Banking Crises, Lending Standards and Misallocation

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Abstract

I analyze bank capital shortfalls through a model in which banks can reject borrowers whose risk is above an endogenous qualification threshold ("the lending standards") at which no lending rate sufficiently compensates banks for the borrower’s default risk. Firms denied credit cut employment and labor reallocates mostly towards safer producers. These producers then become too large and their productivity falls. Lending standards propagate bank capital shortfalls through labor misallocation causing deeper and more persistent real effects. There is mutual feedback between the amount of misallocation in the labor market and the speed of banks’ recapitalization.

Keywords: Bank Capital; Bank Losses; Extensive Margin; Lending Standards; Labor Reallocation; Misallocation.

JEL Classification: E32, E44, E47, G2

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1 Introduction

The 2007-08 crisis triggered a new literature that incorporates an intermediation sector into general equilibrium models. The goal is to study how shocks to financial intermediaries ("banks" for short) affect the real economy (see for example the surveys in Gertler 2012 or Guerrieri et al. 2015). This paper innovates by allowing banks to adjust not only along lending rates, but also through lending standards. That is, banks optimally set lending cut-off rules ("the lending standards") to reject the riskiest borrowers. Laufer and Paciorek (2016) document this behavior of banks. For example, in mortgage markets banks deny applications whose risk is above a threshold inferred from the credit scores of the borrowers. Rodano, Serrano-Velarde and Tarantino (2016) find that most Italian banks adjust their lending standards through higher rejection rates. \(^1\)

In the model, there are entrepreneurs (firms), households and banks. Entrepreneurs use their equity and bank loans to hire labor and produce output. Banks fund loans using their own equity and borrowings from households. Entrepreneurs are subject to idiosyncratic productivity shocks and costly-state verification frictions, as in Bernanke, Gertler and Gilchrist (1999, BGG), that generate equilibrium default and endogenous credit spreads over banks' costs of funds. However, departing from the literature, I assume that entrepreneurs are heterogeneous in the variance ("risk" for short) and the mean of their idiosyncratic shocks.

Banks have a screening technology to perfectly infer if the risk of a borrower is above or below a lending standards threshold. Banks deny credit applications from those borrowers whose risk is above the threshold because, with debt contracts, banks' expected revenue is decreasing in borrower's risk, which increases the probability of default. The threshold is an endogenous rationing limit which depends on banks' costs of funds, among other factors. Changes in the threshold induce changes in the extensive margin of credit. Laufer and Paciorek (2016) show that lenders' minimum credit score lending rules fluctuate over time getting tighter with the financial crisis.

In the model, a bank capital shortfall leads to higher borrowing costs for banks because there is a second costly-state verification friction between banks and their lenders. This is consistent with the evidence discussed in Bindseil and Laeven (2017) that interbank markets (banks' lenders in the model) ex-ante do not observe how credit losses are distributed across individual banks because bank lending is opaque. Thus, when banks lose equity their borrowing costs increase as banks' lenders require compensation since a greater amount of leverage makes bank default more likely.

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\(^1\)In the U.S. no database keeps track of loan denial rates, except HMDA in mortgage markets.
Banking crises are triggered by exogenous shocks to banks’ equity. For example, households default on some loans not included in the model. The shock is a purely financial shock and the equity losses for the banks are equity gains for the households. That is, the shock does not imply per se the depletion of real resources as in real shocks to the quality of the capital stock. Guerrieri et al. (2015) analyze the same financial shock in five recent general equilibrium models of banks.

To illustrate the propagation channel generated by lending standards, first I assume that households’ labor is in fixed supply. In this environment, a pure financial shock has no effect on output when banks cannot deny credit applications. That is, in a model with only intensive credit margin and inelastic labor supply, lower wages counteract the higher credit spreads caused by the bank capital shortfalls and output is constant. Guerrieri et al. (2015) discuss how this result applies to all the existing macro models of banks, even if they allow for physical capital, because with pure financial shocks the immediate fall in output has to ride through a contraction in hours worked. Calibration choices regarding the Frisch elasticity of labor supply become key for the immediate output reduction. For this reason, it is common in the literature to trigger a banking crisis with a real shock, like a reduction of capital quality as in Gertler and Karadi (2011).

When banks can tighten their lending standards, pure financial crises cause output falls, even with inelastic labor supply. Entrepreneurs denied credit must cut employment. In order to clear labor markets, wages fall and labor reallocates towards both the safer producers which still receive credit, and towards those entrepreneurs that were so risky that could not get credit before the crisis. The latter group can now hire more labor with their equity because wages are lower. Output decreases for two reasons: 1) the safer producers become too large and decreasing returns to scale lower their productivity; 2) if risk and productivity are positively related, then tighter lending standards reallocate labor towards low-productivity producers. First, I discuss the results in the benchmark model in which risk and expected productivity are uncorrelated across entrepreneurs. Then I show that allowing for a positive correlation amplifies the results of the model with lending standards.\(^2\)

The model suggests that credit spreads may be insufficient indicators of credit supply disruptions when banks are also changing their denial rates. That is, for the same increase in credit spreads, output is falling faster when denial rates are increasing. Lown and Morgan (2006) and Bassett et al. (2014) show that changes in lending standards affect output even when controlling for credit spreads.

\(^2\) The positive correlation between risk and expected productivity cannot be too large or higher risk would lead to relaxed lending standards, which is counterfactual.
The mechanism of this paper is supported by recent applied work. For example, Bentolila et al. (2015) and Puri, Rocholl and Steffen (2011) document significant increases in loan rejection rates in Germany and Spain following banks’ equity losses. De Jonghe et al. (2016) show that banks facing negative funding shocks reallocate credit towards low-risk firms. Kok and Schepens (2013) also find that undercapitalized banks move away from riskier assets. Finally, several recent papers have shown that contractions of credit supply lead to declines in employment and to labor reallocation, see for example, Bentolila et al. (2015), Berton et al. (2016), Chodorow-Reich (2014), Duygan-Bump, Levkov and Montoriol-Garriga (2015) or Popov and Rocholl (2016). To my knowledge, what the empirical banking literature has not yet studied is the implications for productivity and output of these previous facts and that this paper highlights.

