Abstract

Financial crises tend to follow rapid credit expansions. In this paper we show that this phenomenon arises naturally when financial intermediaries benefit from, and optimally exploit, economic rents that drive their franchise value. Specifically, we explore rents arising from government subsidies in the form of underpriced insurance on deposits. We show that the economic value of these rents varies with the business cycle, which in turn drives bank’s incentives to engage in riskier lending as risk increases, and safer investment strategies as risk vanishes. We use the model to evaluate the effects of recent government subsidies to banking sectors in US and EU. We argue that bank lending responded little to these interventions because government subsidies enhanced franchise value and thus made the value of safe investments relatively higher.
1 Introduction

In the wake of the financial crisis of 2007–2008 and the subsequent Great Recession, economists have closely studied the relation between credit market conditions and the real economy. Empirical studies find that severe economic downturns across time and in many countries predictably follow large credit expansions.\(^1\) This evidence has led some to conclude that credit expansions, driven by investor irrationality, are a main cause of downturns. Indeed, an older literature, e.g. Minsky (1977) and Kindleberger (1978), emphasizes the potential for overoptimism to destabilize the economy. Newer work suggests that competitive pressures to lend combined with behavioral biases, e.g. neglected risks (Gennaioli, Shleifer, and Vishny, 2012) or extrapolative beliefs (Barberis, Shleifer, and Vishny, 1998; Greenwood and Hanson, 2013) may lie behind the expansions and subsequent downturns.

In this paper, we show that banks’ apparent propensity to engage in “riskier lending” is the optimal response to the cyclical variations in economic conditions and franchise values. Instead of suffering from irrational exuberance, in our model bank managers correctly forecast the future of the economy and the financial health of their own bank. Moreover, they make investment and financing decisions with the aim of maximizing the market value of equity. Our key assumption is that banks receive economic rents, which in our setting arise because of subsidized deposits insurance.\(^2\) We show that deposit insurance incentivizes banks to take safer investment positions relative to the no-deposit insurance case. More importantly, the presence of subsidized deposit insurance causes bank lending to respond endogenously to fluctuations in macroeconomic conditions with banks generally taking more risk as franchise values drop.

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\(^1\)See Borio and Lowe (2002); Reinhart and Rogoff (2009); Jordà, Schularick, and Taylor (2011); Schularick and Taylor (2012); Mian and Sufi (2009); Mian, Sufi, and Verner (2017); Krishnamurthy and Muir (2016).

\(^2\)Buser, Chen, and Kane (1981) is an early example documenting how deposit insurance premia is subsidized in the US.
Building on Merton (1978), we model banks as entities with an exogenous supply of deposits, paying a fixed deposit rate subject to a government guarantee. To this basic structure, we add a portfolio decision: banks decide in each period whether they want to invest their assets in a portfolio of risky loans or in floating rate government notes. The government guarantee on deposits provide banks with a source of economic rents. The discounted value of this stream of rents is effectively the bank’s franchise value and its fluctuations over the business cycle drive lending behavior. During expansions, the franchise value is generally large and banks want to protect it by avoiding excessive risks that may lead to bankruptcy. However, as risks eventually build and franchise values fall, banks find it preferable to exploit the additional reward coming from investing in risky assets in risky times (higher risk premia).

Beyond these general findings, our model has important implications for policy evaluation. After the recent recession, central banks in advanced economies responded by providing the banking sector with additional guarantees on funding. Although policymakers intended for banks to increase their lending to the private sector, this did not happen. Instead, banks invested heavily in government bonds or excess reserves with the central bank. We show that this behavior need not be puzzling if we plausibly interpret those guarantees as lowering the cost of financing for banks. In this case our model suggests that by effectively increasing the franchise value of banks these policies only worked to reinforce their incentives to hold more safe assets.

Our work is related to several bodies of literature spanning subfields ranging from corporate finance to macroeconomics. Starting from the empirical evidence that the banking industry is both highly regulated and subject to limited entry, a large literature has shown that competition reduces banks’ franchise value and induces banks to assume more risk.\(^3\) In his seminal paper, Merton (1978) shows that, in the presence of deposit insurance, the usual relation between...

\(^3\)This conclusion found some objections, e.g. Boyd and De Nicoló (2005).
asset volatility and equity value does not necessarily hold since franchise values would be lost when bank’s default. Marcus (1984) and Hellmann, Murdock, and Stiglitz (2000) refined Merton’s idea by linking the bank preference for risky investments to the lower rents following higher competition in the banking industry. The mechanism they proposed is a particular example of the “risk-shifting” theory developed originally by Jensen and Meckling (1976). Keeley (1990) explains the savings and loan crisis of the 1980s and 1990s combining the intuition that higher competition destroys banks’ oligopolistic rents together with the idea that deposit insurance creates moral hazard incentives. Similar to us, due to the presence of franchise value, in those models banks self-impose a strict risk discipline. The key difference in our model is that franchise values endogenously fluctuate over the business cycle as the aggregate state of the economy changes.

Our paper is closely related to recent studies analyzing the problem of jointly determining optimal government and bank policies (Acharya and Yorulmazer, 2007, 2008; Farhi and Tirole, 2012). While those studies support the notion that it is impossible for governments to credibly commit to an ex-ante optimal policy during crises, we study the ex-ante incentives of benevolent pricing of deposit insurance premia.

Finally, this paper is related to the recent literature questioning the causal link between credit and economic cycle. In particular our paper is closely related to Santos and Veronesi (2016) and Gomes, Grotteria, and Wachter (2017). In both works, the authors argue that, while common explanations in the literature propose a causal relationship for the effects of leverage on aggregate economic and financial phenomena, the evidence should be assessed with more caution given that the same facts can be easily explained by rational frictionless models in which leverage is an endogenous quantity. While those two papers focus on the demand side of credit, either households or firms, in this work we concentrate our attention on the supply side of it and on the banking sector.
In the current work, there is no concept of a credit cycle driving the business cycle or of inefficient allocations. Banks correctly forecast future economic growth and optimally respond to changes in the economic environment. In other words, banks optimally act given their correct expectations about the future states of the world. When bankers believe an economic disaster is more likely to occur, they are willing to invest more and more in assets which are riskier, e.g. loans to households.

This paper is organized as follows. Section 2 presents a theoretical framework for addressing the question of optimal bank lending in the presence of deposit insurance. In section 3, the model results are quantitatively assessed, and policy implications carefully described. Section 4 concludes the work.

