

# Public Funding of Banks and Firms in a Time of Crisis\*

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We study public funding of banks and nonfinancial firms in a time of crisis. We find that bank capitalization is more effective in stabilizing the economy than direct funding to firms, but it also creates larger distortions. We show that the optimal, social-welfare-maximizing, structure of a public funding program depends on its size. Small funding programs should target banks, while large programs should be directed at non-financial firms. We provide an interpretation of the result in terms of dominated and undominated policies under genuine uncertainty.

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## 1. Introduction

Governments often provide capital and other direct funding to banks and nonfinancial firms during economic crises. In the crises taking

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place between 1970 and 2007, these resolution measures were present in 33 episodes out of 42, and government capitalization of banks averaged around 8 percent of gross domestic product (GDP) (Laeven and Valencia 2012). During the Great Recession the Federal Reserve System (the Fed) and the U.S. Treasury injected capital and direct funding into both banks and nonfinancial firms, with the sizes of bank and nonbank financing programs reaching close to 5 percent and 3 percent of GDP, respectively (SIGTARP 2014; Labonte 2016).<sup>1</sup> During the COVID-19 crisis the Fed and the U.S. Treasury mostly supported nonfinancial firms, with the size of the funding programs exceeding 15 percent of GDP.<sup>2</sup>

In this paper we consider a government which has, in a time of crisis, decided to provide public funding to the private sector, and ask how the funding should be allocated between banks and nonfinancial firms. We show that the optimal *structure* of the program depends on its *size*: If the program is relatively small, the government should capitalize banks. But if the program is large enough, public funding should be allocated to nonfinancial firms.

To study the effects of public funding programs on banks' and firms' balance sheets, economic activity, and social welfare, we embed the dual moral hazard framework of Holmström and Tirole (1997) into a dynamic macro model. In their flexible framework (see Tirole 2006 for applications) entrepreneurs and banks can tap

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<sup>1</sup>The U.S. Treasury injected equity capital in the financial sector and direct funding to the automotive industry via the Troubled Asset Relief Program (TARP), whose size was decided prior to the allocation of its funds. The Fed created the Commercial Paper Funding Facility and Term Asset-Backed Securities Loan Facility programs to provide liquidity to both the financial and real sectors. Similar funding programs were, for example, implemented in the European Union (EU) and U.K. (European Commission 2014; Grosse-Rueschkamp, Steffen, and Streitz 2019).

<sup>2</sup>Federal government provided lending through the Fed, Treasury, and Small Business Administration (see, e.g., <https://www.covidmoneytracker.org/explore-data/interactive-table>, accessed February 6, 2023). The Fed introduced Primary and Secondary Market Corporate Credit Facilities, the Main Street Business Lending Program, the Paycheck Protection Program Liquidity Facility, and purchased mortgage-backed securities (e.g., <https://www.federalreserve.gov/newsevents/pressreleases/monetary20200409a.htm>, accessed May 12, 2020). Similar and even more sizable support programs were introduced in the EU and U.K.—see, e.g., <https://www.ft.com/content/26af5520-6793-11ea-800d-da70cff6e4d3>, accessed January 12, 2024.

into external funding for leveraging their investments, at the cost of moral hazard problems. Hence sufficiently large banks' and entrepreneurs' own stakes in the investment projects are needed to maintain their incentives. We work with a version of the model with endogenous monitoring intensity, where not only the sum of informed (i.e., bank and entrepreneurial) capital but also its composition matters. Depending on the ratio of aggregate bank capital to aggregate entrepreneurial capital, the basic agency problem in the economy is resolved in different ways: either entrepreneurs have sufficiently large stakes in the investment projects, which renders bankers' intensive monitoring unnecessary, or, alternatively, bankers have large stakes and strong monitoring incentives, in which case entrepreneurs' small stakes are enough to maintain their incentives.

We find an investment- and output-maximizing composition of informed capital, which depends on the efficacy of bankers' monitoring technology. In equilibrium the ratio of aggregate bank capital to aggregate entrepreneurial capital tends to be too low compared with the output-maximizing level. As a result of this relative *scarcity* of bank capital, a given change in bank capital has a larger impact on incentives and aggregate investment than a corresponding change in entrepreneurial capital.

While we model financial frictions as in Holmström and Tirole (1997), banks in our model have large balance sheets and diversified asset portfolios, but nonfinancial firms are small and specialized. As a result, firms are more vulnerable to idiosyncratic shocks while banks are more sensitive to aggregate investment shocks. After a negative aggregate shock, more entrepreneurs fail, but limited liability caps the loss at the micro level, while at the macro level specialization of nonfinancial firms protects entrepreneurs as a group from spillovers: successful entrepreneurs are not responsible for the unpaid debt of bankrupt entrepreneurs. Since banks absorb the loan losses and pay in full to their creditors, the negative *macro shock* has a levered effect on bank capital. Because of this *sensitivity* of bank capital to aggregate shocks, bank capital propagates shocks more extensively than entrepreneurial capital.

In a time of crisis, public funding can improve welfare by rendering the financial system more resilient in the face of adverse macro shocks. We show that the welfare benefits of a public funding program depend on its size, which determines the share of the private

sector's macro risk exposure taken over by the government. A larger program reduces bankers' ex post loan losses due to a macro shock by a larger percentage. The larger the size of the program and the larger the negative shock realization, the larger the welfare benefits (ex post) from the public intervention.

A program of a given size and welfare benefits from improved resilience (upon a shock realization) can be constructed by different combinations of bank capitalization and public funding of nonfinancial firms. We call this the *policy frontier*. We also show that the slope of the policy frontier depends on the size of the program: Due to the sensitivity of bank capital to aggregate shocks, smaller public ownership stakes in banks than in nonfinancial firms implement a given program size. But this relative advantage of bank capitalization becomes smaller as the size of the program grows. If the government has already taken over a large part of the macro risk in the banking sector, strengthening the banks' equity cushions further has a smaller relative effect compared with public funding of firms, which reduces banks' exposure to risks from the real sector.

However, public funding dilutes banks' and nonfinancial firms' existing owners' stakes and incentives. An optimal structure of a program, given its size, is a combination of bank capitalization and public funding of nonfinancial firms that minimizes welfare losses from distorted incentives. The size of the program affects its optimal structure. A given stabilization effect can be attained with a smaller public stake when the government targets banks rather than firms. But due to the relative scarcity of bank capital, each unit of public funds dilutes existing owners' stakes and incentives more when placed in banks rather than nonfinancial firms. Initially, this trade-off favors bank capitalization. When the desired stabilization effect is larger, there is a smaller difference between the required public stakes. Ultimately, for a sufficiently large program, its larger incentive distortions make bank capitalization inferior to the funding of nonfinancial firms from the welfare perspective.

In a time of crisis, policy design may take place under genuine uncertainty: the government does not necessarily know how severe the crisis will be, and it may even be unable to assign a probability distribution. What advice can be given to the government under such circumstances? Our analysis provides an answer to this question, since we characterize the sets of *dominated* and *undominated*,

or *Pareto-optimal*, policies under genuine uncertainty. A policy, say A, dominates another policy, say B, if A generates as high welfare as B after any negative shock realization, and higher welfare after some shock realizations. A policy is undominated, or Pareto optimal, if and only if it is not dominated by any other policy. We show that the mapping from the size of a program to its appropriate structure determines the sets of undominated and dominated policies. Small programs targeting banks, and large programs targeting nonfinancial firms, belong to the undominated set. A small public funding program directed at firms is dominated by a program of the same size directed at banks, while a large program allocated to banks is dominated by a program of the same size allocated to firms. All programs simultaneously funding both banks and firms are dominated by a program funding exclusively banks or firms with an appropriate structure. A government facing genuine uncertainty should select a funding program from the set of undominated options, and never choose a program which is dominated.

Our paper adds to the literature on the effects of government funding of banks and nonfinancial firms in a unified macro framework. Gertler and Kiyotaki (2010) study credit market interventions during the Great Recession, and show how the net benefits of the interventions are increasing with the severity of the crisis. Hirakata, Sudo, and Ueda (2013, 2017) extend the Bernanke, Gertler, and Gilchrist (1999) model to credit chains. In their model, capital injections to banks and firms lower the external finance premiums and stimulate the economy, but may also result in more macro volatility. Capital injections to financial intermediaries boost economic activity more than public funding of nonfinancial firms. Sims and Wu (2020) develop a version of the Gertler and Karadi (2011, 2013) model of financial intermediation, where financial intermediaries' possibilities to absorb corporate bonds depend on corporate cash flows. They compare the Fed's bond purchases from financial intermediaries (Wall Street QE) with bond purchases directly from nonfinancial firms (Main Street QE). If the cash flow constraint is unbinding, Wall Street QE and Main Street QE are substitutes, but if the constraint binds, financial intermediaries are unwilling to buy bonds, making Wall Street QE ineffective, while Main Street QE can still stimulate the economy. We complement the literature by analyzing the socially optimal allocation of public funds between banks

and nonfinancial firms when capital structure decisions and incentive problems in the financial and real sectors determine the social costs and benefits of public policies. We also characterize dominated and undominated policies under genuine uncertainty.

There is also a related literature on public funding of either banks or nonfinancial firms. For example, Philippon and Schnabl (2013) study efficient bank recapitalizations, while Bhattacharya and Nyborg (2013) use the menu of bailout plans as a screening device. In these papers, banks suffer from debt overhang. Curdia and Woodford (2011), Gertler and Karadi (2011, 2013), and Del Negro et al. (2017) study government funding of nonfinancial firms via large-scale asset purchases by the central bank, while Bianchi (2016) analyzes the ex post crisis mitigation and the ex ante moral hazard resulting from firm bailouts. In a difference to these papers, we emphasize the effects of public funding on intratemporal rather than intertemporal incentive problems. We also analyze public funding of both banks and nonfinancial firms, and present a criterion how to choose between these two.

A growing macrofinance literature applies the Holmström and Tirole (1997) framework. Contributions include Chen (2001), Aikman and Paustian (2006), Meh and Moran (2010), Christensen, Meh, and Moran (2011), Chang, Fernández, and Gulan (2017), Faia (2018), and Silvo (2019). We extend this framework in terms of our modeling of banks: a bank is a balance sheet structure with many bankers. We can thus combine diversified portfolios at the bank level with the Holmström and Tirole (1997) type incentive problems at the banker level.<sup>3</sup>

In the next section we describe the basic model. In Section 3, we explain why bank capital is likely to be scarce in equilibrium. In Section 4, we introduce an aggregate investment shock into the model, and explain why bank capital is more sensitive to these shocks than entrepreneurial capital. In Section 5, we calibrate the model,

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<sup>3</sup>In the standard Holmström and Tirole (1997) framework, a bank's asset portfolio is assumed to be completely correlated. Together with the assumption that unsuccessful firm projects return zero, this renders debt indistinguishable from equity on the liability side of the bank's balance sheet: either the bank can pay to all stakeholders or it can pay to nobody. In our model with diversified portfolios, the claims of a bank's creditors and equity holders can be meaningfully distinguished when there are aggregate shocks.

and further analyze and illustrate the scarcity and sensitivity of bank capital. In Section 6, we analyze public funding of banks and nonfinancial firms and characterize the optimal structure of public funding. Section 7 concludes.

## 2. The Model

We consider a discrete-time infinite-horizon economy populated by households with three types of members: workers, entrepreneurs, and bankers. On the financial side of the economy, bankers manage financial intermediaries (banks) that obtain deposits from households and finance entrepreneurs. The real economy contains two sectors: (i) competitive firms producing final goods from labor supplied by workers and capital supplied by entrepreneurs, and (ii) entrepreneurs producing capital goods.

Households own banks and all firms, including those producing capital goods. Households also own the capital stock. The production of capital is subject to a dual moral hazard problem in the sense of Holmström and Tirole (1997). Entrepreneurs, who may obtain external finance from households and banks, are tempted to choose less productive projects with higher nonverifiable returns. Bankers can monitor entrepreneurs to mitigate their moral hazard temptations, but since banks use deposits from households to finance entrepreneurs, bankers have an incentive to avoid costly monitoring. The moral hazard problems may be solved by designing a proper financing contract. The timing of events in each period is summarized in Table 1, while Appendix A.1 provides a still more detailed description. The key part of the model is Stage 2, where finance and the real economy interact.

### 2.1 *Households and Final Good Production*

There is a continuum of identical households of measure unity. Within each household, there are three occupations: in every period  $t$ , a fraction of the household members become entrepreneurs, another fraction become bankers, and the rest remain workers. At the beginning of each period, an entrepreneur and a banker exit from their occupations at random according to a Poisson process with constant exit rates  $1 - \lambda^e$ ,  $\lambda^e \in (0, 1)$  and  $1 - \lambda^b$ ,  $\lambda^b \in (0, 1)$ ,

**Table 1. Timeline of Events**

Period Starts	
Stage 1	<p>Survival probabilities realized and exiting bankers and entrepreneurs give their accumulated assets to households.</p> <p>Household members separate into their occupations.</p> <p>Consumption-savings and labor supply decisions are made.</p> <p>Final goods are produced using capital and labor.</p>
Stage 2	<p>Financial contracts are signed, depositors place their funds in banks, and banks finance entrepreneurs.</p> <p>Bankers choose monitoring intensity.</p> <p>Entrepreneurs choose the project type.</p> <p>Successful projects yield capital goods that are sold.</p> <p>Proceeds are divided according to the contract.</p>
Period Ends	

respectively. The number of household members becoming entrepreneurs and bankers equals the number of exiting entrepreneurs and bankers. This construction permits us to introduce financial frictions in banks and firms, while retaining the tractability of the representative household structure, thus abstracting from consumption heterogeneity across different types of agents.<sup>4</sup>

The head of a household decides on behalf of its members how much they will work, consume, and invest in capital. In Section 2.2, we explain in detail how entrepreneurs invest in risky projects to produce capital goods and how bankers provide funding for

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<sup>4</sup>See, e.g., Gertler and Kiyotaki (2010), Gertler and Karadi (2011, 2013), Christiano, Motto, and Rostagno (2014), Chang, Fernández, and Gulán (2017), Del Negro et al. (2017), Silvo (2019), and Sims and Wu (2020, 2021) for a similar construction.

these investments. In general, entrepreneurs and bankers earn higher returns on their risky investments than workers earn on their deposits. Hence, it is optimal for the household to let its entrepreneurs and bankers keep building up their assets until exiting their occupations. The exiting entrepreneurs and bankers give their accumulated assets to the household, which in turn provides new entrepreneurs and bankers with some initial investment capital. Within the household, there is perfect consumption insurance against the risks of entrepreneurs and bankers. Therefore, all household members consume an equal amount in each period.

The problem of a representative household is

$$\max_{\{C_t \geq 0, L_t \geq 0, K_t \geq 0\}_{t=0}^{\infty}} E_0 \left[ \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\xi}{1+\phi} L_t^{1+\phi} \right) \right],$$

subject to an intertemporal budget constraint:

$$C_t + q_t K_{t+1} = W_t L_t + K_t [r_t^K + q_t(1-\delta)] + T_t. \quad (1)$$

In the household's utility function  $\sigma > 0$ ,  $\xi > 0$ , and  $\phi > 0$  are parameters;  $\beta \in (0, 1)$  is the time preference discount factor; and  $C_t$  and  $L_t$  denote consumption and hours worked in period  $t$ , respectively. In the budget constraint (1),  $W_t$  is the real wage,  $K_t$  the stock of physical capital,  $r_t^K$  the real rental rate of capital,  $q_t$  the price of capital goods,  $\delta \in (0, 1)$  the rate of depreciation of physical capital, and  $T_t$  denotes lump-sum transfers (net payouts from entrepreneurs and bankers) and (possible) taxes. Buying and selling claims to the capital stock allows a household to smooth consumption. We assume, as in Carlstrom and Fuerst (1997), that bank deposits are intraperiod and, consequently, they do not appear in the intertemporal budget constraint (1).<sup>5</sup>

In equilibrium, physical capital stock accumulates according to the law of motion

$$K_{t+1} = (1-\delta)K_t + p_H R I_t, \quad (2)$$

where  $I_t$  is investment in period  $t$ . This accumulation equation is standard save for the two parameters of capital good production,

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<sup>5</sup>See also the discussion in Section 2.2.1.