Kudlyak and Sanchez (2017) find that after the third quarter of 2008 large firms contracted much more than small firms. They hypothesize that it might be the case that small versus large is not a good approximation of the debt constrained versus unconstrained dimension for firms. This paper shows that risky versus safe may be a more adequate approximation.

This paper relates the literature on financial intermediation to the misallocation literature that so far has abstracted from explicitly modelling financial intermediaries. The feedback loop goes in both directions.

Methodologically the paper contributes to the growing literature that analyzes DSGE models with an intermediation sector. For example, some recent publications are Ajello (2016), Andreasen, Ferman and Zabczyk (2013), Angeloni and Faia (2013), Boissay, Collard and Smets (2016), Bocola (2016), Collard et al. (2017), De Fiore, Teles and Tristani (2011), Gertler, Kiyotaki and Queralto (2012), Gertler and Karadi (2011), Gertler and Kiyotaki (2015), Iacoviello (2015) or Ravn (2016) among others. This paper is novel because it allows lenders to deny credit to the riskier borrowers and this leads to labor misallocation. Lending standards is a non-price mechanism that microfound the financial shocks of Jermann and Quadrini (2012).

The paper complements the misallocation literature that argues that financial frictions can cause output losses through input reallocation. For example, Buera and Moll (2015), Buera, Jaef and Shin (2015) and Siemer (2014) analyze labor misallocation. This literature takes financial shocks as exogenous, usually assuming shocks to the collateral constraints without modelling the financial sector. This paper microfound those shocks relating them to banks’ equity and a fly to safety mechanism. To my knowledge the literature has not yet related misallocation with heterogeneity in borrowers’ risk. Also, this paper shows that the intensity and persistence of the collateral-constraint shocks become endogenous when the model includes a financial sector.
There is mutual feedback between the amount of misallocation, the recapitalization of the banks and the status of the economy.

The paper is organized as follows. Section 2 presents the model. Section 3 calibrates it. Section 4 contains the results. Section 5 concludes.

2 Model

In the model there are households, entrepreneurs and banks. Households consume goods, sell their labor to the entrepreneurs and lend to the banks, which then lend to the entrepreneurs. The entrepreneurs produce goods. The model is real.

2.1 Households

There is a continuum of homogeneous households who maximize expected utility over consumption $C_t$, hours worked $H_t^H$ at wage $W_t$, and deposits $D_t$,

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t u(C_t, H_t^H),$$

subject to their budget constraint:

$$C_t + D_t = W_t H_t^H + R_{t-1}^t D_{t-1} + \Pi_t^E + \Pi_t^B + T_t. $$

Where $\Pi_t^E$ and $\Pi_t^B$ are dividends paid by the entrepreneurs and banks respectively. $T_t$ is the exogenous transfer that will trigger the banking crisis as I discuss below. It is lump-sum so it does not distort the households’ decisions. $R_{t-1}^t$ is the risk-free rate between periods $t - 1$ and $t$.

2.2 Entrepreneurs’ technology

Every period there is a continuum of entrepreneurs with mass one. Each entrepreneur $i$ produces output at $t$ according to the function

$$y(\omega_i^t, h_{t-1}^i) = \omega_i^t (h_{t-1}^i)^\alpha,$$
where \( h_{t-1} \) is the number of labor units hired last period and the parameter \( \alpha < 1 \) generates decreasing returns to scale. The idiosyncratic productivity shock \( \omega^i_t \) is realized after labor is hired. Like in BGG models, this shock is i.i.d. across periods. However, a novelty of this paper is that entrepreneurs are heterogeneous in the distribution function of the \( \omega^i_t \) shocks. That is, \( \omega^i_{t+1} \) comes from a log-normal distribution \( F (\omega^i_{t+1}) \),

\[
\omega^i_{t+1} \sim \ln N (\mu^i_t, \sigma^i_t). \tag{4}
\]

where the standard deviation \( \sigma^i_t \) and the mean \( \mu^i_t \) of the back-transformed (logged) scale are i.i.d. and are specific to the entrepreneur. That is, after labor is hired in period \( t \), the entrepreneur \( i \) gets an i.i.d. random draw \( \sigma^i_t \) from a cumulative distribution \( H (\sigma^i_t) \) that is the same across entrepreneurs, and that is constant over time. I will assume \( H (\sigma^i_t) \) is a uniform distribution in the support \([a, b] \). Then \( \mu^i_t \) is a function of \( \sigma^i_t \),

\[
\mu^i_t = \varphi \ln (\sigma^i_t) - \frac{(\sigma^i_t)^2}{2}, \quad \forall i, \forall t. \tag{5}
\]

where \( 0 \leq \varphi < 1 \) is a parameter. In the benchmark case I assume \( \varphi = 0 \) or

\[
\mu^i_t = -\frac{(\sigma^i_t)^2}{2}, \quad \forall i, \forall t. \tag{6}
\]

which implies that the idiosyncratic productivity has mean one,

\[
E_t (\omega^i_{t+1}) = \int_0^\infty \omega^i_{t+1} dF (\omega^i_{t+1}; \sigma^i_t) = \exp \left( \mu^i_t + \frac{(\sigma^i_t)^2}{2} \right) = 1, \quad \forall i, \forall t. \tag{7}
\]

When (7) holds then entrepreneurs only differ in risk. That is, entrepreneurs have the same \( E_t (\omega^i_{t+1}) \) but differ in their variances \( \forall var_t (\omega^i_{t+1}) \). I also allow for the case in which the riskier entrepreneurs are expected to be the more productive. That is, I assume \( 0 < \varphi < 1 \). Then, the mean of \( \omega^i_t \) is increasing in the risk parameter \( \sigma^i_t \),

\[
E_t (\omega^i_{t+1}) = \int_0^\infty \omega^i_{t+1} dF (\omega^i_{t+1}; \sigma^i_t) = (\sigma^i_t)^\varphi. \tag{8}
\]

