$\frac{P_{i,2}}{P_2} = \mathfrak{c}_{i,2}\,,$$

where $\mathfrak{c}_{i,2} = \frac{1}{\alpha a^{1/\alpha}} R_2^k \left(Y_{i,2}\right)^{\frac{1-\alpha}{\alpha}}$ is the marginal cost, which with $\alpha < 1$ is itself endogenous. In fact after inserting back (3.17) and solving for $\frac{P_{i,2}}{P_2}$ we get that firms optimally choose the same price $\frac{P^o_{i,2}}{P_2}$:

$$\frac{P_{i,2}}{P_2} = \frac{P_2^o}{P_2} = \left(\frac{1}{\alpha a^{1/\alpha}} R_2^k \left(Y_2\right)^{\frac{1-\alpha}{\alpha}}\right)^{\frac{\alpha}{\alpha+\theta(1-\alpha)}}\,, \tag{3.21}$$

Notice that optimal pricing equation (3.21) imposes a relationship between prices and real variables in the economy in equilibrium. From this equation its clear that increases in the real return of capital impact positively the marginal cost and with it the real prices that firms set.

In equilibrium, equation (3.21) and the consistent aggregate price index, P_2 (3.18),

$$P_2 = \left[\left(1-\gamma\right)\left(P_2^o\right)^{1-\theta} + \gamma\left(P_1\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}\,, \tag{3.22}$$

determine the aggregate supply curve of economy or the Phillips curve. [10] In the aggregate price index we set $P_{i,2} = P_2^o$ for all firms of measure $1-\gamma$ that can adjust their prices and $P_{i,2} = P_1$ for all firms that can not set prices.[11]

3.3.5 Market Clearing

In equilibrium, market clearing in the capital market requires:

$$K_2 = \int_0^1 K_{i,2}di = \left(\frac{Y_2}{a}\right)^{1/\alpha}\Delta$$

Thus, solving the GDP at $t = 2$ we find:

$$Y_2 = \Delta^{-1} a K_2^{\alpha},$$

where, $\Delta = \int_0^1 \left(\frac{P_{i,2}}{P_2}\right)^{-\theta/\alpha} di$ is the price dispersion. The equilibria in the deposit market and credit market requires

$$B_2 = D_2 + N_{1,b},$$
$$K_2 = B_2 + N_{1,e}.$$

[9]Note that with capital subsidy to the firm,

$$\frac{P_{i,2}}{P_2} = (1-\tau)\mathcal{M}\mathfrak{c}_{i,2}$$

. As shown in Galí (2015) one can eliminate the markup distortion on prices by considering a capital subsidy for the firm: $\tau = \frac{1}{\theta}$. Where $\mathcal{M} = \frac{\theta}{\theta-1}$ denotes the constant markup of the monopolistic firm. See more details in the Appendix 3.C.

[10]See Appendix 3.D for log linear representation of the Phillips curve.

[11]For simplicity, we assume that P_1/P_2 is high enough so that the equilibrium is governed by the demand curve, i.e., at P_1/P_2 there is an excess of supply of intermediate goods.

The market clearings in final goods market are,

$$c_1 = y_1 - K_2 \tag{3.23}$$

$$c_2 = Y_2 - \mu G(\bar{\omega}_2) R_2^k K_2 = \Delta^{-1} a K_2^{\alpha} - \mu G(\bar{\omega}_2) R_2^k K_2, \tag{3.24}$$

In equilibrium, the aggregate demand curve of the economy is given by Euler equation, (3.2) which is also the supply curve of deposits in the economy,

$$R_2 = \frac{1}{\beta} \left(\frac{\Delta^{-1} a (D_2 + N_{1,b} + N_{1,e})^{\alpha} - \mu G(\bar{\omega}_2) R_2^k (D_2 + N_{1,b} + N_{1,e})}{y_1 - (D_2 + N_{1,b} + N_{1,e})} \right)^{\sigma} \tag{3.25}$$

where GDP, Y_2, reflects price dispersion. This supply curve is the aggregate version of equation (3.3), and it shows a positive relationship between R_2 and D_2.

The demand curve for capital, which relates the return on capital with the marginal productivity of capital, and represents the supply side of the economy is given by[12]

$$R_2^k = \mathcal{W}\left(\frac{P_1}{P_2}\right) \alpha a K_2^{\alpha - 1}, \tag{3.26}$$

where $\mathcal{W}\left(\frac{P_1}{P_2}\right) = \left(\frac{1-\gamma\left(\frac{P_1}{P_2}\right)^{1-\theta}}{(1-\gamma)}\right)^{\frac{\alpha+\theta(1-\alpha)}{(1-\theta)\alpha}} \Delta^{\frac{1-\alpha}{\alpha}}$ is a wedge between the return on capital and marginal productivity of capital. This wedge only reflect nominal rigidities, and it is a function of gross inflation or the ratio P_2/P_1. If $\gamma = 0$ (i.e., flexible prices), $\mathcal{W} = 1$.

3.3.6 Conventional Monetary policy: Taylor rule

We assume that the central bank sets the nominal interest rate i_1 via a Taylor rule, where the short-term nominal rate is related to inflation:

$$i_1 = max(i_{min}, R_2^* (1 + \pi_2)^{\phi_\pi} - 1), \tag{3.27}$$

where i_{min} is the lower bound for the nominal interest rate, R_2^* is the natural real interest rate or the real interest rate under flexible prices, and $\pi_2 = (P_2/P_1 - 1)$, with the Fisher equation being :

$$R_2 = \frac{1 + i_1}{1 + \pi_2}. \tag{3.28}$$

Furthermore, in this simple model we assume that the central bank follows an optimal monetary policy rule or equivalently follows an Inflation Targeting at a targeted inflation of zero, i.e., $\pi_2 = 0$.[13] Therefore, if there is not an ZLB equilibrium, inflation is zero and the nominal interest rate is set as follows:

$$i_1 = R_2^* - 1,$$

and the central bank is able to replicate the flexible price equilibrium. In particular, with $\pi_2 = 0$, via the Fisher equation:

$$R_2 = 1 + i_1 = R_2^*.$$

However, if the economy is at a ZLB equilibrium where $R_2^* (1 + \pi_2)^{\phi_\pi} - 1 < i_{min}$, the central bank cannot implement a flexible price equilibrium, and $i_1 = i_{min} = 0$, $R_2 \neq R_2^*$, $\pi_2 \neq 0$.

[12] See Appendix 3.E.

[13] See Appendix 3.F

3.3.7 Equilibrium

In this economy the equilibrium is the set of 9 endogenous variables that solve the system of 9 equations for a given set of as a function of the exogenous variables y_1, a, $N_{1,e}$, $N_{1,b}$. In particular, $\{D_2\,, R_2\}$ is the solution to the deposit market equilibrium, (3.25), (3.8), $\{B_2\,, R_2^l, \bar{\omega}_2\}$ is the solution to the credit market equilibrium, (3.4), (3.14), (3.15); $\{K_2\,, R_2^k\}$ the capital market equilibrium, (3.26), (3.10); and $\{i_1\,, \pi_2 = P_2/P_1 - 1\}$ satisfy the MP rule,(3.27), and the Fisher identify, (3.28).

3.3.8 Calibration used in numerical examples

In all our next numerical examples we turn off the effect of the price dispersion variable, i.e., $\Delta = 1$. Price dispersion has second order effects, and for simplicity, we ignore them to abstract in our analysis from second order effects of price distortions.

For illustrative purposes, we set $\beta = 0.99$, $\sigma = 2$, $a = 5$, $\alpha = 0.33$, $\theta = 4.1$, $\phi_\pi = 1.25$, $\gamma = 0.7$. In addition, we set y_1, σ_ω, λ, μ, $N_{1,b}$ and $N_{1,e}$ so that without price rigidities we have a bank leverage ratio ($B_2/N_{1,b}$) of 4, an entrepreneur leverage ratio ($K_2/N_{1,e}$) of 4, an annualized entrepreneur's default probability of 15%, an annualized spread $R_2^k - R_2^l$ of 5%, an annualized spread $R_2^l - R_2$ of 5% and an annualized net real interest rate of 5%. Clearly, in the baseline the ZLB constraint does not bind. However, in section 3.6 when assessing the implications of the ZLB, we recalibrate the model so that the ZLB binds.

3.4 Analysis of Deposit and Credit Market

In this section we study the how credit and deposit markets are interlinked and the interaction of the credit demand and credit supply frictions. Figure 3.2 depicts the deposit and credit markets equilibria: an equilibrium in an economy without credit frictions, an equilibrium with only credit demand frictions, equilibrium with only credit supply frictions and the equilibrium with both credit demand and credit supply frictions.[14]

Point A in Figure (3.2) show an economy without credit frictions. Panel (a) depicts the equilibrium in the deposit market, which is given by the intersection of the Euler equation (supply curve) and a perfectly elastic demand curve, i.e a horizontal line at $R_2 = R_2^l$ (demand curve). Panel (a) shows the equilibrium in the credit market, which is given by the intersection of the capital marginal productivity (demand curve), R_2^k, and the horizontal line at $R_2^l = R_2$ (a perfectly elastic supply curve). As a result, in equilibrium $R_2 = R_2^l = R_2^k$, and there are not risk premia.

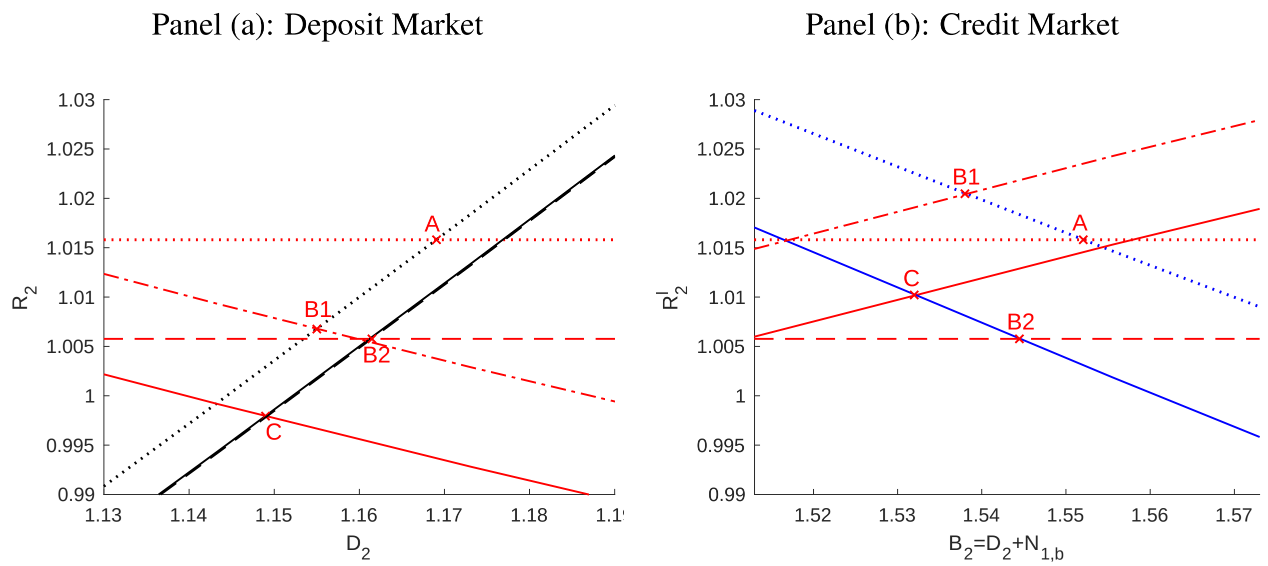
Figure (3.2) also shows the equilibrium when there is either only credit supply frictions, point B1, or only credit demand frictions, point B2. Relative to the frictionless benchmark, both types of frictions reduce the amount of credit in equilibrium but due to different reasons. In point B1, credit supply frictions prevent the flow of deposits to loans. Bank's demand for deposits is constrained by their net worth. So, relative to the frictionless benchmark, credit supply frictions reduce banks' deposit demand, and as a consequence there is a decrease in the deposit interest rate in equilibrium. Thus, a lower deposits intermediation limits lending, and the new credit market equilibrium is one with lower credit and higher lending rate.

