The Funding Gap in the Credit Cycle

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Abstract

I build a dynamic stochastic general equilibrium model with endogenous financial intermediary leverage and costly state verification to study credit cycle dynamics. Intermediary leverage is driven by a trade-off between costly bank capital and a benefit of capital as a buffer against adverse shocks. Capital is costly because it is wiped out when borrowers default, whereas deposits are insured. On the other hand, higher capital reduces the bank’s ‘funding gap’ in times of distress. Changes in this funding gap drive the intermediary credit supply. The model displays three active credit channels: the business conditions channel, the bank net worth channel, and the funding cost channel. The model delivers empirically observed procyclical credit conditions. (JEL E32, G21, G32)

1 Introduction

Interactions between financial intermediation and the macroeconomic environment may generate business cycle fluctuations. This credit cycle functions via several channels. In their survey on financial intermediation, Gorton and Winton (2003) distinguish between the broad lending channel, where business conditions influence intermediaries, and the bank lending channel, where variations in intermediation activity influence the business cycle. Much of the current literature on credit cycles emphasizes bank net worth channels. In the literature, this channel typically features intermediaries with lending activity constrained by their net worth. The key contribution of this paper

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is to propose a new model of credit cycles with endogenous intermediary leverage where three credit channels are simultaneously active.

There is some evidence of the interaction between credit conditions and the business cycle. Figure 1 shows cyclical output per capita and the Federal Reserve’s Senior Loan Officer Opinion Survey (SLOOS) from 1990Q2 to 2012Q3. Shaded areas indicate NBER recessions. The graph shows the net percentage of survey respondents who indicate they are tightening lending standards for medium and large companies. The SLOOS numbers for small companies are very similar. The figure shows that tightening credit conditions are associated with contractions in cyclical output.

In order to look more quantitatively at the relation between credit and business conditions, I run a vector auto-regression (VAR) of cyclical real output per capita against the cyclical credit spread. The credit spread is the difference between secondary market yields on BAA corporate bonds and US 3-month treasuries. The spread is a measure of credit conditions, where a widening credit spread indicates tighter credit conditions. Both the series are de-trended using the HP filter for quarterly data. The data are from 1980Q1 to 2012Q3. Figure 2 shows the impulse response of the VAR. The figure shows that spreads respond negatively to an output shock, which is a reflection of the business conditions channel. The impulse response also show that output responds negatively to tighter credit conditions.

The model proposed here features endogenous intermediary leverage where intermediaries are free to payout and raise capital. Figure 3 shows financial

Figure 1: Tightening credit conditions associated with contraction in output.
business capital payouts over time using data from the Flow of Funds Accounts. An implicit assumption in standard capital constraint models is that the capital payout is always 0. Figure 3 shows that payouts are highly volatile and frequently negative, indicating capital raising by financial businesses. This highlights the importance of endogenous leverage in intermediation models.

I model the credit cycle using a dynamic stochastic general equilibrium model with financial intermediation. The role of intermediaries is to perform a costly state verification following a default. Intermediaries can only recover a portion of the defaulted firm’s assets. The non-recoverable portion is a monitoring cost, or a bankruptcy cost. Each bank lends money to one firm by combining capital with risk-free deposits. In the event of a default, the bank faces a funding gap where its outstanding deposit obligations are larger than the recovered loan amount, and a deposit insurer meets this gap. Each bank pays a premium for this insurance, and the premium is convex in the bank’s funding needs. When the capital cushion is greater, the funding requirement and the insurance premium are lower. Thus, bank capital in the model has value as a buffer against adverse times when the bank holds defaulted loans. The bank is free to manage its funding structure dynamically. Banks prefer deposits for funding the balance sheet because of deposit insurance and because capital is wiped out when a borrower defaults.

Changes in the funding gap generate a credit cycle:
Figure 3: Financial business capital payout is volatile

Capital payout calculated as net dividends paid (F7 line 19) + undistributed profits (F7 line 23) - equities (F107 line 27). Shaded areas indicate NBER recessions.

- Broad lending channel

  1. Business conditions channel: An improvement in business conditions improves recovery rates on collateral and reduces bank funding needs. This leads to lower insurance premia and allows banks to expand their balance sheets.

- Bank lending channel

  2. Bank net worth channel: Bank net worth has a mixed effect in the model. A greater capital cushion means a lower funding gap in distress times and hence lower insurance premia. On the other hand, capital is a costly way of finance for banks, increasing required returns and credit spreads. Equilibrium bank leverage is optimal so that an increase or decrease in capital would reduce welfare.