If \( H (\sigma^i_t) \) becomes a degenerate distribution, then the entrepreneurs of the model converge with the entrepreneurs of BGG. Christiano, Motto and Rostagno (2014) is the case when \( H (\sigma^i_t) \) is degenerate and the cross-sectional dispersion of idiosyncratic productivity is time-varying.
2.3 Lending standards and financed entrepreneurs

Banks screen entrepreneurs and observe whether the borrower $\sigma^i_t$ is above or below an endogenous lending standard threshold $\bar{\sigma}_t$. For example, banks have the expertise to do a risk assessment and ensure that no borrower above a certain risk-level is financed. Laufer and Paciorek (2016) document that this is how banks operate in mortgage markets. Lenders set time-varying minimum thresholds for acceptable credit scores and reject all credit applications whose risk is larger than the threshold. Similarly, I assume that when a potential borrower applies for a loan of size $l_t$, the bank screens the entrepreneur and denies applications that are too risky in the sense that $\sigma^i_t \geq \bar{\sigma}_t$. That is,

$$
l^i_t (\sigma^i_t) = \begin{cases} 
0 & \text{if } \sigma^i_t > \bar{\sigma}_t \\
l_t & \text{if } \sigma^i_t \leq \bar{\sigma}_t
\end{cases}.
$$

(9)

The lending rule (9) assumes that the bank can only detect whether a borrower qualifies for credit or not. This assumption simplifies (without altering the insights) because all borrowers below $\bar{\sigma}_t$ receive the same credit conditions that will be endogenously determined below. Financed entrepreneurs use their funds (equity $N^E_t$, and borrowings $l_t$) to hire workers:

$$
h^i_t = l_t + \frac{N^E_t}{W_t} \text{ if } \sigma^i_t \leq \bar{\sigma}_t
$$

(10)

Banks set their lending standards $\bar{\sigma}_t$ to reject those entrepreneurs for which there is no interest rate at which they expect to break-even. Like in BGG, I characterize lending rates by a default threshold $\hat{\omega}_{t+1}$ such that for realizations of the idiosyncratic shock above $\hat{\omega}_{t+1}$ the borrower pays $\hat{\omega}_{t+1} \left( \frac{l_t + N^E_t}{W_t} \right)^{\alpha}$ to the bank. For realizations below $\hat{\omega}_{t+1}$, the lender seizes borrower’s assets after paying a proportional deadweight cost $\mu_E$. Banks’ lending rate to entrepreneurs ($R^L_{E,t+1}$) can be defined as an increasing function of the default threshold $\hat{\omega}_{t+1}$,

$$
R^L_{E,t+1} l_t = \hat{\omega}_{t+1} \left( \frac{l_t + N^E_t}{W_t} \right)^{\alpha}.
$$

(11)

First, I define banks’ expected revenue as a function of the default threshold, borrower’s

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3 Section 2.3 has the problem of the financed entrepreneurs in which they choose optimally their borrowings and hence the amount of labor they hire. The calibration ensures that entrepreneurs’ equity is small enough such that entrepreneurs never have enough equity to hire without credit all workers they optimally would like to hire.

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risk and loan amount:

\[
\Omega \left( \hat{\omega}_{t+1}, \sigma^i_t, l_t \right) = \mathbb{E}_t \left[ \int_{\hat{\omega}_{t+1}}^{\infty} \hat{\omega}_{t+1} \left( \frac{l_t + N_E^i}{W_t} \right)^\alpha dF \left( \omega^i_{t+1}; \sigma^i_t \right) + \int_{0}^{\hat{\omega}_{t+1}} (1 - \mu_E) \omega^i_{t+1} \left( \frac{l_t + N_E^i}{W_t} \right)^\alpha dF \left( \omega^i_{t+1}; \sigma^i_t \right) \right].
\]

(12)

The first integral is the revenue for the bank when the borrower is expected to repay. The second integral is the revenue when the borrower defaults.

Figure 1 plots banks’ expected revenue \( \Omega \left( \hat{\omega}_{t+1}, \sigma^i_t, l_t \right) \) as a function of the default threshold \( \hat{\omega}_{t+1} \).

I denote by \( \bar{\omega} \left( \sigma^i_t \right) \) the default threshold maximizing banks’ revenue, that is,4

\[
\bar{\omega} \left( \sigma^i_t \right) = \arg \max_{\hat{\omega}_{t+1}} \Omega \left( \hat{\omega}_{t+1}, \sigma^i_t, l_t \right).
\]

(13)

There are two things to notice in Figure 1:

a) Two opposing channels deliver an interior solution for \( \bar{\omega} \left( \sigma^i_t \right) \), that is the peak of the revenue function of a borrower with volatility parameter \( \sigma^i_t \). For low lending rates, banks’ revenue is increasing in the lending rate. That is, when the borrower can repay, higher lending rates lead to more revenue for the bank. However, for high lending rates, revenue is decreasing. This is because higher rates increase the likelihood of default and this entails deadweight losses. The optimal \( \bar{\omega} \left( \sigma^i_t \right) \) is an interior solution that compromises between the previous two channels.

b) The maximum revenue is decreasing in borrower’s volatility parameter \( \sigma^i_t \). Higher volatility of borrower’s income increases the area of default and, since in debt contracts lenders’ payoffs are concave in the value of borrower’s income, it decreases lenders’ revenue.5

The optimal lending standard \( \bar{\sigma}_t \) is the riskiest borrower at which the bank can break-even. That is, given the function \( \bar{\omega} \left( \sigma^i_t \right) \) defined in (13) that governs the maximum revenue the bank can obtain, the bank computes the riskiest borrower \( \bar{\sigma}_t \) at which the maximum revenue covers

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4 The default threshold maximizing banks’ revenue, \( \bar{\omega} \left( \sigma^i_t \right) \), is not a function of loan size \( l_t \) because \( l_t \) cancels out in the first-order condition.