2 Model

We purposively keep our model simple. We assume three elementary units: a banking sector, a representative firm and a representative agent. These units share exposure to an extreme economic adverse event, or “crisis,” which occurs with a time-varying probability. To focus on our main underlying mechanism, we assume these sectors are otherwise separate. That is, banks lend to households who are not the representative agent, and may be subject to behavioral biases (we do not model the borrowing decisions of these households). Banks do not necessarily lend to the production sector; indeed the production sector faces no financial frictions, and may be all-equity financed. The representative agent owns the bank and the production sector; investment decisions by these entities are made in a manner consistent with the representative agent’s pricing of risk. Key to our analysis is the definition of a bank:

**Definition 1.** A bank is an investment management company whose risky investments are financed by equity and guaranteed deposits.
The bank takes advantage of stochastic investment opportunities while responding to unexpected changes in the economic environment. Every period, we can think of bank managers as deciding whether to invest in a riskless asset or in a portfolio of risky loans as well as the amount of equity to hold. The bank managers maximize the value of the equityholders by making optimal investment and payout decisions.\(^4\) The risky loan portfolio consists of infinitesimal loans whose collateral only lasts for one period and is subject to bank-specific shocks.

### 2.1 The Stochastic Discount Factor

We assume that all financial claims are owned and priced by an infinitely-lived representative household with an Epstein and Zin (1989) utility function. The representative agent’s utility is identified by a time preference rate \(\beta \in (0, 1)\), a relative risk aversion parameter \(\gamma\), and an elasticity of intertemporal substitution \(\psi\). It follows that the stochastic discount factor is given by:

\[
M_{t+1} = \beta^\theta \left( \frac{C_{t+1}}{C_t} \right)^{-\gamma} \left( \frac{S_{t+1} + 1}{S_t} \right)^{-1+\theta}
\]

where \(S\) denotes the wealth-consumption ratio and \(\theta = \frac{1-\gamma}{1-\psi}\).

### 2.2 Consumption and Uncertainty

The stochastic process for aggregate consumption is assumed to be:

\[
C_{t+1} = C_t e^{\mu+\sigma \epsilon_{c,t+1}+\xi_{x,t+1}}
\]

where \(\epsilon_{ct}\) is a standard normal random variable that is iid over time. Importantly, this process also allows for rare economic disasters (Rietz, 1988; Barro, 2006). We assume \(x_{t+1} = 1\) with probability \(p_t\) and zero otherwise. The realization

\(^4\)The equity holder is the representative agent. For reasons that we do not model, the representative agent does not internalize the cost of the program of deposit guarantees.
of $x_{t+1}$, conditional on $p_t$, is independent of $\epsilon_{e,t+1}$. If a disaster realizes, consumption falls by a fixed percentage $\xi$.

The natural log of the disaster probability, $p_t$, follows a first-order autoregressive process with autocorrelation $\rho_p$ such that $|\rho_p|<1$, and mean log $\bar{p}$:

$$\log p_{t+1} = (1 - \rho_p) \log \bar{p} + \rho_p \log p_t + \sigma_p \epsilon_{p,t+1},$$

where $\epsilon_{pt}$ is standard normal, iid over time, and independent of $\epsilon_{ct}$ and $x_t$. Under these assumptions, the wealth-consumption ratio satisfies

$$E_t \left[ \beta^\theta \left( \frac{C_{t+1}}{C_t} \right)^{1-\gamma} \left( S(p_{t+1}) + 1 \right)^\theta \right] = S(p_t)^\theta, \quad (4)$$

so that the stochastic discount factor can be written as

$$M_{t+1} = \beta^\theta e^{-\gamma(\mu_c + \sigma_c \epsilon_{e,t+1} + \xi x_{t+1})} \left( \frac{S(p_{t+1}) + 1}{S(p_t)} \right)^{-1+\theta}. \quad (5)$$

We consider a government bill which may default in the case of disaster.\(^5\)

Let $x_{Gt} \in \{0, 1\}$ be the indicator for default on the government bill. Assume that $\text{Prob}(x_{Gt} = 1) = q$ if $x_t = 1$ and 0 otherwise. Namely, if a disaster occurs ($x_t = 1$), the government defaults with probability $q$. For convenience, we assume that the loss, in percentage terms, is the same as the decline in consumption. Under these assumptions, the price of the government bill is

$$P_{Gt} = E_t[M_{t+1}(1 - x_{G,t+1} + e^\xi x_{G,t+1})]$$

$$= E_t[M_{t+1}(1 - x_{t+1} + (1 - q + qe^\xi)x_{t+1})]. \quad (6)$$

The realized return is

$$r_{t+1}^G = \frac{1 - x_{G,t+1} + e^\xi x_{G,t+1}}{P_{Gt}} - 1. \quad (7)$$

\(^5\)See, for example, Barro (2006).
While outright government default is possible, this assumption can also capture
the tendency of inflation and currency devaluation to lower the real value of
debt in the event of a disaster.

2.3 The Bank’s Problem

2.3.1 The Bank’s Balance Sheet

At time $t$, bank $i$ owns $A_{it}$ of assets available for lending and $D_{it}$ of deposits.
Define book value of equity as the difference between the two: $BE_{it} = A_{it} - D_{it}$.
Following Merton (1978), we assume a constant growth rate in deposits:

$$\log D_{i,t+1} - \log D_{it} = g.$$  \hfill (8)

We calibrate this growth rate so that, in expectation, it equals the growth rate
of consumption.

$$g = \log((1 - \bar{p})e^{\mu_c + \sigma_c^2/2} + \bar{pc}^{\mu_c + \sigma_c^2/2 + \xi}).$$  \hfill (9)

By definition, assets available for lending then equal assets in the previous
period, plus any change in book value of equity, plus the growth in deposits:

$$A_{i,t+1} = A_{it} + \Delta BE_{i,t+1} + D_{it}(e^g - 1).$$  \hfill (10)

We assume the cost of deposit to be constant and equal to $r^D$. At time
$t + 1$, returns on assets ($r^A_{i,t+1}$) are realized and the bank pays dividends or
defaults (as explained further below). Asset returns depend on the banks’ loan
portfolio and the overall economic conditions. Specifically, let $r^G_{t+1}$ be the net
return on government bonds between $t$ and $t + 1$ and $r^L_{i,t+1}$ be the net return
on a portfolio of private sector (household) loans during the same period. The
return on assets equals

\[ r_{i,t+1}^A = \varphi_{it} r_{i,t+1}^L + (1 - \varphi_{it}) r_{t+1}^G. \]

where \( \varphi_{it} \) is the share of the private sector loans in the overall portfolio. We preclude short-selling loans or government bonds, namely \( \varphi_{it} \in [0, 1] \).