$p_H \in (0, 1)$  and  $R > 1$ , which will be defined more precisely in Section 2.2.

Solving the household's dynamic optimization problem yields the familiar first-order conditions for  $L_t$  and  $C_t$ , respectively:  $\xi L_t^\phi C_t^\sigma = W_t$  and

$$1 = \beta E_t \left[ (1 + r_{t+1}) \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \right], \quad (3)$$

where  $(1 + r_{t+1}) \equiv [r_{t+1}^K + q_{t+1}(1 - \delta)]/q_t$  is the intertemporal real interest rate. Competitive firms in the final good sector combine capital  $K_t$  and labor  $L_t$  using the Cobb-Douglas production function  $Y_t = K_t^\alpha L_t^{1-\alpha}$ , where  $\alpha \in (0, 1)$ . Profit maximization results in the familiar equations for optimality conditions:  $W_t = (1 - \alpha)Y_t/L_t$  and  $r_t^K = \alpha Y_t/K_t$ .

## 2.2 Financial Frictions

Capital demanded by firms in the final good sector is produced by entrepreneurs who are endowed with investment projects and some initial wealth. Entrepreneurs can also attempt to leverage their investments by borrowing from bankers and workers. It may be best to think that intermediation of entrepreneurial finance occurs only among households. To clarify how financial intermediation takes place, let us consider three households: A, B, and C. We can think that the workers of household A first deposit their funds with the banks of household B, who then invest the deposits in projects of household C's entrepreneurs along with their own bank capital. The term "deposits" should be interpreted broadly, encompassing both retail deposits and wholesale debt funding of banks. In particular, the marginal unit is always wholesale funding, and not covered by any deposit insurance scheme.

All successful investment projects transform  $i_t$  units of final goods into  $Ri_t$  ( $R > 1$ ) verifiable units of capital goods, while failed projects yield nothing. The projects differ in their probability of success and in the amount of nonverifiable revenues they create. There is a "good" project that is successful with probability  $p_H$  and involves no nonverifiable revenues to the entrepreneur. We adopt the normalization  $p_H R = 1$ , so that the equilibrium law of motion of capital (2) is the same as in a standard growth model or real business cycle (RBC) model.

There is also a continuum of bad projects with a common success probability  $p_L = p_H - \Delta p$ , where  $0 \leq p_L < p_H < 1$  and  $\Delta p > 0$ , but with differing amounts of nonverifiable revenues  $h_t i_t$ ,  $h_t \in (0, \bar{h}]$  attached to them. Nonverifiable revenues are proportional to investment size as in Holmström and Tirole (1997). Departing from Holmström and Tirole (1997), where bad projects generate nontransferable private benefit, we assume, in line with Meh and Moran (2010), Christensen, Meh, and Moran (2011), Faia (2018), and Silvo (2019), that private benefits are divisible and transferable.<sup>6</sup> In our case, this assumption is only needed to ensure the smoothness of out-of-equilibrium payoffs. If, in an out-of-equilibrium event, an entrepreneur had picked a bad project, her project returns should be transferable and divisible among her household members upon her exit from entrepreneurship. Further, we assume that  $q_t p_H R = q_t > q_t p_L R + \bar{h}$  to ensure that the good project is preferable to all bad projects from the household's point of view.

Bankers are endowed with a variable-scale monitoring technology that enables them to constrain the entrepreneurs' project choice. Monitoring at the intensity level  $m_t$  ( $m_t \geq 0$ ) eliminates all bad projects where  $h_t \geq h(m_t)$  from the entrepreneur's project choice set. The threshold level of nonverifiable revenues  $h(m_t)$  is decreasing and convex in monitoring intensity:  $h'(m_t) \leq 0$ ,  $h''(m_t) \geq 0$ , and  $\lim_{m_t \rightarrow \infty} h'(m_t) = 0$ . As in Christensen, Meh, and Moran (2011) and Silvo (2019), monitoring involves real costs for the bank: to obtain monitoring intensity  $m_t$ , a bank must pay  $m_t i_t$  units of final goods to workers.<sup>7</sup> That is, the more a banker invests in monitoring, the less his bank can lend to entrepreneurs.

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<sup>6</sup>An interpretation is, reminiscent of Bolton and Scharfstein (1990), that project revenues are verifiable outside a household only up to  $R$ , or that only revenues in terms of capital goods are verifiable outside a household. Alternatively, following, e.g., Burkart, Gromb, and Panunzi (1998), we may think that an entrepreneur is able to divert part of her firm's resources to her own use at an interim stage. As in Burkart, Gromb, and Panunzi (1998), such expropriation of outside investors is costly. Here it is captured by the lower expected project returns if diversion takes place.

<sup>7</sup>Monitoring costs are transfers to workers, which do not enter the real resource constraint of the economy. This assumption is not quantitatively restrictive, as the total monitoring cost—while crucial for bankers' incentives—is very small relative to the size of the real economy. In the baseline calibration of the model, the steady-state monitoring cost  $mI$  is approximately 0.15 percent of total output  $Y$ , whereas consumption  $C$  is roughly 80 percent and investment  $I$  is roughly

Our assumption of variable-scale and endogenous monitoring intensity follows the modeling strategy in Holmström and Tirole (1997, Section IV.4). As explained by Holmström and Tirole (1997), endogenous monitoring intensity is needed for bank and entrepreneurial capital to have distinct roles at the macro level. If instead the monitoring intensity were fixed, the aggregate production of capital goods would only depend on the total amount of informed capital, i.e., the sum of bank and entrepreneurial capital. With endogenous monitoring intensity, also the composition of informed capital matters. This is an important feature for our analysis of public funding of banks and firms.

### 2.2.1 *The Financing Contract*

In each period  $t$ , there are three contracting parties: entrepreneurs, bankers, and depositors (workers). Following standard practice,<sup>8</sup> we assume limited liability and interperiod anonymity, and focus on the class of one-period optimal contracts where entrepreneurs invest all their own wealth  $n_t$  in their projects. The financial contract then stipulates how much of the required funding of the project of size  $i_t$  comes from banks ( $a_t$ ) and depositors ( $d_t$ ) and how the project's return  $R$ , in case of success, is distributed among the entrepreneur ( $R_t^e$ ), her bankers ( $R_t^b$ ), and depositors ( $R_t^w$ ).

A banker, given his share of project returns, maximizes the bank's profits by choosing monitoring intensity,  $m_t$ . Banks behave

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20 percent. (See Appendix C, especially Equation (C.4).) However, omitting the cost from the resource constraint allows the analytical characterization of the optimal structure of public funding in Section 6. Technically, this is because the model becomes modular such that frictions in financial intermediation affect the real part of the economy only indirectly through the agency problems.

<sup>8</sup>Similar one-period contracts are used in the macrofinance literature. Examples include models applying the Bernanke, Gertler, and Gilchrist (1999) financial accelerator (e.g., Hirakata, Sudo, and Ueda 2013, 2017; Christiano, Motto, and Rostagno 2014), the financial intermediation model of Gertler and Karadi (2011, 2013) and its extensions (e.g., Sims and Wu 2020, 2021), and macrofinance models using the Holmström and Tirole (1997) approach, cited in the Introduction. While evidently simplifying, the assumption is less controversial in our case, where the focus is not on relationship lending (in which case multiperiod contracts would be quintessential). A future work could, e.g., build on Holmström and Tirole (1998) and consider crisis management policies in a more dynamic macrofinance setting—see, e.g., Farhi and Tirole (2012) for an advance to this direction.

competitively. As a result, they choose the same financing contract and monitoring intensity that would be chosen by a single bank maximizing the entrepreneur's expected profits.<sup>9</sup> Intuitively, each entrepreneur chooses a bank that offers it the most favorable contract and monitoring intensity, and no bank is able to attract entrepreneurs if it does not choose a contract or monitoring intensity that maximizes firm profits. An optimal financing contract therefore solves the following program:

$$\max_{\{i_t, a_t, d_t, R_t^e, R_t^b, R_t^w, m_t\}} q_t p_H R_t^e i_t$$

subject to the entrepreneur's and her banker's incentive constraints,

$$q_t p_H R_t^e i_t \geq q_t p_L R_t^e i_t + h(m_t) i_t, \quad (4a)$$

$$q_t p_H R_t^b i_t \geq q_t p_L R_t^b i_t + (1 + r_t^d) m_t i_t, \quad (4b)$$

the depositors' and banker's participation constraints,

$$q_t p_H R_t^w i_t \geq (1 + r_t^d) d_t, \quad (4c)$$

$$q_t p_H R_t^b i_t \geq (1 + r_t^a) a_t, \quad (4d)$$

and two resource constraints on investment inputs and outputs,

$$a_t + d_t - m_t i_t \geq i_t - n_t, \quad (4e)$$

$$R \geq R_t^e + R_t^b + R_t^w. \quad (4f)$$

According to Equations (4e) and (4f), the aggregate supply of investment funds must satisfy their aggregate demand equation and the total returns must be enough to cover the total payments. Variable  $r_t^a$  in the banker's participation constraint (4d) denotes the rate of return on bank capital in period  $t$  and, similarly, variable  $r_t^d$  in the

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<sup>9</sup>Alternatively, we could assume that a banker maximizes his own expected profits, with the banker's participation constraint (4d) being replaced by the entrepreneur's participation constraint  $q_t p_H R_t^e i_t \geq (1 + r_t^n) n_t$ , where  $r_t^n$  is the market rate of return to entrepreneurial capital. This alternative way of setting up and solving the contracting problem leads to exactly the same equilibrium relationships as the approach taken in the paper.

banker's incentive constraint (4b) and in the depositors' participation constraint (4c) is the rate of return on deposits during the capital good production stage of period  $t$ , i.e., Stage 2 in Table 1. Since deposits are intraperiod, we follow Carlstrom and Fuerst (1997) and set  $r_t^d = 0$ , so that the gross rate of return earned by households—or workers—in the capital good production stage is  $1 + r_t^d = 1$ . One may think that the alternative available for the households is to store the representative consumption good during Stage 2 of the period, to be consumed at the end of Stage 2; the rate of return to storage is 1. This assumption is also in line with simple RBC and growth models, where the representative consumption good is transformed one-to-one into capital goods, and the gross rate of return in this capital good production stage is 1.

Each entrepreneur wants to invest as much as possible without breaking the depositors' and the banker's participation and incentive constraints. Hence, all constraints bind in equilibrium. Using this equilibrium property, we solve the entrepreneur's program in two steps. First, we take the intensity of monitoring  $m_t$  and, by implication, the level of private revenues  $h(m_t)$  as given and solve for the maximum size of the investment project  $i_t$  for a given level of entrepreneurial wealth  $n_t$ . Second, we solve for the equilibrium level of monitoring  $m_t$ .

### 2.2.2 *Investment, Leverage, and Monitoring at the Project Level*

In the Holmström and Tirole (1997) framework, the maximum investment size depends on the amount of funds that can be raised from the outside, which in turn depends on the amount of the project returns that can credibly be pledged to depositors. In Appendix A.2 we show that maximum investment size is

$$i_t = \frac{n_t}{g(r_t^a, q_t, m_t)}, \quad (5a)$$

in which

$$g(r_t^a, q_t, m_t) \equiv \frac{p_H}{\Delta p} h(m_t) + \left[ 1 + \frac{p_H}{\Delta p} \left( 1 - \frac{1}{1 + r_t^a} \right) \right] m_t - \rho_t \quad (5b)$$

is the inverse degree of leverage, i.e., the smaller the value of  $g(\cdot)$ , the larger the size of the investment project  $i_t$  for a given level of

entrepreneurial wealth  $n_t$ . The first term on the right-hand side of Equation (5b) shows how agency problems in the nonfinancial firm reduce leverage by discouraging participation by outside investors. These agency problems can be mitigated through increased monitoring. However, the second term reveals that intense monitoring has two negative effects on leverage: it consumes resources that could otherwise have been invested in the project and makes it harder to satisfy the banker's incentive constraint. These two effects are captured by the first and second terms in square brackets, respectively.<sup>10</sup> In other words, more extensive monitoring activity worsens the agency problem between a bank and a depositor. To overcome this moral hazard and attract more deposits, a larger share of the investment project must be financed by bank capital. Finally, the term  $\rho_t \equiv q_t - 1 > 0$  denotes the net rate of return on the good investment project; the larger the rate of return, the easier it is to attract outside funding.<sup>11</sup>

Given the competitively behaving banking sector, the optimal choice of  $m_t$  maximizes the entrepreneur's expected profits  $p_H q_t R_t^e i_t$ , which may be rewritten, by using Equations (4a) and (5a), as  $(p_H / \Delta p) h(m_t) n_t / g(r_t^a, q_t, m_t)$ . Therefore, the optimal level of monitoring solves the problem

$$\max_{m_t \geq 0} \frac{h(m_t)}{g(r_t^a, q_t, m_t)}. \quad (6)$$

As can be seen from Equations (5b) and (6), the effects of monitoring on the entrepreneur's expected payoff are complex. The numerator in problem (6) shows how a larger scope of extracting private revenues implies a larger equilibrium share of the project returns for the entrepreneur, which dilutes the monitoring incentives. Monitoring incentives are also adversely affected by the negative effects of monitoring costs on leverage (second term in  $g(\cdot)$  in Equation (5b)). However, smaller agency problems enable larger leverage (first term in  $g(\cdot)$  in Equation (5b)). This provides an incentive for monitoring.

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<sup>10</sup>Note that in equilibrium we must have  $r_t^a \geq 0$ .

<sup>11</sup>See Lian and Ma (2021) for evidence on related cashflow-based financial constraints.

To derive a tractable analytic solution to problem (6), we specify the following functional form for  $h(m_t)$ :

$$h(m_t) = \begin{cases} \Gamma m_t^{-\frac{\gamma}{1-\gamma}} & \text{if } m_t > \underline{m} \\ \bar{h} & \text{if } m_t \leq \underline{m}, \end{cases} \quad (7)$$

where  $\Gamma > 0$ ,  $\bar{h} > 0$ ,  $\gamma \in (0, 1)$ , and  $\underline{m} \geq 0$ . The first row of Equation (7) shows how  $h(m_t)$  is differentiable and strictly convex for  $m_t > \underline{m}$  and that the monitoring technology is more efficient, the larger the value of  $\gamma$  or the smaller the  $\Gamma$ . The second row implies that there is a minimum efficient scale for monitoring investments or an upper bound for private revenues. This upper bound ensures that a bad project has a lower rate of return than a good project, even for low levels of  $m_t$ .<sup>12</sup>

Under the minimum scale requirement, the entrepreneur may choose a corner solution with no monitoring  $m_t = 0$ ,  $h(m_t) = \bar{h}$ , or a unique interior solution with  $m_t > \underline{m}$ . In Appendix D.3 we determine the conditions under which we can rule out the corner solution. These conditions are met around the steady state, on which we focus in this paper. After substitution of Equations (5b) and (7), we can write the unique interior solution to the entrepreneur's problem (6) as

$$m_t = \frac{\gamma \rho_t}{1 + \frac{p_H}{\Delta p} \left(1 - \frac{1}{1+r_t^a}\right)}. \quad (8)$$

The optimal level of monitoring intensity characterized by Equation (8) has intuitive properties. It increases with the elasticity of monitoring technology (directly related to  $\gamma$ ) and the rate of return on a good project ( $\rho_t$ ). Moreover, the larger the negative effects of monitoring on leverage (which are in the denominator), the lower the optimal level of monitoring.