  3. Funding cost channel: Higher funding costs of deposits mean banks need more funds to support the same balance sheet size. This leads to higher insurance premia and forces banks to contract balance sheets. Higher net worth funding costs mean that
the bank prefers to hold less net worth leading to a bigger funding gap and reduced credit supply.

This paper is related to and draws from the extensive work on credit cycles and financial features in business cycles. There are several approaches in the literature for generating credit cycles. Holmstrom and Tirole (1997) use a net worth channel where both banks and firms face moral hazard constraints. In their framework, better capitalized banks can monitor firms better, and firms with less capital take more risk. Diamond and Rajan (2000) have a framework where banks can threaten to withhold their loan collection skills and extract rent from external equity holders. Higher deposits increase the threat of a bank run in adverse times. When business conditions improve, there is lower chance of distress and bank runs, and the banks can expand balance sheets. Adrian and Shin (2010b) have a risk-appetite approach, where improving business conditions reduces the maximum loss that intermediaries face, allowing them to expand balance sheets. I introduce a different ‘funding gap’ approach that allows for multiple credit channels.

This paper is also related to recent dynamic financial friction literature. A small sample of this literature includes Bernanke, Gertler, and Gilchrist (1999), Christiano, Motto, and Rostagno (2010), Gertler and Kiyotaki (2011), Mendoza (2010), and Jermann and Quadrini (2012). Much of the literature focuses on net worth channels. This paper proposes a model where capital structure is flexible so that funding channels and business conditions channels are more prominent.

Jermann and Quadrini (2012) look at the effects of financial shocks in the business cycle. They allow for a dynamic capital structure for firms, who choose equity payouts to maximize shareholder value. Endogenous leverage emerges as firms balance tax benefits of debts versus a dynamic borrowing constraint. Jermann and Quadrini (2012) abstract from intermediation and introduce the financial shock as an exogenous disturbance in the borrowing constraint parameter. The shock is a reflection of credit conditions, where a tighter borrowing constraint indicates tougher access to credit. They show that financing conditions are influential in the business cycle.

The remaining article is structured as follows. Section 2 describes the model and the calibration. Section 3 explores the credit channels active in the model and looks briefly at the evidence of credit channels. Section 4 concludes.
2 Model

2.1 Households

There is a continuum of households mass 1. Each household may save using either bank capital, $n_t$, or risk-free bank deposits, $d_t$. Each bank can lend to one firm, a fraction $\omega$ of firms default each period. If the firm defaults, the lender bank’s capital is wiped out. Households are diversified across banks, so they receive capital payouts from a fraction $1 - \omega$ of banks. The household chooses the bank capital to hold next period $n_{t+1}$, deposits for next period $d_{t+1}$, labour hours $h_t$ to supply for the period, and consumption $c_t$ to maximize its preferences. Households solve

$$\max_{\{d_{t+1}, n_{t+1}, h_t, c_t\}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t)$$

subject to the period state-wise budget constraints

$$c_t + \frac{d_{t+1}}{r_t} + n_{t+1} = w_t h_t + \frac{d_t}{\pi_t} + (1 - \omega) div^b n_t + \tau_t$$

where $w_t$ is the real wage, $r_t$ is the nominal risk-free interest rate, $\pi_t$ is inflation, and $div^b$ is the real bank capital payout rate. The quantity $\tau_t$ captures transfers from the insurer and firms.

The resulting first order condition for deposits is

$$1 = E_t \left\{ \frac{r_t}{\pi_{t+1}} \Lambda_{t,t+1} \right\}$$

where $\Lambda_{t,t+1}$ is the household’s stochastic discount factor for real payoffs,

$$\Lambda_{t,t+1} = \beta \frac{U'_{c_{t+1}}}{U'_{c_t}}$$

Households can also choose to save in bank capital. If the bank holds a good asset, it commits to payout its entire profits to households, who receive a payment of $div^b n_t$. If the bank holds a defaulted asset then the equity payout from the bank is 0. Since each bank lends to one firm, a fraction $\omega$ of banks hold defaulted assets. The first order condition for $n_t$ is

$$1 = E_t \left\{ \Lambda_{t,t+1} (1 - \omega) div^b_{t+1} \right\}$$

Here $div^b$ represents the household’s required payout rate on bank capital.