5 Gete and Melkadze (2016) elaborate on this result in a model with both aggregate and idiosyncratic uncertainty.
the bank’s costs of funds,

\[ E_t \left[ \int_{\tilde{\omega}_{t+1}}^{\infty} \tilde{\omega}_{t+1} \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_{t+1}^{i}; \sigma_t \right) + \right. \]
\[ \left. + \int_0^{\tilde{\omega}_{t+1}} (1 - \mu_E) \omega_{t+1}^{i} \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_{t+1}^{i}; \sigma_t \right) \right] = R^b_{t+1} l_t. \quad (14) \]

Equation (14) pins down the lending standards \( \sigma_t \) as the intersection of the peak of the revenue function that Figure 1 plots with a flat line that captures the right-hand side of equation (14). For borrowers with risk above \( \sigma_t \) there is no rate at which the bank can cover its cost of funds. A key result for the analysis below is that \( \sigma_t \) is decreasing in banks’ cost of funds, \( R'^b_t \). Higher costs of funds require banks to have greater expected revenues. This, in turn, leads banks to accept less borrower risk.

Equations (13) and (14) are a system of two equations with two unknowns, lending standards \( \tilde{\omega}_{t+1} \) and default threshold \( \omega_{t+1}^{i} \) maximizing banks’ revenue, which together with the financial contract that I describe next generate a system of equations that jointly determines the lending standards, the loan size \( (l_t) \) and the interest rate (borrower’s default threshold \( \omega_{t+1}^{i} \)).

The financial contract between financed entrepreneurs and banks maximizes entrepreneurs’ payoffs subject to the banks’ zero-profit condition.\(^6\),\(^7\) That is,

\[
\max_{l_t, \tilde{\omega}_{t+1}} \mathbb{E}_t \left[ \int_{\tilde{\sigma}_t}^{\bar{\sigma}_t} \int_{\tilde{\omega}_{t+1}}^{\infty} \left( \omega_{t+1}^{i} - \tilde{\omega}_{t+1} \right) \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_{t+1}^{i}; \sigma_t^{i} \right) dH \left( \sigma_t^{i} \right| \sigma_t \leq \tilde{\sigma}_t \right] \quad (15)
\]

subject to

\[
\int_{\tilde{\sigma}_t}^{\bar{\sigma}_t} \int_{\tilde{\omega}_{t+1}}^{\infty} \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_{t+1}^{i}; \sigma_t^{i} \right) + \int_{\tilde{\omega}_{t+1}}^{\infty} (1 - \mu_E) \omega_{t+1}^{i} \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_{t+1}^{i}; \sigma_t^{i} \right) \right] dH \left( \sigma_t^{i} \right| \sigma_t \leq \tilde{\sigma}_t ) = R^b_{t+1} l_t. \quad (16)
\]

The contract has double integrals because ex-ante borrowers and lenders do not know either the exact risk parameter \( \sigma_t^{i} \) or the borrower’s productivity \( \omega_{t+1}^{i} \). However, they know that risk is below the lending standards threshold \( (\sigma_t^{i} \leq \tilde{\sigma}_t) \) and thus the expectations are conditional.\(^8\)

\(^6\)Like in BGG, I assume that lenders’ zero-profit condition holds state-by-state. This is not an important assumption for the results and it makes the paper more similar to the literature.

\(^7\)By choosing loan size \( (l_t) \), entrepreneurs are also choosing employment since I focus on calibrations in which entrepreneurs’ have higher labor demand than what their equity allows to hire.

\(^8\)Allowing banks to see \( \sigma_t^{i} \) would introduce heterogeneity in lending rates and loan amounts, as they can be a function of \( \sigma_t^{i} \). This would not invalidate the new mechanism of the paper.


2.4 Banks

There is a continuum of banks with mass one. The total amount of credit \( B_t^E \) extended by the banks is the aggregate of the loans given to the qualified borrowers:

\[
B_t^E = \int_a^{\sigma_t} l_t dH (\sigma_t^i). \tag{17}
\]

Banks finance \( B_t^E \) with their equity \( N_t^B \), and with borrowings \( B_t^B \),

\[
B_t^E = N_t^B + B_t^B. \tag{18}
\]

I assume that banks are subject to idiosyncratic i.i.d. shocks \( u_t \), and \( u_t R_t^b B_t^E \) is the effective return on assets for a bank with shock \( u \). The \( u \) shocks capture that some banks hold high quality loans while others hold low quality loans. That is, banks’ revenue from lending, \( R_t^b B_t^E \), is unevenly distributed across banks such that some banks cannot repay their borrowings. The \( u \) shocks are lognormally distributed with cumulative density function \( G(u) \) with mean one, \( \mathbb{E}[u] = 1 \). The parameter \( \sigma_B \) controls the dispersion of these shocks. The \( u \) shocks are realized in the period when the banks need to return their borrowings. Thus, the lenders of the banks are exposed to bank default risk and will price this risk with an endogenous spread over the risk-free rate.