In the second case, in point B2, the credit demand friction lowers the marginal value of capital and distorts the credit demand. Since entrepreneurs are constrained by their net worth, the demand for credit falls. Relative to the frictionless benchmark, the new credit market equilibrium is one with lower credit and lower lending rates. Consequently, it drives a reduction in the demand for deposits and a fall in

[14]In any scenario for comparison reasons we set R_2^* as R_2 as in the baseline calibration, so in equilibrium $P_2/P_1 = 1$, i.e., the central bank MP can replicate the flexible price equilibrium.

the deposit interest rate. Also notice the credit demand frictions create losses (due to the monitoring cost) which in turn reduces future households' consumption, increasing households' incentive to supply deposits in order to smooth consumption, as indicated by the shift to the right of the credit supply curve. This positive effect on deposits, however, is not dominant.

Figure 3.2: Deposit and Credit Market Equilibrium



Note: Credit and deposit market equilibria under different assumptions about the credit demand and credit supply frictions. Black lines are deposit supply curves. Red lines are deposit demand and credit supply curves. Blue lines are credit demand curves. A: No credit frictions. B1: Only credit supply frictions (moral hazard problem between banks and depositors). B2: Only credit demand frictions (asymmetric information and CSV). C: Both credit frictions.

Point C in figure (3.2) shows the equilibrium when both credit frictions are in place. Supply and demand frictions amplify each other and the credit reduction in equilibrium is stronger. As the flow of deposits to loans is now distorted by a restriction on the deposit demand (an hence loan supply) and lower credit demand, lending and deposit intermediation is much lower. One clear result is that deposit interest rates fall to clear the deposit market. This is, we observe a stronger reduction of the deposit interest rate when both frictions are in place. Starting from an economy with credit supply frictions, when adding credit demand frictions, there is a smaller demand of credit which in turn reduces the lending interest rates and reduces banks' capacity to demand deposits, shifting to the left the deposit demand curve and reducing even more the deposit interest rate. Therefore, the presence of credit frictions takes the economy closer to the ZLB equilibrium. However, the impact on the lending rate will depend on the relative forces of the credit supply and demand frictions. In the particular case of point C in Figure (3.2) the demand side credit friction is relatively much stronger than the supply side credit friction and hence it is observed a lower lending rate in equilibrium.

3.5 Unconventional Credit Policy

In this section studies the effects of a tool that central banks use during periods of crisis to prevent the amplifying effects of credit frictions during a period of crisis: an unconventional credit policy characterized by central bank's liquidity injection to banks provided they commit to issue guaranteed-government loans to entrepreneurs, which is the same described in Chapter 2.[15] We might refer to these as (indirect) CB loans, B_2^g. Indirectly we are assuming the CB loans are not subject to the credit supply frictions,[16] as the central bank has better enforcement power over banks than depositors and hence it can avoid that banks divert CB loans. Given that CB lending is guaranteed by the government there is no incentive for the central bank to run.[17]

Notice that, in the model, the CB liquidity injection is not accompanied with a central bank REPO intervention. In practice, by issuing a REPO the central bank can ensure the liquidity injection is fully repaid at the end of the loan contract, as a REPO contract states that the central bank will directly receive the guarantees payments if CB loans default. However, in the model we adopt the simplifying assumption that CB can perfectly enforce banks fully honor CB liquidity injection with guarantee payments received from the government if CB loans default.[18]

We assume central bank is willing to provide a fraction $\psi_{CB,2}$ of the total external funding (traditional loans + indirect CB loans) of entrepreneurs through banks, i.e.,

$$B_2^g = \psi_{CB,t}(K_2 - N_{1,e}). \tag{3.29}$$

Notice that since entrepreneurs are ex-ante identical, (3.29) holds at the individual entrepreneur level. We assume that entrepreneur does not internalize the effects of her capital and credit decisions on the CB loans injections. Hence, from entrepreneur's perspective the marginal cost of external funding is still given by the required return on bank loans.[19]

3.5.1 CB credit policy and supply side frictions

We assume that the central bank is willing to give funding (or inject liquidity) to banks at the risk-free gross interest rate R_2 with the commitment that (1) banks give at least the same amount of loans (CB loans) to entrepreneurs[20] and (2) charge some agreed (non-default) lending interest rate Z_2^g to entrepreneurs for these indirect CB loans. This is given in three steps. Step 1: CB offers the funds in an auction. Step 2: banks demand these funds and propose Z_2^g. Step 3: CB gives the funding to those banks that offer the lowest Z_2^g in order to benefit the most to entrepreneurs. Since all banks are identical and compete perfectly with other banks, at the end of the day they all offer the same and the smallest feasible lending rate, Z_2^g. We assume that CB can costlessly enforce banks to perform (1) and (2).

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[15]For simplicity, For simplicity, we assume these loans funded by CB liquidity injection are 100% guaranteed by the government. We assume that the central bank obtains the funds from households through lump-sum taxes at $t = 1$.

[16]We are conscious that this assumption implies that the central bank can act better as a lender than a traditional private bank, or that the central bank can replace banks in lending intermediation. However, we model the unconventional credit policy as one that is only active during periods of crisis/boom. Also, the CB loans are not better than traditional loans when dealing with credit demand frictions. i.e, CB loans can also be defaulted.

[17]We assume that the government pays the monitoring costs of observing the entrepreneur's realized revenues that go to repay CB loans. Since CB loans are guaranteed, banks do not have any incentives to pay the monitoring costs associated to observe realized revenues that go to pay CB loans. Similarly, the central bank does not have any incentive to do so due to the government guarantee. Hence, we believe it is a reasonable assumption to say that since the government takes care of her budget, she is the more interested in recovering as much as it can from entrepreneur revenues and hence pays the monitoring costs.

[18]Chapter 2 investigates this policy on a dynamic setup and the alternative case that CB lending is given directly to firms, rather indirectly via banks' intermediation. As discussed in Chapter 2, under some circumstances both forms are equivalent.

[19]This seems a reasonable assumption in a context of unconventional credit policy, in the sense that entrepreneur cannot predict if central bank will provide lending facilities.

[20]In other words, CB funding to banks and CB loans to firms intermediated by banks are both equal to B^g.

First, since these indirect CB loans are guaranteed by the government, if an entrepreneur is not able to fully pay back Z_2^g per unit of CB loans, government transfers enough resources so it ensures the bank receives the agreed return, R_2^l.[21] Hence, in equilibrium the required return for indirect CB loans from bank perspective, $R_2^{L,g}$, is the same as the (non-default) lending interest rate.

$$Z_2^g - R_2^{L,g} = 0 \tag{3.30}$$

In other words, in contrast to the traditional bank loans, banks do not need to add any entrepreneur default risk premium to the (no-default) lending interest rate, Z_2^g [22].

Second, we assume that there is not a moral hazard problem between banks and CB. In other words, we assume that bankers cannot divert bank assets that are funded by the CB liquidity (indirect CB loans)[23]. As a result, banks do not need to put more equity due to the CB loans or equivalently banks do not need to reduce their traditional bank loans in order to issue indirect CB loans. In addition, we assume that banks do not incur in any administrative cost (or these are negligible) for collecting CB funding and giving these to entrepreneurs as CB loans. Hence, the cost for banks of issuing CB loans is just the interest rate claimed by the central bank, i.e,

$$Z_2^g - R_2 = 0. \tag{3.31}$$

In other words, in contrast to the traditional bank loans, there is not a risk premium due to a moral hazard problem between CB and bankers and hence banks do not need to add any spread to the required return for CB loans, $R_2^{L,g} = R_2$.

Finally, jointly equations (3.30) and (3.31) imply that all banks commit to charge a (no-default) lending rate for the indirect CB loans equals to the risk-free interest rate R_2. As a result all banks equally obtain the funding from CB to issue the indirect CB loans.[24] As a result, CB loans are cheaper than bank loans due to (i) government guarantees and (ii) the fact that indirect CB loans cannot be diverted.

Entrepreneurs demand and deplete these cheaper CB loans first and then bank loans. As a result, we cannot expect a one to one multiplier effect of the credit policy on aggregate lending. With this in mind, we can see how the credit policy will affect aggregate credit supply.

- First, as in Gertler and Kiyotaki (2011) since CB loans cannot be diverted by banks, the CB credit policy is diminishing the impact moral hazard problem between banks and depositors on this economy. In other words, banks required equity per unit of aggregate credit decreases, which allows for a smaller required return on bank loans for a given aggregate credit level. As a result, credit policy increases the aggregate supply of credit.

- Second, since the required return on central bank loans is smaller than those of the traditional bank loans, entrepreneurs now face a limited supply of cheap CB loans in addition to the supply curve of bank loans, equation (3.8), which is not affected by the credit policy.

The bank loans supply curve matters in the margin since the last external funding comes from bank loans. As a result, we can say that the aggregate credit supply curve changes, but the aggregate supply curve

[21] We assume government funds their activities with lump-sum taxes to households at $t = 2$.

[22] Notice that we implicitly assume that there is government credibility. In other words, banks ex-ante believe that government will honour the guarantee for the CB loans. And we also assume, for simplicity, that ex-post the government always honor the guarantee.

[23] We believe this is a realistic assumption, since the central bank might have more monitoring and enforcement power over banks than depositors

[24] Notice that it doesn't make sense that banks propose a (non-default) lending rate below the risk-free interest rate.

of bank loans that in the margin (together with the aggregate demand curve) determines the equilibrium level of credit is not affected directly.

In equilibrium, banks issue CB loans by exactly the same amount of funds received from the CB.[25] Hence, banks balance sheet becomes,

$$B_2^g + B_2 = B_2^g + D_2 + N_{1,b}, \tag{3.32}$$

where B_2^g is not only the amount of CB loans issued to entrepreneurs but also the amount of funds received from CB to finance these loans. As a result, equation (3.32) collapses to the balance sheet (3.4) and so traditional bank loans are still funded with both households' deposits and bank's initial equity. Hence, banks profits are not affected given that by definition CB revenues are perfectly cancelled out with their own funding costs. Thus, the maximization problem of banks is not affected. This implies that the demand curve of deposits and the supply curve of traditional bank loans, equations (3.8) and (3.9), still hold with credit policy intervention.

In addition, the aggregate supply curve of deposits (Euler equation) is indeed affected by the policy intervention,

$$R_2 = \frac{1}{\beta}\left(\frac{\Delta^{-1}a(D_2 + B_2^g + N_{1,b} + N_{1,e})^{\alpha} - \mu G(\bar{\omega}_2)R_2^k(D_2 + B_2^g + N_{1,b} + N_{1,e})}{y_1 - (D_2 + B_2^g + N_{1,b} + N_{1,e})}\right)^{\sigma}.$$

Since in the calibration μ and the entrepreneur's default probability are very small, a positive credit policy intervention, i.e., $B_2^g > 0$, which transfer households' resources across periods, reduces households' incentives to supply deposits. In other words, $B_2^g > 0$ produces a shift to the left of the deposit supply curve.

And, as it is shown next the maximization problem of entrepreneurs is also affected by the policy intervention.

3.5.2 CB credit policy and demand side frictions

Recall, we assume that the entrepreneur is not aware of this credit injection rule, equation (3.29), and hence she cannot internalize the effects of their decisions on B_2^g. Entrepreneur balance sheet becomes,

$$K_2 = B_2^g + B_2 + N_{1,e}. \tag{3.33}$$

In this chapter, we solve the model assuming that bank loans and central bank loans have the same seniority[26]. This is, when entrepreneur defaults at $t = 2$, realized revenues are use to repay CB loans and bank loans proportionally to their values at $t = 2$.