The household also supplies labour to firms.

$$-U'_h = w_t U'_c$$
2.2 Banks and Public Deposit Insurance

A bank enters the period with $n_t$ as capital from the owner household, $d_t$ in deposits, and outstanding loans $b_t$. The bank commits to paying out its entire profits, $s_t$. If the bank holds a non-defaulted asset, it collects interest and principal payment from the firm, pays out depositors, pays an insurance premium, and transfers remaining funds as distribution to the owner household. If on the other hand the bank holds a defaulted asset, it transfers the recovered portion of the loan as well as deposits to the public deposit insurer. The capital payout in that case is 0. Banks cannot diversify the default risk across firms.

The bank has capital collateral equal to the principal amount $b_t/z_{t-1}$, where $z_t$ is the interest rate on loans. If the event of a firm default, the bank recovers a fraction $\mu q_t$ of the collateral, where $q_t$ is the real price of capital. The bank still owes depositors $d_t/\pi_t$, and hence the bank faces a funding gap equal to $(d_t/\pi_t) - \mu q_t (b_t/z_{t-1})$. The deposit insurer receives the recovered collateral value and the deposits, and meets payments to depositors. In return for this insurance service the insurer collects a premium from banks. This costly insurance is central in this model. It captures a buffer value of capital for banks. The premium is convex in the expected funding gap, and takes the functional form $\phi j_t^\gamma$, where $\phi$ and $\gamma$ are parameters, and $j_t$ is defined as the funding gap per unit asset,

$$j_t = \left\{ \frac{(d_t/\pi_t) - \mu q_t (b_t/z_{t-1})}{b_t} \right\}$$

(5)

$j_t$ is a key variable in the model. It is a measure of intermediary risk. This model has multiple credit channels because several different variables affect the funding gap and $j_t$. Improved business conditions raise $q_t$ and reduce $j_t$, higher risk-free interest rates raise $d_t$ and raise $j_t$, higher $n_t$ reduces $j_t$, and a greater asset size $b_t$ does not affect $j_t$ unless intermediary leverage changes.

The parameter $\gamma$ governs the insurance premium elasticity of $j_t$. When $j_t$ rises by 1%, the insurance premium rises by $\gamma\%$. Greater elasticity of the premium means that the buffer value of capital is more volatile, and so bank leverage is also more volatile.

Banks prefer financing with deposits rather than capital. Deposit insurance makes deposits attractive to banks, whereas households require greater returns on capital making capital costly. On the other hand, the insurance premium is lower when the bank has more capital cushion. Banks balance between these effects to choose their capital structure. The insurance premium captures the role of bank capital as a buffer against adverse times when the bank holds a defaulted loan. Endogenous leverage emerges in the model.
as banks balance this buffer value of capital against the capital funding cost.

Spreads arise in this model because of the insurance premium, and because capital financing is more costly than risk-free deposits. Intermediaries pass some cost of the insurance premium to borrowers in the form of higher spreads.

Intermediaries combine capital and deposits from households to lend \( b_{t+1}/z_t \) to firms. This is the bank’s balance sheet constraint,

\[
\frac{b_{t+1}}{z_t} = n_{t+1} + \frac{d_{t+1}}{r_t} \tag{6}
\]

The bank’s leverage is equal to the assets over the bank capital,

\[
lev^b = \frac{b_{t+1}}{z_t n_{t+1}}
\]

When it holds a non-defaulted asset, the bank receives a nominal payment \( b_t \) from firms, and it pays out \( d_t \) to depositors, and pays out the insurance premium. The bank’s real profit \( s_t^b \) is given by

\[
s_t^b = \frac{b_t}{\pi_t} - \frac{d_t}{\pi_t} - \phi j_t^\gamma \tag{7}
\]

A bank that holds defaulted assets simply transfers liabilities and assets to the insurer and continues business as normal in the following period. The bank maximizes lifetime profits, subject to the balance sheet constraint (6), and the bank profit equation (7).

\[
\max_{\{n_{t+1}, d_{t+1}, b_{t+1}\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} (1 - \omega)^t s_t^b
\]

Since the bank commits to payout all its profits, we have

\[
s_t^b = div_t^b n_t \tag{8}
\]

The resulting first order condition for credit supply can be expressed in terms of the credit spread, \( z_t - r_t \),

\[
z_t - r_t = \frac{\gamma \phi j_t^{\gamma - 1} (r_t b_{t+1} - z_t d_{t+1})}{b_{t+1}^2} \tag{9}
\]

This condition says that credit supply expands (spreads tighten) when \( j_t \) drops. When the premium is elastic and \( \gamma \) is high, the credit supply shifts farther in response to shifts in \( j_t \).
The public insurer receives the premium payment from the $1 - \omega$ banks that are solvent, and it also takes over assets and liabilities from the distressed banks. This means it pays out deposits for the banks with defaulted assets. The insurer can transfer lump-sum amounts to households to meet any excess or shortfall from the transactions. I assume that there is no moral hazard between the insurer and the insolvent bank, so that the bank collects on the defaulted loan. The insurance premium penalizes banks for maintaining a lower capital cushion. In this sense the insurer may be viewed as a regulator who discourages banks from keeping a fragile capital structure.

$$\xi_t = (1 - \omega) \phi_j^\gamma - \omega \left( \frac{d_t}{\pi_t} - \mu q_t \frac{b_t}{z_{t-1}} \right)$$

(10)

where $\xi_t$ is a lump-sum transfer to households.