Denoting the banks’ endogenous borrowing rate as \( R_t^L B_t^B \), the banks’ default threshold \( \hat{u}_t \) is the bank whose assets equal in value its debt:

\[
R_t^L B_t^B = \hat{u}_t R_t^b B_t^E. \tag{19}
\]

Bank’s borrowing rate \( R_t^L B_t^B \) is determined by the participation constraint of the banks’ lenders that invest \( B_t^B \) in the continuum of banks (\( u \) is not observable ex-ante):

\[
\int_{\hat{u}_t}^{\infty} R_t^L B_t^B dG(u) + \int_0^{\hat{u}_t} (1 - \mu_B) u_t R_t^b B_t^E dG(u) = R_t^f B_t^B. \tag{20}
\]

The first integral in (20) is the revenue from the banks repaying \( R_t^L B_t^B \), the second integral is the revenue (net of bankruptcy cost \( \mu_B \)) from those banks that default. Banks’ lenders are guaranteed a risk-free return \( R_t^f \). Equation 20 implies that, as long as there is positive probability of the banks’ default, then banks will borrow at some positive spread relative to the risk-free rate \( \left(R_t^L B_t^B - R_t^f > 0 \right) \).
Moreover, to pin-down the cost of funds for the banks \( R_t^b \) we need the participation constraint for the banks’ shareholders. They require that banks’ expected profits cover the opportunity cost of banks’ equity, that I assume is the risk-free rate since aggregate banks profits are not exposed to aggregate shocks.\(^9\)

\[
\int_{\hat{u}_t}^{\infty} \left[ uR_t^b B_t^E - R_{B,t}^L B_t^B \right] dG(u) = R_t^f N_t^B. \tag{21}
\]

Equations (20) and (21) pin down the banks’ borrowing rate \( R_{B,t}^L \), and banks’ required rate of return \( R_t^b \). These equations connect the entrepreneurs and banks’ borrowing costs. When the banks’ borrowing costs are higher, their lending rates to the entrepreneurs are also higher to ensure that the banks’ lenders and equity holders get an expected return \( R_t^f \).

### 2.5 Output and market clearing

Entrepreneurs denied credit invest their equity on hiring workers.\(^10\) Those financed also use their borrowings to hire workers. Aggregate output is the sum of the production of the entrepreneurs receiving credit and those rejected credit:

\[
Y_{t+1} = \int_{a}^{a'} \int_{0}^{\infty} \omega_i^{i+1} \left( \frac{l_t + N_t^E}{W_t} \right)^\alpha dF \left( \omega_i^{i+1}; \sigma_i \right) dH \left( \sigma_i \right) + \int_{a}^{b} \int_{0}^{\infty} \omega_i^{i+1} \left( \frac{N_t^E}{W_t} \right)^\alpha dF \left( \omega_i^{i+1}; \sigma_i \right) dH \left( \sigma_i \right) . \tag{22}
\]

Labor market clearing requires that the sum of the labor demand by the entrepreneurs receiving credit, and by those rejected credit, equals the endogenous labor supply of the households plus the exogenous labor supply of entrepreneurs and banks:\(^11\)

\[
\int_{a}^{a'} \left( \frac{l_t + N_t^E}{W_t} \right) dH \left( \sigma_i \right) + \int_{a}^{b} \left( \frac{N_t^E}{W_t} \right) dH \left( \sigma_i \right) = H_t^H + H_t^E + H_t^B. \tag{23}
\]

To isolate the role of the risk-free rate, first I will consider a small open economy. Then the general equilibrium case. In general equilibrium, credit markets clear when household’s

\(^9\)The mechanism of the paper also applies if banks’ profits are priced using households’ stochastic discount factor.

\(^10\)I focus on equilibria in which entrepreneurs’ equity is small enough such that entrepreneurs denied credit cannot hire all workers they optimally would like to hire.

\(^11\)This is common in models of financial frictions to ensure inflows into the equity of entrepreneurs and banks.
deposits equals banks’ borrowings:

\[ D_t = B_t^B. \]  

(24)

### 2.6 Equity dynamics

The aggregate profits of the entrepreneurs are the realized profits of the financed entrepreneurs, plus the profits of the credit-rationed entrepreneurs:

\[
V_{t+1} = \int_{\hat{\omega}_t}^{\dot{\omega}_t} \int_{\hat{\omega}_t}^{\infty} \left( \omega_{t+1}^i - \hat{\omega}_{t+1}^i \right) \left( \frac{l_t + N_t^E}{W_t} \right)^{\alpha} dF \left( \omega_{t+1}^i; \sigma_t^i \right) dH \left( \sigma_t^i \right) + \int_{\sigma_t}^{\dot{\sigma}_t} \int_{\hat{\omega}_t}^{\infty} \omega_{t+1}^i \left( \frac{N_t^E}{W_t} \right)^{\alpha} dF \left( \omega_{t+1}^i; \sigma_t^i \right) dH \left( \sigma_t^i \right). 
\]

(25)

Entrepreneurs’ equity evolves as retained earnings plus labor income, \( W_t H^E \). This income is a standard mechanism to model new equity inflows and ensure that equity is never zero. The labor supply of entrepreneurs and banks is exogenous and constant over time.

\[ N_{t+1}^E = \gamma_E V_{t+1} + W_t H^E. \]

(26)

Entrepreneurs pay their profits minus the retained earnings as dividends to the households:

\[ \Pi_{t+1}^E = (1 - \gamma_E) V_{t+1}. \]

The parameter \( \gamma_E \) needs to be small enough to ensure that retained profits are not large enough and entrepreneurs always want to borrow.

Similarly, at the end of each period, banks pay a fraction \( (1 - \gamma_B) \) of their profits as dividends:

\[ \Pi_t^B = (1 - \gamma_B) \left[ \int_{u_{t-1}}^{\infty} \left[ u R_{t-1}^B B_{t-1}^E - R_{B,t-1}^L B_{t-1}^B \right] dG(u) \right]. \]

(27)

Banks’ aggregate equity \( N_{B,t} \) is the sum of past retained profits and bankers’ labor income:

\[ N_t^B = \gamma_B \left[ \int_{u_{t-1}}^{\infty} \left[ u R_{t-1}^B B_{t-1}^E - R_{B,t-1}^L B_{t-1}^B \right] dG(u) \right] + W_{t-1} H^B - T_t. \]

(28)

\( T_t \) is a one-time transfer shock to the households, and is zero at steady state.
3 Calibration

In the benchmark case, (7) holds and entrepreneurs only differ in risk. For the utility function, I use GHH preferences,

\[
U(C_t, H_t^H) = \frac{\left[ C_t - v(H_t^H)^\gamma \right]^{1-\gamma}}{1 - \gamma} - 1.
\] (29)

One period in the model is one quarter. Table 1 contains the parameters, which are divided into two groups. Some parameters are chosen exogenously following standard values in the literature: (i) the share of labor in output \( \alpha = 0.67 \); (ii) a discount factor \( \beta = 0.99 \) that generates a 1% quarterly risk-free rate in steady state; (iii) a risk aversion parameter \( \gamma = 2 \); (iv) an elasticity of labor supply of \( \frac{1}{\beta - 1} = 1.67 \).