### 2.2.3 Aggregate Investment, Bank Capital, and Firm Capital

We proceed under the assumption that all projects will be monitored with the intensity given by Equation (8) and, as a result, all

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<sup>12</sup>We experimented with many other functional forms besides specification (7), without gaining additional insights or simpler expressions.

entrepreneurial firms have the same capital structure. That is, for all projects, the ratios  $a_t/i_t$ ,  $d_t/i_t$ , and  $n_t/i_t$  are the same.<sup>13</sup> Given this symmetry, moving from project level to economy-wide level in terms of capital structures is simple. Clearly,

$$\frac{a_t}{i_t} = \frac{A_t}{I_t}, \quad \frac{d_t}{i_t} = \frac{D_t}{I_t}, \quad \text{and} \quad \frac{n_t}{i_t} = \frac{N_t}{I_t}, \quad (9)$$

where capital letters stand for aggregate-level variables.

Combining (9) with the banker's incentive and participation constraints (4b) and (4d) links the equilibrium monitoring intensity  $m_t$  to the ratio  $A_t/I_t$  and to the rate of return to bank capital:  $m_t = (\Delta p/p_H)(A_t/I_t)(1+r_t^a)$ . Since in equilibrium this must be the same as the monitoring intensity chosen at the project level, Equation (8), we get

$$1+r_t^a = \left(1 + \frac{\Delta p}{p_H}\right)^{-1} \left(1 + \gamma \rho_t \frac{I_t}{A_t}\right). \quad (10)$$

For Equation (10) to characterize the equilibrium rate of return on bank capital,  $1+r_t^a$  has to be greater than 1, the rate of return available for households from deposits, or the storage technology. Near the steady state, the inequality  $1+r_t^a > 1$  holds if  $\lambda^b < \beta$  (see Appendix D.2); this is the case with our baseline calibration (see Section 5).

Next, plugging (10) into (8) allows us to write

$$m_t = \left(1 + \frac{p_H}{\Delta p}\right)^{-1} \left(\frac{A_t}{I_t} + \gamma \rho_t\right). \quad (11)$$

The larger (relative) stakes the bankers have in the projects (high  $A_t/I_t$ ), the greater their incentives to monitor intensively.

But by (5a) and (9), inverse firm leverage satisfies the equation  $N_t/I_t = g(\cdot)$ , where  $g(\cdot)$  is given by (5b). Then applying Equations (10) and (11) allows us to express the entrepreneurs' maximum

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<sup>13</sup>But project sizes differ: the larger the entrepreneur's wealth  $n_t$ , the larger her investment  $i_t$ .

incentive-compatible nonverifiable revenue from a “bad” project in terms of aggregate variables,

$$h_t = \frac{\Delta p}{p_H} \left( \frac{N_t}{I_t} + (1 - \gamma) \rho_t \right). \quad (12)$$

In other words, if the nonverifiable revenue is at or below the threshold value given by Equation (12), the entrepreneurs choose the “good” project rather than the “bad” project. The larger the entrepreneurs’ (relative) stakes in the projects (high  $N_t/I_t$ ), the greater their incentives to choose the “good” project even when they are not subject to intense monitoring by bankers (i.e., when  $h_t$  is high). In equilibrium both bankers and entrepreneurs must face proper incentives.

Using (11) and (12), and noting that by (7) there is a trade-off between moral hazard in banks and firms, yields

$$\left( \frac{A_t}{I_t} + \gamma \rho_t \right)^\gamma \left( \frac{N_t}{I_t} + (1 - \gamma) \rho_t \right)^{1-\gamma} = \left( \Gamma \frac{p_H}{\Delta p} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right)^\gamma. \quad (13)$$

Equation (13) says that in equilibrium the aggregate investment level  $I_t$  in the economy depends on both aggregate bank capital  $A_t$  and aggregate entrepreneurial capital  $N_t$ .

The remaining period  $t$  equilibrium conditions are simple. Equations (4e) and (9) imply that aggregate deposits in the banking system are given by  $D_t = (1 + m_t) I_t - (A_t + N_t)$ . The aggregate investment level is part of a simple aggregate resource constraint  $Y_t = C_t + I_t$ . While monitoring involves real costs for banks, it consumes no aggregate resources. As explained at the beginning of Section 2.2, monitoring involves a transfer of final goods from banks to workers, and is hence included in the lump-sum transfers  $T_t$  in the household’s budget constraint (1). For more discussion, see also footnote 7.

Finally, we need to determine the evolution of aggregate bank and entrepreneurial capital. At the beginning of the next period  $t + 1$ , the shares  $1 - \lambda^e$  and  $1 - \lambda^b$  of entrepreneurs and bankers, respectively, exit their professions and surrender their wealth to the household. More concretely, one may think that in each period the banks and firms pay a constant share of their (gross) revenue as

dividends to the households who own them.<sup>14</sup> The surviving entrepreneurs and bankers then have aggregate wealth  $\lambda^e q_t p_H R_t^e I_t$  and  $\lambda^b q_t p_H R_t^b I_t$ , respectively. In Stage 1 of period  $t + 1$  they place their funds in the production of the final good, earning the same rate of return as the households. As a result, the aggregate amount of capital held by bankers at the beginning of (the investment) Stage 2 of period  $t + 1$  is given by  $A_{t+1} = \lambda^b q_t p_H R_t^b I_t (1 + r_{t+1})$ , which can be combined with conditions (4d) and (9) to obtain the following law of motion for the aggregate bank capital:

$$A_{t+1} = A_t (1 + r_t^a) \lambda^b (1 + r_{t+1}), \quad (14)$$

where  $(1 + r_t^a)$  is given by (10). The law of motion of aggregate entrepreneurial capital is  $N_{t+1} = \lambda^e q_t p_H R_t^e I_t (1 + r_{t+1})$ , which we can rewrite as

$$N_{t+1} = N_t (1 + r_t^n) \lambda^e (1 + r_{t+1}), \quad (15a)$$

where

$$1 + r_t^n \equiv q_t p_H R_t^e \left( \frac{I_t}{N_t} \right) = 1 + (1 - \gamma) \rho_t \left( \frac{I_t}{N_t} \right) \quad (15b)$$

denotes the rate of return on entrepreneurial capital during Stage 2 of period  $t$ . The latter form of (15b) follows from (4a), (9), and (12).

### 2.3 Equilibrium

The equilibrium of the model is a sequence

$$\left\{ K_{t+1}, L_t, Y_t, r_{t+1}, W_t, r_t^K, C_t, I_t, q_t, \rho_t, r_t^a, r_t^n, m_t, h_t, A_{t+1}, N_{t+1}, D_t \right\}_{t=0}^{\infty}$$

that satisfies Equations (2)–(3), (10)–(15a,b), and the following unnumbered equations presented in Sections 2.1 and 2.2:  $1 + r_{t+1} = [r_{t+1}^K + q_{t+1}(1 - \delta)]/q_t$ ,  $\xi L_t^\phi C_t^\sigma = W_t$ ,  $Y_t = K_t^\alpha L_t^{1-\alpha}$ ,  $W_t = (1 - \alpha)Y_t/L_t$ ,  $r_t^K = \alpha Y_t/K_t$ ,  $Y_t = C_t + I_t$ ,  $D_t = (1 + m_t) I_t - (A_t + N_t)$ , and  $\rho_t = q_t - 1$ .

<sup>14</sup>This assumption is standard in much of the macrofinance literature. There is also empirical evidence backing the view that especially banks strive to keep their dividend stream rather stable. One reason may be that dividend payments signal economic strength. See e.g., Floyd, Li, and Skinner (2015).

### 3. Relative Scarcity of Bank Capital

We provide an analytical solution of the steady state in Appendix D.2. If  $\max\{\lambda^e, \lambda^b\} < \beta$  financial constraints bind in (and near) the steady state, essentially bank capital and entrepreneurial capital are scarce.<sup>15</sup> As explained in Section 2.2, the production of capital goods is constrained by the availability of  $A_t$  and  $N_t$  (see Equation (13)). The level of investments is suboptimally low in the following sense. Consider a small perturbation where, starting from the steady state, investments rise by a small amount  $dI$  in the current period, and the proceeds are consumed in the next period. In the current period, there is less consumption, which implies a decrease in current-period utility equal to  $-U_C dI$  (where  $U_C$  is marginal utility of consumption in steady state). In the next period, (discounted) utility rises by  $\beta U_C (r^K + 1 - \delta) dI$ , where  $r^K + 1 - \delta$  is the (social) rate of return to investment (in steady state). Hence, the overall change in utility is  $\Delta U = [\beta (r^K + 1 - \delta) - 1] U_C dI$ . The household's Euler equation (3), however, implies that in steady state  $\beta (r^K/q + 1 - \delta) - 1 = 0$ , where the steady-state price of capital  $q > 1$ , due to financial frictions in capital good production. Then  $\Delta U = \rho [1 - \beta (1 - \delta)] U_C dI > 0$ , where  $\rho = q - 1 > 0$  is the steady-state net return on the investment project. Hence, an increase in the level of investments raises welfare, and likewise a decrease of investments from the steady-state level lowers welfare.

While both bank capital and firm capital are scarce, also the composition of informed capital—the relative scarcity of  $A_t$  and  $N_t$ —affects investments in an important way. Let  $\nu_t \equiv A_t/N_t$  denote the ratio of bank capital to entrepreneurial capital, and call it the ratio of informed capital. We show in Appendix A.3 that if  $\max\{\lambda^e, \lambda^b\} < \beta$ , there exists a steady state where the ratio of informed capital ( $\nu$ ) is given by

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<sup>15</sup>A similar condition arises in many models with macrofinancial linkages. Examples include models applying the Bernanke, Gertler, and Gilchrist (1999) financial accelerator (e.g., Hirakata, Sudo, and Ueda 2013, 2017; Christiano, Motto, and Rostagno 2014), the model of financial intermediation developed by Gertler and Karadi (2011, 2013) and recently extended by Sims and Wu (2020, 2021), and macrofinance models using the Holmström and Tirole (1997) approach, cited in the Introduction. Intuitively, the exit rate of entrepreneurs and bankers has to be high enough so that the economy does not outgrow financial constraints.

$$\nu = \frac{\gamma}{1 - \gamma} \left( \frac{\frac{\beta}{\lambda^e} - 1}{\frac{\beta}{\lambda^b} \left( 1 + \frac{\Delta p}{p_H} \right) - 1} \right). \tag{16}$$

Next, we determine the value of  $\nu_t$  (denoted by  $\nu^{**}$ ) that would maximize leverage and investments in the economy and, by implication, the economy’s output. We show in Appendix A.4 that

$$\nu^{**} = \frac{\gamma}{1 - \gamma}. \tag{17}$$

Hence, the investment-maximizing ratio of informed capital is equal to the elasticity of monitoring technology. To interpret this result, first recall that in equilibrium both bankers and entrepreneurs channel all their wealth into the investment projects, and the ratio  $\nu = A/N$  reflects their relative stakes. Now, suppose that banks have access to an efficient monitoring technology (the elasticity  $\gamma/(1 - \gamma)$  is large). In such case, an arrangement that maximizes aggregate investments involves intense monitoring. As the entrepreneurs’ moral hazard problems are effectively alleviated, more funds for entrepreneurs’ investments can be raised from depositors. Ensuring that bankers have incentives to monitor intensively, however, requires sufficiently large banker stakes (i.e., a high ratio  $\nu^{**} = A/N$ ).

In contrast, if the monitoring technology is not efficient (the elasticity  $\gamma/(1 - \gamma)$  is small), intensive monitoring is less useful. Then, in order to attract funding from depositors, it is better that entrepreneurs, rather than bankers, have large stakes and strong incentives to see that the projects succeed. Hence a low ratio  $\nu^{**} = A/N$  maximizes investment scale.

Comparison of Equations (16) and (17) yields the following result:

**PROPOSITION 1.**  $\nu \leq \nu^{**}$  if  $\frac{\lambda^b}{\lambda^e} \leq 1 + \frac{\Delta p}{p_H}$ , i.e., bank capital is scarcer than firm capital if  $\frac{\lambda^b}{\lambda^e} < 1 + \frac{\Delta p}{p_H}$ , while firm capital is scarcer than bank capital if  $\frac{\lambda^b}{\lambda^e} > 1 + \frac{\Delta p}{p_H}$ .

Holmström and Tirole (1997, Section IV.4) conjecture that bank capital is likely to be scarcer than firm capital. Proposition 1 suggests that this conjecture is likely to be true when the dual moral

hazard model, with endogenous monitoring intensity, is embedded into a dynamic macro framework. The scarcity of bank capital prevails in a steady state for a larger range of parameter values than the scarcity of entrepreneurial capital: only if the bankers' survival probability is higher than the entrepreneurs' survival probability by a factor strictly larger than 1 can the bankers accumulate more capital than that needed to maximize investments and output in the economy. In Section 5, we further argue that the relative scarcity of bank capital is the empirically relevant case.

Differentiating Equation (13) around the steady state yields (see Appendix A.5)

$$\left. \frac{dN}{dA} \right|_I = - \frac{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}}{\left(1 + \frac{\Delta p}{p_H}\right) \left(1 - \frac{\lambda^e}{\beta}\right)}. \quad (18)$$

We view  $I_t(A_t, N_t)$  as given by Equation (13) as the economy's production technology. Then, we may define  $|dN/dA|_I \equiv MRTS$  as the absolute value of the steady-state marginal rate of technical substitution of bank and entrepreneurial capital. We state the following result:

**COROLLARY 1.**  *$MRTS \gtrless 1$  if  $\frac{\lambda^b}{\lambda^e} \gtrless 1 + \frac{\Delta p}{p_H}$ , i.e., if bank capital is scarcer than firm capital,  $MRTS > 1$ , while if firm capital is scarcer than bank capital,  $MRTS < 1$ .*

Corollary 1 has the following interpretation: if bank capital is scarcer than firm capital, increasing bank capital boosts aggregate investment more than increasing firm capital by an equal amount (and vice versa if firm capital is scarce). Corollary 1 will play a key role in our analysis of (Pareto) optimal public funding policies, in Section 6.

To better understand the mechanism that leads to the (relative) underprovision of bank capital, we consider the case where  $\lambda^e = \lambda^b$ . Then, Proposition 1 unambiguously implies that in a steady state bank capital is scarce relative to firm capital.

Dividing the law of motion of  $A_{t+1}$  by that of  $N_{t+1}$  (see the derivation of Equations (14) and (15a,b)) shows that in a steady state we have

$$\nu = \frac{R^b}{R^e}.$$

That is, because it is optimal for the household to let its entrepreneurs and bankers retain and reinvest all their earnings, bankers and entrepreneurs accumulate capital in relation to their conditional project returns in a steady state. Next note that maximizing leverage is practically equivalent to maximizing the (expected) pledgeable income,  $p_H q_t (R - R_t^b - R_t^e)$  (i.e., the highest revenue share that can be pledged to depositors without jeopardizing entrepreneurs' and bankers' incentives), minus the cost of monitoring,  $m_t$ . But there is a trade-off: an increase in the bank monitoring will increase the entrepreneur's pledgeable income but reduce the banker's pledgeable income and consume funds that could otherwise have been loaned to entrepreneurs. Therefore the investment-maximizing amount of bank involvement solves the following program:  $\max_{m_t \geq 0} p_H q_t (R - R_t^b - R_t^e) - m_t$  subject to Equations (4a), (4b), (7), and  $r_t^d = 0$ . The first-order condition for this problem may be written as  $(R_t^b + m_t / (p_H q_t)) / R_t^e = \gamma / (1 - \gamma)$ . Using  $\nu^{**} \equiv \gamma / (1 - \gamma)$ , a steady-state version of this condition can be written as

$$\nu^{**} = \frac{R^b + \frac{m}{p_H q}}{R^e}.$$

This suggests how the aggregate leverage is maximized when bankers' accumulation of capital also takes into account the real costs of monitoring in addition to their revenue share. In a steady state, however, the bankers' capital accumulation only reflects their revenue share. Therefore, in a steady state bank capital is scarce.