We assume that a bank lends to a large number of households within a local economy.\(^6\) Under this assumption, we derive the distribution of the bank’s loan portfolio, \( r_{i,t+1}^L \), in Appendix A. The value of the collateral for each loan depends on the aggregate economic variables, a borrower-specific shock, and a persistent variable (\( \omega_i \)) specific to the local market. \( \omega_i \) can be interpreted as, for example, a local determinant of house prices. We assume \( \omega_i \) evolves according to the process:

\[ \omega_{i,t+1} = \rho_\omega \omega_{it} + \sigma_\omega \epsilon_{\omega_i,t+1} \]  

(11)

where \( \epsilon_{\omega_i,t} \) is iid over time, and independent of \( \epsilon_{ct}, x_t, \) and \( \epsilon_{pt} \). Appendix A shows that \( r_{i,t+1}^L \) depends on \( \epsilon_{ct+1}, x_{t+1}, \) and \( \omega_{i,t+1}, \) and so its distribution, as of time \( t \), depends on \( p_t \) and \( \omega_{it} \).

### 2.3.2 Regulation and Default

Banks face regulatory requirements. Define the planned debt-to-asset ratio for tomorrow as

\[ \zeta_{it} = \frac{D_{it} e^g}{A_{i,t+1}} \]

We assume that if \( \zeta_{it} \) is above a threshold \( \chi \), the bank will have to pay a cost \( f \) proportional to the amount of deposits. The time \( t \) subscript refers to the fact that the value of \( \zeta \) is in the time-\( t \) information set of the banks. Under

\(^6\)Yeager (2004) shows the vast majority of the U.S. banks remain small and geographically concentrated and 61% have operated within a single county.
our calibration, the bank will always avoid paying the regulatory costs.

Finally we impose some costs to adjust leverage $\Phi_{it}$ in the form of

$$
\Phi_{it} = \eta_B A_{it} \left( \frac{A_{i,t+1} - A_{it} - \nu(D_{i,t+1} - D_{it})}{A_{it}} \right)^2,
$$

where $\nu$ and $\eta_B$ are adjustment costs parameters.\(^7\)

From what has been said so far, it follows that the dividends paid to equity holders equal

$$
Div_{it} = r^A_{it} A_{it} - r^D D_{it} - \Delta BE_{i,t+1} - \Phi_{it} - fD_{it} \mathbb{1}_{\xi_{it} > \chi}
$$

or

$$
Div_{i,t} = r^A_{it} A_{it} - r^D D_{it} - \Delta BE_{i,t+1} - \Phi_{it} - fD_{it} \mathbb{1}_{\xi_{it} > \chi}
$$

We assume that banks default if assets plus the realized return on them is not sufficient to cover the interest and dollar value of deposits.\(^8\) That is, the bank defaults if $(1 + r^A_{it})A_{it} < (1 + r^D)D_{it}$. The condition $(1 + r^A_{i,t})A_{it} < (1 + r^D)D_{it}$ requires that at the beginning of each period $t$ the sum of the book value of equity determined in the previous period and the profits realized between $t-1$ and $t$ must always be positive. The condition being $(1 + r^A_{i,t})A_{it} < (1 + r^D)D_{it}$ rather than $A_{it} < D_{it}$ follows the realistic assumption that once the bank is close to default, it cannot avoid default by raising new equity (setting $Div_{it} < 0$), or by funding interest from new deposits. Under our calibration, the bank will always choose to ex-post avoid default by raising equity if it could do so.

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\(^7\)This specification of adjustment costs ensures stationary bank leverage.

\(^8\)In effect we assume, as does Merton (1978), that an agency monitors banks. Here, for simplicity, we assume that the monitoring occurs with probability 1.
Define the stochastic default time for bank \( i \) as

\[
T_i^* = \inf\{ t : (1 + r_{it}^A)A_{it} < (1 + r^D)D_{it} \}. \tag{14}
\]

We assume that when the bank defaults, the termination payoff to equityholders is zero. The market value of equity at time \( t \) \((V_{it})\) then equals the sum of expected dividends up to default discounted back to time \( t \), i.e.

\[
V_{it} = \begin{cases} 
E_t \left[ \sum_{s=t}^{T_i^*-1} M_{t,s} Div_{is} \right], & t < T_i^* \\
0, & t \geq T_i^*
\end{cases} \tag{15}
\]

where \( M_{t,s} \) is the SDF between time \( t \) and time \( s \).

Conjecture that the value function is \( V_{it} = V(r_{it}^A, A_{it}, D_{it}, p_t, \omega_{jt}) \). We can rewrite (14) recursively for time \( t \in \{0, \ldots, T_i^* - 1\} \) as:

\[
V_{it} = \max_{\phi_{it}, A_{i,t+1}} Div_{it} + E_t [M_{t,t+1} V_{i,t+1}] \tag{16}
\]

subject to

\[
V_{i,T_i^*} = 0 \tag{17}
\]

\[
T_i^* : \quad (1 + r_{i,T_i^*}^A)A_{i,T_i^*} < (1 + r^D)D_{i,T_i^*} \tag{18}
\]

\[
D_{i,t+1} = D_{it}e^g \tag{19}
\]

\[
r_{i,t+1}^A = \phi_{it}r_{i,t+1}^L + (1 - \phi_{it})r_{t+1}^G \tag{20}
\]

\[
Div_{it} = r_{it}^A A_{it} - r^D D_{it} + D_{i,t+1} - D_{it} - A_{i,t+1} + A_{it} \tag{21}
\]

\[\quad - \Phi_{it} - f D_{it} \mathbb{1}_{\zeta_{it} > \chi}\]

The value function summarizes the effects of the decisions about future investment and financing on equity values.