Second, the remaining parameters are chosen to calibrate the model to the following annualized targets reported in Table 2: (i) A spread in the model between banks’ borrowing costs and the risk-free rate of 1.88%. In the data, the spread between interbank loans and U.S. government debt (the TED spread) fluctuates between 1% and 3%; (ii) A spread between banks’ lending rate and the risk-free rate of 4.6%. In the U.S. the average spread since 1995 between the bank prime loan rate and the 3-months T-Bill is 3.3%. This value is a lower bound for the model because the prime loan rate only applies to the borrowers with the best credit records. An upper-bound would be 6%, the average spread on bank loans according to the IMF International Financial Statistics in 2015 that includes advanced and emerging countries; (iii) In the 2015 Small Business Credit Survey the credit approval rate is 82% and in the model the loan approval rate is 81.95%; (iv) Households’ labor supply of 0.33, approximately 8 hours per day; (v) Default rate of entrepreneurs of 4.83%, which is in line with the 5.1% estimated by Fernandez and Gulan (2015), and within the 4.96% to 5.37% range reported by De Fiore and Uhlig (2011) for the E.U. and U.S.; (vi) Default rate of banks of 3.89%, which is consistent with the 2% to 6% range reported by IMF (2007); (vii) Equity share for financed entrepreneurs of 26.65% which implies a leverage ratio \( \left( \frac{N^E + L}{N^E} \right) \) of 3.8, close to the 4.2 estimated by Fernandez and Gulan (2015); (viii) Equity share of banks of 12.2%, which is within the recent range of the U.S. banks (Kaul and Goodman 2016); (ix) and (x) Financed entrepreneurs accounting for around 90% of output and employment. It is difficult to obtain the data counterparts for the U.S. because the most popular data for small and medium firms (the Community Reinvestment Act, CRA) does not record denial rates. Buera, Jaf and Shin (2015) report that in the U.S., in 2000, the decile of the largest establishments (in terms of employment) accounts for 69 percent
of total employment. Thus, most of the employment and activity takes place in firms with access to credit. In the model, financed entrepreneurs account for 94% of the employment and 91% of the output.

Insert Tables 1 and 2 about here

4 Results

First, I study a model with inelastic households’ labor supply to illustrate the propagation mechanism created by the lending standards. Second, I endogenize labor supply. Third, to highlight the role of the risk-free rate in a banking crisis, I compare general equilibrium and small open economy versions of the model. Fourth, I study the case when borrowers’ risk and expected volatility are related. Finally, I show the mutual feedback between the amount of misallocation and the speed of banks’ recapitalization.\footnote{All results come from solving a loglinearized version of the model around its steady state.}

4.1 Inelastic labor supply

Figures 2 and 3 plot the financial and real effects of a bank capital shortfall when households’ labor supply is inelastic and the risk-free rate is constant.\footnote{In this case the model becomes a small open economy and the market clearing equation (24) for credit markets does not hold. To ensure a well-defined steady state I add a small adjustment cost $\frac{\phi_B}{2} (B_t^H)^2$ to households’ budget constraint, with parameter $\phi_B = \frac{7}{10\pi}$.} The figures compare the benchmark model with endogenous lending standards to a model without lending standards ($\bar{\sigma}_t = b, \forall t$).\footnote{The calibration ensures that bank leverage is the same whether the model has or not lending standards. To do so I alter the banks’ labor supply parameter $H^B$ in the model without lending standards.}

Insert Figures 2 and 3 about here

The upper left panel of Figure 2 shows the exogenous one period shock $T_t$ hitting both models. It is a one time transfer of wealth from banks to households with no persistence. Figure 2 also plots banks’ borrowing, lending rates and their loan rejection rates that capture their lending standards. A bank capital shortfall increases banks’ borrowing costs as banks’ lenders price the higher risk of bank default. Banks react by charging higher lending rates and, in the model that allows for it, tightening their standards.

Figure 3 shows the key differences across models. Output only falls in the model with endogenous lending standards. This result is due to the reallocation of labor caused by the
higher denial rates. In the model without lending standards, Figure 3 shows that employment per firm does not change. Without lending standards, the model is basically a standard BGG model. All borrowers receive credit and hire the same number of workers. Since labor is in fixed supply, to clear labor markets, wages decrease and counteract the higher borrowing costs that entrepreneurs face. Output is constant because labor supply did not change. Guerrieri et al. (2015) discuss that, because capital is pre-determined, this result holds for all models with banking crises triggered by financial shocks.

When banks can screen and change their approval rates, the banking crisis is associated with a labor reallocation from the mid-risk entrepreneurs now denied credit towards the safest borrowers who still qualify for credit (upper-right panel of Figure 3), and towards the riskiest entrepreneurs, which were already excluded from credit markets before the shock and are able now to expand when wages are lower. Because of decreasing returns to scale, as the number of financed entrepreneurs become too large, their productivity decreases and aggregate total factor productivity (TFP) falls.\footnote{I define aggregate measured TFP as $\frac{Y_t}{(H_t^{h-1} + H_t^S + H_t^B)^{\gamma_t}}$.} Lower TFP leads to lower output. Thus, endogenous lending standards propagate bank capital shortfalls through labor misallocation.