#### 4. Aggregate Uncertainty and Sensitivity of Bank Capital

Until now we have assumed that investment projects only involve idiosyncratic uncertainty. In this section, we introduce an aggregate shock by assuming that in some period  $t$  project success probabilities are given by  $\tilde{p}_{\tau t} \equiv p_{\tau}(1 + \varepsilon_t)$ ,  $\tau \in \{H, L\}$ , in which  $\varepsilon_t \in [\underline{\varepsilon}, 1/p_H - 1)$ , with  $\underline{\varepsilon} > -1$ , is an unanticipated change in the success probabilities of all projects. Such an investment shock may be due, e.g., to a disruptive technology or to a correction to initial

market misperceptions. The shock is realized after financing contracts have been signed, monitoring and project choices have been made, and the price of capital goods has been determined.

Neither the pricing of capital goods nor financial contracts can be made contingent on realization of the unanticipated shock. While in theory it could be possible to contract on the aggregate level of capital goods produced, in practice such contracts are rare. For example, Allen and Gale (1997) argue that financial crises are rare and thus have minor implications on contracts; in our case the shock capturing a crisis event is unexpected and hence noncontractible. In essence, capital goods are sold via forward contracts where the price of capital goods is agreed upon simultaneously with the (other) terms of the financing contract, before the delivery of capital goods occurs (see Appendix A.1 for a detailed timing of events). Thus, the price of capital goods in period  $t$ ,  $q_t$ , is unaffected by the shock in period  $t$ .

To model the effects of an aggregate shock, we make the distinction between *bankers* and *banks* explicit. In our model, each bank employs a large number of bankers. Funds from the depositors are collected at the bank level and are allocated to individual bankers in such a way that the constraints of the financial contract (Equations (4)) are satisfied.<sup>16</sup> Each banker monitors a single investment project. If the project succeeds, the entrepreneur retains her share of the project returns ( $R_t^e$ ). The rest of the returns ( $R - R_t^e$ ) are credited to the common account of the bank. If the project fails, neither the entrepreneur nor the bank gets anything. After the returns from all successful projects of the bank are collected, the bank compensates its bankers and refunds depositors according to the financing contract. A banker is paid only if the project that he monitored was successful. In other words, we assume that depositors' claims are senior within a bank; depositors are first paid from the bank's common funds, after which the successful bankers share the remainder.

For brevity, we assume the success probability of the good project is large enough so that a bank never defaults on deposit contracts on the equilibrium path and, hence, in equilibrium deposits are always redeemed at par and the bank's sequential service constraint never binds. As a result, entrepreneurs and depositors always receive their

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<sup>16</sup>This is in the interest of the bank. If an individual banker does not monitor, the remaining bankers within the bank suffer expected losses.

promised share of project returns, whereas bankers may get less (in the case of a negative shock) or more (in the case of a positive shock) than stipulated by the initial financing contract.

Following an investment shock in period  $t$ , the aggregate entrepreneurial capital at the end of period  $t$  is given by  $\tilde{N}_t(\varepsilon_t) = I_t p_H q_t R_t^e (1 + \varepsilon_t)$ . Even though each successful entrepreneur gets her share  $R_t^e$  according to the financing contract, the aggregate entrepreneurial capital is reduced (increased) in the aftermath of a negative (positive) investment shock because a smaller (larger) fraction of the entrepreneurs are successful. The evolution of aggregate entrepreneurial capital can be rewritten as

$$\tilde{N}_t(\varepsilon_t) = N_t (1 + r_t^n) (1 + \varepsilon_t), \quad (19)$$

where  $N_t$  is (period  $t$ ) entrepreneurial capital before the investment stage (Stage 2 in Table 1) and  $(1 + r_t^n)$  is the expected rate of return to entrepreneurial capital in the investment stage, in the absence of an aggregate investment shock, given by (15b).

In contrast, following an investment shock in period  $t$ , the aggregate bank capital at the end of period  $t$  is given by  $\tilde{A}_t(\varepsilon_t) = I_t p_H q_t [R_t^b + (R - R_t^e) \varepsilon_t]$ . Using conditions (4b), (4c) (recalling that  $r_t^d = 0$ ), (4d), (4f), and (9), the evolution of aggregate bank capital can be rewritten as

$$\tilde{A}_t(\varepsilon_t) = A_t (1 + r_t^a) (1 + BL_t \varepsilon_t), \quad (20a)$$

where  $A_t$  is (period  $t$ ) bank capital before the investment stage and  $(1 + r_t^a)$  is the rate of return to bank capital in the investment stage, in the absence of an aggregate investment shock, given by (10), while

$$BL_t = 1 + \frac{D_t}{(1 + r_t^a) A_t} \quad (20b)$$

is the *bank leverage accelerator of shocks*. Equation (20b) shows how, compared with the effect of the shock on aggregate entrepreneurial capital, its effect on aggregate bank capital is amplified by the term  $D_t / ((1 + r_t^a) A_t)$ . In the aftermath of a negative shock, not only do fewer bankers see their projects succeed, but each successful banker gets a smaller share of the revenues because of the seniority of depositors' claims. As a result, the higher the bank leverage (the

debt-to-equity ratio  $D_t/((1 + r_t^a)A_t)$ , the higher the multiplier of the shock.

The dynamics of entrepreneurial and bank capitals differ after an aggregate shock because banks are larger and more diversified than firms: each bank intermediates funding to many firms. The small size of an individual firm protects entrepreneurs as a group against levered impacts of adverse shocks: if an investment project fails, the firm goes bankrupt and the entrepreneur loses her equity, but other entrepreneurs cannot be held accountable for these losses. In contrast, even when a (larger-than-expected) number of investment projects in a bank's portfolio fail, the bank pays its creditors in full and the adverse shocks are absorbed by bankers' equity.

The period  $t + 1$  values of entrepreneurial capital and bank capital, before the period  $t + 1$  capital good production stage (i.e., after Stage 1, but before Stage 2 of period  $t + 1$ ), are linked to the end-of-period  $t$  values by the equations

$$N_{t+1}(\varepsilon_t) = \lambda^e(1 + r_{t+1})\tilde{N}_t(\varepsilon_t) \quad (21)$$

and

$$A_{t+1}(\varepsilon_t) = \lambda^b(1 + r_{t+1})\tilde{A}_t(\varepsilon_t). \quad (22)$$

Here, the only difference in the dynamics of entrepreneurial capital and bank capital derives from the different exit rates of entrepreneurs and bankers ( $\lambda^e$  and  $\lambda^b$ ). Although a shock has an asymmetric effect on the sharing of project revenues, it does not affect the conditional project returns. Therefore, the effect of the shock on the accumulation of physical capital is again directly related to its effect on project success probability. The aggregate physical capital in period  $t + 1$ , following an investment shock in period  $t$ , is given by  $K_{t+1}(\varepsilon_t) = (1 - \delta)K_t + I_t(1 + \varepsilon_t)$ .

## 5. Calibration

We follow the RBC literature in calibrating the parameters of the real block (see Appendix C.1). The upper panel of Table 2 shows the resulting parameters (the period is one year and the parameter values are adjusted accordingly). Calibration of the parameters of the financial block involves matching the steady-state

**Table 2. Calibrated Parameter Values**

Parameter	Value	Note
<i>Parameters of the Macro Block</i>		
$\beta$	0.98	Discount Factor
$\alpha$	0.33	Capital Share
$\delta$	0.10	Rate of Decay of Capital
$\xi$	2	Parameter of the Disutility of Labor
$\phi$	0.5	$1/\phi$ Frisch Elasticity of Labor Supply
$\sigma$	2	$1/\sigma$ Elasticity of Intertemporal Substitution
<i>Parameters of the Financial Block</i>		
$\lambda^e$	0.9382	Survival Rate of Entrepreneurs
$\lambda^b$	0.8754	Survival Rate of Bankers
$p_H$	0.95	Success Probability of a Good Project
$\frac{\Delta p}{p_H}$	0.1674	$\Delta p \equiv p_H - p_L = 0.159$
$\gamma$	0.4005	$\frac{\gamma}{1-\gamma}$ Elasticity of Monitoring Function
$\Gamma$	0.0032	Parameter of Monitoring Function

values of the financial variables to empirical moments. Based on the findings in the empirical literature (see Appendix C.1), we set the excess return on entrepreneurial capital ( $r^n$ ) to 4.5 percent nonfinancial firms' capital-asset ratio ( $CRF$ ) to 45 percent, the excess returns on bank capital ( $r^a$ ) to 12 percent, banks' capital-asset ratio ( $CRB$ ) to 8 percent, and their monitoring-cost-asset ratio ( $MRB$ ) to 1.5 percent. In Appendix C.2, we show that the parameters of the financial block can be expressed in terms of the matched data moments as follows:  $\lambda^e = \frac{\beta}{1+r^n}$ ,  $\lambda^b = \frac{\beta}{1+r^a}$ ,  $\frac{\Delta p}{p_H} = \frac{MRB}{CRB(1+r^a)}$ ,  $\frac{\gamma}{1-\gamma} = \left(\frac{r^a CRB + MRB}{r^n CRF}\right)(1 - CRF)$ , and  $\Gamma = \left(\frac{1+r^n}{1+r^a}\right) \left(\frac{CRF}{CRB}\right) (1 - CRF)^{\frac{\gamma}{1-\gamma}} MRB^{\frac{1}{1-\gamma}}$ .

With the calibration based on observed data moments, we can have a new look at the relative scarcity and sensitivity of bank capital. Proposition 1 implies that bank capital is scarce if  $\lambda^b/\lambda^e < 1 + \Delta p/p_H$ . Our calibration suggests that  $\lambda^b/\lambda^e = 0.93$ , whereas  $1 + \Delta p/p_H = 1.17$ . More precisely, Equations (C.5) and (C.6) in Appendix C.2 imply that  $\lambda^b/\lambda^e = (1 + r^n)/(1 + r^a)$ . Hence, the relative excess returns reflect relative scarcity. Next, using the banker's incentive constraint (4b) and participation constraint (4d), together with the aggregation equation (9), all evaluated at the steady state,

yields  $\Delta p/p_H = mI/((1+r^a)A)$ . This expression has a natural interpretation. Monitoring costs  $mI$  constitute a part of the cost of financial intermediation and, unlike the return to bank capital  $(1+r^a)A$ , this part of the cost of intermediation does not translate into new banker-owned capital. As argued in Section 3, this is one reason why bank capital is scarce in equilibrium. While these observations are useful for interpreting Proposition 1, Equation (C.7) in Appendix C.2 (re)expresses  $\Delta p/p_H$  in terms of the data moments we match:  $\Delta p/p_H = MRB/((1+r^a)CRB)$ . In sum, the relative scarcity of bank capital prevails if

$$r^n < r^a + \frac{MRB}{CRB}.$$

This condition is likely to hold: e.g., Hirtle and Stiroh (2007) and Albertazzi and Gambacorta (2009) estimate the return on bank equity ( $r^a$ ) to be 12–14 percent in the U.S., whereas the average return on firm capital ( $r^n$ ) is often estimated to be much lower (see, e.g., Fama and French 2002).

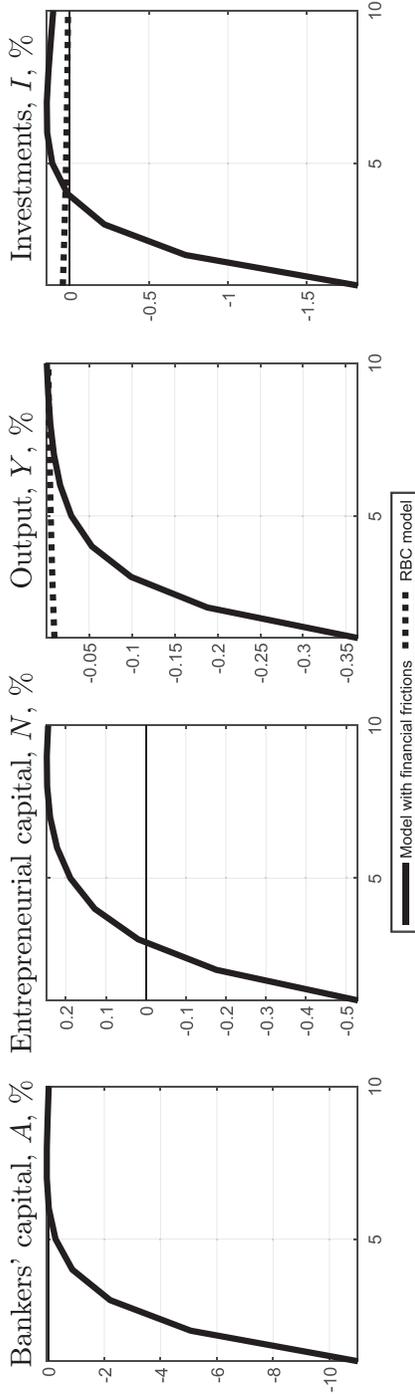
Figure 1 shows the impulse responses of some key real- and financial-sector variables to a negative investment shock. (The impulse responses of the whole set of variables to an investment shock are given in Appendix C.3.) As a (first-best) benchmark, we show the impulse responses of the macrovariables for the standard RBC model.<sup>17</sup> In the RBC model, the shock has small effects. There is a little less physical capital after a negative investment shock, and this slightly lowers the production capacity and output of the economy. Investments increase a little to restore the lower-than-anticipated capital stock.

In our model with banks, investment falls and financial intermediation greatly amplifies the impact of the investment shock on aggregate investment and output. The reason is threefold. First, as shown in Section 2.2, aggregate investment scale depends on bank capital and firm capital. Second, as discussed in Section 3, as well as in the present section, bank capital is scarce relative to entrepreneurial wealth: a change in bank capital has a larger effect on aggregate investment than an equal change in entrepreneurial wealth. Third,

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<sup>17</sup>Equations in Section 2.1, together with  $q_t = 1 \forall t$  and  $Y_t = C_t + I_t$ , characterize the textbook RBC model.

**Figure 1. Impulse Responses to a Negative Investment Shock  
(1 percentage point decrease in success probabilities)**



**Note:** The shock has zero persistence. Horizontal scale refers to years.

as explained in Section 4, an investment shock has a strong effect on bank capital. Also output (the production of the representative good) drops significantly. This is because the capital-good-producing entrepreneurial firms demand less of the representative good, which they use as an input. Due to lower demand, output declines in equilibrium. Financial frictions amplify the effect of the shock on other macrovariables as well (Figure C.1 in Appendix C.3).