To make computations easier, we rewrite the equations as in Gomes, Jer-
mann, and Schmid (2016). Define \( \tilde{V}_{it} = V_{it} - (r_{it}^A + r_{it}^D D_{it}) \), and conjecture that \( \tilde{V}_{it} = \tilde{V}(A_{it}, D_{it}, p_t, \omega_{it}) \). Also define

\[
J(r_{it}^A, A_{it}, D_{it}, p_t, \omega_{it}) = \left( r_{it}^A A_{it} - r_{it}^D D_{it} + \tilde{V}(A_{it}, D_{it}, p_t, \omega_{it}) \right) I(1 + r_{it}^A A_{it} > (1 + r_{it}^D D_{it})
\]

The function \( \tilde{V}(\cdot) \) then obeys the following Bellman equation:

\[
\tilde{V}(A_{it}, D_{it}, p_t, \omega_{it}) = \max_{\phi_{it}, a_{i,t+1}} \left\{ D_{it} (e^g - 1) - A_{i,t+1} + A_{it} - \Phi_{it} + 
- f D_{it} \mathbb{1}_{\zeta_{it} > \chi} + E_t \left[ M_{t,t+1} J(r_{i,t+1}^A, A_{i,t+1}, D_{i,t+1}, p_{t+1}, \omega_{i,t+1}) \right] \right\}
\] (22)

subject to

\[
\tilde{V}_{i,T_t} = - (r_{i,T_t}^A A_{i,T_t} - r_{i,T_t}^D D_{i,T_t})
\] (23)

and to constraints (17) through (19). This formulation exploits the fact that cash-flows from operations at time \( t \) (from Equation 11) are predetermined and do not affect the optimization problem of the bank.

We simplify the problem even further, by scaling the new value function by \( D_{it} \). Define variables divided by \( D_{it} \) with the corresponding lower case letters. Conjecture that \( \tilde{V}(A_{it}, D_{it}, p_t, \omega_{it}) = D_{it} \tilde{v}(a_{it}, p_t, \omega_{it}) \). Dividing Equation 21 by \( D_{it} \), we prove the conjecture, where \( \tilde{v}(a_{it}, p_t, \omega_{it}) \) is:

\[
\tilde{v}(a_{it}, p_t, \omega_{it}) = \max_{\phi_{it}, a_{i,t+1}} \left\{ e^g - 1 - a_{i,t+1} e^g + a_{it} - \phi_{it} +
- f \mathbb{1}_{\zeta_{it} > \chi} + E_t \left[ M_{t,t+1} e^g j_{t+1} \right] \right\}
\] (24)
subject to

\[ \tilde{v}_{i,T_i^*} = -(r_{i,T_i^*}^A a_{i,T_i^*} - r^D) \] (25)

where

\[ j_{t+1} = (r_{i,t+1}^A a_{i,t+1} - r^D + \tilde{v}(a_{i,t+1}, p_{t+1}, \omega_{i,t+1})) 1_{(1+r^A_{i,t+1})a_{i,t+1} \geq (1+r^D)}. \]

From the accounting identity of assets equal the sum of book equity and deposits, the book value equity is

\[ be_{it} = a_{it} - 1. \]

2.3.3 The Bank’s Solution

Following Merton (1978), we assume that the interest rate on deposits is constant and below the average risk-free rate, namely \( r^D < \bar{r}^G \). This is well-known in the data. Figure 1 shows the time series for the 1 month T-bill rates compared to the average national rate on interest checking accounts in the $2,500 product tier. While this latter is clearly sticky and low, T-bill rates fluctuate sharply over time. The literature has micro-founded this assumption through the liquidity value short term deposits provide or through a money-in-utility function (Sidrauski, 1967). We will be agnostic as to the micro-foundations of this assumption.

We solve the model using value function iteration. Figure 2 shows the bank value as a function of initial equity capital and disaster probability. The value function is monotonically increasing and concave in the level of initial equity-to-asset ratio, i.e. the higher the initial equity capital (relative to the assets) the higher the value the bank has. The value function is also monotonically decreasing with respect to the disaster probability \( p_t \). A higher disaster probability makes the bank more likely to default and the discounted value of future dividends (up to default) lower. The only reason why in our model the market value of bank’s equity is higher than the book value of this latter is because the bank has access to a subsidized source of financing.
Figure 3 shows the equity-to-asset policy function, while Figure 4 shows the optimal portfolio choice. Two features are evident from Figure 3. First, the higher the initial capital ratio, the higher will be the new capital ratio chosen for next period, given the presence of adjustment costs on leverage. The second noticeable fact is that the optimal level of equity is decreasing in the probability of disaster. In fact, equity in this model is the most expensive source of capital for the bank (relative to subsidized deposits). The bank would optimally choose to hold zero equity if there were no franchise value to protect, which is lost in default. The way banks take the most advantage of subsidies, in our model, is by reducing/eliminating default risk and enjoying for longer periods the differential between the return on assets and the return they need to pay on their deposits. They achieve their goal by investing in government bonds. However, it is not always worthwhile to invest in government bonds. When the risk in the economy is high, for instance, because of precautionary savings, government bonds will provide a too low return. The bank would then take more risk. It will adjust both the assets (investing in risky loans) and liabilities (decreasing its capitalization). Bank’s exposure to default explains also the deceptive discontinuity in Figure 3. To sum it up, when the probability of an economic disaster increases and default cannot be avoided any longer, banks lower the equity at stake, increase their leverage and the risk-exposure of assets.

Our solution delivers two types of banks’ behavior often emphasized in the academic literature: “gambling for resurrection” and “reaching for the yield”.

1. *Gambling for Resurrection*: when the bank has a low ratio of equity over assets, it is costly to move to a higher equity-to-asset ratio. Once default cannot be avoided by simply investing in government bonds, the bank

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9 It can be proven analytically that in the case of no subsidies and no adjustment costs on leverage, each dollar of book equity capital is exactly worth 1 dollar.
chooses to take more risk also on the asset side. Due to limited liability, the maximum loss shareholders can incur is the equity value, but they will retain any upside.

2. Reaching for yield: Given a certain amount of equity, a higher probability of disasters increases the risk premium in the economy (making loans to households more profitable from the equityholders point of view) and reduces the rate on government bills due to the precautionary saving behavior of the representative household.

The interaction of individual bank equity capitalization and probability of a disaster also offers an explanation for the run-up of credit and low mortgage spreads from 2003 to 2006 and the following increase in spreads right before the crisis. In fact, in the model, if the disaster probability is low (2003-2006), spreads are also low. Nonetheless, if banks are highly levered, we will still observe an increase in bank’s lending to risky households. It is, however, when the probability of an economic disaster increases (2006-2008) that we observe a joint rise in spreads and in credit to households until the recession actually occurs.

2.4 Production Sector

The production sector is made by one representative firm. The firm’s manager maximizes the present value of cash-flows, taking the investors’ stochastic discount factor as given.