### 2.3 Capital Owner Firms

There is a continuum of capital owner firms with mass 1. They borrow from banks to purchase capital, which they lease out to intermediate good producer firms. A fraction $\omega$ of capital owner firms default each period. If a firm defaults, all the capital income for the period is lost and the lender bank takes control of the firm’s capital. There is no other default penalty and the firm functions as normal the following period. A capital owner firm solves

$$\max_{\{k_{t+1}, b_{t+1}\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} (1 - \omega) \left( r^t_k k_t + (1 - \delta) q_t k_t - \frac{b_t}{\pi_t} \right)$$

$$r^k_t$$ represents the real capital rental rate, $\delta$ is the capital depreciation rate, and $b_t/\pi_t$ is the real loan payment to banks. The firm’s balance sheet constraint is

$$q_t k_{t+1} = \frac{b_{t+1}}{z_t}$$

(11)

where $b_{t+1}/z_t$ is the loan principal.

The firm takes $r^k_t$ and $z_t$ as given, and the associated first order condition for credit demand is

$$r^k_{t+1} + (1 - \delta) q_{t+1} = q_t \frac{z_t}{\pi_{t+1}}$$

(12)
2.4 Goods Producer Firms

Goods production in the model follows a standard setup. The final good in the economy, $Y_t$, is a composite of intermediate goods $y_{i,t}$,

$$Y_t = \left( \int_0^1 y_{i,t}^{-\frac{1}{\epsilon}} di \right)^{1/(1-\frac{1}{\epsilon})} \tag{13}$$

The final good producers solve

$$\max_{y_{i,t}} \left\{ P_t Y_t - \int_0^1 p_{i,t} y_{i,t} di \right\}$$

where $P_t$ is the aggregate price index and $p_{i,t}$ is the price of an intermediate good $y_{i,t}$. This gives the demand for intermediate goods,

$$y_{i,t} = \left( \frac{p_{i,t}}{P_t} \right)^{-\epsilon} Y_t \tag{14}$$

Final goods producers are perfectly competitive, so the aggregate price index is

$$P_t = \left( \int_0^1 p_{i,t}^{1-\epsilon} di \right)^{1/(1-\epsilon)} \tag{15}$$

There is a continuum of monopolistically competitive intermediate good producers indexed by $i \in [0, 1]$. Prices are sticky and a fraction $1 - \theta$ of firms can reset their prices in a period. The production technology has a Cobb-Douglas form,

$$y_{i,t} = A_t^{\alpha} K_{i,t}^{\alpha} H_{i,t}^{1-\alpha} \tag{16}$$

Here $A_t$ represents the aggregate total factor productivity (TFP), which follows an AR(1) process with a shock $\nu_A$,

$$\ln(A_t) = \rho_A \ln(A_{t-1}) + \nu_A \tag{17}$$

The intermediate good producer firm tries to maximize the lifetime value of profits, which are distributed to households,

$$\max_{p_{i,t}, k_{i,t}, h_{i,t}} \mathbb{E}_t \sum_{t=0}^{\infty} \theta^t \Lambda_{0,t} \left( \frac{p_{i,t} y_{i,t}}{P_t} - r_t k_{i,t} - w_t h_{i,t} \right)$$

subject to the demand constraint (14) and the production technology (16).

The associated real marginal cost is

$$mc_t = \frac{r_t^k}{\alpha A_t^{\alpha-1} K_{i,t}^{\alpha-1} H_{i,t}^{1-\alpha}} \tag{18}$$
The homogeneous production technology means that marginal cost for all firms is identical at \( mc_t \).