Figure 2 shows that lending rates increase by a smaller amount when banks can also tighten their standards. This suggests that lending spreads may be insufficient indicators of credit supply disruptions when banks are also changing their denial rates. That is, for the same increase in credit spreads, output falls faster when denial rates are increasing. This result may explain why the literature on lending standards finds predictive power in this variable, even when controlling for credit spreads.

4.2 Elastic labor supply

Figure 4 compares the models with and without lending standards when households’ labor supply is endogenous. The bank capital shortfall is the same one time shock shown in the upper left panel of Figure 2. With elastic labor supply, the model without lending standards has a fall in output following a bank capital shortfall. This is a standard channel in the literature: the cost of credit increases, producers borrow less and demand less inputs, wages decrease, labor supply contracts and output falls. There is no reallocation of labor, just a downward shift in employment. This mechanism is also present in the model with lending standards. Moreover, in that model there is the labor misallocation channel discussed before. The result is that the model with lending standards generates a deeper and more persistent recession than the model...
4.3 The role of the risk-free rate

The previous results were obtained in an economy with an exogenous risk-free rate (small open economy assumption). Figure 5 illustrates a key role of the risk-free rate in a banking crisis. It compares the general equilibrium model with endogenous risk-free rates with the small open economy in which that rate is constant. The bank capital shortfall is the same one time shock shown in the upper left panel of Figure 2.

The risk-free rate falls because households try to save part of the wealth transfer. This fall cushions the impact of the higher borrowing spreads that banks face (banks borrowing costs are the risk-free rate plus the spread) and mitigates the aggregate negative effects of the shock. Later on, risk-free rates increase to discourage households from borrowing to smooth the lower consumption caused by the crisis. Higher risk-free rates amplify the impact of the higher borrowing spreads making the crisis more persistent in the general equilibrium model. Thus, Figure 5 shows that the dynamics of the risk-free rate are key for the shape of the reaction of the economy to a one time bank capital shock.

4.4 When risk and productivity are related

All the previous results assumed that (7) holds and entrepreneurs only differ in risk. In this case, the misallocation induced by the tighter lending standards is due to the concavity of the production function, it lowers aggregate productivity as the safest entrepreneurs hire too many workers. Figure 6 compares that case with the case when the riskier entrepreneurs are also those expected to be more productive, that is (8) holds.16

Figure 6 shows that when risk and productivity are related then tighter lending standards

\[^{16}\text{The calibration ensures that bank leverage is the same in both cases. To do so I alter the banks’ labor income parameter in the model in which (5) holds. Also, the parameter } \varphi \text{ in (8) is set to 0.05.}\]
have larger real effects following a shock to banks’ equity. Intuitively, there is an extra amplification channel because now tight standards reallocate labor away from the risky, but also more productive, producers. As a consequence both aggregate productivity and output fall by a larger amount when (8) holds instead of (7).

Table 3 summarizes the different cases discussed before. Four years after the one-time shock (this is the median duration of a banking crisis in Laeven and Valencia 2013), the model with endogenous lending standards generates output losses that are around two hundred basis points larger than the model without lending standards. The difference is amplified to around 300 basis points when (8) holds instead of (7). Thus, quantitatively, adding endogenous lending standards matters.

4.5 Misallocation and banks’ capital

The goal of this subsection is to illustrate the mutual feedback between the amount of misallocation in the labor market and the speed of banks’ recapitalization. Figure 7 compares the benchmark economy with endogenous lending standards with an economy in which the lending standards are exogenous but subject to shocks. In the misallocation literature it is common to study shocks to the collateral constraints abstracting from the banks that cause those shocks. This is similar to a model with exogenous lending standards subject to shocks because in this model banks’ capital by construction cannot affect the lending standards.

In the model with exogenous lending standards I input the exogenous path for the lending standards reported in the upper-left panel of Figure 7. In the model with endogenous lending standards I add a one time exogenous shock to lending standards to generate the same initial jump in lending standards as in the exogenous case. Thus, at impact both models have the same increase in lending standards. The difference is that in one model the standards remain exogenous while in the other model the standards are endogenous as in the benchmark model.

Figure 7 shows that in both models there is labor misallocation and lower output because of the reasons discussed before. The difference is that in the model with endogenous lending standards the amplification and persistence are larger. This is because the standards depend

\[17\] Both models have the same steady state.
on banks’ equity. Misallocation leads to lower output and lower banks’ recapitalization. In addition, slower banks’ recapitalization generates tighter standards and more misallocation because, as Figure 7 shows, the lending standards take more time to return to steady state in the model in which the standards are endogenous. Thus, Figure 7 shows that there is mutual feedback between the amount of misallocation and the speed of banks’ recapitalization.

5 Conclusions

This paper studied shocks to bank capital in a model which is novel because it allows banks to adjust their qualification threshold (lending standards) to deny loan applications. Facing higher borrowing costs, banks reject the riskier borrowers at which no lending rate sufficiently compensates banks for the borrower’s default risk. Tighter lending standards is a non-price mechanism that may generate misallocation between safe and risky firms. Employment flows towards the safest producers that become too large and aggregate productivity falls. The effect is reinforced when the riskier borrowers are the more productive entrepreneurs. There is mutual feedback between the amount of misallocation in the labor market and the speed of banks’ recapitalization. Larger misallocation makes the process of bank recapitalization slower, which causes even more misallocation and endogenously amplifies the persistence of the crisis.

There are several avenues for future research. For example, as discussed in the literature review, empirical work has so far documented the effects of bank capital shortfalls on denial rates and employment, not the effects of these changes on productivity. Another avenue for future research is to incorporate the channel of this paper into a DSGE model which can be estimated and could evaluate the importance of prices versus non-price mechanisms. The mechanism of lending standards studied in this paper could also be useful to study monetary policy.
References


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Rodano, G., Serrano-Velarde, N. and Tarantino, E.: 2016, Lending standards over the credit cycle.