2.4.1 Technology

The firm uses capital $K_t$ to produce output $Y_t$ according to the Cobb-Douglas production function

$$ Y_t = z_t^{1-\alpha} K_t^\alpha, $$

(26)
where $\alpha$ determines the returns to scale of production and $z_t$ is the productivity level. We assume $z_t$ follows the process

$$\log z_{t+1} = \log z_t + \mu_c + \epsilon_{c,t+1} + \phi \xi x_{t+1}. \quad (27)$$

During normal-times, productivity grows at rate $\mu$ and is subject to the same shocks as consumption ($\epsilon_{c,t+1}$). Importantly, the firm is exposed to the same Bernoulli shocks as consumption through the term $\phi \xi x_{t+1}$. The term $\phi$ captures exposure to these shocks.

### 2.4.2 Investment Opportunities

The law of motion for firm’s capital stock is:

$$K_{t+1} = \left[(1 - \delta)K_t + I_t\right]e^{\phi\xi x_{t+1}}, \quad (28)$$

where $\delta$ is depreciation and $I_t$ is firm’s investment at time $t$. Equation 27 captures the depreciation cost necessary to maintain existing capital stock. It also, following the approach of Gourio (2012), captures destruction of capital that occurs during disasters. This can proxy for either literal capital destruction (in the case of war), or misallocation of capital due to economic disruption.

The firm faces costs when adjusting capital (Hayashi, 1982). We assume that each dollar of added productive capacity requires $1 + \lambda(I_t, K_t)$ dollars of expenditures, where

$$\lambda(I_t, K_t) = \eta_F \left(\frac{I_t}{K_t}\right)^2 K_t, \quad (29)$$

and where $\eta_F > 0$ determines the severity of the adjustment cost. Firm’s
payout to investors is thus

\[ \Pi_t = z_t^{1-\alpha}K_t^\alpha - I_t - \lambda(I_t,K_t). \]  

(30)

2.4.3 Firm Value, Optimal Investment and Payout

Given production and investment decisions, the total value of the firm obeys the following Bellman equation:

\[ V_f(K_t,z_t,p_t) = \max_{I_t,K_{t+1}} \left[ z_t^{1-\alpha}K_t^\alpha - I_t - \lambda(I_t,K_t) + \right. \]

\[ \left. E_t[M_{t+1}V_f(K_{t+1},z_{t+1},p_{t+1})] \right], \]

subject to (27), where \( V_f \) is the firm’s cum-dividend value.

3 Model Evaluation

3.1 Calibration

The model is solved and simulated at the annual frequency. We report parameter values in Tables 1 through 3. The values for \( \mu_c, \sigma_c, \beta, \alpha, \delta \) are from Cooley and Prescott (1995) and they have a long tradition in the business cycle literature. The values for \( \gamma \) and \( \psi \) are also common in the literature (see for instance Gourio (2012) or Gomes, Grotteria, and Wachter (2017)).

Due to their nature as rare events precise calculations of the probability and distributions of rare events are not possible. We choose parameters that are conservative given prior studies. We set the average probability of a disaster \( \bar{p} \) to be 2% per annum (Barro and Ursua (2008) estimates 2.9% based on OECD countries and 3.7% based on all countries). We assume the average consumption lost in a disaster state is 30% , which is close to the average
disaster size from Barro and Ursua (2008). We also follow Barro (2006) and many subsequent studies, and choose the probability of government default conditional on disaster to be 40%.

The process for \( p_t \) is latent to the econometrician. We assume values that give a reasonable amount of volatility and persistence, while implying stability of the numerical solution. We set the autoregressive coefficient to be 0.8 (annually) with an unconditional standard deviation of 0.7 (following Gourio (2013)). We solve for the equilibrium wealth-consumption ratio using (4), assuming a twenty-node Markov chain for \( p_t \). We choose \( \eta^F \) to match the volatility of investment growth relative to the volatility of output growth in the data.

As regards the bank’s problem, \( \varphi \) the loss given default on bank loans to the real economy is set to match the recovery rate on senior secured debt, i.e. 60% (Ou, Chlu, and Metz, 2011). The loan to value ratio is set to match the fact that when properties trade or are refinanced, their LTV is typically set to 80% (Korteweg and Sorensen, 2016). The volatility of houses (\( \sigma_W \)) follows Landvoigt, Piazzesi, and Schneider (2015), who estimated an annual volatility of house prices between 8% and 11%.

The regulatory requirement parameter \( \chi \) is set to be 0.92, which corresponds to an 8% equity to asset ratio, in accordance to Basel rules. We choose \( f \) to be a large number so as to severely punish banks who do not comply with capital regulations.\(^\text{10}\) Precise estimates for the volatility of local market loan profitability are not easily available. We then use an annual volatility of 4% which is consistent with ... . Adjustment costs on bank capital are set to match the volatility of the unconditional distribution for bank-level asset-to-debt ratio for US bank holding companies.

\(^{10}\) The exact value for the fixed cost parameter is not important and it is useful only to make banks avoid choose equity-to-asset ratios below what regulation requires.
3.2 Quantitative Evaluation

We simulate an economy made by 1000 banks for 10000 periods. For each bank, we normalize loans by the amount of deposits. We then compute aggregate lending as

\[ L_t = \int \varphi_i \frac{A_{i,t+1}}{D_{i,t+1}} di. \]

We find a positive correlation of 35% between the growth in aggregate bank lending and the disaster probability (in log). This simple statistics tells us that in our economy banks lend more as disasters become more likely, qualitatively matching the effect in the data.

To evaluate the model’s ability to quantitatively match the relation between credit and economic activity, we see to replicate the empirical estimates by Schularick and Taylor (2012). This requires a mapping of financial crises (which is what Schularick and Taylor predict) to observable measures of low \( p_t \) in our model. In what follows, we label crises to be periods in which GDP growth is in its lowest ventile, similarly to what is observed by Schularick and Taylor. Our results show that growth in bank loans is a leading indicator of crises in the model as well. Table 4 presents the estimated coefficients for the relationship between GDP and credit in the data as well as in the model.

3.3 Policy Evaluation

We finally test the effects of higher government subsidies in our model by lowering the return on deposit to a new \( \tilde{r}^D < r^D \) (ignoring the transition path). We want, in fact, to understand what are the model predictions about those government interventions aimed at lowering the bank’s cost of financing. Such government policies were widely employed during the recent recession as a tool to stabilize the banking system and to boost private lending by banks.