## 6. Public Funding of Banks and Firms

We characterize the optimal allocation of the public support between banks and nonfinancial firms at an early stage of a crisis. For example, public funding policies and credit guarantees designed in the early stages of the Global Financial Crisis and the COVID-19 crisis broadly targeted banks and firms rather than just troubled ones, strengthening their balance sheets and shifting aggregate risk to the public sector.<sup>18</sup> In our model, debt and equity are distinct components of banks' capital structure, and we model government support of banks to take place in terms of equity injections. In the case of nonfinancial firms, debt and (outside) equity are indistinguishable,

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<sup>18</sup>For example, TARP was introduced in October 2008 to make the financial system more crisis resilient, and it primarily targeted healthy institutions, often against their own wishes (see, e.g., Veronesi and Zingales 2010; Bernanke 2015; Bernanke, Geithner, and Paulson Jr. 2019; Berger and Roman 2020). As Bernanke, Geithner, and Paulson Jr. (2019, pp. 90–91) write:

We needed to launch the program quickly . . . so on Columbus Day, Hank summoned the CEOs of nine of the most important financial firms to the Treasury. The three of us . . . explained that we expected all nine of them to accept Treasury capital up to equivalent of 3 percent of their risk-weighted assets, a total of \$125 billion in TARP investments, along with FDIC guarantees of any new debt they issued through June 2009 . . . all of the banks were reluctant to take the government as an investor. But we reminded them that none of them should be confident they had enough capital to survive the severe recession that lay ahead, much less the runs that would accompany a meltdown of the system . . . In the ensuing months, we would move quickly to inject capital into nearly 700 smaller banks, a critically important step toward stabilizing and recapitalizing the entire banking system.

In the COVID-19 crisis, many public funding programs were already introduced in March 2020—see, e.g., <https://www.ft.com/content/26af5520-6793-11ea-800d-da70cff6e4d3>, accessed January 12, 2024.

as in Holmström and Tirole (1997), making both debt and equity interpretations of public funding to nonfinancial firms possible.<sup>19</sup>

The government demands for its investments an expected rate of return of  $1 + r_t^g$ , which includes a penalty relative to the market rate,  $r_t^g > 0$ . Otherwise, banks and firms would want to be funded by the government. Also, the need of politicians to signal their toughness to voters may motivate such a penalty rate in practice. Public funding is provided for a single period and injected before the financial contracts are signed. Participation in the government funding program is mandatory for all banks and firms. Although the mandatory participation here is a simplifying assumption, it also mitigates potential problems arising from the stigma associated with the use of government funds with a penalty rate.<sup>20</sup> Finally, while the government provides funding, it does not participate in running or monitoring the investment projects.

We summarize the main insights from the analysis of optimal policies in three remarks and one proposition. Remark 1 characterizes the (relative) incentive distortions and welfare losses caused by public bank and firm funding. Remark 2 establishes that welfare benefits from a more resilient financial system are proportional to the size of the funding program and (ex post) to the size of the shock, but do not depend on its structure. Remark 3 tells how a program of a given size can be constructed with different combinations of public bank and firm funding. These remarks lead to the main result of the paper, Proposition 2, which shows how the optimal structure of a funding program depends on its size.

### 6.1 *Social Costs of Public Funding: Distorted Incentives*

We show in Appendix B.1 that the public funding of banks and non-financial firms results in an aggregate investment level ( $I_t^*$ ) that is implicitly given by the equation

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<sup>19</sup>If the investment project succeeds, the firm can pay both creditors and equity holders. If the project fails, the firm can pay neither.

<sup>20</sup>The penalty rate is in line with Bagehot's dictum. As explained by Bernanke (2015, p. 148): "The penalty rate encourages banks to look first to private markets for funding, rather than relying on the Fed. But a side effect of this arrangement was that banks feared they would look weak if it became known that they had borrowed from the Fed—and that would make it even harder from them to attract private funding."

$$\begin{aligned} & \left( \frac{A_t - r_t^g A_t^g}{I_t^*} + \gamma \rho_t \right)^\gamma \left( \frac{N_t - r_t^g N_t^g}{I_t^*} + (1 - \gamma) \rho_t \right)^{1-\gamma} \\ & = \left( \Gamma \frac{p_H}{\Delta p} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right)^\gamma, \end{aligned} \quad (23)$$

in which  $A_t^g \geq 0$  and  $N_t^g \geq 0$  denote the aggregate amounts of government funds injected into banks and entrepreneurial firms, respectively.

Equation (23) is identical to Equation (13) except for the negative terms  $-r_t^g A_t^g$  and  $-r_t^g N_t^g$  in the numerators of the left-hand side. Thus, public funding of banks and nonfinancial firms *lowers* the aggregate investment level. Since  $r_t^g > 0$ , government-owned capital dilutes bankers' and entrepreneurs' stakes in the projects and, consequently, their incentives to monitor and invest. Bankers' weaker monitoring incentives make bank participation costlier for entrepreneurs, further reducing their investment incentive.

Since lower investments imply lower welfare (see Section 3), the government keeps the premium on its funding small to minimize these adverse welfare effects of public funding. Assuming that  $r_t^g = dr^g$  is small, and totally differentiating (23) at the steady state, yields

$$\left| \frac{N^g}{A^g} \right|_I = \frac{-\frac{dI}{dA} dr^g}{-\frac{dI}{dN} dr^g} = \left| \frac{dN}{dA} \right|_I = MRTS = \frac{1 - \frac{\lambda^b}{\beta} + \frac{\Delta p}{p_H}}{\left( 1 + \frac{\Delta p}{p_H} \right) \left( 1 - \frac{\lambda^e}{\beta} \right)},$$

in which we use the definition  $MRTS$  familiar from Equation (18) and Corollary 1. Here  $MRTS$  tells how many units of public funds in nonfinancial firms correspond to a unit of public funds in banks in terms of welfare losses. Since  $MRTS > 1$  is likely to hold (see Sections 3 and 5), public funding invested in banks tends to be more distortionary than when invested in nonfinancial firms. This property reflects the scarcity of banker-owned capital near the steady state (Proposition 1, Corollary 1): capital injections into banks dilute bankers proportionally more than corresponding injections into firms dilute entrepreneurs. Our baseline calibration yields  $MRTS = 5.5$ .

Besides its distortionary effects in the current period, public funding, which commands a premium, is costly for bankers and

entrepreneurs in terms of lower revenues and wealth in the subsequent periods. We assume that the government grants the entrepreneurs and bankers a lump-sum refund from its premium revenues. Such a refund eliminates the harmful effects of lower insider wealth on future investments, while keeping public funding unattractive for individual entrepreneurs and bankers—see Appendix B.1.3.

Thanks to this elimination of harmful effects of public funding on the future periods, all welfare losses from public funding are transmitted through its distorting effects on current investments. We can then apply the result established in Equation (18) and Corollary 1 to analytically compare the funding of banks and firms in terms of welfare losses. We summarize the key finding of this subsection by the following remark:

REMARK 1. *Public stakes in banks and firms distort incentives, which lowers welfare. In terms of the welfare losses, each unit of public funds in banks equals MRTS units of public funds in firms where MRTS is likely to be larger than one.*

## 6.2 Social Benefits of Public Funding: Enhanced Resilience

Although public funding causes distortions, it also renders the financial system more resilient to negative aggregate shocks. In Appendix B.1.4, we show that when the government provides funding for banks ( $A_t^g$ ) and nonfinancial firms ( $N_t^g$ ), the dynamics of nongovernment-owned bank capital after an investment shock ( $\varepsilon_t$ ) is characterized by Equation (22) in which  $\tilde{A}_t(\varepsilon_t)$  and  $BL_t$  of Equations (20a) and (20b), respectively, are replaced by<sup>21</sup>

$$\tilde{A}_t^*(\varepsilon_t) = A_t(1 + r_t^a)(1 + BL_t^*\varepsilon_t) \quad (24a)$$

and

$$BL_t^* = 1 + \frac{D_t - A_t^g - N_t^g}{(1 + r_t^a)A_t + A_t^g}. \quad (24b)$$

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<sup>21</sup>The expression (24b) holds as an approximation in the sense that  $BL(A_t^g, N_t^g, dr_t^g)\varepsilon_t$  (the effect of the shock on banker-owned capital; see Equation (24a)) is equal to  $BL^*(A_t^g, N_t^g)\varepsilon_t$  plus additional terms which are proportional to the product  $dr_t^g \times \varepsilon_t$ . We assume that these additional terms are so small that they can be ignored (see Appendix B.1.4).

Comparison of Equations (20b) and (24b) suggests that government funding of banks lowers their leverage because the total bank equity is enhanced, thanks to equity  $A_t^g$  purchased by the government (see the denominator of the last term of Equation (24b)), and because government-owned capital  $A_t^g$  crowds out debt funding from households (the numerator of the last term of Equation (24b)): since banks need to pledge a part of their income to the government, less can be pledged to households. Public funding of nonfinancial firms  $N_t^g$  also lowers bank leverage: if the government funds nonfinancial firms, they borrow less from banks, which in turn borrow less from households. Crowding out happens since firms need to pledge a part of their revenues to the government, and as a result they can pledge less to banks, which can in turn pledge less to households. However, public funding of nonfinancial firms does not strengthen the equity buffer of the banking system.

Equations (24a) and (24b) show how public funding changes the structure of bank balance sheets, making the banking sector more resilient to negative aggregate shocks. Since banks are large and diversified, aggregate shocks have a levered impact on their equity (see Section 4). Public funding lowers the shock accelerator on the bank side. However, public funding has no impact on the vulnerability of the entrepreneurial sector as a whole to the aggregate shock. Entrepreneurial firms are small and nondiversified, and limited liability protects entrepreneurs as a group against negative spillovers. While a negative aggregate investment shock increases entrepreneurial failures, there is no shock accelerator. The loss of aggregate entrepreneurial wealth is proportional to the number of failing projects, and hence to the size of the negative aggregate shock, irrespective of whether the entrepreneurs are funded by banks or by the government. Similarly, public funding leaves the dynamics of capital stock intact, since the accumulation of new capital also depends on the share of failing projects, and is therefore directly related to the size of the investment shock.

Since public funding only affects the resilience of banks, the welfare benefits of public funding focus on the banking sector. We show in Appendix B.2 that the welfare benefits of public funding, in the face of a negative macro shock  $\varepsilon_t < 0$ , are given by the measure

$$\Delta \tilde{V} = -\tilde{V}_{\tilde{\lambda}} BRE_t S_t \varepsilon_t, \quad (25)$$

in which  $\tilde{V}_A > 0$  is the steady-state value of the derivative of the household's value function with respect to the bankers' end-of-period capital,  $BRE_t = (1 + r_t^a) BL_t A_t$  is the *banks' risk exposure* to a (negative) macro shock under laissez-faire, and

$$S_t = 1 - \frac{BL_t^*}{BL_t} \quad (26)$$

measures the share of the risk exposure shifted from banks to the government.

Equation (25) shows how public funding makes banks less vulnerable to a negative aggregate investment shock and therefore reduces the welfare losses due to the shock:  $\Delta \tilde{V} > 0$  if  $\varepsilon_t < 0$ . Government-owned capital absorbs part of the loan losses and, hence, mitigates the bankers' loan losses. After a negative shock hits, banks are better capitalized than they would be under laissez-faire and can lend more to nonfinancial firms which, as a result, can invest more than they could in a laissez-faire scenario. Since investments are suboptimally low (see Section 3), this improves welfare, compared with laissez-faire.

According to Equation (25) the social benefits of the program are proportional to the measure  $S_t$ , which can take values between 0 and  $1 - 1/BL_t$  (where the maximum  $S_t$  corresponds to  $BL_t^* = 1$ ). We can also call  $S_t$  the *size* of the public funding program. A public funding program of, say, size  $S_t = 0.2$  means that the government takes over 20 percent of banks' total macro risk exposure—and the program reduces bankers' loan losses by 20 percent following a negative macro shock.

We show in Appendix B.3 that the fiscal costs of the funding program are given by  $FC_t = -BRE_t S_t \varepsilon_t$ , which measures the government's losses from a public funding program of size  $S_t$  if a negative shock  $\varepsilon_t < 0$  hits the economy. If the fiscal costs have to be covered by distortionary taxes, the resulting welfare losses from taxation depend on  $FC_t$ . Hence, although modeling distortionary taxes is beyond the scope of this paper, combining this observation with Equation (25) implies that the net welfare benefits of the program, net of possible losses from distortionary taxation, depend on the size of the program,  $S_t$ .

The following remark summarizes the main result of this subsection:

REMARK 2. *A public funding program makes the economy more resilient in the face of a negative macro shock. Welfare gains of the program are proportional to the size of the program and to the size of the realized macro shock.*

Equation (25) also implies that if there is a *positive* aggregate shock ( $\varepsilon_t > 0$ ), public funding *lowers* social welfare:  $\Delta \tilde{V} < 0$  if  $\varepsilon_t > 0$ . Since public funding distorts incentives irrespective of the sign of  $\varepsilon_t$  (see Section 6.1), the government should consider financial support of banks and firms only in times of economic hardship.

### 6.3 The Policy Frontier

To relate the size of the program  $S_t$  to the public funding of banks and firms, we show in Appendix B.3 that

$$BRE_t S_t = BL_t^* A_t^g + N_t^g. \quad (27)$$

Hence, a program of size  $S_t$  can be implemented with any combination of  $A_t^g$  and  $N_t^g$  satisfying Equation (27). We call the different combinations of  $A_t^g$  and  $N_t^g$  satisfying Equation (27) the *policy frontier*. A particular combination of  $A_t^g$  and  $N_t^g$  from the policy frontier defines the *structure* of the program.

In Equation (27),  $BL_t^*$  is (the absolute value of) the slope of the policy frontier: in terms of resilience, each unit of  $A_t^g$  corresponds to  $BL_t^* \geq 1$  units of  $N_t^g$ . The relative efficiency of bank capitalization in stabilization reflects the effects captured by Equation (24b). Bank capitalization ( $A_t^g$ ) makes the banks less vulnerable to a negative aggregate shock both by strengthening their equity cushion and by reducing the amount of outside debt on the liability side of their balance sheets. If the government funds firms, they borrow less from banks, which in turn borrow less from households. Hence public funding of firms also makes banks less vulnerable to aggregate shocks by reducing the asset side of their balance sheets, i.e., the banks' firm loan portfolios. Here  $BL_t^*$  is not only the slope of the policy frontier but also a measure of bank leverage when public policy is in place. A policy that essentially works through the asset side of bank balance sheets (firm funding) requires  $BL_t^*$  times larger public stakes than a policy which boosts bank equity (bank capitalization). The slope of the policy frontier depends on the size of the

program: we can rewrite Equation (26) as  $BL_t^* = BL_t(1 - S_t)$ . To summarize, we have the following remark:

REMARK 3. *In terms of the resilience of the economy, each unit of public funding in banks equals  $BL_t^* = BL_t(1 - S_t)$  units of public funding in nonfinancial firms.*

#### 6.4 *Optimal Structure of Public Funding: Targeting Banks or Firms?*

We take the size of a public funding program ( $S_t$ ) as predetermined, e.g., by a political process, and characterize an optimal structure of the program: how should the public funds be allocated between banks and nonfinancial firms? Our choice to focus on the optimal structure with a given size is motivated by uncertainty faced by the government in a time of crisis. Genuine uncertainty might even prevent the government from assigning a distribution to a negative macro shock, which would make the determination of an optimal  $S_t$  impossible. If we assume away genuine uncertainty, finding the optimal level of  $S_t$  would imply balancing the welfare gains from stabilization against the welfare losses from distorted incentives and from distortionary taxes (which we do not model). Alternatively, since the welfare benefits of stabilization and the possible welfare losses due to distortionary taxes are both proportional to the program size (Remark 2) and independent of its structure, we may regard  $S_t$  as being fixed at a desired level and seek an optimal structure of the funding program that minimizes its incentive distortions.<sup>22</sup> In Section 6.5 we discuss how the optimal structure of the public funding program relates to the notion of dominated and undominated policies.