The first order condition for firms is

\[
E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \theta^t \left( \frac{p_{t,t}^*}{P_t} \right)^{-1-\epsilon} Y_t \left( mc_t - \frac{\epsilon - 1}{\epsilon} \frac{p_{t,t}^*}{P_t} \right) = 0
\]

(20)

All firms that re-optimize prices in the period choose the same price, so that \( p_{t,t}^* = p_t^* \). Following Schmitt-Grohé and Uribe (2007), I express this first order condition recursively with non-zero inflation in steady state, and track the price dispersion cost \( \iota_t \).

\[
\iota_t = (1 - \theta) P_t^{\pi - \epsilon} + \theta \pi^{\epsilon} \iota_{t-1}
\]

(21)

Equation (15) gives the price evolution equation,

\[
1 = \pi^{1+\epsilon} + (1 - \alpha) P_t^{1-\epsilon}
\]

(22)

where \( P_t^* \) is \( p_t^*/P_t \).

### 2.5 Capital Goods Producer Firm

The capital goods producer buys existing capital from the market at price \( q_t \), makes new capital using old capital and goods, and then sells it. Capital goods production is subject to flow investment adjustment costs. The firm solves

\[
\max_{K_{t+1}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left( q_t I_t - I_t \left[ 1 + F \left( \frac{I_t}{I_{t-1}} \right) \right] \right)
\]

The law of motion of capital gives \( I_t \),

\[
K_{t+1} = ((1 - \delta) (1 - \omega) + \omega \mu) K_t + I_t
\]

(23)

Capital from the non-defaulted capital owners depreciates at the rate \( \delta \), and banks can only recover a fraction \( \mu \) of capital from defaulted firms.

The first order condition for capital production is given by

\[
q_t = 1 + F \left( \frac{I_t}{I_{t-1}} \right) + I_t F_t' \left( \frac{I_t}{I_{t-1}} \right) + \Lambda_{t,t+1} I_{t+1} F_{t+1}' \left( \frac{I_{t+1}}{I_t} \right)
\]

(24)
2.6 Monetary Policy and Equilibrium

The monetary authority follows a smoothed Taylor rule,

\[
\ln \left( \frac{r_t}{r^*} \right) = \Phi_r \ln \left( \frac{r_{t-1}}{r^{*}} \right) + (1 - \Phi_r) \left[ \Phi_\pi \ln \left( \frac{\pi_t}{\pi^*} \right) + \Phi_y \ln \left( \frac{y_t}{y^*} \right) \right] + \varsigma_t \tag{25}
\]

The starred variables represent steady states, and \( \varsigma_t \) is an exogenous stochastic process,

\[
\varsigma_t = \rho_\varsigma \varsigma_{t-1} + \nu_\varsigma \tag{26}
\]

where \( \nu_\varsigma \) is a monetary policy shock.

Aggregation for the final good gives

\[
Y_t = C_t + I_t \left( 1 + F \left( \frac{I_t}{I_{t-1}} \right) \right) \tag{27}
\]

After accounting for price dispersion, the aggregate output is given by

\[
Y_t = \left( A_t K_t^\alpha H_t^{1-\alpha} \right) \frac{1}{\iota_t} \tag{28}
\]

Competitive equilibrium for the economy is the set of processes \( \{c_t, h_t, \text{div}, r_t, \pi_t, z_t, q_t, j_t, s_t^k, \xi_t, \nu_t^k, w_t, mc_t, Y_t, P_t^*, I_t, k_{t+1}, b_{t+1}, d_{t+1}, n_{t+1}, \iota_t\}_{t=0}^{\infty} \) that satisfy equations (2) - (12), (18)-(25), (27), and (28), given \( k_0, b_0, d_0, n_0, \iota_0 \), and the exogenous stochastic processes \( \{A_t\}_{t=0}^{\infty} \) and \( \{\varsigma_t\}_{t=0}^{\infty} \).

2.7 Calibration

I calibrate steady state inflation to 0.5% per quarter. I calibrate the time discount factor \( \beta \) to 0.996 to give a nominal risk-free rate of 3.7% annually in steady state. The production parameter \( \alpha \) is set to 0.36, and the depreciation parameter \( \delta \) is 0.025. The values for the intermediate goods firms are in standard ranges - the CES parameter \( \epsilon \) is 6, and price stickiness parameter \( \theta \) is 0.75.

The utility functional form is separable in labor and consumption with the following form, where I calibrate \( \eta \) to 1, and \( \chi \) to 7.69 to get steady state \( h \) equal to 0.3 in steady state.

\[
U(c_t, h_t) = \log(c_t) - \chi \frac{h_t^{1+\eta}}{1+\eta}
\]

Following Christiano, Eichenbaum, and Evans (2005), the investment adjustment cost function has a flow specification

\[
F \left( \frac{I_t}{I_{t-1}} \right) = \frac{\kappa}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2
\]
where $\kappa$ is set to 2.48.