The longer-term refinancing operations (or LTROs) are a form of regular
open market operations in the Eurosystem, i.e. 3-month liquidity providing operations. To respond to the recent recession, however, the ECB employed some non-standard monetary policy measures like the three-year LTROs. One of the reasons why those measures were considered necessary to boost private credit after banks suffered equity capital losses. The ECB started a massive €1 trillion program. Results clearly underperformed expectations. Bocola (2016) argues, in fact, that banks mainly used LTROs to cheaply substitute liabilities.

The United States provide another example of a country in which such non-conventional monetary policies have been adopted. Also in this latter case, empirical evidence shows that the quantitative easing by the Federal Reserve did not boost private credit as expected. Maggio, Kermani, and Palmer (2016), among others, show a flypaper effect of unconventional monetary policy during QE1. A “flypaper effect” occurs when banks do not reinvest the money injected by the central bank to lend more to the private sector, but instead hold excess reserves with the central bank.

Our stylized model explains why banks opted for safer investments when their cost of funding gets lower. In our model, a lower cost of financing simply increases the franchise value of the bank. Banks can then finance their operations at a rate well below market rates. They will then become more scared of bankruptcy and they will fear the possibility of losing the new additional gift made by the government. The way banks can take the most advantage of this new low rates is by simply remaining in the business: safe investment strategies help in this direction.

Figure 5 through 7 provide a clear comparison between the case of low subsidies (high cost of deposits) and high subsidy (low cost of deposits). When banks benefit from lower rates on their funding, the value to equity holders is unquestionably higher (Figure 5). As Figure 6 demonstrates, for low levels of disaster probabilities, banks will also choose to hold more equity (because default will now cause larger losses to equityholders). Finally, Figure 7 compares
the portfolio allocation under the two scenarios. When cost of funding gets lower, the wealth effect dominates banks’ choices. For a larger set of states in which default is more costly (high equity, low $p_t$), banks shift their portfolio from loans to the real economy to government bonds.

4 Conclusions

A large literature, motivated by empirical linkages between leverage and crises, argues that excessive household leverage is a cause of subsequent crises, and specifically the financial crisis of 2008. However, leverage is itself an outcome of endogenous decision-making. While it may be plausible that households, perhaps based on lack of experience, overoptimism, or simply rule-of-thumb behavior, took more risk than, ex post, proved optimal, it is harder to believe that banks, en masse, decided to lend to such households purely based on overoptimism, as economic conditions worsened.

This paper offers a quantitative resolution of this conundrum based on a dynamic model of risk-shifting by banks. In our model, banks endogenously provide more leverage to households in times of worsening economic conditions. The subsequent economic decline is in no way caused by household’s overleveraging. Rather, leverage and the subsequent crisis are caused by the same economic phenomenon: in this model, a time-varying likelihood of an economic disaster.

Our study suggests that recent policy toward banks might have effects counter to what is intended. Banks’ decisions over time are driven by fluctuations in their franchise value. Methods to strengthen banks, while conferring long-run benefits, might actually result in less lending because they increase the franchise value. On the flip side, any policy with the side effect that weakens banks might actually result in more undesirable lending, and further bank instability, as banks gamble for resurrection. In both cases, ignoring the
incentive effects of policy on banks, which operate through fluctuating franchise values, could itself exacerbate underlying risks.
References


Appendix A  Bank Loans

The model for loans extends that of Vasicek (2002). Similar models have been used by Gornall and Strebulaev (2015), and Nagel and Purnanandam (2017).

Assume bank $j$ has access to a local market for loans. Let $i = 1, \ldots, n$ index borrowers for bank $j$.$^{11}$ Let

$$W_{jit} = e^{\sigma_c c_t + \xi x_t + \omega_{jt} + \sigma_W \epsilon_{it}^W}$$

(A.1)

denote the time-$t$ collateral value for borrower $i$ of bank $j$. This collateral value depends on the shocks to the aggregate economy, a borrower-specific shock $\epsilon_{it}^W$, and a bank-specific random variable $\omega_{jt}$ that follows the process specified in Equation 10.

Shocks are iid and independent with each other unless stated otherwise.

Let $\kappa$ denote the (common) face value of the loan. Borrower $i$ is said to default at time $t$ if $W_{ijt} < \kappa$.

We now determine the distribution of the time-$(t+1)$ payoff for bank $j$, conditional on time-$t$ variables. We will write this payoff as a function of the aggregate shocks and the bank-specific shocks by integrating out over the individual borrower shocks. Note that whether or not a borrower repays depends on the state of the aggregate economy. In what follows, we suppress the $j$ subscript.

First consider the probability of default assuming no disaster at time $t$, as a function of the aggregate and bank-specific variables. This is:

$$p_0(\bar{\epsilon}, \bar{\omega}) = \text{Prob} (\log W_{it} < \log \kappa | \epsilon_{ct} = \bar{\epsilon}, \omega_t = \bar{\omega}, x_t = 0) = \mathcal{N} \left( \frac{1}{\sigma_W} (\log(\kappa) - \sigma_c \bar{\epsilon} - \bar{\omega}) \right) = \mathcal{N} (f_0(\bar{\epsilon}, \bar{\omega})),$$

$^{11}$This is with some abuse of notation because we assume that banks have different pools of borrowers. We will assume that any risk of borrowers is uncorrelated across banks. In what follows, we use the central limit theorem to integrate out over borrower risk.
where \( \mathcal{N}(\cdot) \) denotes the normal cumulative density function. Likewise, consider the probability of default assuming that there is a disaster at time \( t \):

\[
p_1(\bar{\epsilon}, \bar{\omega}) = \text{Prob}(\log W_{it} < \log \kappa \mid \epsilon_{ct} = \bar{\epsilon}, \omega_t = \bar{\omega}, x_t = 1) = \mathcal{N}\left( \frac{1}{\sigma_W} (\log(\kappa) - \sigma \bar{\epsilon} - \xi - \bar{\omega}) \right) = \mathcal{N}(f_1(\bar{\epsilon}, \bar{\omega})).
\]

Note that \( p_1(\bar{\epsilon}, \bar{\omega}) > p_0(\bar{\epsilon}, \bar{\omega}) \).