# Tables

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<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Labor share in production</td>
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<td>Risk aversion</td>
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<td>Labor supply elasticity</td>
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<tr>
<td><strong>Endogenously Determined</strong></td>
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<td></td>
</tr>
<tr>
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<tr>
<td>Upper bound of support of entrepreneurs’ volatility</td>
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<td>Dispersion of banks’ revenue</td>
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<td>Entrepreneurs’ default cost</td>
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<td>Banks’ default cost</td>
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<td>Steady State</td>
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<td>Banks’ borrowing spread</td>
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<td>Banks’ lending spread</td>
<td>3.3 – 6%</td>
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<td>Banks’ loan approval rate</td>
<td>82%</td>
<td>81.95%</td>
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<td>Households’ share of time working</td>
<td>0.33</td>
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<td>Default rate of entrepreneurs</td>
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<td>Equity-to-assets of banks</td>
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<td>Financed entrepreneurs % of total</td>
<td>90%</td>
<td>94%</td>
</tr>
<tr>
<td>employment</td>
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<tr>
<td>Financed entrepreneurs % of total</td>
<td>90%</td>
<td>91%</td>
</tr>
<tr>
<td>output</td>
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Table 3: Comparing Transmission Channels After Bank Capital Shortfall
Cumulative dev. from steady-state, 4 years after shock

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constant risk-free rate</th>
<th>Endogenous risk-free rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No LS</td>
<td>With LS</td>
</tr>
<tr>
<td>$\mathbb{E}(\omega) = 1$</td>
<td>$\mathbb{E}(\omega) = 1$</td>
<td>$\mathbb{E}(\omega) = 1$</td>
</tr>
<tr>
<td>Output</td>
<td>3.2%</td>
<td>5.30%</td>
</tr>
<tr>
<td>Employment</td>
<td>5.03%</td>
<td>7.09%</td>
</tr>
<tr>
<td>Measured TFP</td>
<td>0%</td>
<td>0.78%</td>
</tr>
</tbody>
</table>

Note: In all cases, households’ labor supply is elastic. LS refers to lending standards. "No LS" means the model with no lending standards ($\bar{\sigma}_t = b, \forall t$). "Constant risk-free rate" refers to the small open economy discussed in Section 4.2, while "Endogenous risk-free rate" refers to the general equilibrium case studied in Section 4.3. $\mathbb{E}(\omega) = 1$ refers to the case when the expected borrower’s productivity is one, that is $\mu^i = -\left(\frac{\sigma^i}{2}\right)$ holds. $\mathbb{E}(\omega) \neq 1$ refers to the case discussed in Section 4.4, that is, $\mu^i$ is the increasing function of $\sigma^i$ specified in (8).
Figure 1. Banks’ revenue as a function of the borrower’s default threshold for different levels of volatility of borrower’s productivity. This figure plots the banks’ revenue defined in (13) as a function of the default threshold \( \hat{\omega} (\sigma_t^i) \) for different levels of the borrower’s idiosyncratic productivity \( \omega \). In all cases the expected borrower’s productivity, \( \mathbb{E}_t (\omega_{t+1}^i) \), is one, that is \( \mu_t^i = -\frac{(\sigma_t^i)^2}{2} \) holds.
Figure 2. Financial effects from bank capital shortfall when households’ labor supply is inelastic and the risk-free rate is constant. The upper left panel is the exogenous shock to bank capital. Each panel compares a model with endogenous lending standards with a model with no lending standards ($\hat{\sigma}_t = b, \forall t$). In all the cases the expected borrower’s productivity, $\mathbb{E}_t(\omega_{i,t+1})$, is one, that is $\mu_t^i = -\frac{(\sigma_t^i)^2}{2}$ holds.
Figure 3. Real effects from bank capital shortfall when households’ labor supply is inelastic and the risk-free rate is constant. The panels report the reaction to the shock to bank capital shown in Figure 2. Each panel compares a model with endogenous lending standards to a model with no lending standards ($\bar{\sigma}_t = b, \forall t$). In all the cases the expected borrower’s productivity, $E_t (\omega_{t+1})$, is one, that is $\mu_t = \frac{(-\sigma_t)^2}{2}$ holds.
Figure 4. Real effects from bank capital shortfall when households’ labor supply is elastic and the risk-free rate is constant. The panels report the reaction to the shock to bank capital shown in Figure 2. Each panel compares a model with endogenous lending standards with a model with no lending standards \((\bar{\sigma}_t = b, \forall t)\). In all the cases the expected borrower’s productivity, \(E_t(\omega_{t+1})\), is one, that is \(\mu^i_t = \frac{(\sigma^i_t)^2}{2}\) holds.
Figure 5. The role of the risk-free rate after a bank capital shortfall. The panels report the reaction to the shock to bank capital shown in Figure 2. All panels refer to the model with endogenous lending standards when households’ labor supply is elastic. In all the cases the expected borrower’s productivity, \( \mathbb{E}_t (\omega_{t+1}^i) \), is one, that is \( \mu_t^i = -\frac{(\alpha_i^i)^2}{2} \) holds.
Figure 6. Effects from bank capital shortfall when the expected idiosyncratic productivity $\mathbb{E}(\omega)$ is increasing in $\sigma^i$. The panels report the reaction to the shock to bank capital shown in Figure 2. All panels refer to the model with endogenous lending standards when households’ labor supply is elastic and the risk-free rate is constant. In the solid line the expected borrower’s productivity, $\mathbb{E}_t(\omega_{t+1}^i)$, is one, that is $\mu^i = -\frac{(\sigma^i)^2}{2}$ holds. In the dashed line, $\mu^i$ is the increasing function of $\sigma^i$ specified in (8).
Figure 7. Effects from higher lending standards when the standards are endogenous and when they are exogenous. The dashed line is a model with exogenous lending standards subject to shocks. The solid line is the benchmark model with endogenous lending standards but subject to an exogenous shock to generate at impact the same increase in rejection rates as in the model with exogenous lending standards.