Banks and government pay monitoring costs to observe entrepreneur' realized return when she defaults. Further, we assume the fixed proportional auditing cost μ is the same for both banks and for central bank. Hence, total monitoring costs must add up $\mu\omega_2 R_2^k K_2$. Thus, the threshold value of the idiosyncratic productivity, $\bar{\omega}_2$, is defined as,

$$\bar{\omega}_2 R_2^k K_2 = Z_2 B_2 + R_2 B_2^g. \tag{3.34}$$

[25]Clearly, banks are not willing to issue central bank loans funded with households deposits and/or bank equity, since the cost of collecting households deposits end up being higher than the risk-free interest rate, due to the moral hazard problem between banks and households, which is the return that they will obtain for issuing central bank loans.

[26]Each time an entrepreneur defaults, she needs to know the payment order to their creditors (CB and banks). There are three alternative assumptions: (1) Both CB loans and bank loans have the same seniority, (2) bank loans have higher seniority and (3) CB loans have higher seniority. In (1) both loans are paid with the same priority and hence each time entrepreneur defaults she transfers her realized capital payoffs to their creditors proportionally. In (2) if entrepreneur defaults it repays first bank loans, and then she cares on repaying CB loans. In (3) the opposite occurs. Chapter 2 explores in detail the effects of seniority

Furthermore, if $\omega_2 < \bar{\omega}_2$, government makes sure that CB loans are fully repaid by collecting lump-sum taxes. A defaulting entrepreneur receives nothing.

Combining equations (3.29) and (3.34) yields

$$\bar{\omega}_2 R_2^k K_2 = Z_2 B_2 + R_2 B_2^g \Rightarrow \bar{\omega}_2 = \frac{Z_2(1-\psi_{CB,2}) + R_2\psi_{CB,2}}{R_2^k}\frac{\phi_{2,e}-1}{\phi_{2,e}} < \bar{\omega}_2\Big|_{\psi_{CB,2}=0}, \tag{3.35}$$

where $\phi_{2,e} = K_2/N_{1,e}$ is the leverage of the representative entrepreneur. From equation (3.35), ceteris paribus, a higher fraction $\psi_{CB,2}$ of cheap loans reduce $\bar{\omega}_2$ and hence the entrepreneur's default probability, which in turn it results in lower expected monitoring cots. Consequently, it increases the marginal benefit of capital and hence increases demand for bank loans. Furthermore, according to (3.35) what drives the smaller $\bar{\omega}_2$ for a given R_2^k is the difference between the cost of CB loans R_2 and the traditional bank loans Z_2, i.e., the difference is that the cost of the CB loans does not include a risk premium due to the moral hazard problem between banks and depositors and an entrepreneur default risk premium.

The bank loan contract ($\bar{\omega}_2$, Z_2), in equation (3.12), which satisfies that banks always receive a gross return R_2^l per unit of bank loans, becomes:

$$[1 - F(\bar{\omega}_2)]Z_2 B_2 + (1-\mu)\int_0^{\bar{\omega}_2} \omega R_2^k K_2 x_2 dF(\omega) = R_2^l B_2, \tag{3.36}$$

where $x_2 = Z_2 B_2/(Z_2 B_2 + R_2 B_2^g)$ is the proportion of the realized revenues that goes to repay bank loans when the entrepreneur defaults. For a given K_2 the differences with respect to a bank loan contract without credit policy, equation (3.12), are two. i) Only a fraction $(1-\psi_{CB,2})$ of external funding comes from bank loans. In other words, without credit policy $B_2 = K_2 - N_{1,e}$, while with credit policy $B_2 = (1-\psi_{CB,2})(K_2 - N_{1,e})$. ii) Only a fraction x_2 of $\omega R_2^k K_2$ goes to pay bank loans each time an entrepreneur defaults.

For convenience the bank loan contract is written as,[27]

$$(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2))\, R_2^k K_2 = R_2^l\,(K_2 - B_2^g - N_{1,e}) + \Psi(\bar{\omega}_2) R_2 B_2^g, \tag{3.37}$$

where Γ and G are already defined in (3.46) and,

$$\Psi(\bar{\omega}_2) = (1-\mu)\frac{1}{\bar{\omega}_2}G(\bar{\omega}_2) + (1 - F(\bar{\omega}_2)) < 1.$$

In the left-hand side of equation (3.37) we have the resources available to repay funding. From the right-hand side those resources are used to fully cover the required return on the cost of funds, $R_2^l B_2$ and to partially pay the CB loans $\Psi(\bar{\omega}_2) R_2 B_2^g$. So, $\Psi(\bar{\omega}_2) R_2 B_2^g$ is the effective gross return repaid to CB loans by the entrepreneur. It is composed by the amount that non default entrepreneurs transfer to repay central bank loans $(1 - F(\bar{\omega}_2)) R_2 B_2^g$ and the value of seized projects from defaulting entrepreneurs $(1-\mu)\frac{1}{\bar{\omega}_2} G(\bar{\omega}_2) R_2 B_2^g$, net of monitoring costs, to repay central bank loans. Note that each time an entrepreneur defaults, government honours the guarantee and hence transfers resources to ensure CB loans receive the agreed return. This implies that entrepreneurs' transfers are not enough to fully pay CB loans. i.e., $\Psi(\bar{\omega}_2) < 1$, or equivalently the effective cost of CB loans from entrepreneur perspective is smaller than the risk-free interest rate, i.e., $\Psi(\bar{\omega}_2) R_2 < R_2$. This means that government transfers destined to repay CB loans are $(1 - \Psi(\bar{\omega}_2)) R_2 B_2^g$.

With unconventional credit, the entrepreneur aims to maximize their expected profits,

$$\int_{\bar{\omega}_2}^{+\infty} \left(\omega R_2^k K_2 - Z_2 B_2 - R_2 B_2^g\right) dF(\omega),$$

[27] Proof in Appendix 3.G.

taking as given R_2^k and B_2^g. Using (3.34) it yields,

$$[1-\Gamma(\bar{\omega}_2)]\, R_2^k K_2. \tag{3.38}$$

We arrive to an expression identical to the one without credit policy which is independent of the loan seniority assumption. Entrepreneur chooses K_2 and a schedule for $\bar{\omega}_2$ to maximize equation (3.38), subject to the constraint implied by equation (3.37).[28] The aggregate credit demand curve, equation (3.14), becomes,[29]

$$\left[[1-\Gamma(\bar{\omega}_2)]\,\frac{\Upsilon_2+1-F(\bar{\omega}_2)-\mu\bar{\omega}_2 f(\bar{\omega}_2)}{1-F(\bar{\omega}_2)}+(\Gamma(\bar{\omega}_2)-\mu G(\bar{\omega}_2))\right] R_2^k - R_2^l = 0\,, \tag{3.39}$$

together with (3.37) and where,

$$\Upsilon_2 = -\frac{\partial\Psi(\bar{\omega}_2)}{\partial\bar{\omega}_2}\frac{R_2 B_2^g}{R_2^k K_2} > 0. \tag{3.40}$$

Since $\Upsilon_2 > 0$, and comparing (3.39) with (3.14), we observe that credit policy positively affects the net marginal benefit of capital and hence aggregate demand for bank loans. The intuition is that the credit policy is reducing the transfer from entrepreneur to partially repay CB loans (or equivalently is increasing the transfers from government to repay CB loans), which in turn reduces the entrepreneur's default probability and hence the expected defaulting costs, which in turns raises incentives to demand capital and hence bank loans.

We can say that according to (3.35), for a given K_2, the credit policy reduces the entrepreneur's default probability and from (3.39), for a given $\bar{\omega}_2$, the net marginal benefit of capital increases. [30] Both positively affect aggregate credit demand:

- First, since the opportunity cost of the central bank is the risk-free interest rate R_2, banks or the central bank require a lower return per unit of these CB loans than the one required by bank loans, i.e., $R_2 < R_2^l$.[31] This reduces the entrepreneur's default probability and hence reduces the defaulting costs and pushes up the aggregate demand of capital and hence of demand for credit.

- Second, the guarantee of the government avoids that the (non-default) lending interest rate associated with the CB loans reflects any risk premium. In other words, while the (non-default) lending rate on banks loans is Z_2, the (non-default) lending rate on CB loans is R_2, with $Z_2 > R_2$. Ceteris paribus for given capital and equity, CB loans reduce entrepreneur obligations, default probability and reliance on bank loans. This in turn reduces the defaulting costs and pushes up the aggregate demand of capital and hence of credit.

Hence, the credit policy stimulates the aggregate credit supply and credit demand. In other words, the credit policy is expected to produce an increase in aggregate credit. Clearly, without frictions on the credit supply side, the credit policy does not increase aggregate credit supply and the first effect on aggregate demand is null.

[28] The first order conditions are found in Appendix 3.G.

[29] This is obtained from aggregating equation (3.14) in Appendix 3.G.

[30] Inserting equation (3.37) into equation (3.38) yields

$$[1-\mu G(\bar{\omega}_2]\, R_2^k K_2 - R_2^l(K_2 - B_2^g - N_{1,e}) - \Psi(\bar{\omega}_2)R_2 B_2^g. \tag{3.41}$$

Equation (3.41) says that the marginal cost of capital is not affected directly by the credit policy and so it continues to be R_2^l. This is because entrepreneur is not internalizing the effects of their capital decision on B_2 since they are not aware of the credit policy rule, equation (3.29). Otherwise, they are aware that one unit of external funding is funded with both cheap CB loans and bank loans, reducing the marginal cost of capital from entrepreneur's perspective.

[31] Recall that the return required by bank loans is higher than the risk-free interest rate due to the moral hazard problem between banks and depositors and the asymmetric information problem between banks and firms.

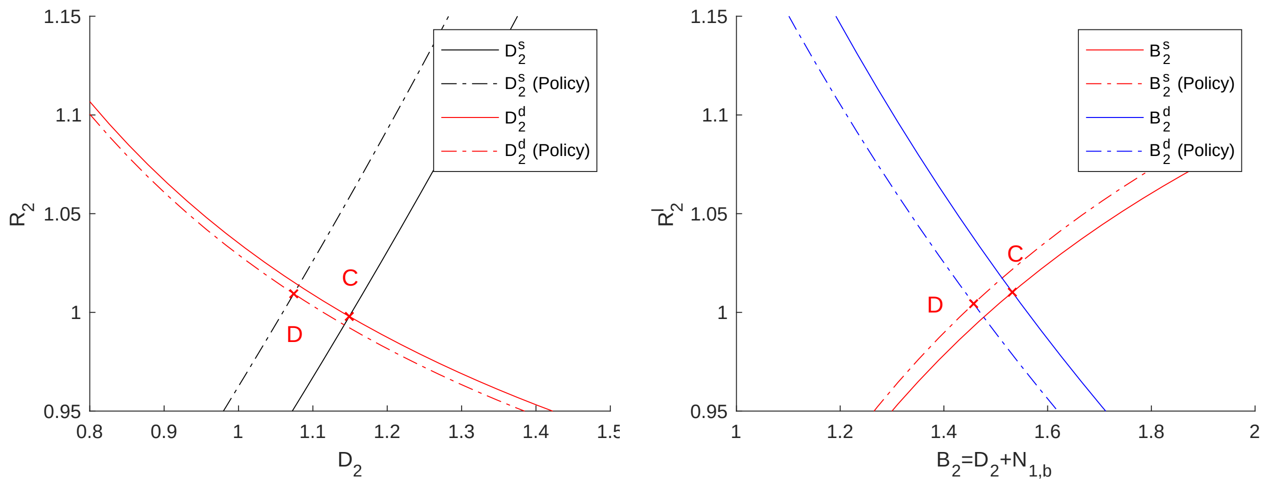
3.5.3 The effects of CB credit policy: a simulation exercise

In this subsection, in order to qualitatively assess the effects of the credit policy when the ZLB does not bind, we describe the credit policy intervention as exogenous. In particular, we set $\psi_{CB,2} = 6\%$.[32]

With credit policy intervention, banks substitute expensive traditional loans with cheaper indirect CB loans. But there is not only a substitution effect, since we observe also a higher total level of loans ($B_2^T = B_2^g + B_2$). In fact, total loans increases in 1.2%. This implies that this credit policy might attenuate a negative impact on the economy. Recall the effects of the credit policy on credit supply and on credit demand. Credit supply: Since CB loans cannot be diverted by banks, there is a higher aggregate supply of credit. Credit demand: Since the cost of CB loans is the risk-free interest rate and the lending rate does not have any risk premium, the entrepreneur's default probability decreases, which in turn increases the marginal benefit of capital. This pushes up entrepreneurs' incentives to demand credit.[33]

Figure 3.3: Deposit and Credit Market

Panel (a) Deposit Market | Panel (b) Traditional bank loans Market



Note: C: Both credit frictions. D: Equilibrium with unconventional credit policy, $\psi_{CB,2} = 6\%$. D_2^s : deposit supply curve. D_2^d : deposit demand curve. B_2^s : traditional bank loans supply curve. B_2^d : traditional bank loans demand curve.