For each \( i \)-th borrower, the cash flow the bank receives as loan repayment is

\[
\text{Rep}_{ji,t+1} = \kappa 1_{W_{i,t+1} \geq \kappa} + (1 - \mathcal{L}) W_{i,t+1} 1_{W_{i,t+1} < \kappa}
\]

with \( \mathcal{L} \) being the loss given default on loans.

Each bank \( j \) invested \( \frac{1}{n} \) in each loan. The portfolio of loans has a total repayment equal to

\[
\text{Rep}_{j,t+1} = \frac{\sum_i \text{Rep}_{ji,t+1}}{n}.
\]

Conditional on \( (\epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1}) \), and assuming \( n \to \infty \), the law of large numbers ensures that \( \frac{\sum \text{Rep}_{ji,t+1}}{n} \) converges almost surely to \( E_{\text{Rep}} [\text{Rep}_{ji,t+1} \mid \epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1}] \) (strong convergence).

\[
E_{\text{Rep}} [\text{Rep}_{ji,t+1} \mid \epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1}] = \kappa \text{Prob}(\kappa \leq W_{i,t+1} \mid \epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1}) + (1 - \mathcal{L}) E \left[ W_{i,t+1} 1_{\kappa > W_{i,t+1}} \mid \epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1} \right]
\]

\[
E \left[ W_{i,t+1} 1_{\kappa > W_{i,t+1}} \mid \epsilon_{c,t+1}, \omega_{j,t+1}, x_{t+1} \right] = \begin{cases} 
\int_{-\infty}^{\infty} f_0(\bar{\epsilon}, \bar{\omega}) e^{-(z - \sigma W)^2} \frac{e^{-\left(\frac{z}{\sqrt{2\pi}}\right)^2}}{\sqrt{2\pi}} dz & x_{t+1} = 0 \\
\int_{-\infty}^{\infty} f_1(\bar{\epsilon}, \bar{\omega}) e^{-(z - \sigma W)^2} \frac{e^{-\left(\frac{z}{\sqrt{2\pi}}\right)^2}}{\sqrt{2\pi}} dz & x_{t+1} = 1
\end{cases}
\]

The result of this last expectation is derived substituting the expression for the probability density function of a standard normal distribution and observing
that
\[
\int_{-\infty}^{a} e^{\sigma W z - \frac{z^2}{2}} \frac{dz}{\sqrt{2\pi}} = e^{\frac{\sigma^2 W^2}{2}} \int_{-\infty}^{a} e^{-\frac{(z-\sigma W)^2}{2}} \frac{dz}{\sqrt{2\pi}}
\]  
where \( a \) is the upper bound of integration.

Repayments on the portfolio of loans are a function of the probability of disasters \( p_t \), as well as the shocks \( \epsilon_{c,t+1}, \omega_{j,t+1} \) and \( x_{t+1} \). The price for the portfolio of loans is
\[
P_{Rep}^{jt} = E_t [M_{t+1} Rep_{j,t+1}].
\]
It follows that the price, \( P_{Rep}^{jt} \), depends on the probability of disaster \( p_t \) and the state variable of bank \( j \), \( \omega_{jt} \).

The return on the portfolio of loans is then defined as
\[
r_{j,t+1}^{L} = \frac{Rep_{j,t+1}}{P_{Rep}^{jt}}.
\]

The realized returns depend on \( p_t, \epsilon_{c,t+1}, \omega_{j,t+1}, \) and \( x_{t+1} \). However, given our assumptions on the distribution of \( \epsilon_{c,t+1} \), the distribution of returns tomorrow conditional on time-\( t \) information depends only on \( p_t \) and \( \omega_{jt} \).
Table 1. Parameter Values for the Aggregate Economy

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative risk aversion</td>
<td>$\gamma$</td>
<td>3</td>
</tr>
<tr>
<td>Rate of time preference</td>
<td>$\beta$</td>
<td>0.987</td>
</tr>
<tr>
<td>Elasticity of intertemporal substitution</td>
<td>$\psi$</td>
<td>2</td>
</tr>
<tr>
<td>Persistence of probability of disaster</td>
<td>$\rho$</td>
<td>0.8</td>
</tr>
<tr>
<td>Volatility of log probability of disaster</td>
<td>$\sigma_p$</td>
<td>1.17</td>
</tr>
<tr>
<td>Average probability of disaster</td>
<td>$\bar{p}$</td>
<td>0.02</td>
</tr>
<tr>
<td>Disaster size</td>
<td>$\xi$</td>
<td>$\log(1 - 0.30)$</td>
</tr>
<tr>
<td>Average growth in log consumption (normal times)</td>
<td>$\mu_c$</td>
<td>0.01</td>
</tr>
<tr>
<td>Volatility of log consumption growth (normal times)</td>
<td>$\sigma_c$</td>
<td>0.015</td>
</tr>
<tr>
<td>Probability of government default given disaster</td>
<td>$q$</td>
<td>0.40</td>
</tr>
</tbody>
</table>

_Notes:_ The representative agent has Epstein and Zin (1989) utility with risk aversion $\gamma$, elasticity of intertemporal substitution $\psi$, and time discount factor $\beta$. The aggregate endowment is given by

$$C_{t+1} = C_t e^{\mu_c + \epsilon_{c,t+1} + \xi x_{t+1}}$$

where $x_{t+1}$ is a disaster indicator that takes the value 1 with probability $p_t$. The variable $\xi$ is the size of an economic disaster. We assume that the logarithm of $p_t$ follows a Markov process with persistence $\rho_p$ and volatility $\sigma_p$. In the model, we assume that the government bill experiences a loss, conditional on a disaster, with probability $q$; in this case the percentage loss is equal to the percent decline in consumption.