Considering an economy near the steady state and taking  $S$  as given, we maximize welfare with respect to the structure of the public funding program. Our main result, which holds even if the

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<sup>22</sup>One may think, e.g., that the government knows the tax system in place and can assess its distortionary impact. In the absence of genuine uncertainty, the government may find the optimal trade-off between (expected) welfare gains from resilience and (expected) welfare losses from distorted incentives and distortionary taxes. A more explicit treatment of distortionary taxes, along the lines of Holmström and Tirole (2013), is a topic for future research.

program is implemented under genuine uncertainty and financed by distorting taxes, follows:

**PROPOSITION 2.** *Assume that  $1 < MRTS < BL$ . There exists a threshold value  $S^* = 1 - MRTS/BL$  such that  $0 < S^* < 1 - 1/BL$ . (a) If  $S < S^*$ , it is optimal to capitalize banks,  $A^g = S \times BRE / [(1 - S)BL]$  and  $N^g = 0$ . (b) If  $S > S^*$ , it is optimal to fund nonfinancial firms,  $A^g = 0$  and  $N^g = S \times BRE$ .*

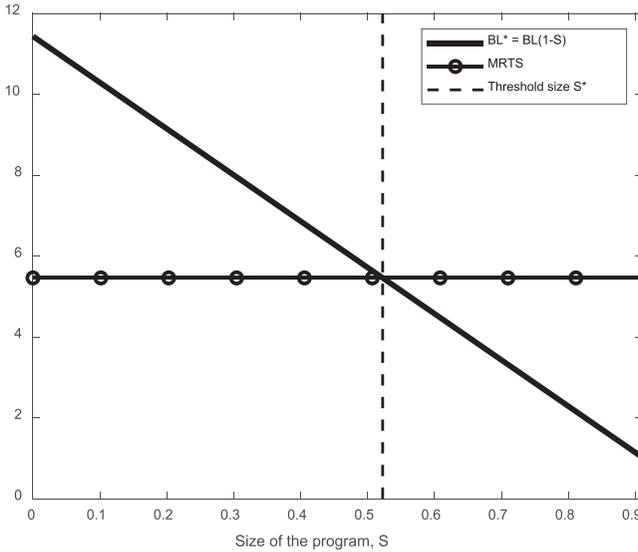
*Proof.* See Appendix B.4.

If the size of the funding program is below the threshold  $S^*$ , the government should target banks, while if the program size is above  $S^*$ , the government should target nonfinancial firms. The threshold  $S^*$  is increasing in the *sensitivity* of bank capital to macro shocks under *laissez-faire* (captured by  $BL$ ) and decreasing in the relative *scarcity* of bank capital (captured by  $MRTS$ ). We show in Appendix B.5 that in any equilibrium (or model calibration) with a meaningful role for financial intermediation,  $MRTS/BL < 1$ . Intuitively, the opposite case  $MRTS/BL > 1$ , characterized by scarce bank capital and a banking system struggling to raise outside funding, would correspond to a situation (or model calibration) where financial intermediation is so ineffective and costly that the entrepreneurial firms choose to bypass the banking system and raise funding directly from households.<sup>23</sup> Thus, if the condition in Proposition 1 holds and  $MRTS > 1$ , the optimal policy consists of two regimes, with a threshold value  $S^* \in (0, 1 - 1/BL)$ . Our baseline calibration with  $MRTS = 5.5$  and  $BL = 11.4$  yields  $S^* = 0.52$ . Hence, the threshold  $S^*$  corresponds to the government taking over roughly half of the banks' macro risk exposure. In Appendix B.5, we present equations linking  $MRTS$ ,  $BL$ , and  $S^*$  to the data moments used in the calibration of the model, and conduct robustness analysis with respect to the calibration.

Using Equation (26), we may rewrite the condition  $S \stackrel{\leq}{\geq} S^*$  as  $MRTS \stackrel{\leq}{\geq} BL^*$ . To interpret this condition, think of implementing a program of size  $S$  by funding either banks or firms. Given Remark 3,  $BL^*$  times smaller public ownership stakes are needed if

<sup>23</sup>This is the corner solution with  $m_t = 0$  and  $h_t = \bar{h}$ .

**Figure 2. The Optimal Structure of a Program Depends on Its Size**



**Note:** If  $BL^*$  is larger (smaller) than  $MRTS$ , it is optimal to fund banks (firms).

the government targets banks rather than nonfinancial firms. However, since each unit of public funds creates  $MRTS$  times larger distortions in banks (Remark 1), the relative welfare losses from distortions are given by  $\widehat{WLD} = WLD^{A^g} / WLD^{N^g} = MRTS / BL^*$ , where  $WLD^{A^g}$  and  $WLD^{N^g}$  denote welfare losses when the government targets banks and firms, respectively. Evidently, the program should target banks if  $\widehat{WLD} < 1$ , and firms if  $\widehat{WLD} > 1$ . Hence, the choice boils down to comparing  $MRTS$  and  $BL^*$ . See Figure 2.

The size of the program matters for the optimal structure because (the absolute value of) the slope of the policy frontier equals the target level of the bank leverage accelerator, which in turn decreases with the size of the program  $BL^* = BL(1 - S)$ —see Remark 3 and Figure 2. Recall that the government can lower the bank leverage accelerator to the target level  $BL^*$  either by (i) strengthening the banks’ balance sheets through public bank capitalization or (ii) reducing the size of banks’ balance sheets, and the

exposure of banks to nonfinancial firms, by providing public funding directly to nonfinancial firms. Alternative (ii), which essentially works through the asset side of bank balance sheets, requires  $BL^*$  times larger public (ownership) stakes than alternative (i), which works through the equity buffer. This is intuitive, as  $BL^*$  also measures the assets-to-equity ratio of banks when policy (ii) is in place. The more (fewer) assets there are compared with equity, the more (less) effective, in relative terms, the policy that strengthens equity. The banks' assets-to-equity ratio, however, decreases with the size of the program.

### 6.5 *Dominated and Undominated Policies*

Proposition 2 may also be interpreted as characterizing the sets of *dominated* and *undominated*, or *Pareto-optimal*, policies (for a formal proof, see Appendix B.4). A policy  $(A^g, N^g, S)$  dominates an alternative policy  $(A^{g'}, N^{g'}, S')$  if  $(A^g, N^g, S)$  generates as high social welfare as  $(A^{g'}, N^{g'}, S')$  for all shock realizations  $\varepsilon_t < 0$ , and strictly higher welfare for some shock realizations. A policy  $(A^g, N^g, S)$  is undominated if and only if there is no alternative that dominates it.

The sets of dominated and undominated policies are characterized by the mapping from the size of a program to its appropriate structure given in Proposition 2. Since the distortions and the welfare losses caused by a public funding program depend on its structure while the welfare benefits of the program depend on its size and (ex post) on the shock realization (the larger the program and the larger the negative shock realization, the larger the benefits), but are independent of the structure, the program can belong to the set of undominated policies if and only if its structure minimizes the welfare losses from distortions, given its size. If not, welfare (after any shock realization) could be raised by keeping the size of the program fixed but reoptimizing its structure—meaning that the policy is dominated.

Proposition 2 implies that small funding programs ( $S < S^*$ ) targeting banks and large programs ( $S > S^*$ ) targeting firms are undominated. If the government implements one of these programs, there exists no alternative program that would generate as high welfare after all (negative) shock realizations. By contrast, any small

public funding program ( $S < S^*$ ) targeting firms is dominated by a program of the same size but targeting banks, while any large program ( $S > S^*$ ) funding banks is dominated by a program of the same size but directed at firms. Similarly, all mixed programs, simultaneously funding both banks and firms, are dominated by pure programs with the structure described in Proposition 2.

These results are useful for decision-making under genuine uncertainty, as they indicate funding policies to be considered and policies to be avoided. A benevolent, welfare-maximizing government should choose a policy that belongs to the undominated set. It should implement no dominated policy, irrespective of its beliefs about the probability and severity of the crisis. See Appendix B.6 for a numerical example.

### *6.6 Welfare Losses from Non-optimal Structure of Public Funding*

Assume that the government fails to follow the prescriptions of Proposition 2 and implements a relatively small funding program ( $S < S^*$ ) for nonfinancial firms or a relatively large program ( $S > S^*$ ) for banks, or, alternatively, finances both banks and firms simultaneously. How significant are the welfare losses resulting from such non-optimal structures?

We examine this question in Appendix B.7. We find that if the program size  $S$  is around the threshold  $S^*$ , it does not matter much whether the government allocates funds to banks, firms, or both. However, the larger the gap between  $S^*$  and  $S$ , the larger the excess welfare losses from a non-optimal structure (see Figures B.1 and B.2 in Appendix B.7). From a policy perspective, the result is reassuring: the larger the welfare losses from a suboptimal structure, the easier it is to follow the prescriptions of Proposition 2 even if the threshold  $S^*$  is not known exactly.

We also show in Appendix B.7 that funding simultaneously both banks and firms creates a smaller excess welfare loss than funding exclusively either banks or firms with a wrong amount. Thus, if the government is uncertain about the desired size of the program, choosing a mixed program may be a robustly optimal strategy. (Robust optimization here means minimizing the maximum excess welfare loss due to a suboptimal structure.) In Appendix B.8, we

study the implementation of such a robust optimal mixed program under two scenarios: (i) The government does not know  $S^*$  for sure. (ii) The government implements a staggered program which can initially be smaller than  $S^*$ , but has an option to expand the program so that eventually  $S > S^*$ . We show that in a robust optimal mixed program the share of funds allocated to nonfinancial firms relative to banks should be increasing in  $S$ , a finding that echoes the results of Proposition 2.

## 7. Conclusions

In this paper we develop a macrofinance model in which both banks' and firms' balance sheets matter. We show that, in equilibrium, bank capital tends to be scarce compared with firm capital. Then, a given change in bank capital has a larger impact on aggregate investment than a corresponding change in firm capital. We also show that bank capital is more sensitive to aggregate shocks than firm capital.

Public funding affects the incentives and the balance sheet structures of banks and firms. Our main result links the socially optimal composition of a crisis funding program to its size. Small programs should target banks, while large programs should be directed at nonfinancial firms. Our baseline calibrations suggest that programs in which the government takes over more (less) than 50 percent of the macro risk from the private sector should be implemented through firm (bank) funding.

The result reflects the relative scarcity and sensitivity of bank capital. Due to its scarcity, public funding distorts incentives more when placed in banks rather than in nonfinancial firms. Given the sensitivity of bank capital, however, smaller public stakes are needed in banks than in firms to stabilize the economy. The relative effectiveness of bank capitalization in stabilizing the economy depends on the size of the program. Initially, capital injections to banks have a large proportional effect on the resilience of the financial system, but this effect diminishes if the government takes over a larger share of the macro risk.

In terms of policy design under genuine uncertainty, a contribution of this paper is to characterize the menu of crisis funding programs from which the government should choose: which policies

to consider and which to exclude. Our results imply that small funding programs targeting banks and large programs targeting firms are on the table since they belong to the set of undominated policies. The government should pick its policy from this set. Conversely, small funding programs targeting firms and large funding programs targeting banks are off the table, since they are dominated.

## **Appendix A. Model**

### *A.1 Timing of Events*

Within each period  $t$  there are two main stages. At the beginning of Stage 1, the survival probabilities of bankers and entrepreneurs are realized and exiting bankers and entrepreneurs give their accumulated assets to households. Household members then separate into their occupations, the heads of households make their consumption-savings decisions, and final goods are produced using capital and labor.

The production of capital goods takes place in Stage 2, which is divided into five substages: First, financing contracts among entrepreneurs, bankers, and depositors (workers) are signed. These contracts determine whether and how the project is financed, its size, and how eventual revenues are divided. Depositors place their funds in banks, which extend funding to entrepreneurs according to the financing contract. Second, bankers choose their intensity of monitoring. Third, entrepreneurs choose their projects. Fourth, successful projects yield new units of capital goods that are sold. Finally, the proceeds are divided among depositors, bankers, and entrepreneurs according to the terms of the financial contract.

While entrepreneurs are assumed to sell the capital goods that they produce, note that our equations in Section 2.1 show that final good firms rent (rather than own) the capital stock that they need in production. This is consistent with the existence of perfectly competitive capital rental firms, fully owned by households. These capital rental firms purchase capital goods from successful entrepreneurs, rent capital services to final goods firms, and refund the rental income to their owners. Note also that, as in Holmström and Tirole (1997), bankers can commit to monitoring before

entrepreneurs make their project choice. This sequential timing rules out mixed strategy equilibria.

### A.2 Investment Size at Project Level

In this appendix section, we derive Equations (5a) and (5b). From the entrepreneur's and banker's incentive constraints, (4a) and (4b), we see that the entrepreneur and the banker must get no less than  $R_t^e = \frac{h(m_t)}{q_t \Delta p}$  and  $R_t^b = \frac{m_t}{q_t \Delta p}$ , respectively, in case of success, as otherwise they will misbehave. Then the return-sharing constraint (4f) shows that depositors can be promised at most

$$R_t^w = R - \frac{m_t + h(m_t)}{q_t \Delta p}. \quad (\text{A.1})$$

Substituting Equation (A.1) for the depositor's participation constraint (4c) yields

$$p_H \left\{ q_t R - \frac{m_t + h(m_t)}{\Delta p} \right\} = \frac{d_t}{i_t}. \quad (\text{A.2})$$

Next, we combine the banker's incentive constraint (4b) with his participation constraint (4d) and the input resource constraint (4e) to obtain

$$\frac{d_t}{i_t} = 1 + m_t - \frac{p_H}{\Delta p} \left( \frac{1}{1 + r_t^a} \right) m_t - \frac{n_t}{i_t},$$

which can be then substituted for Equation (A.2). Solving the resulting equation for  $i_t$  gives Equation (5a) and expression (5b).

### A.3 Steady-State Structure of Informed Capital

In this section, we derive Equation (16). Substitution of the incentive constraints (4a) and (4b), together with Equation (7) and  $r^d = 0$  for law of motion of  $A_{t+1}$  and that of  $N_{t+1}$  (see the derivation of Equations (14) and (15a)) gives

$$A_{t+1} = (1 + r_{t+1}) \frac{p_H}{\Delta p} \lambda^b m_t I_t$$

and

$$N_{t+1} = (1 + r_{t+1}) \frac{p_H}{\Delta p} \lambda^e \Gamma m_t^{-\frac{\gamma}{1-\gamma}} I_t.$$

Thus, in a steady state we must have

$$A = (1 + r) \frac{p_H}{\Delta p} \lambda^b m I \quad (\text{A.3})$$

and

$$N = (1 + r) \frac{p_H}{\Delta p} \lambda^e \Gamma m^{-\frac{\gamma}{1-\gamma}} I. \quad (\text{A.4})$$

Here and in what follows we denote a steady state of some time-dependent variable  $X_t$  by  $X$ , i.e.,  $\lim_{t \rightarrow \infty} X_t = X$ . Dividing Equation (A.3) by Equation (A.4) implies that

$$\nu \equiv \frac{A}{N} = \frac{\lambda^b m^{\frac{1}{1-\gamma}}}{\lambda^e \Gamma}. \quad (\text{A.5})$$

Next, substitution of Equation (10) for Equation (8) yields, after some algebra, the steady-state value of  $m$  as

$$m = \frac{\gamma \rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}}. \quad (\text{A.6})$$

Equation (13) can be rewritten at a steady state as

$$\frac{\gamma \rho + \frac{A}{I}}{1 + \frac{p_H}{\Delta p}} = \left[ \frac{\frac{p_H}{\Delta p} \Gamma}{(1 - \gamma) \rho + \frac{N}{I}} \right]^{\frac{1-\gamma}{\gamma}}. \quad (\text{A.7})$$

Combining Equations (A.6) and (A.7) and solving for  $\rho$  yields

$$\rho = \frac{1}{1 - \gamma} \left( \frac{p_H}{\Delta p} \Gamma m^{-\frac{\gamma}{1-\gamma}} - \frac{N}{I} \right). \quad (\text{A.8})$$

Inserting Equation (A.8) into (A.6) gives

$$m \left( 1 + \frac{p_H}{\Delta p} \right) = \frac{\gamma p_H \Gamma}{(1 - \gamma) \Delta p} m^{-\frac{\gamma}{1-\gamma}} + \frac{A}{I} - \frac{\gamma N}{(1 - \gamma) I}.$$