Figure (3.3) shows the equilibrium in the deposit and traditional bank loans market with and without the unconventional credit policy intervention. Interestingly, unconventional credit policy intervention raises the deposit interest rate (Panel (a): the deposit market equilibrium moves point C to D). This implies that the credit policy moves the economy away from being closer to the ZLB. This in turn suggests that there is more space for implementing conventional monetary policy. This is because with policy intervention the central bank is collecting lump-sum taxes on households and hence is moving households' wealth across time. As a result, in order to smooth consumption households reduce their supply of deposits. This raises the deposit interest rate and the nominal interest rate as well.

[32]Recall that we assume that even after the credit policy intervention, the central bank can reach the target inflation of zero. This is performed by updating R_2^* in the Taylor rule so it is equal to the deposit interest rate R_2 without sticky prices.

[33]Although credit policy has a negative effect on the entrepreneur's default probability, pushing up credit demand, the general equilibrium effects of higher capital on this probability outweigh this effect. As a result, we observe that the entrepreneur's default probability (or the fraction of defaulting entrepreneurs at $t = 2$) increases.

In addition, Panel (b) in Figure (3.3) reports that there is a shift to the left of the traditional bank loans demand curve due to (i) the higher default probability of entrepreneurs due to higher total credit in equilibrium and (ii) the fact that entrepreneurs require a smaller amount of these traditional bank loans since they substitute these expensive traditional bank loans with cheap indirect CB loans.[34] These push down the required return on traditional bank loans (Panel (b): the traditional bank loans market equilibrium moves point C to D), which leads to a smaller bank capacity to demand deposits moving to the left the deposit demand curve. However, this is not enough to generate a lower deposit rate in equilibrium.

3.6 The Impact of the Zero Lower Bound

Here, we study the impact of the ZLB on credit policy effectiveness to diminish the impact of a shock that takes the economy to the ZLB. In particular, we assume a productivity level change takes the economy to the ZLB (Fernández-Villaverde Gordon, Guerrón-Quintana and Rubio-Ramírez, 2015; Garín, Lester and Sims, 2019). According to Figure 3.4, a lower productivity level might move the economy to a low enough nominal interest rate so that the ZLB binds.[35] Notice that we assume the central bank successfully implements inflation targeting.[36] We set the credit policy intervention $\psi_{CB,2}$ as a linear and decreasing function of the relative deviation of the productivity level from its baseline, i.e., $\psi_{CB,2} = -3\Delta a$, so it behaves as a "countercyclical" intervention. For the next numerical results, since we assume a ZLB, $i_{min} = 0$.[37] Then, according to our baseline calibration, the distance of the nominal interest rate to is ZLB is 1.23% (5% in annual terms).

When the ZLB binds, the nominal interest rate and the real interest rate (deposit interest rate) stop reducing. This constraint on the nominal interest rate avoids that the central bank can implement a monetary policy (a low enough nominal interest rate) so that inflation yields its target value, which is zero. As a result, inflation moves above its target value.[38] Intuitively, the higher real interest rate increases households' incentives to save[39] and to consume more at $t = 2$, which in turn increases aggregate demand and future inflation. This in turn increases entrepreneurs' incentives to produce and hence to demand credit. Thus, the ZLB produces a positive impact on capital and credit.[40]

According to Figure 3.4, the unconventional credit policy can reduce the likelihood of reaching the ZLB. This is, as commented in the previous section, because the unconventional credit policy reduces the deposit supply of households pushing upwards pressure on the real interest rate. This implies that the

[34]This shift to left implies that (i) and (ii) clearly outweigh the positive effect of the credit policy on traditional loans demand, $\Upsilon_2 > 0$.

[35]In Appendix 3.I, in Figure 3.8, we report the case where a lower $N_{1,b}$ can take the economy to the ZLB. In any case, all the conclusions from this section hold and hence the impact of the ZLB on the effectiveness of credit policy to improve capital and credit is qualitatively the same.

[36]In other words, we update R_2^* with the movement of a and with the policy intervention. This means that when the ZLB does not bind inflation is zero. However, when the ZLB binds, the central bank cannot implement inflation targeting and it becomes positive. This assumption is due to the two-period feature of the model; otherwise, the model might suggest the central bank can never reach its target inflation.

[37]It is easy to see that the results qualitatively holds for the case of a different value of i_{min} below the baseline value of the nominal interest rate.

[38]Note that this departs from the literature (based on dynamics models) that suggest that when the ZLB binds, the economy falls in a deflation spiral. In other words, in a dynamic NK model it is possible to find a stable solution for inflation. However, in this two-period model this is not the case.

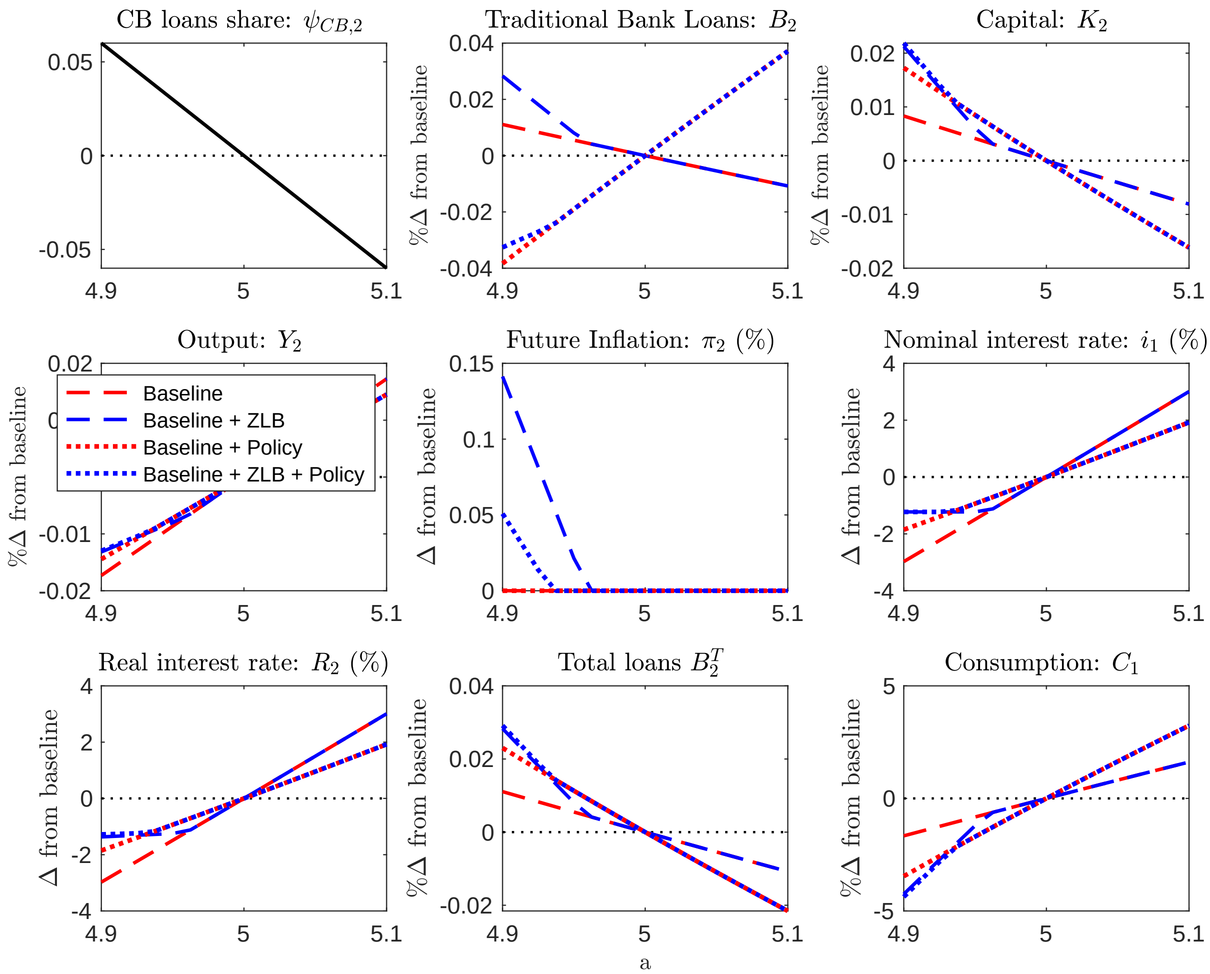
[39]Under the model calibration a lower a raises credit and capital due to an increase in household deposit supply, as wealth effects outweigh the substitution effect of a lower real interest rate.

[40]In Appendix 3.H we display the shifts of the supply and demand curves in the deposit and credit market due to the ZLB.

credit policy might give more space to implement a stronger conventional monetary policy. In the same line, Figure 3.4 also shows that a strong enough credit policy can take us out of the ZLB environment.

Figure 3.4 also suggests that in an economy with a ZLB the impact of the credit policy, assuming that the ZLB binds before and after the policy intervention, is weaker. In other words, when the ZLB already binds (even after the policy intervention) the effectiveness of the credit policy to increase total credit and hence capital is diminished. We compare the impact of the credit policy on capital, credit and output in Figure 3.5 in an economy with and without ZLB. For example, at a productivity level 2% smaller than its baseline value (i.e., at $a = 4.9$, the lowest value in the figure), the policy intervention (i.e., the participation of CB loans to total loans) of 6% produces increments of 1.2% in total loans (B_2+B_2^g) and 0.9% in capital in an economy without a ZLB; while these increments become 0.08% and 0.06% respectively in an economy with an already binding ZLB.

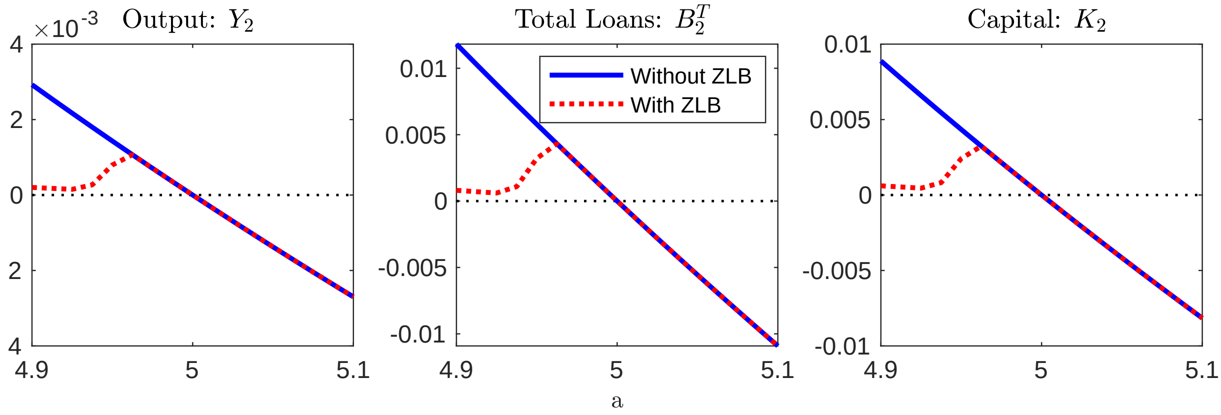
Figure 3.4: Credit policy and ZLB



Note: Figure shows the solutions for different values of the productivity level, a. These go from 0.98 to 1.02 times its baseline value. Distance to the $i_{min} = 0$ is 1.23%. Credit policy intervention is "countercyclical". All solutions are identical at baseline calibration. $B_2^T = B_2 + B_2^g$. $\psi_{CB,2} = -3\Delta a$, where Δa is the relative deviation of the productivity level from its baseline.