We calibrate the model at an annual frequency.
Table 2. Parameter Values for Individual Banks

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatility of idiosyncratic local market profitability</td>
<td>$\sigma_\omega$</td>
<td>0.02</td>
</tr>
<tr>
<td>Persistence of idiosyncratic local market profitability</td>
<td>$\rho_\omega$</td>
<td>0.90</td>
</tr>
<tr>
<td>Adjustment cost on capital</td>
<td>$\eta_B$</td>
<td>6</td>
</tr>
<tr>
<td>Target Asset to Debt Ratio</td>
<td>$\nu$</td>
<td>1.17</td>
</tr>
<tr>
<td>Volatility Household Collateral Value</td>
<td>$\sigma_W$</td>
<td>0.10</td>
</tr>
<tr>
<td>Loss given Default on Households loans</td>
<td>$\mathcal{L}$</td>
<td>0.40</td>
</tr>
<tr>
<td>Loan to Value Ratio</td>
<td>$\kappa$</td>
<td>0.792</td>
</tr>
<tr>
<td>Capital regulation requirement</td>
<td>$\chi$</td>
<td>0.92</td>
</tr>
<tr>
<td>Punishment under no compliance</td>
<td>$f$</td>
<td>1000</td>
</tr>
</tbody>
</table>

Notes: The table shows parameter values for the individual bank’s problem. Each bank $i$ has access to a portfolio of $n$ infinitesimal one-period loans with the same loan to value ratio ($\kappa$) at the issuance, and whose collateral has the following process:

$$W_{i,t+1} = e^{\mu_c + \sigma_c \epsilon_{c,t+1} + \xi_{t+1} + \sigma_W \epsilon^W_{i,t+1}}$$

If a loan default the bank will recover $1 - \mathcal{L}$ of its collateral value $W_{i,t+1}$. The dividends for bank $i$ are:

$$Div_{it} = r^A_i A_{it} - r^D_i D_{it} + (D_{i,t+1} - D_{it}) - A_{i,t+1} + A_{it} - \Phi_{it} - f D_{it} 1_{\xi_{it} > \chi}$$

where $\Phi(\cdot)$ are the monetary costs the bank needs to sustain to adjust its assets and they are given by:

$$\Phi_{it} = \eta_B \left( \frac{A_{i,t+1} - A_{it} - \nu(D_{i,t+1} - D_{it})}{A_t} \right)^2 A_{it}$$

The bank $i$ deposits grow exogenously according to:

$$D_{i,t+1} = D_{it} e^g.$$
### Table 3. Parameter Values for Representative Firm

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns to scale</td>
<td>( \alpha )</td>
<td>0.40</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>( \delta )</td>
<td>0.08</td>
</tr>
<tr>
<td>Adjustment cost on capital</td>
<td>( \eta_F )</td>
<td>5</td>
</tr>
<tr>
<td>Sensitivity to disasters</td>
<td>( \phi )</td>
<td>2</td>
</tr>
</tbody>
</table>

**Notes:** The table shows parameter values for the firm’s problem. We assume that the firm has a Cobb-Douglas production function of the form

\[
Y_t = z_t^{1-\alpha} K_t^\alpha
\]

where the logarithm of the firm productivity level, \( z_t \), follows a random walk process given by:

\[
\log z_{t+1} = \log z_t + \mu_c + \epsilon_{t+1} + \phi \xi X_{t+1}
\]

The law of motion for each firm’s capital stock is:

\[
K_{t+1} = [(1 - \delta)K_t + I_t]e^{\phi \xi x_{t+1}}.
\]

We calibrate the model at an annual frequency.
<table>
<thead>
<tr>
<th></th>
<th>OLS – Data</th>
<th>OLS – Model</th>
<th>Logit – Data</th>
<th>Logit – Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta l_{t-1}$</td>
<td>-0.0182</td>
<td>0.3447</td>
<td>-0.0917</td>
<td>5.4577</td>
</tr>
<tr>
<td>$\Delta l_{t-2}$</td>
<td>0.260</td>
<td>0.1796</td>
<td>6.641</td>
<td>3.2724</td>
</tr>
<tr>
<td>$\Delta l_{t-3}$</td>
<td>0.0638</td>
<td>-0.0642</td>
<td>1.675</td>
<td>-1.2427</td>
</tr>
<tr>
<td>$\Delta l_{t-4}$</td>
<td>-0.00423</td>
<td>-0.0748</td>
<td>0.0881</td>
<td>-1.5019</td>
</tr>
<tr>
<td>$\Delta l_{t-5}$</td>
<td>0.0443</td>
<td>-0.0237</td>
<td>0.998</td>
<td>-0.3880</td>
</tr>
<tr>
<td>Sum of lag coefficients</td>
<td>0.345</td>
<td>0.3615</td>
<td>9.311</td>
<td>5.7512</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0126</td>
<td>0.0029</td>
<td>0.0379</td>
<td>0.0028</td>
</tr>
</tbody>
</table>

*Notes:* The table shows the coefficients and $R^2$ for the crisis prediction equation as estimated by Schularick and Taylor (2012). In the data $l$ stands for total bank loans in real terms, while in the model $l$ is the average loans over deposits.
Fig. 1. Deposit rates (US national average) and Tbill (BEY). The figure shows the rates on interest checking accounts ($2.5k) and the yields on the 1 month and 3 month Tbill. Data are from FRED and FDIC.
Fig. 2. Value Function. The figure shows the value function of an individual bank ($\bar{v}_t$) for different levels of probability of disaster $p_t$ and initial equity capitalization ratios $BE_t/A_t$, fixing $\omega_{it} = 0$. 
Fig. 3. Optimal Equity Capital. The figure shows the optimal equity capitalization ratios of an individual bank \((BE_{t+1}/A_{t+1})\) for different levels of probability of disaster \(pt\) and initial equity capitalization ratios \(BE_t/A_t\), fixing \(\omega_{it} = 0\).
Fig. 4. Portfolio Allocation. The figure shows the policy for portfolio allocation of an individual bank \((\varphi_t)\) for different levels of probability of disaster \(p_t\) and initial equity capitalization ratios \(BE_t/A_t\), fixing \(\omega_{it} = 0\). 1 represents investment in the portfolio of household loans, while 0 stands for investment in the government T-bill.
Fig. 5. **Value Function for different subsidies.** The figure shows the value function of an individual bank ($\tilde{V}_t$) for high and low subsidies (solid and dashed line respectively) and different probabilities of disaster $p_t$ keeping fixed the initial equity capitalization ratio $BE_t/A_t$, and $\omega_{it} = 0$.

Fig. 6. **Optimal Equity Capital for different subsidies.** The figure shows the optimal equity capitalization ratios of an individual bank ($BE_{t+1}/A_{t+1}$) for high and low subsidies (solid and dashed line respectively) and different probabilities of disaster $p_t$ keeping fixed the initial equity capitalization ratio $BE_t/A_t$, and $\omega_{it} = 0$. 
Fig. 7. Portfolio Allocation for different subsidies. The figure shows the portfolio allocation of an individual bank ($\varphi_t$) for different levels of the probability of disaster $p_t$ and initial equity capitalization ratios $BE_t/A_t$, for the case of low and high subsidies (left and right figure respectively), fixing $\omega_{it} = 0$. 

(a) Low

(b) High