After substituting Equations (A.3) and (A.4) for the above formula, we obtain

$$1 + \frac{\Delta p}{p_H} = \Gamma m^{-\frac{1}{1-\gamma}} \left[ \frac{\gamma}{1 - \gamma} + \lambda^e (1 + r) \left( \frac{\lambda^b m^{1+\frac{\gamma}{1-\gamma}}}{\lambda^e \Gamma} - \frac{\gamma}{1 - \gamma} \right) \right].$$

By using the definition of  $\nu$  from Equation (A.5), this can be rewritten as

$$\nu \frac{\lambda^e}{\lambda^b} \left( 1 + \frac{\Delta p}{p_H} \right) = \frac{\gamma}{1-\gamma} + \lambda^e (1+r) \left( \nu - \frac{\gamma}{1-\gamma} \right).$$

Solving for  $\nu$  from the above equation gives

$$\nu = \left( \frac{\gamma}{1-\gamma} \right) \left[ \frac{\frac{1}{\lambda^e} - 1 - r}{\frac{1}{\lambda^b} \left( 1 + \frac{\Delta p}{p_H} \right) - 1 - r} \right]. \quad (\text{A.9})$$

Finally, from the household's Euler equation (3), we see that in steady state we must have

$$1 + r = \frac{1}{\beta}. \quad (\text{A.10})$$

Using Equation (A.10), Equation (A.9) can be rewritten as

$$\nu = \left( \frac{\gamma}{1-\gamma} \right) \left[ \frac{\frac{\beta}{\lambda^e} - 1}{\frac{\beta}{\lambda^b} \left( 1 + \frac{\Delta p}{p_H} \right) - 1} \right]. \quad (\text{A.11})$$

It is evident that  $\nu > 0$  if the following condition holds:

$$\beta > \max \{ \lambda^e, \lambda^b \}. \quad (\text{A.12})$$

#### A.4 Investment-Maximizing Structure of Informed Capital

In this section, we derive Equation (17). Let  $G_t = (A_t + N_t)/I_t$ . We study the following (dual) problem. We take the level of aggregate investment  $I_t$  as given. We seek the value of  $\nu_t$  that maximizes the aggregate leverage  $1/G_t = I_t/(A_t + N_t)$  and, by implication, minimizes the aggregate amount of informed capital  $A_t + N_t$  needed for a given level of aggregate investment. Using  $A_t/I_t = \nu_t G_t/(1 + \nu_t)$  and  $N_t/I_t = G_t/(1 + \nu_t)$  (and recalling that  $r_t^d = 0$ ), we can rewrite Equation (13)—which determines the equilibrium aggregate investment level  $I_t$ —as

$$\left( \frac{\nu_t G_t}{1 + \nu_t} + \gamma \rho_t \right)^\gamma \left[ \frac{G_t}{1 + \nu_t} + (1 - \gamma) \rho_t \right]^{1-\gamma} = \left( \frac{\Gamma p_H}{\Delta p} \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right).$$

Differentiating this equation with respect to  $G_t$  and  $\nu_t$  gives

$$\frac{dG_t}{d\nu_t} \Big|_{I_t} = \frac{G_t \left\{ 1 - \gamma - \left( \frac{\nu_t G_t}{1 + \nu_t} + \gamma \rho_t \right)^{-1} \left[ \frac{G_t}{1 + \nu_t} + (1 - \gamma) \rho_t \right] \gamma \right\}}{(1 + \nu_t) \left\{ \left( \frac{\nu_t G_t}{1 + \nu_t} + \gamma \rho_t \right)^{-1} \left[ \frac{G_t}{1 + \nu_t} + (1 - \gamma) \rho_t \right] \gamma \nu_t + 1 - \gamma \right\}}. \tag{A.13}$$

The aggregate leverage is maximized when  $G_t$  is minimized. A potential minimum is obtained if the term in the curly brackets in the numerator on the right-hand side of Equation (A.13) is zero, i.e., if

$$\frac{\frac{\nu_t}{1 + \nu_t} G_t + \gamma \rho_t}{\frac{G_t}{1 + \nu_t} + (1 - \gamma) \rho_t} = \frac{\gamma}{1 - \gamma}.$$

This equation simplifies to

$$\nu_t = \frac{\gamma}{1 - \gamma} \equiv \nu^{**}.$$

From Equation (A.13), we then observe that  $dG_t/d\nu_t|_{I_t} < 0$  for  $\nu_t < \nu^{**}$  and  $dG_t/d\nu_t|_{I_t} > 0$  for  $\nu_t > \nu^{**}$ . Therefore,  $\nu^{**}$  characterizes the value of  $\nu_t$  that minimizes  $G_t$  and thereby maximizes the aggregate leverage and output.

### A.5 Calculation of Marginal Rate of Technical Substitution

Differentiating (13) with respect to  $A_t$  and  $N_t$  gives

$$\frac{dN_t}{dA_t} \Big|_I = - \left( \frac{\gamma}{1 - \gamma} \right) \left[ \frac{\frac{N_t}{I_t} + (1 - \gamma) \rho_t}{\frac{A_t}{I_t} + \gamma \rho_t} \right].$$

Evaluating this at a steady state and using Equations (A.8) and (A.6) in the numerator and the denominator of the term in the square brackets, respectively, yields, after some algebra,

$$\frac{dN}{dA} \Big|_I = - \left( \frac{\gamma}{1 - \gamma} \right) \left( \frac{\Gamma m^{-\frac{1}{1-\gamma}}}{1 + \frac{\Delta p}{\rho_H}} \right).$$

Using Equation (A.5) to substitute  $\lambda^b / (\lambda^e \nu)$  for  $\Gamma m^{-\frac{1}{1-\gamma}}$  and Equation (A.11) to eliminate  $\gamma / [(1-\gamma)\nu]$ , we get

$$\left. \frac{dN}{dA} \right|_I = - \frac{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}}{\left(1 + \frac{\Delta p}{p_H}\right) \left(1 - \frac{\lambda^e}{\beta}\right)}.$$

## Appendix B. Policy

### B.1 Public Funding

Assume that the government injects an aggregate amount  $A_t^g$  of capital into the banking system and an aggregate amount  $N_t^g$  of capital into nonfinancial corporations. The government demands the rate of return  $r_t^g > 0$  for its investments. One may think that the government buys bank equity at the (unit) price  $Q_t^b = (1 + r_t^{a*}) / (1 + r_t^g)$  and firm equity at the price  $Q_t^e = (1 + r_t^{n*}) / (1 + r_t^g)$ , where  $r_t^{a*}$  and  $r_t^{n*}$  denote the (expected) rate of return of bank capital and firm capital, respectively, when the public funding program is in place.

Let  $\omega_t^b \equiv R_t^g / A_t \geq 0$  and  $\omega_t^e \equiv N_t^g / N_t \geq 0$ . Then  $a_t^g = \omega_t^b a_t$  is the quantity of government-owned capital in an individual bank's balance sheet, and  $n_t^g = \omega_t^e n_t$  public funding allocated to nonfinancial firms. Also,  $R_t^{gb} = R_t^b \omega_t^b / Q_t^b$  and  $R_t^{ge} = R_t^e \omega_t^e / Q_t^e$  are the (expected) shares of the proceeds going to the government in the banking sector and in the nonfinancial corporate sector, respectively.

#### B.1.1 Implications for the Financing Contract

With government participation, the optimal financing contract solves the following program:

$$\max_{\{i_t, a_t, a_t^g, n_t^g, d_t, R_t^e, R_t^b, R_t^{gb}, R_t^{ge}, R_t^w, m_t\}} q_t p_H R_t^e i_t$$

subject to the entrepreneur's and her banker's incentive constraints (4a) and (4b), the depositors' and the banker's participation constraints (4c) and (4d), the resource constraints for investment inputs and outputs

$$a_t + a_t^g + d_t - m_t i_t \geq i_t - n_t - n_t^g, \tag{B.1}$$

$$R \geq R_t^e + R_t^b + R_t^{gb} + R_t^{ge} + R_t^w, \tag{B.2}$$

the sizes of government capital injections in banks and nonfinancial corporations

$$a_t^g = \omega_t^b a_t, \tag{B.3}$$

$$n_t^g = \omega_t^e n_t, \tag{B.4}$$

and the terms of those injections

$$R_t^{gb} = \frac{\omega_t^b}{Q_t^b} R_t^b \tag{B.5}$$

$$R_t^{ge} = \frac{\omega_t^e}{Q_t^e} R_t^e. \tag{B.6}$$

Substitution of  $R_t^b = m_t / (q_t \Delta p)$ ,  $R_t^e = h(m_t) / (q_t \Delta p)$ , and Equations (B.5) and (B.6) into the return-sharing constraint (B.2) shows that depositors can be promised at most

$$R_t^w = R - \frac{\left(1 + \frac{\omega_t^b}{Q_t^b}\right) m_t + \left(1 + \frac{\omega_t^e}{Q_t^e}\right) h(m_t)}{q_t \Delta p}. \tag{B.7}$$

Substituting Equation (B.7) for the depositor’s participation constraint (4c) yields

$$p_H \left\{ q_t R - \frac{\left[\left(1 + \frac{\omega_t^b}{Q_t^b}\right) m_t + \left(1 + \frac{\omega_t^e}{Q_t^e}\right) h(m_t)\right]}{\Delta p} \right\} = \frac{d_t}{i_t}. \tag{B.8}$$

Next, we combine the banker’s incentive constraint (4b) with his participation constraint (4d), the input resource constraint (4e), and the sizes of government capital injections (B.3) and (B.4) to obtain

$$\frac{d_t}{i_t} = 1 + m_t - (1 + \omega_t^b) \frac{p_H}{\Delta p} \left( \frac{1}{1 + r_t^a} \right) m_t - (1 + \omega_t^e) \frac{n_t}{i_t}. \tag{B.9}$$

Combining Equations (B.8) and (B.9), and noting that  $Q_t^b = (1 + r_t^a)/(1 + r_t^g)$  and  $Q_t^e = (1 + r_t^n)/(1 + r_t^g)$ , the program boils down to

$$\max_{m_t \geq 0} \frac{h(m_t)}{\widehat{g}(r_t^a, r_t^g, q_t, m_t)}, \quad (\text{B.10})$$

in which

$$\begin{aligned} \widehat{g}(r_t^a, r_t^g, q_t, m_t) &\equiv (1 + \omega_t^e (1 + r_t^g)) \frac{p_H}{\Delta p} h_t(m_t) \\ &+ \left[ 1 + \frac{p_H}{\Delta p} \left( 1 - \frac{1}{1 + r_t^a} \right) + \omega_t^b \frac{p_H}{\Delta p} \left( \frac{r_t^g}{1 + r_t^a} \right) \right] m_t - \rho_t \end{aligned}$$

is the inverse firm leverage. Given the monitoring technology (7), the unique interior solution to the problem (B.10) is

$$m_t^* = \frac{\gamma \rho_t}{1 + \frac{p_H}{\Delta p} \left( 1 - \frac{1}{1 + r_t^a} \right) + \omega_t^b \frac{p_H}{\Delta p} \left( \frac{r_t^g}{1 + r_t^a} \right)}. \quad (\text{B.11})$$

Comparing (B.11) with (8) indicates that public ownership in banks, which dilutes bankers' stakes, lowers monitoring intensity.

### B.1.2 Implications for Incentives and Investments

Equation (B.11) characterizes the equilibrium monitoring intensity with government participation. Note that the banker's incentive and participation constraints (4b) and (4d) (together with the aggregation condition (9)) imply that in equilibrium the bankers' monitoring intensity must also be characterized by  $m_t = (\Delta p/p_H) (A_t/I_t) (1 + r_t^{a*})$ . Combining these observations, we get the rate of return to banker-owned capital

$$1 + r_t^{a*} = \frac{1 + \gamma \rho_t \frac{I_t^*}{A_t} - \omega_t^b r_t^g}{1 + \frac{\Delta p}{p_H}} = \frac{1 + \gamma \rho_t \frac{I_t^*}{A_t} - r_t^g \frac{A_t^g}{A_t}}{1 + \frac{\Delta p}{p_H}}. \quad (\text{B.12})$$

Comparing (B.12) with (10) indicates that the return to banker-owned capital is lower when public policies are in place. Plugging Equation (B.12) into (B.11) then yields

$$\begin{aligned}
m_t^* &= \left(1 + \frac{p_H}{\Delta p}\right)^{-1} \left( (1 - \omega_t^b r_t^g) \frac{A_t}{I_t^*} + \gamma \rho_t \right) \\
&= \left(1 + \frac{p_H}{\Delta p}\right)^{-1} \left( \frac{A_t - r_t^g A_t^g}{I_t^*} + \gamma \rho_t \right). \tag{B.13}
\end{aligned}$$

Comparing Equations (B.13) and (11) reveals that public ownership in banks dilutes bankers' stakes. Hence, bankers have weaker incentives to monitor intensively. Next, Equations (B.1), (B.3), and (B.4) together with the aggregation Equation (9) imply that

$$\begin{aligned}
\frac{D_t^*}{I_t^*} &= 1 + m_t^* - \frac{(1 + \omega_t^b) A_t + (1 + \omega_t^e) N_t}{I_t^*} \\
&= 1 + m_t^* - \frac{A_t + A_t^g + N_t + N_t^g}{I_t^*}. \tag{B.14}
\end{aligned}$$

Then applying (9) to Equation (B.8), and plugging in expressions (B.12), (B.13), and (B.14), allows us to see how the entrepreneurs' maximum incentive-compatible nonverifiable revenue from a "bad" project depends on public policies and aggregate variables

$$h_t^* = \frac{\Delta p}{p_H} \left( \frac{N_t - r_t^g N_t^g}{I_t^*} + (1 - \gamma) \rho_t \right). \tag{B.15}$$

Comparing (12) and (B.15) reveals that public stakes in firms dilute the entrepreneurs' stakes. As a result the entrepreneurs have weaker incentives to choose the "good" project. Combining (B.15) with (4a) yields the expected rate of return to entrepreneurial capital

$$\begin{aligned}
1 + r_t^{n*} &= 1 + (1 - \gamma) \rho_t \left( \frac{I_t^*}{N_t} \right) - \omega_t^e r_t^g \\
&= 1 + (1 - \gamma) \rho_t \left( \frac{I_t^*}{N_t} \right) - r_t^g \left( \frac{N_t^g}{N_t} \right), \tag{B.16}
\end{aligned}$$

which is defined in the same way as in (15b). Comparing (B.16) with (15b) indicates that the return to entrepreneurial capital is lower when public policies are in place. But  $m^*$  given by (B.13) and  $h^*$

given by (B.15) are linked by the monitoring technology (7). Then, assuming that there is monitoring in equilibrium, we get

$$\begin{aligned} & \left( \frac{A_t - r_t^g A_t^g}{I_t^*} + \gamma \rho_t \right)^\gamma \left( \frac{N_t - r_t^g N_t^g}{I_t^*} + (1 - \gamma) \rho_t \right)^{1-\gamma} \\ &= \left( \frac{p_H}{\Delta p} \Gamma \right)^{1-\gamma} \left( 1 + \frac{p_H}{\Delta p} \right)^\gamma. \end{aligned} \quad (\text{B.17})$$

This is Equation (23) of the main text. This equation implicitly determines the aggregate investment level  $I_t^*$  in the economy when the government funds banks, nonfinancial firms, or both.

Taken together, Equations (B.12), (B.13), (B.15), (B.16), and (B.17) indicate that public funding dilutes the insiders' stakes in the investment projects, and as a result bankers find it more tempting not to monitor, while entrepreneurs face stronger incentives to choose a "bad" project with nonverifiable revenues. Since the severity of these moral hazard problems also increases with the scale of the investment projects, aggregate investments in equilibrium must be lower when the public funding program is in place.