The reduced effectiveness of the unconventional credit policy when the ZLB binds is explained by two features: (i) When the ZLB is reached, since the policy maker cannot reach the target inflation, it moves above its target level; however, credit policy pushes down inflation. This negative impact on inflation of the credit policy is not observed when the ZLB does not bind (i.e., when the policy maker reaches its target inflation). Then, this negative impact reduces firms' incentives to demand capital and then entrepreneurs' incentives to demand credit. As a result, we observe a relatively stronger shift to the left of the credit demand curve of entrepreneurs (see Figure 3.6) when the ZLB binds. And (ii) when the ZLB is reached, the policy's benefits of providing relatively cheaper funding to entrepreneurs is diminished. This is because the relative cost reduction from having access to cheaper CB loans, $(Z_2 - R_2)/(Z_2 - 1)$, is smaller when the ZLB binds.[41] When the ZLB binds both the non-default lending interest rate, $Z_2 - 1$, and the spread, $Z_2 - R_2$, are higher than in economy without a ZLB; however, the former increases faster and hence the cost savings of the policy intervention are relatively smaller than in an economy without a ZLB (See Figure 3.9 in Appendix 3.I).

Figure 3.5: Impact of the credit policy with and without ZLB



Note: Figure shows the percentage difference between the equilibrium solutions of output, total loans and capital without and with unconventional credit policy for different values of a, the productivity level, for an economy with and without ZLB. Distance to the $i_{min} = 0$ is 1.23%. Credit policy intervention is "countercyclical". All solutions are identical at baseline calibration. $B_2^T = B_2 + B_2^g$. $\psi_{CB,2} = -3\Delta a$, where Δa is the relative deviation of the productivity level from its baseline.

In order to explain the importance of these two features in this economy, we compare the impacts of the unconventional and the conventional credit policies.[42] With the conventional credit policy we turn off the beneficial effects on entrepreneurs' profits of cheaper CB loans. According to Figure 3.10 in Appendix 3.I, the impact of the conventional credit policy is almost identical to the impact of the unconventional credit policy. This implies that the reduction of unconventional credit policy effectiveness when the ZLB binds is not mainly driven by a smaller relative cost reduction from having access to cheaper CB loans.[43]

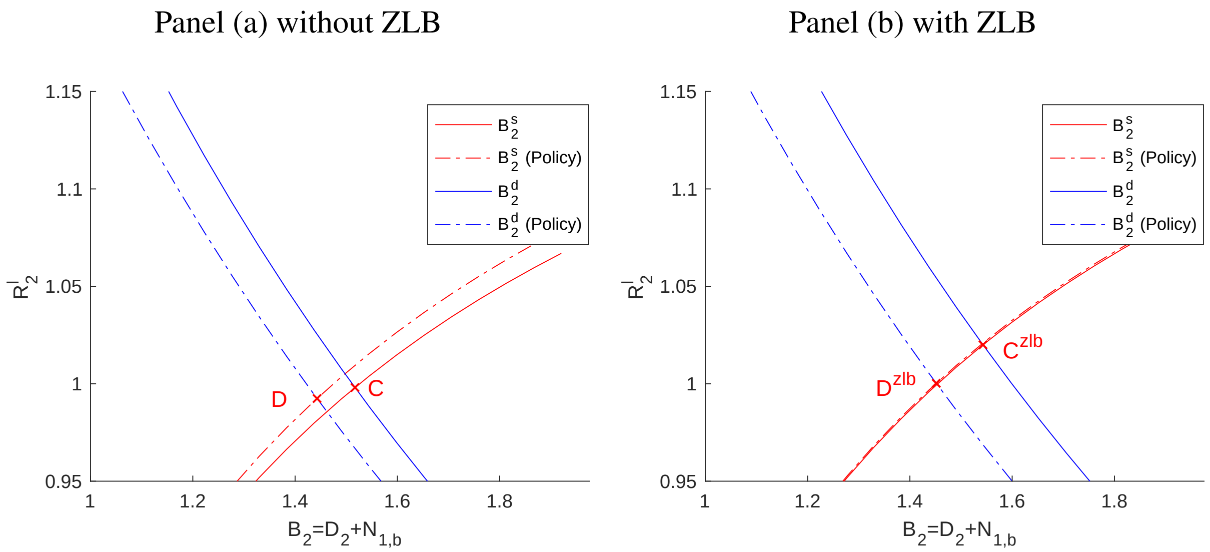
[41]Using (3.33) we can rewrite equation (3.35), $\bar{\omega}_2 R_2^k K_2 = Z_2 B_2 + R_2 B_2^g$ as $\frac{\bar{\omega}_2 R_2^k - 1}{Z_2 - 1} = \frac{B_2 + B_2^g}{K_2} - \frac{Z_2 - R_2}{Z_2 - 1}\frac{B_2^g}{K_2} - \frac{N_{1,e}}{K_2}\frac{1}{Z_2 - 1}$. Then, we should measure the impact of cheaper funding (B_2^g/K_2) on the entrepreneur's default probability as the relative cost savings of borrowing CB loans, $\frac{Z_2 - R_2}{Z_2 - 1}$.

[42]Recall that a conventional credit policy is defined as an unconventional central bank credit policy without government guarantees and assuming that CB charges to banks an interest rate R_2^l for the liquidity injection. As a result, the (non-default) interest rate of CB loans is the same as the traditional bank loans, Z_2.

[43]However, as discussed in Chapter 2, in times of very high uncertainty the beneficial effects of government guarantees (and hence cheaper CB loans) might become more economically significant; and hence smaller relative cost reduction from getting CB loans when the ZLB is reached might significantly affect the effectiveness of the unconventional credit policy.

Furthermore, this result highlights the importance of having a proactive central bank. In other words, according to the model central banks have stronger incentives to implement unconventional credit policy before the economy reaches the ZLB.

Figure 3.6: Traditional bank loans market



Note: Figure plots supply and demand curves of traditional bank loans at a productivity level 2% below its baseline value. At this point the ZLB binds (even after the credit policy intervention of $\psi_{CB,2} = 6\%$). Point C (C^{zlb}) indicates the equilibrium without policy intervention and without (with) ZLB. Point D (D^{zlb}) indicates the equilibrium with policy intervention and without (with) ZLB. D_2^s : deposit supply curve. D_2^d : deposit demand curve. B_2^s : traditional bank loans supply curve. B_2^d : traditional bank loans demand curve.

3.7 Conclusions

In this chapter we use a simple two-period model that incorporates credit supply and credit demand frictions together to understand the role of an unconventional credit policy in an economy with a ZLB constraint. First, the model is stylized enough that it can show the main mechanisms that operate in the interaction between deposits and credit markets in a two-period model. Second, we show that presence of credit frictions makes more likely that a ZLB equilibrium occurs. Third, unconventional credit policy has a positive impact on capital and credit by partially undoing the effects of credit frictions in the resource allocation of the economy. Fourth, more interestingly, the presence of the unconventional credit policy reduces the likelihood of reaching the ZLB. Furthermore, if the economy begins in an equilibrium near the ZLB and experiences a contractionary change, a strong enough policy intervention may be sufficient to lift the economy out of the ZLB. Fifth, unconventional credit policy has its limits. When the economy starts from an equilibrium in which the ZLB binds and then it experiences a contractionary change, the effectiveness of the credit policy is diminished.

However, since our model is very simple, and involves only two periods, our analysis has limits. First, we cannot respond questions related to the effects of unconventional credit on future expected inflation, or about the duration of ZLB under credit policy actions. Second, our analysis abstracts from optimal credit policy intervention and/or fiscal and monetary policy coordination. It is part of our future research agenda to study if the unconventional credit policy presented here is more or less effective than other forms of credit government interventions as the ones discussed in Christiano and Ikeda (2013). Third, a more realistic ZLB environment requires to think about the risks of a deflationary spiral.

3.8 Appendices

3.A Credit Supply Frictions curve of deposits

Credit Supply friction are modeled a la Gertler and Karadi 2011. A Bank.
Problem of Banks:

$$\max_{D_2} \quad R_2^l(N_{1,b} + D_2) - R_2 D_2$$
$$\text{s.t Incentive constraint (IC):}$$
$$R_2^l(N_{1,b} + D_2) - RD_2 \geq \lambda(N_{1,b} + D_2)R_2^l$$

The first order condition with respect to D_2 is

$$(R_2^l - R_2) + \nu((R_2^l - R_2) - \lambda) = 0, \tag{3.42}$$

where $\nu \geq 0$ is the Lagrange multiplier associate with the incentive constraint. We calibrate our model so that (3.5) binds: Without credit supply frictions, $R_2^l = R_2$ and then $V_1 = R_2 N_{1,b}$ and so we calibrate the model such that $R_2 N_{1,b} < \lambda B_2$. This results in $\nu > 0$ and from (3.42) it arises a credit risk premium $R_2^l - R_2 > 0$:

$$R_2^l - R_2 = \frac{\nu\lambda}{(1+\nu)}. \tag{3.43}$$

And from the binding incentive constraint, we solve for D_2, to obtain the demand curve for deposits:

$$D_2 = N_{1,b} \frac{(1-\lambda)R_2^l}{R_2 - (1-\lambda)R_2^l}. \tag{3.44}$$

3.B Entrepreneurs: Lending diversification and credit demand frictions

The incentive constraint for bank's loan contract $(\bar{\omega}_2, Z_2)$ in equation (3.11) can be rewritten by using (3.10) and (3.11) as follow

$$[\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)]\, R_2^k K_2 = R_2^l(K_2 - N_{1,e}), \tag{3.45}$$

where,

$$\Gamma(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega) + (1 - F(\bar{\omega}_2))\bar{\omega}_2, \qquad G(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega). \tag{3.46}$$

The expected profits to the entrepreneur in equation (3.13) by using (3.11) is rewritten as,

$$[1 - \Gamma(\bar{\omega}_2]\, R_2^k K_2. \tag{3.47}$$

Entrepreneurs aim to maximize (3.47) optimally choosing K_2 and $\bar{\omega}_2$ subject to the constraint implied by the bank loan contract, equation (3.45). Formally, the optimal problem may be now written as:

$$\max_{K_2, \bar{\omega}_2} (1 - \Gamma(\bar{\omega}_2))\, R_2^k K_2 + \eta_2 \left[(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2))\, R_2^k K_2 - R_2 B_2 \right],$$

where η_2 is the Lagrange multiplier associated with the loan contract. The first order conditions for $\bar{\omega}_2$ is,

$$-\frac{\partial \Gamma(\bar{\omega}_2)}{\partial \bar{\omega}_2} + \eta_2 \left(\frac{\partial \Gamma(\bar{\omega}_2)}{\partial \bar{\omega}_2} - \mu \frac{G(\bar{\omega}_2)}{\partial \bar{\omega}_2} \right) = 0. \tag{3.48}$$

The first order conditions for K_2 is,

$$(1-\Gamma(\bar{\omega}_2))\, R_2^k + \eta_2 \left[(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2))\, R_2^k - R_2^l \right] = 0. \tag{3.49}$$

The first order condition for η_2 yields the constrain, equation (3.45), where,[44]

$$\frac{\partial \Gamma(\bar{\omega}_2)}{\partial \bar{\omega}_2} = 1 - F(\bar{\omega}_2), \qquad \frac{\partial G(\bar{\omega}_2)}{\partial \bar{\omega}_2} = \bar{\omega}_2 f(\bar{\omega}_2).$$

Combining equations (3.48) and (3.49) yields the credit demand curve of the representative entrepreneurs, given by

$$\left[[1-\Gamma(\bar{\omega}_2)] \frac{1 - F(\bar{\omega}_2) - \mu \bar{\omega}_2 f(\bar{\omega}_2)}{1 - F(\bar{\omega}_2)} + (\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)) \right] R_2^k - R_2^l = 0\,, \tag{3.50}$$

and equation (3.45).