TFP shock persistence $\rho_A$ is 0.95 and the shock standard deviation $\sigma_A$ is 0.007. Monetary shock persistence $\rho_\varsigma$ is 0.5 and standard deviation $\sigma_\varsigma$ is 0.0025. I calibrate the monetary policy rule parameters $\Phi_r$, $\Phi_\pi$, and $\Phi_y$ to 0.75, 2.4, and 0 respectively. These values for shocks and policy rule parameters are in line with estimates in Smets and Wouters (2007).

The default parameter $\omega$ is calibrated to 0.011 and the recovery parameter $\mu$ to 0.65. The value for $\mu$ is comparable to the long run average recovery rate on loans given default, according to data from the 2010 Moody’s default study\(^1\). The parameter $\omega$ is higher than comparable values in the literature. The long run annual default rate for speculative grade companies is a bit higher than 4% based on default studies from the credit rating agencies, so the average economy-wide marginal default rate may be a bit lower. Coupled with the recovery rate $\mu$ the parametrization is moderate.

The financial parameters $\phi$ and $\gamma$ are specific to this model. $\gamma$ governs the elasticity of the insurance premium to the funding gap, $j_t$, and $\phi$ is the insurance cost scale parameter. $\gamma$ and $\phi$ are calibrated simultaneously to match target steady state spread and intermediary leverage. The target quarterly steady state spread is 0.84%, which is the long run average spread between secondary market yields of BAA corporate bonds and US 3 month treasuries. The target steady state bank leverage is 12. This is the average leverage for commercial banks since 1980 based on data from the Federal Reserve’s H8 release. Commercial bank leverage has trended downwards significantly over time, especially since the 1990s. However, leverage for shadow banks and capital market intermediaries is much higher than commercial banks as discussed in Adrian and Shin (2010a). $\gamma$ and $\phi$ are set to 3.636 and 7.14 respectively. Table 1 summarizes the calibration.

Table 2 shows selected moments from the model. The model does well in matching correlation between spreads and output. The empirical correlation of spreads and output is -0.6, compared to -0.76 in the model. While the model has volatile spreads, empirically spreads are even more volatile.

### 3 Credit Channels

#### Endogenous Leverage

We can derive the bank’s capital structure decision in the model. Re-writing the bank’s profit equation (7) after using the balance sheet condition (6) and

Table 1: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>$\pi^*$</td>
<td>inflation</td>
<td>1.005</td>
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<tr>
<td>$\beta$</td>
<td>intertemporal discount</td>
<td>0.996</td>
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<tr>
<td>$\alpha$</td>
<td>intermediate good production</td>
<td>0.36</td>
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<tr>
<td>$\delta$</td>
<td>depreciation</td>
<td>0.025</td>
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<tr>
<td>$\epsilon$</td>
<td>final goods CES production</td>
<td>6</td>
</tr>
<tr>
<td>$\theta$</td>
<td>price stickiness</td>
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<tr>
<td>$\eta$</td>
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<td>$\chi$</td>
<td>labour utility</td>
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<td>$\kappa$</td>
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<td>$\rho_A$</td>
<td>TFP shock persistence</td>
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<tr>
<td>$\rho_e$</td>
<td>Monetary shock persistence</td>
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<td>$\sigma_A$</td>
<td>TFP standard deviation</td>
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<tr>
<td>$\sigma_e$</td>
<td>Monetary shock standard deviation</td>
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<td>$\Phi_r$</td>
<td>Taylor rule smoothing</td>
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<td>$\mu$</td>
<td>recovery rate</td>
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<tr>
<td>$\phi$</td>
<td>insurance premium scale</td>
<td>7.14</td>
</tr>
</tbody>
</table>

the payout equation (8) gives

$$n_t \left( d \pi_t^b - \frac{r_{t-1}}{\pi_t} \right) = \frac{b_t}{\pi_t} \left( \frac{z_t - r_t}{z_t} \right) - \phi j_{t+1}^\gamma$$

We further manipulate the equation using the household Euler equations and the credit supply equation (9). The resulting expression is shifted one period forward to give the capital asset ratio,

$$\frac{n_{t+1}}{b_{t+1}} = E_t \left\{ \frac{-\pi_{t+1} (1 - \omega) \phi j_{t+1}^\gamma}{r_t b_{t+1} \omega - (1 - \omega) r_t \phi j_{t+1}^\gamma} \right\} \tag{29}$$

This expression gives

$$\frac{\partial (n_{t+1}/b_{t+1})}{\partial r_t} = - \frac{(n_{t+1}/b_{t+1})}{r_t}$$