3.C Sticky prices: Final goods and intermediate firms

The final goods are produced by competitive firms, takes price, P_2, as given, and combines substitute intermediate domestic goods into a homogeneous good using the following CES technology, by solving the following profit maximization problem:

$$\max_{Y_{i,2}} \; P_2 Y_2 - \int_0^1 P_{i,2} Y_{i,2} di,$$

s.a

$$Y_2 = \left[\int_0^1 Y_{i,2}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} ,$$

where $\theta > 1$. The solution of maximization problem yields the demand schedule for a domestic intermediate i:

$$Y_{i,2} = \left(\frac{P_{i,2}}{P_2} \right)^{-\theta} Y_2, \tag{3.51}$$

and an aggregate price index,

$$P_2 = \left[\int_0^1 P_{i,2}^{1-\theta} dz \right]^{\frac{1}{1-\theta}} . \tag{3.52}$$

Intermediate good producers

Given the Decreasing Return to Scale technology, with $\alpha < 1$:

$$Y_{i,2} = a\,(K_{i,2})^{\alpha} \;,$$

[44] We assume $ln(\omega) \sim \mathcal{N}\left(-0.5\sigma_\omega^2, \sigma_\omega^2\right)$ so we have $\mathbb{E}(\omega) = 1$ and then $\Gamma(\bar{\omega}) = \Phi(z - \sigma_\omega) + \bar{\omega}[1 - \Phi(z)]$, $G(\bar{\omega}) = \Phi(z - \sigma_\omega)$, $\partial\Gamma(\bar{\omega})/\partial\bar{\omega} = 1 - \Phi(z)$ and $\partial G(\bar{\omega})/\partial\bar{\omega} = \bar{\omega}\Phi'(z)$, where $\Phi(.)$ and $\Phi'(.)$ are the c.d.f. and the p.d.f., respectively, of the standard normal and z is related to $\bar{\omega}$ through $z = (ln(\bar{\omega}) + 0.5\sigma_\omega^2)/\sigma_\omega$.

the inverse demand curve from (3.17),

$$p_{i,2} = \frac{P_{i,2}}{P_2} = \left(\frac{Y_{i,2}}{Y_2}\right)^{-\frac{1}{\theta}},$$

and the total cost function $\mathcal{C}(Y_{i,2}) = R_2^k K_{i,2}$ and where $K_{i,2}$ is found in the production function (3.19), the problem of an intermediate firm i that has the opportunity to change prices, is to maximize profits, which can be rewritten, in terms of $Y_{i,2}$ defining the relative prices as a function of output,

$$\max_{Y_{i,2}} \left[p_{i,2}(Y_{i,2})Y_{i,2} - R_2^k \left(\frac{Y_{i,2}}{a}\right)^{1/\alpha} \right], \tag{3.53}$$

with F.O.C.,

$$\begin{aligned} \frac{d(.)}{dY_{i,2}}: \qquad & p_{i,2}(Y_{i,2}) + Y_{i,2}\frac{dp_{i,2}}{dY_{i,2}} - \frac{1}{\alpha a^{1/\alpha}} R_2^k (Y_{i,2})^{\frac{1-\alpha}{\alpha}} = MR - \mathfrak{c}_{it} = 0 \\ & p_{i,2}\left(1 + \frac{dp_{i,2}}{dY_{i,2}}\frac{Y_{i,2}}{p_{i,2}}\right) - \mathfrak{c}_{it} = MR - \mathfrak{c}_{it} = 0, \end{aligned}$$

where the MR is the marginal revenue and $\mathfrak{c}_{it} := \partial\mathcal{C}(Y_{i,2})/\partial Y_{i,2}$ is the marginal cost. From the demand curve for intermediate firm, (3.17), $\frac{dp_{i,2}}{dY_{i,2}}\frac{Y_{i,2}}{p_{i,2}} = -\frac{1}{\theta}$, the optimal pricing is:

$$\frac{P_{i,2}}{P_2} = \mathcal{M}\mathfrak{c}_{i,2},$$

where $\mathcal{M} :\equiv \frac{\theta}{\theta-1}$ denotes the constant markup of the monopolistic firm. As shown in Galí (2015) one can eliminate the markup distortion on prices by considering a capital subsidy for the firm: $\tau = \frac{1}{\theta}$. Thus the optimal price without price distortions is[45]:

$$\frac{P_{i,2}}{P_2} = \mathfrak{c}_{i,2}, \tag{3.54}$$

Notice that with $\alpha < 1$, a decreasing return to scale in capital, the marginal cost is itself endogenous,

$$\mathfrak{c}_{i,2} = \frac{1}{\alpha a^{1/\alpha}} R_2^k (Y_{i,2})^{\frac{1-\alpha}{\alpha}} \underbrace{=}_{\text{from (3.17)}} \frac{1}{\alpha a^{1/\alpha}} R_2^k \left(\left(\frac{P_{i,2}}{P_2}\right)^{-\theta} Y_2\right)^{\frac{1-\alpha}{\alpha}} \tag{3.55}$$

and by inserting back into (3.54) and solving for $p_{i,2}$ we get that firms that optimally choose a price and denoting P_2^o as the optimal price for those firms that can update prices:

$$\frac{P_{i,2}}{P_2} = \frac{P_2^o}{P_2} = \left(\frac{1}{\alpha a^{1/\alpha}} R_2^k (Y_2)^{\frac{1-\alpha}{\alpha}}\right)^{\frac{\alpha}{\alpha+\theta(1-\alpha)}}. \tag{3.56}$$

In equilibrium, the consistent aggregate price index, (3.18), P_2 is

$$P_2 = \left[(1-\gamma)(P_2^o)^{1-\theta} + \gamma (P_1)^{1-\theta}\right]^{\frac{1}{1-\theta}},$$

where the all firms of measure γ that can not adjust their prices set $P_{i,2} = P_1$.

[45]Note that with capital subsidy to the firm,

$$\frac{P_{i,2}}{P_2} = (1-\tau)\mathcal{M}\mathfrak{c}_{i,2}$$

, where $\tau = \frac{1}{\theta}$ and $\mathcal{M} = \frac{\theta}{\theta-1}$

3.C.1 Market Clearing

In equilibrium, market clearing in the capital market requires:

$$K_2 = \int_0^1 K_{i,2}di = \int_0^1 \left(\frac{Y_{i,2}}{a}\right)^{1/\alpha} di = \int_0^1 \left(\frac{\left(\frac{P_{i,2}}{P_2}\right)^{-\theta} Y_2}{a}\right)^{1/\alpha} di$$
$$= \left(\frac{Y_2}{a}\right)^{1/\alpha} \int_0^1 \left(\frac{P_{i,2}}{P_2}\right)^{-\theta/\alpha} di$$

Thus, solving the GDP at $t = 2$ we find:

$$Y_2 = \Delta^{-1} a K_2^{\alpha},$$

where,

$$\Delta = \int_0^1 \left(\frac{P_{i,2}}{P_2}\right)^{-\theta/\alpha} di = \left[(1-\gamma)\left(\frac{P_2^o}{P_2}\right)^{-\theta/\alpha} + \gamma\left(\frac{P_1}{P_2}\right)^{-\theta/\alpha}\right], \tag{3.57}$$

is the price dispersion. **Market clearing in final goods market**,

$$C_1 = y_1 - N_e - N_b - D_2 = y_1 - K_2$$
$$C_2 = Y_2 - \mu G(\bar{\omega}_2) R_2^k K_2.$$

3.D Gap Representation: Phillips curve & IS curve

We represent the system in terms of gaps as in Woodford (2003). This is a practical representation for models with price rigidities. To do so, we apply a first order log-linearization to our non linear system, where for any X, its log-linear approximation around the natural equilibrium, X^n, is $\hat{x} = logX - logX^n \approx \frac{X-X^n}{X^n}$. .

First, we log-linearize the production function, equation (3.24),

$$\hat{y}_2 = logY_2 - logY_2^n = (log\, a + \alpha\, logK_2 - log\, \Delta) - (log\, a + \alpha\, logK_2^n)$$
$$= \alpha \hat{k}_2 - log\, \Delta$$

From the equation (3.57) we know that $log\, \Delta$,

$$log\, \Delta = log\left[(1-\gamma)\left(\frac{P_2^o}{P_2}\right)^{-\theta/\alpha} + \gamma\left(\frac{P_1}{P_2}\right)^{-\theta/\alpha}\right]$$

We know that $\Delta = 1$ at $P_2/P_1 = 1$ or at zero inflation, .i.e., $\Delta^n = 1$. Using this fact, and differentiate around the natural equilibrium,

$$log\, \Delta = -\frac{1}{1}\left[(1-\gamma)\frac{\theta}{\alpha}(p_2^o - p_2) - \gamma\frac{\theta}{\alpha}(p_2 - p_1)\right]$$
$$= \frac{\theta}{\alpha}\left[-(1-\gamma)(p_2^o - p_2) + \gamma(p_2 - p_1)\right],$$

where we used the facts of the natural equilibrium, and zero inflation: $\frac{\hat{p^o_2}}{p^o_2} = log\frac{P^o_2}{P_2} - log1 = p^o_2 - p_2 \approx \frac{\frac{P^o_2}{P_2}-1}{1}$ and $\frac{\hat{p_2}}{p_1} = log\frac{P_2}{P_1} - log1 = p_2 - p_1 \approx \frac{\frac{P_2}{P_1}-1}{1}$, given $P^n_2/P^n_1 = 1$ and $P^{n,o}_2/P^n_2 = 1$.

And from the aggregate price index, (3.62)

$$log\frac{P^o_2}{P_2} = \frac{1}{1-\theta}log\left(\frac{1-\gamma\left(\frac{P_1}{P_2}\right)^{1-\theta}}{(1-\gamma)}\right)$$

a log-linearization around the natural equilibrium,

$$p^o_2 - p_2 = \frac{\gamma}{1-\gamma}\left(p_2 - p_1\right)\,, \tag{3.58}$$

shows that actual inflation is a constant proportion of the optimal reset price relative to aggregate prices. Now if we use this in the expression for price dispersion we are left with

$$log\Delta = 0\,,$$

which confirms the results from Galí (2015) and price dispersion is a second order phenomenon. Thus in this first order approximation around the zero inflation, $P^n_2/P^n_1 = 1$, we can ignore the role of price dispersion, and log-linearized production function is just:

$$\hat{y}_2 = \alpha\hat{k}_2$$

Phillips curve

Using the definition of natural equilibrium, (3.26), we can rewrite the equation (3.21) which impose a constraint on the output,

$$\frac{P^o_2}{P_2} = \left(\frac{R^k_2}{R^{K,n}}\left(\frac{Y_2}{Y^n_2}\right)^{\frac{1-\alpha}{\alpha}}\right)^{\frac{\alpha}{\alpha+\theta(1-\alpha)}} \tag{3.59}$$

in which $P_{i,2} = P^o_2$ for all firms of measure $1-\gamma$ that can adjust their prices. A log-linear approximation to (3.59)

$$p^o_2 - p_2 = \frac{\alpha}{\alpha+\theta(1-\alpha)}\left(logR^k - logR^{K,n}\right) + \frac{1-\alpha}{\alpha+\theta(1-\alpha)}\left(logY_2 - logY^n_2\right)$$

where $p = log(P)$. By inserting the log-linear version of the aggregate price index (3.58) into the this, we have an aggregate supply equation.

$$p_2 - p_1 = \frac{\alpha(1-\gamma)}{\gamma\left(\alpha+\theta(1-\alpha)\right)}\left(\hat{r}_2\right) + \frac{(1-\alpha)(1-\gamma)}{\gamma\left(\alpha+\theta(1-\alpha)\right)}\left(\hat{y}_2\right)$$

where $\hat{r} = logR_2 - logR^n = logR^k - logR^{K,n}$, where we use the frictionless the credit market equilibrium condition, $R = R^k$, and $\hat{y}_2 = logY_2 - logY^n_2$.

IS curve

The log-linear version of the supply curve of capital, which is a the pricing of deposits or the Euler equation (3.25) is

$$logR_2 - logR^n_2 = \sigma\left((logC_2 - logC^n_2) - (logC_1 - logC^n_1)\right)$$

where we have replaced the market clearing conditions $C_1 = \Delta^{-1}aK_2 :\equiv Y_2$ and $C_1 = y_1 - K_2$, which have as a log-linear transformation $\hat{c}_2 = \hat{y}_2$ and $\hat{c}_1 = -\frac{K^n}{y-K^n}\hat{k}_2$, respectively. Notice that if we use the log-linear version of the production function, we can further use rewrite $\hat{c}_1 = -\frac{K^n}{\alpha(y-K^n)}\hat{y}_2$. With this, the Euler equation becomes:

$$\hat{r}_2 = \sigma\left(1+\frac{K^n}{\alpha\left(y-K^n\right)}\right)\hat{y}_2$$

Further, the log of real interest rate, by the Fisher equation is, $logR_2 = i-(p_2-p_1) = i-\pi_2$, in the later equality we define $\pi_2 \equiv p_2 - p_1$.

Finally, the IS curve is:

$$0 = \sigma\left(1+\frac{K^n}{\alpha\left(y-K^n\right)}\right)\hat{y}_2 - \left(i-\pi_2-r^n\right), \tag{3.60}$$

and the Phillips Curve is

$$\pi_2 = \frac{\alpha(1-\gamma)}{\gamma\left(\alpha+\theta(1-\alpha)\right)}\left(i-\pi_2-r^n\right) + \frac{(1-\alpha)(1-\gamma)}{\gamma\left(\alpha+\theta(1-\alpha)\right)}\left(\hat{y}_2\right) \tag{3.61}$$

where $r^n = log(R^n)$ is the real natural rate and defined in the flexible price equilibrium. Together, the IS curve and Phillips Curve, summarize the equilibrium as the deviation of output from its natural level and interest from its natural level.

3.E Demand for capital

Notice that from (3.22), $\frac{P_2^o}{P_2}$ is a function of the ratio $\frac{P_1}{P_2}$, which is the inverse of inflation,

$$\frac{P_2^o}{P_2}\left(\frac{P_1}{P_2}\right) = \left(\frac{1-\gamma\left(\frac{P_1}{P_2}\right)^{1-\theta}}{(1-\gamma)}\right)^{\frac{1}{1-\theta}}. \tag{3.62}$$

Further, the dispersion of prices, (3.57), is also a function of P_1/P_2:

$$\Delta = \Delta\left(\frac{P_1}{P_2}\right) = \left[(1-\gamma)\left(\left(\frac{1-\gamma\left(\frac{P_1}{P_2}\right)^{1-\theta}}{(1-\gamma)}\right)^{\frac{1}{1-\theta}}\right)^{-\theta/\alpha} + \gamma\left(\frac{P_1}{P_2}\right)^{-\theta/\alpha}\right]. \tag{3.63}$$

Then, using (3.24) and the two previous computations, one can rewrite (3.21),

$$\frac{P_2^o}{P_2}\left(\frac{P_1}{P_2}\right) = \left(\frac{R_2^k}{\alpha a K^{\alpha-1}}\left(\frac{1}{\Delta\left(\frac{P_1}{P_2}\right)}\right)^{\frac{1-\alpha}{\alpha}}\right)^{\frac{\alpha}{\alpha+\theta(1-\alpha)}}. \tag{3.64}$$

After some algebra, the demand for capital equation becomes,

$$R^k = \mathcal{W}\left(\frac{P_1}{P_2}\right)\alpha a K^{\alpha-1}, \tag{3.65}$$

where,

$$\mathcal{W}\left(\frac{P_1}{P_2}\right) = \left(\frac{1-\gamma\left(\frac{P_1}{P_2}\right)^{1-\theta}}{(1-\gamma)}\right)^{\frac{\alpha+\theta(1-\alpha)}{(1-\theta)\alpha}}\Delta^{\frac{1-\alpha}{\alpha}}, \tag{3.66}$$

where Δ is defined in (3.63). $\mathcal{W}$ is a wedge between the return on capital. Notice that if $\gamma = 0$ (i.e., non sticky prices), $\mathcal{W}\left(\frac{P_1}{P_2}\right) = 1$.

3.F Optimal policy and loss function

In this section we develop an optimal monetary policy rule in an economy without financial frictions. As in Woodford (2003) an optimal MP is one that minimizes a loss function:

$$\min_{y_2,\hat{p}_2,\hat{r}} L = \frac{1}{2}\left(\hat{y}_2\right)^2 + \kappa\frac{1}{2}\left(\hat{p}_2 - \hat{p}^e\right)^2$$

subject to (3.61). After replacing (3.61) into the loss function and solving for y , $\hat{r}$, the first order conditions are:

$$\hat{y}_2 + \Psi\left(\hat{p}_2 - \hat{p}^e\right) = 0$$
$$r = r^n$$

where $\Psi = \kappa\frac{(1-\alpha)(1-\gamma)}{\gamma(\alpha+\theta(1-\alpha))}$.

From the this it is clear that optimal MP requires that the real interest rate must be equal to the natural real interest rate. and that inflation is negatively related to output gap.

3.G Maximization problem of entrepreneurs with credit policy

Recalling the bank loan contract, equation (3.36),

$$[1 - F(\bar{\omega}_2)]Z_2B_2 + (1-\mu)\int_0^{\bar{\omega}_2} \omega R_2^k K_2 x_2 dF(\omega) = R_2^l B_t. \tag{3.67}$$

Recalling Z_2 is obtained in equation (3.34). Then,

$$x_2 = (\bar{\omega}_2 R_2^k K_2 - R_2 B_2^g)/(\bar{\omega}_2 R_2^k K_2) = 1 - \frac{R_2 B_2^g}{\bar{\omega}_2 R_2^k K_2}, \tag{3.68}$$

and so equation (3.67) becomes,

$$[1 - F(\bar{\omega}_2)](\bar{\omega}_2 R_2^k K_2 - R_2 B_2^g) + (1-\mu)\int_0^{\bar{\omega}_2}\left(\omega R_2^k K_2 - \frac{\omega}{\bar{\omega}_2} R_2 B_2^g\right) dF(\omega) = R_2^l B_2.$$

For convenience, this is written as,

$$-\Psi(\bar{\omega}_2) R_2 B_2^g + \left(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)\right) R_2^k K_2 = R_2^l \left(K_2 - B_2^g - N_{1,e}\right), \tag{3.69}$$

where,

$$\Gamma(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega) + (1 - F(\bar{\omega}_2))\bar{\omega}_2, \qquad G(\bar{\omega}_2) = \int_0^{\bar{\omega}_2} \omega dF(\omega).$$

$$\Psi(\bar{\omega}_2) = (1-\mu)\frac{1}{\bar{\omega}_2} G(\bar{\omega}_2) + (1 - F(\bar{\omega}_2)).$$

The optimal contracting problem may be now written as:

$$\max_{K_t,\bar{\omega}_2} \mathbb{E}_t\{(1 - \Gamma(\bar{\omega}_2)) R_2^k K_2 + \eta_2\left[-\Psi(\bar{\omega}_2) R_2 B_2^g + \left(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)\right) R_2^k K_2 - R_2^l B_2\right]\},$$

where $B_2^j = K_2 - B_2^g - N_{1,e}$. The first order condition for $\bar{\omega}_2$:

$$-\frac{\partial\Gamma(\bar{\omega}_2)}{\partial\bar{\omega}_2} R_2^k K_2 + \eta_2\left[-\frac{\partial\Psi(\bar{\omega}_2)}{\partial\bar{\omega}_2} R_2 B_2^g + \left(\frac{\partial\Gamma(\bar{\omega}_2)}{\partial\bar{\omega}_2} - \mu\frac{G(\bar{\omega}_2)}{\partial\bar{\omega}_2}\right) R_2^k K_2\right] = 0. \tag{3.70}$$

The first order condition for K_2:

$$\mathbb{E}_t \left\{ (1-\Gamma(\bar{\omega}_2))\, R_2^k + \eta_2 \left[(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2)) R_2^k - R_2^l \right] \right\} = 0. \tag{3.71}$$

The first order condition for η_2 yields equation (3.69), where,

$$\frac{\partial \Gamma(\bar{\omega}_2)}{\partial \bar{\omega}_2} = 1 - F(\bar{\omega}_2), \qquad \frac{\partial G(\bar{\omega}_2)}{\partial \bar{\omega}_2} = \bar{\omega}_2 f(\bar{\omega}_2).$$

$$\frac{\partial \Psi(\bar{\omega}_2)}{\partial \bar{\omega}_2} = (1-\mu) \left(-\frac{G(\bar{\omega}_2)}{(\bar{\omega}_2)^2} + \frac{1}{\bar{\omega}_2} \frac{\partial G(\bar{\omega}_2)}{\partial \bar{\omega}_2} \right) - f(\bar{\omega}_2) = -(1-\mu) \frac{G(\bar{\omega}_2)}{(\bar{\omega}_2)^2} - \mu f(\bar{\omega}_2) < 0.$$

Combining equations (3.70) with (3.71) yields,

$$\mathbb{E}_t \left\{ (1-\Gamma(\bar{\omega}_2))\, R_2^k + \frac{1 - F(\bar{\omega}_2)}{\Upsilon + 1 - F(\bar{\omega}^j) - \mu \bar{\omega}_2 f(\bar{\omega}_2)} \left[(\Gamma(\bar{\omega}_2) - \mu G(\bar{\omega}_2))\, R_2^k - R_2^l \right] \right\} = 0.$$

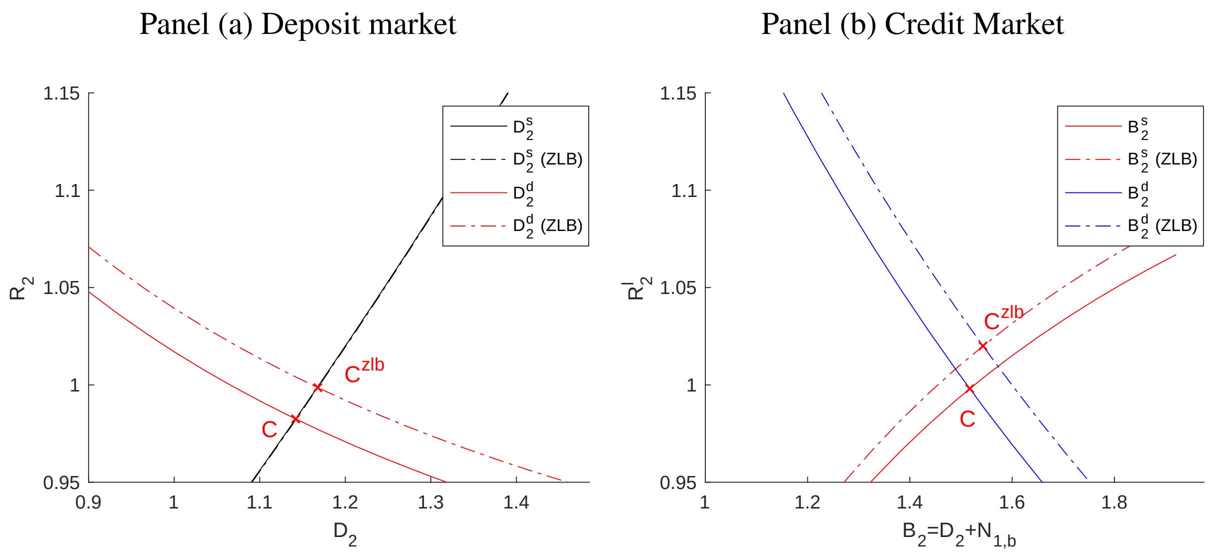
where,

$$\Upsilon = -\frac{\partial \Psi(\bar{\omega}_2)}{\partial \bar{\omega}_2} \frac{R_2 B_2^g}{R_2^k K_2} > 0.$$

3.H Zero Lower Bound

Figure 3.7 reports the effects of the ZLB on demand and supply curves in the deposit and credit market and hence their impact on the real interest rate and the return of traditional bank loans. The ZLB avoids a lower nominal interest rate and hence a lower real interest rate, so it pushes up this latter. Since the nominal interest rate cannot adjust, inflation moves. In particular, since the central bank cannot longer achieve its target inflation, and inflation moves above its target value. This higher inflation produces a shift to the right of the credit demand of entrepreneurs. This raises the return of loans and increases the demand curve of deposits of banks, which in turn explains the higher real interest rate in equilibrium.