A rise in interest rates increases the opportunity cost of bank capital, and banks respond by increasing leverage. Figure 4 shows the VAR of interest
Table 2: Moments

<table>
<thead>
<tr>
<th></th>
<th>spread</th>
<th>$z_t$</th>
<th>Total credit</th>
<th>Bank capital</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation with output</td>
<td>Data</td>
<td>-0.608</td>
<td>0.209</td>
<td>0.483</td>
<td>0.813</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>-0.764</td>
<td>0.822</td>
<td>0.621</td>
<td>0.869</td>
</tr>
<tr>
<td>Volatility relative to output</td>
<td>Data</td>
<td>24.5</td>
<td>1.86</td>
<td>3.76</td>
<td>4.75</td>
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<tr>
<td></td>
<td>Model</td>
<td>8.28</td>
<td>0.87</td>
<td>2.62</td>
<td>2.23</td>
</tr>
</tbody>
</table>

Note: Output, total credit, bank capital, and investment are in real per capita terms, logged and de-trended using the HP-filter. $z_t$ is the de-trended BAA yield. Total credit is the credit outstanding to non-financial business. Bank capital is net assets for commercial banks. Data from the Federal Reserve and BEA.

rates and the capital-asset ratio of commercial banks. Following an interest rate shock, capital asset ratios seem to rise initially and then fall. This might be a reflection of adjustment costs in capital structure for intermediaries.

\[
\frac{\partial (n_{t+1}/b_{t+1})}{\partial j_{t+1}} = \gamma \phi (1 - \omega) \pi_{t+1} j_{t+1}^{\gamma - 1} r_t \left(-b_{t+1} \omega + \phi j_{t+1}^{\gamma - 1} (1 - \omega)\right)
\]

$\partial (n_{t+1}/b_{t+1})/\partial j_{t+1} > 0$ in the baseline calibration. However, it can be negative if default rates $\omega$ are high so that fewer banks pay the insurance premium. $\partial (n_{t+1}/b_{t+1})/\partial j_{t+1}$ increases with $\phi$, $r_t$, and $j_{t+1}$.

The funding gap approach in this model looks at changes in credit supply and the effects on the business cycle. Figure 5 shows some evidence of the role of credit supply. The figure shows the impulse response from a VAR of lending rates and total credit outstanding. Lending rates are de-trended secondary market BAA yields, and total credit is de-trended total credit outstanding to non-financial business. The figure shows that higher lending rates are associated with reduction in credit outstanding. This implies that credit supply conditions are particularly influential during contractions in credit.

One of the key drivers of the credit channels in the model is equation (9), which governs the credit supply. Equation (9) is shown here for convenience:

\[
z_t - r_t = \gamma \phi j_t^{\gamma - 1} \left( r_t b_{t+1} - z_t d_{t+1} \right) b_{t+1}^2
\]

From equation (9), we have

\[
\frac{\partial (z_t - r_t)}{\partial j_t} = (z_t - r_t) (\gamma - 1) \frac{1}{j_t} > 0
\]
Figure 4: VAR of detrended interest rates and de-trended capital-asset ratio for commercial banks. Data for the capital asset ratio derived from the Federal Reserve's H8 release for commercial banks. Interest rates are secondary market yields on US 3-month treasuries. Capital asset ratios rise and then fall following an interest rate shock.

Figure 5: VAR of lending rates and total credit outstanding. Credit supply conditions influential in credit contraction as total credit drops following a lending rate shock.
When the funding gap per unit asset, \( j_t \), rises, the credit spread rises and banks supply less credit. This is because intermediaries’ marginal costs for insurance premium rise. Intermediaries also have to hold more capital to offset the rise in premium, so their marginal funding costs rise. Due to the convexity of insurance premia, the effect is larger if the spreads are large to begin with.

### 3.1 Broad Lending Channel

#### 3.1.1 Business Conditions Channel

An improvement in business conditions increases the willingness of intermediaries to lend. In this model the business conditions channel works principally through asset prices \( q_t \). The credit supply condition (9) shows that \( \partial (z_t - r_t) / \partial q_t \) is negative and so the credit supply increases in \( q_t \).

Consider a TFP shock to look at the business conditions channel. A shock that improves TFP increases the demand for credit as measured by a rise in \( r_k \) and a boom in investment. Asset prices rise, driving down the funding gap, reflecting an improvement in collateral conditions. The insurance premium drops, and banks can afford to expand the balance sheet using deposits, the cheaper funding source. This drives down spreads.