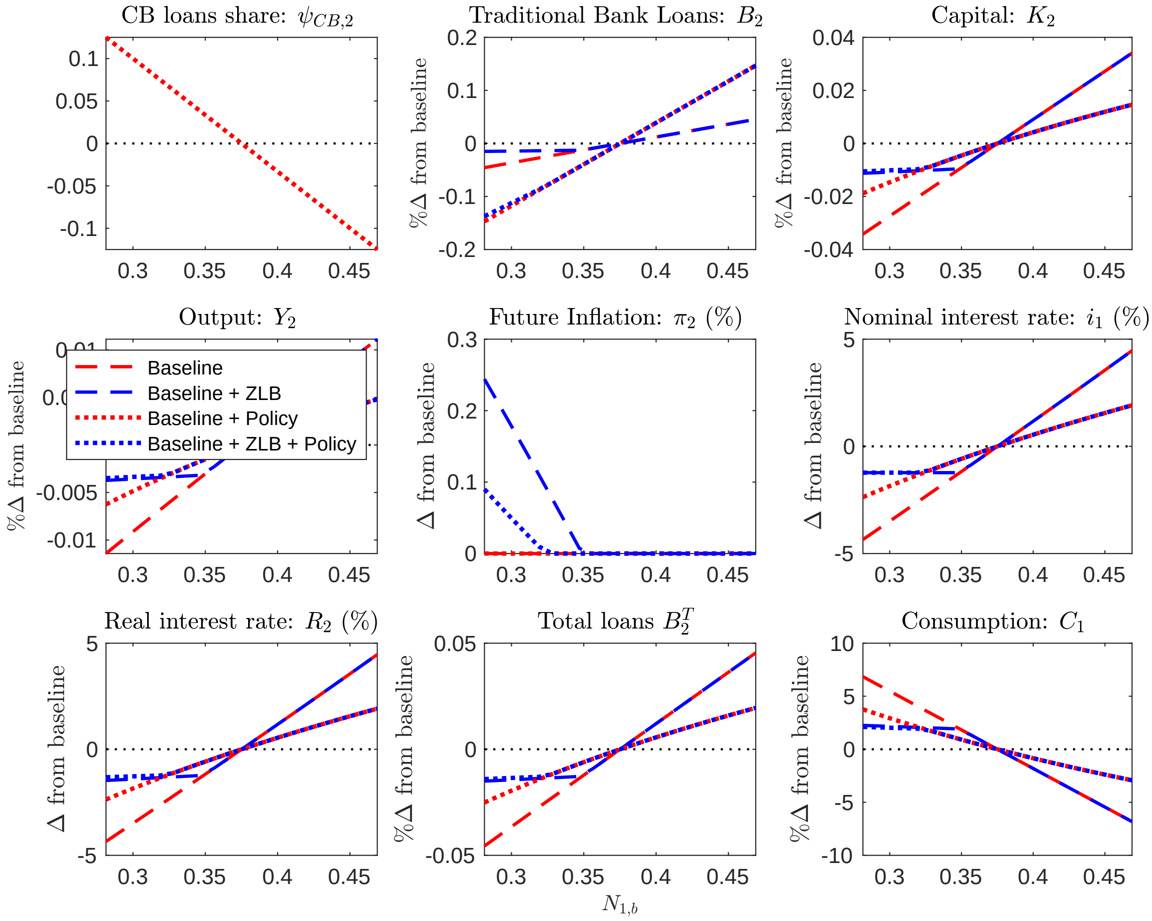
Figure 3.7: Deposits and traditional bank loans market



Note: Figure plots the demand and supply curves of deposits and traditional bank loans at a productivity level 2% below its baseline value. At this point the ZLB binds. Point C (C^{zlb}) indicates the equilibrium without policy intervention and without (with) ZLB.

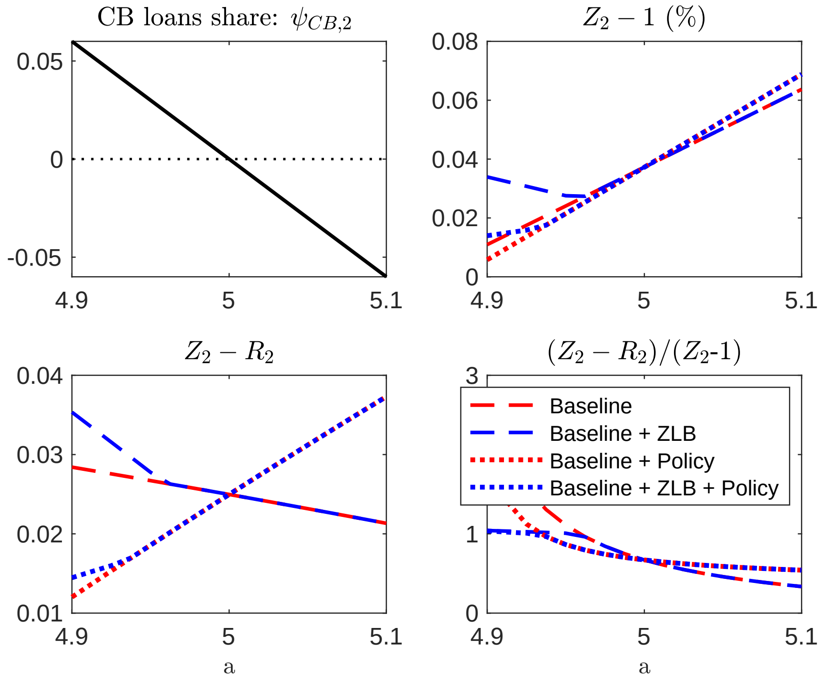
3.I Figures

Figure 3.8: ZLB and Bank Net Worth



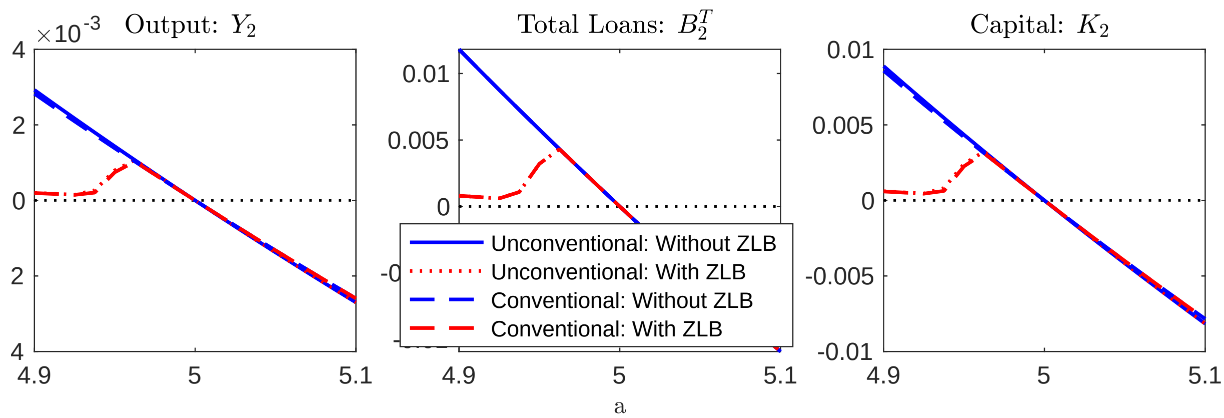
Note: Figure shows the solutions for different values of $N_{1,b}$, the bank net worth. These go from 0.75 to1.25 times its baseline value. Distance to the $i_{min} = 0$ is 1.23%. Credit policy intervention is "countercyclical". All solutions are identical at baseline calibration. $B_2^T = B_2 + B_2^g$.

Figure 3.9: Interest rates spreads, credit policy and ZLB



Note: Figure spreads for different values of the productivity level, a. These go from 0.98 to 1.02 times its baseline value. Distance to the $i_{min} = 0$ is 1.23%. Credit policy intervention is "countercyclical". All solutions are identical at baseline calibration. $B_2^T = B_2 + B_2^g$. $\psi_{CB,2} = -3\Delta a$, where Δa is the relative deviation of the productivity level from its baseline.

Figure 3.10: Impact of the unconventional vs. conventional credit policy with and without ZLB



Note: Figure shows the percentage difference between the equilibrium solutions of output, total loans and capital without and with unconventional credit policy for different values of a, the productivity level, for an economy with and without ZLB. Distance to the $i_{min} = 0$ is 1.23%. Credit policy intervention is "countercyclical". All solutions are identical at baseline calibration. $B_2^T = B_2 + B_2^g$. $\psi_{CB,2} = -3\Delta a$, where Δa is the relative deviation of the productivity level from its baseline.

3.J Conventional Credit Policy

Here we assume that CB charges to banks an interest rate of R_2^l for the liquidity injection and that CB loans are not longer guaranteed by the government. As a result, the (non-default) lending interest rate of CB loans is Z_2 assuming that bank loans and traditional bank loans have the same seniority (i.e., are repaid with the same priority). In this scenario, the credit policy becomes conventional and only increments the aggregate total credit supply as in Gertler and Kiyotaki (2011); and thus does not longer provider relatively cheaper CB loans to entrepreneurs.

The threshold value of the idiosyncratic productivity, equation 3.34, is rewritten as,

$$\bar{\omega}_2 R_2^k K_2 = Z_2 B_2 + Z_2 B_2^g = Z_2(K_2 - N_{1,e}). \tag{3.72}$$

However, it is identical to equation 3.34 if we rewrite both in terms of K_2. Hence, CB loans do not reduces funding costs of entrepreneurs for a given level of K_2. The contract of both bank loans and CB loans ($\bar{\omega}_2$, Z_2), equation (3.12), becomes,

$$[1 - F(\bar{\omega}_2)]Z_2(B_2 + B_2^g) + (1 - \mu)\int_0^{\bar{\omega}_2} \omega R_2^k K_2 dF(\omega) = R_2^l(B_2 + B_2^g), \tag{3.73}$$

Indeed, this identical to equation (3.12) if we replace $B_2 + B_2^g = K_2 - N_{1,e}$. This implies that for a given level of total credit or capital, the credit policy does not affect the loan contract.

With conventional credit policy, the entrepreneur aims to maximize their expected profits,

$$\int_{\bar{\omega}_2}^{+\infty} \left(\omega R_2^k K_2 - Z_2(B_2 - B_2^g)\right) dF(\omega),$$

taking as given R_2^k and B_2^g. Using (3.72) it yields,

$$[1 - \Gamma(\bar{\omega}_2)]\, R_2^k K_2. \tag{3.74}$$

We arrive to an expression identical to the one without credit policy. Entrepreneur chooses K_2 and a schedule for $\bar{\omega}_2$ to maximize equation (3.74), subject to the constraint implied by equation (3.73). It is easy to verify that the aggregate credit demand curve is identical to equation (3.14). As a result, conventional credit policy does not affect at all the aggregate credit demand curve. In other words, the policy does not diminish the credit demand frictions as the unconventional credit policy does.

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