The monetary authority responds to the TFP shock by reducing the nominal rate \( r_t \), triggering the funding cost channel. A drop in \( div_b \) means that capital is cheaper and hence banks can afford to keep more capital and drive the insurance premium further down. The net effect is that the bank expands the credit supply. Firms can afford to borrow more resulting in an amplified boom in investment. Figure 6 shows the summary impulse response for a TFP shock. For comparison, I show the same model with \( \phi \) set to 0. When insurance is costless in this way, the optimal bank capital is 0, the credit spread is 0 too, and the credit channels are closed.

I look at the aggregate level empirical evidence for a link between asset prices and credit supply conditions. I run a VAR of the de-trended S&P 500 index and de-trended credit spreads. The VAR shows that credit spreads tighten when asset prices rise. Figure 7 shows the impulse response of the VAR.

### 3.2 Bank Lending Channel

#### 3.2.1 Bank Net Worth Channel

Bank net worth has an ambiguous effect in the model. Capital is a costly way of financing bank assets, but it also reduces the insurance premium and
Figure 6: Response to 0.7% (1 standard deviation) TFP shock

Figure 7: VAR of detrended asset prices and de-trended credit spreads. A rise in asset prices leads to tighter spreads, showing the asset price channel is active.
hence marginal lending costs. Equilibrium capital is optimal in the model so that there is no welfare gain from increasing or decreasing capital levels. One situation where more capital would improve welfare is if banks overestimate their loan recovery rate $\mu q(b_{t-1}/z_{t-1})$.

At the aggregate level, cyclical bank capital changes do not seem to affect spreads. Figure 8 shows the VAR of bank capital per capita and credit spreads. Bank capital data is obtained from the Federal Reserve H8 Release using data for all commercial banks. Several studies look at the effect of bank capital on lending activity. Gambacorta and Mistrulli (2004) find that better capitalized banks can absorb temporary GDP shocks better, consistent with the model in the paper. Lown and Morgan (2006) also find that bank capital does not appear to affect standards, which is consistent with the results here. They argue that book value of capital may not be the ideal measure for bank capital.

3.2.2 Funding Cost Channel

The household Euler equations imply that $div^b_t$ is related to $r_t$,

$$E_t \left\{ (1 - \omega) div^b_{t+1}U'_{c_{t+1}} \right\} = E_t \frac{r_tU'_{c_{t+1}}}{\pi_{t+1}}$$

This means that when the real interest rate rises, the required return on capital, $div^b_t$, also rises. Banks pass on this increase in funding costs to
firms. Intermediaries’ profitability is eroded and they respond by charging higher spreads to borrowers. In addition, there is a secondary effect as the real funding gap rises and $j_t$ rises. This increases the funding costs and forces banks to rein in credit supply. The result is higher spreads and lower investment. The rise in required returns also increases the average cost of capital. If $n_t$ remains the same, banks need to make more profit to distribute the required return according to the profit equation (7) and profit distribution (8). This causes banks to hold less capital following the increase in $r_t$.

Figure 9 shows the effect of a monetary policy shock $\nu_\varsigma$ with size 0.0025. The size of the shock is one standard deviation, estimated in Smets and Wouters (2007) and other related studies. It implies that if inflation is constant, the nominal rate would rise by 0.25%. The relatively small shock size induces small movements in most variables except the spread, which jumps by more than 5%.

Some empirical work investigates funding channels for banks. Kishan and Opiela (2000), for instance, find that monetary policy effects are largest for
small banks with lower capital buffers. Marginal funding costs for banks are not apparent as banks may use a variety of funding methods with different durations.

4 Conclusion

This paper proposes a model of credit cycles where three credit channels are simultaneously active. Intermediaries face a funding gap when they hold a defaulted asset. More capital reduces this funding gap, acting as a buffer against adverse times. Capital is costly because household desire compensation for the extra risk of holding capital versus risk free deposits, and intermediaries prefer funding using deposits because of deposit insurance. Changes in the funding gap through the different channels shift the amount banks are willing to lend.

I show that capital payouts for financial businesses are volatile indicating the need to consider endogenous leverage in financial intermediation models. I also present some evidence of the credit channels. I show using a vector auto-regression that credit conditions improve over the business cycle (i.e. they are procyclical). In addition, total credit outstanding drops when lending rates rise, indicating that credit supply is particularly influential in credit crunches. At the aggregate level, bank net worth does not seem to influence credit spreads. Evidence from VARs shows that a rise in asset prices improves credit conditions, indicating the business conditions channel is active.

References