When public policy is introduced, Stage 1 of period  $t$  is already behind. Hence,  $L_t$  and  $Y_t$  are given, and these variables are not affected by policy. Then period  $t$  consumption  $C_t^*$  is given by the aggregate resource constraint  $C_t^* = Y_t - I_t^*$ . Therefore, current investment,  $I_t^*$ , is a sufficient statistic when evaluating how the distortions from period  $t$  public policy affect the current period  $t$ .

### B.1.3 Public Funding: Dynamic Implications of Distortions

Given Equation (B.16), the end-of-period  $t$  entrepreneurial capital is given by

$$\tilde{N}_t^* = (1 + r_t^{n*}) N_t = N_t + (1 - \gamma) \rho_t I_t^* - r_t^g N_t^g. \quad (\text{B.18})$$

In particular, the last term  $-r_t^g N_t^g$  is the direct effect of public funding. Since government funding commands a premium  $r_t^g$ , it raises revenues equal to  $r_t^g N_t^g$ , and this in turn lowers the revenues accruing to the entrepreneurs.

Given Equation (B.12), the end-of-period  $t$  banker-owned capital is given by

$$\tilde{A}_t^* = (1 + r_t^{a*}) A_t = \frac{A_t + \gamma \rho_t I_t^*}{1 + \frac{\Delta p}{p_H}} - \frac{r_t^g A_t^g}{1 + \frac{\Delta p}{p_H}}. \quad (\text{B.19})$$

Once again, the last term in (B.19) is the direct effect of public funding. To understand why the direct effect is equal to  $-r_t^g A_t^g / (1 + \frac{\Delta p}{p_H})$ , rather than  $-r_t^g A_t^g$  (as it might seem intuitive), note that, given Equation (B.13), public funding lowers banks' monitoring intensity and monitoring costs:

$$m_t^* I_t^* = \frac{A_t + \gamma \rho_t I_t^*}{1 + \frac{p_H}{\Delta p}} - \frac{r_t^g A_t^g}{1 + \frac{p_H}{\Delta p}},$$

where  $-r_t^g A_t^g / (1 + \frac{p_H}{\Delta p}) = -\frac{\Delta p}{p_H} r_t^g A_t^g / (1 + \frac{\Delta p}{p_H})$  is the direct effect. Now, while the government earns the amount  $r_t^g A_t^g$ , only the share

$$r_t^g A_t^g - \left( \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \right) r_t^g A_t^g = \frac{r_t^g A_t^g}{1 + \frac{\Delta p}{p_H}}$$

is paid by the bankers, while the remaining share  $\frac{\Delta p}{p_H} r_t^g A_t^g / (1 + \frac{\Delta p}{p_H})$  is paid by the workers—or households. (Remember that we assume that the banks pay the monitoring costs to the workers.)

To eliminate the harmful direct effects on future bank and firm capital, we assume that the government rebates the revenues from the premium back to the entrepreneurs, bankers, and workers in a lump-sum manner. This minimizes welfare losses while still keeping public funding unattractive for individual entrepreneurs and bankers, and hence avoiding intertemporal moral hazard. Since entrepreneurs receive a lump-sum rebate  $r_t^g N_t^g$  and bankers receive a lump-sum rebate  $r_t^g A_t^g / (1 + \frac{\Delta p}{p_H})$ , Equations (B.18) and (B.19) yield

$$\tilde{N}_t^* = N_t + (1 - \gamma) \rho_t I_t^* = (1 + r_t^n) N_t \quad (\text{B.20})$$

and

$$\tilde{A}_t^* = \frac{A_t + \gamma \rho_t I_t^*}{1 + \frac{\Delta p}{p_H}} = (1 + r_t^a) A_t, \quad (\text{B.21})$$

where  $(1 + r_t^n)$  and  $(1 + r_t^a)$  are given by Equations (15b) and (10), respectively, (with  $I_t$  replaced by  $I_t^*$  in these equations) while the (middle-of) period  $t + 1$  values are given by

$$N_{t+1}^* = \lambda^e \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) \tilde{N}_t^* \quad (\text{B.22})$$

and

$$A_{t+1}^* = \lambda^b \left( \frac{r_{t+1}^K + (1 - \delta) q_{t+1}}{q_t} \right) \tilde{A}_t^*. \quad (\text{B.23})$$

Hence, since the lump-sum rebates eliminate the direct effects, all the distorting effects of period  $t$  public funding to future insider wealth run through period  $t$  investments  $I_t^*$ .

Note that the distorting effects of the program affect also physical capital  $K_{t+1}^*$ , the third period  $t + 1$  state variable, through period  $t$  investments  $I_t^*$ . Hence,  $I_t^*$  is a sufficient statistic when evaluating how the distortions from period  $t$  public policy affect future periods. Finally, since  $I_t^*$  is a sufficient statistic for both period  $t$  (see Section B.1.2 of this appendix) and for future periods,  $I_t^*$  is also a sufficient statistic for the (current and future) price of capital,  $q_t$ .

#### B.1.4 Implications for Effects of an Investment Shock

In the aftermath of an investment shock, the project success probabilities are given by  $\tilde{p}_{\tau t} \equiv p_{\tau}(1 + \varepsilon_t)$ ,  $\tau \in \{H, L\}$ . Then, in equilibrium, the aggregate revenue from the projects is  $\tilde{p}_{Ht} q_t R I_t^*$ . From that revenue, entrepreneurs and the government (which has invested in nonfinancial firms) are paid  $\tilde{p}_{Ht} q_t R_t^e I_t^*$  and  $\tilde{p}_{Ht} q_t R_t^{ge} I_t$ , respectively. The remaining, stochastic, revenue is left to banks, which have to pay the fixed sum  $D_t^*$  to depositors, or outside debt holders. What is left is divided between bankers ( $\tilde{p}_{Ht} q_t \tilde{R}_t^b I_t$ ) and the government ( $\tilde{p}_{Ht} q_t \tilde{R}_t^{gb} I_t$ ), where the ex post shares  $\tilde{R}_t^b$  and  $\tilde{R}_t^{gb}$  depend on the shock realization  $\varepsilon_t$ . Since the bankers' and the government's revenues are proportional to their respective ownership shares, the ratio  $\tilde{R}_t^{gb} / \tilde{R}_t^b$  must be the same as the ratio  $R_t^{gb} / R_t^b$ , given by Equation (B.5). Evidently, bankers and the government absorb the losses due to the aggregate investment shock in proportion to their revenue/ownership shares, implying that the share of losses absorbed by bankers is  $R_t^b / (R_t^b + R_t^{gb}) = \left(1 + \frac{\omega_t^b}{Q_t^b}\right)^{-1}$ .

Then, following an investment shock in period  $t$ , the aggregate bank capital at the end of period  $t$  is given by

$$\begin{aligned} \tilde{A}_t^*(\varepsilon_t) &= I_t^* p_H q_t \left[ R_t^b + \left( \frac{R_t^b}{R_t^b + R_t^{gb}} \right) (R - R_t^e - R_t^{ge}) \varepsilon_t \right] \\ &= I_t^* p_H q_t \left[ R_t^b + \left( \frac{R_t^b}{R_t^b + R_t^{gb}} \right) (R_t^b + R_t^{gb} + R_t^w) \varepsilon_t \right], \end{aligned} \tag{B.24}$$

where the last form follows from Equation (B.2). Using (4b), (4c), (4d), (9), (B.5), and (B.11), together with  $Q_t^b = (1 + r_t^{a*}) / (1 + r_t^g)$ ,  $\omega_t^b = A_t^g / A_t$ , and  $r_t^d = 0$ , allows us to rewrite (B.24) as follows:

$$\begin{aligned} \tilde{A}_t^*(\varepsilon_t) &= A_t (1 + r_t^{a*}) \left[ 1 + \left\{ 1 + \left( \frac{1}{1 + r_t^g} \right) \left( \frac{D_t^*}{(1 + r_t^{a*}) A_t + A_t^*} \right) \right\} \varepsilon_t \right], \end{aligned} \tag{B.25}$$

where  $(1 + r_t^{a*})$  is given by (B.12) while (B.14) implies that

$$D_t^* = (1 + m_t^*) I_t^* - (A_t + A_t^g + N_t + N_t^g).$$

Next, assuming that (i) bankers receive a lump-sum rebate  $r_t^g A_t^g / (1 + \frac{\Delta p}{p_H})$  (see Appendix B.1.3) and (ii)  $r_t^g = dr_t^g > 0$  is small, we get

$$\tilde{A}_t^*(\varepsilon_t) = A_t (1 + r_t^a) (1 + BL_t^* \varepsilon_t) + O(dr_t^g \varepsilon_t), \tag{B.26}$$

where

$$BL_t^* = 1 + \frac{D_t - A_t^g - N_t^g}{(1 + r_t^a) A_t + A_t^g}. \tag{B.27}$$

Assuming that the terms  $O(dr_t^g \varepsilon_t)$ , which are of the order  $dr_t^g \times \varepsilon_t$ , can be disregarded, Equation (B.26) yields (24a) in the main text, while (B.27) is (24b).

### B.2 Public Funding and the Resilience of the Banking Sector: Welfare Implications

Let us consider the welfare implications of public funding when a (negative) aggregate shock hits the economy. To do so, it is useful to

analyze the end-of-period values of bankers' wealth,  $\tilde{A}_t(\varepsilon_t)$ , entrepreneurial wealth,  $\tilde{N}_t(\varepsilon_t)$ , and physical capital,  $\tilde{K}_t(\varepsilon_t)$ .  $\tilde{A}_t(\varepsilon_t)$ ,  $\tilde{N}_t(\varepsilon_t)$ , and  $\tilde{K}_t(\varepsilon_t)$  are the values of the state variables after the investment stage of period  $t$ , when the investment shock is realized, while  $A_t$ ,  $N_t$ , and  $K_t$  are the corresponding values before the investment stage of period  $t$  (but after the production stage of period  $t$ ). (Also note that  $A_{t+1}$ ,  $N_{t+1}$ , and  $K_{t+1}$  are the values of the state variables in period  $t + 1$ , after the production stage but before the investment stage). Under *laissez-faire*, the end-of-period aggregate banker-owned wealth is given by Equation (20a). If there is a public funding program in place, the end-of-period bankers' wealth is given by Equation (24a). The end-of-period entrepreneurial wealth is given by the Equation (19) and the end-of-period physical capital is characterized by

$$\tilde{K}_t(\varepsilon_t) = K_t + I_t(1 + \varepsilon_t)$$

whether or not public policies are in place.<sup>24</sup>

The welfare of the representative household from the next period ( $t + 1$ ) onward depends on these end-of-period ( $t$ ) values of the state variables. Under *laissez-faire*, the value function is  $\tilde{V}(\tilde{A}_t(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t))$ , while if there is a public funding program in place, welfare is given by  $\tilde{V}(\tilde{A}_t^*(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t))$ . Since  $\tilde{A}_t^*(\varepsilon_t) > \tilde{A}_t(\varepsilon_t)$ , when  $\varepsilon_t < 0$ , we have  $\tilde{V}(\tilde{A}_t^*(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t)) > \tilde{V}(\tilde{A}_t(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t))$ . In particular (if  $\varepsilon_t$  is small enough), the welfare gain from public funding can be approximated by

$$\begin{aligned} \Delta \tilde{V} &= \tilde{V}(\tilde{A}_t^*(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t)) - \tilde{V}(\tilde{A}_t(\varepsilon_t), \tilde{N}_t(\varepsilon_t), \tilde{K}_t(\varepsilon_t)) \\ &\approx \tilde{V}_{\tilde{A}} \left[ \tilde{A}_t^*(\varepsilon_t) - \tilde{A}_t(\varepsilon_t) \right] = \tilde{V}_{\tilde{A}} (1 + r_t^a) A_t (BL_t^* - BL_t) \varepsilon_t \\ &= -\tilde{V}_{\tilde{A}} BRE_t S_t \varepsilon_t, \end{aligned}$$

where  $\tilde{V}_{\tilde{A}}$  is the derivative of the value function with respect to  $\tilde{A}$ ,  $BRE_t = (1 + r_t^a) BL_t A_t$  is the banks' (macro) risk exposure

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<sup>24</sup>Note that the impact of the shock on the (middle-of-period)  $t + 1$  entrepreneurial wealth  $\tilde{N}_{t+1}^*(\varepsilon_t)$  depends on public funding. This is because the impact of the shock on the period  $t + 1$  price of capital  $q_{t+1}$  depends on public policies. However, the connection from (period  $t$ ) public policies to  $q_{t+1}$  and  $\tilde{N}_{t+1}^*(\varepsilon_t)$  goes through  $\tilde{A}_t^*(\varepsilon_t)$ .

under laissez-faire, and  $S_t = (BL_t - BL_t^*)/BL_t$  measures the size of the public funding program. This is Equation (25) in the main text.

### B.3 *The Fiscal Size of the Funding Program and Derivation of the Policy Frontier*

If the government funds nonfinancial firms—say the government buys a diversified (market) portfolio of firm debt—the losses it incurs are directly proportional to the size of the firm funding program  $N_t^g$  and to the size of the (negative shock)  $\varepsilon_t$ . However, if the government capitalizes banks, its losses are amplified. With an equity stake  $A_t^g$  in banks, the government stands to lose  $A_t^g BL_t^* (A_t^*, N_t^g; r_t^g) \varepsilon_t$  if a negative shock  $\varepsilon_t < 0$  hits. Taken together, the losses, or the fiscal costs, of a public funding program  $(A_t^g, N_t^g)$  can be expressed as

$$FC(A_t^g, N_t^g; r_t^g, \varepsilon_t) = -A_t^g BL_t^* (A_t^*, N_t^g; r_t^g) \varepsilon_t - N_t^g \varepsilon_t. \quad (\text{B.28})$$

Assuming  $r_t^g = dr_t^g$  is small, so that terms of the order  $dr_t^g \varepsilon_t$  can be disregarded, Equation (B.28) can be rewritten as

$$\begin{aligned} FC(A_t^g, N_t^g; \varepsilon_t) &= -A_t^g \left( 1 + \frac{D_t - A_t^g - N_t^g}{Q_t^b A_t + A_t^g} \right) \varepsilon_t - N_t^g \varepsilon_t \\ &= - \left( \frac{Q_t^b A_t}{Q_t^b A_t + A_t^g} (A_t^g + N_t^g) + \frac{A_t^g}{Q_t^b A_t + A_t^g} D_t \right) \varepsilon_t \\ &= -Q_t^b A_t \left( \frac{D_t}{Q_t^b A_t} - \frac{D_t - A_t^g - N_t^g}{Q_t^b A_t + A_t^g} \right) \varepsilon_t \\ &= -(1 + r_t^a) A_t (BL_t - BL_t^*) \varepsilon_t = -BRE_t S_t \varepsilon_t. \end{aligned}$$

However, since  $FC(A_t^g, N_t^g; r_t^g, \varepsilon_t) = BRE_t S_t \varepsilon_t$ , Equation (B.28) yields

$$BRE_t S_t = BL_t^* A_t^g + N_t^g.$$

This is the policy frontier (27).

### B.4 *Proof of Proposition 2*

The aim here is to find the optimal structure of public funding  $(A_t^g, N_t^g)$ , and to link the desired structure to the size of the funding program  $S_t$ . We also show how the mapping from the size to

the appropriate structure defines the sets of undominated and dominated policies.

Assume that the economy is initially in a steady state, and is hit by a negative investment shock ( $\varepsilon_t < 0$ ). We assume that there is genuine uncertainty, and we do not specify a probability distribution over the negative shock realizations. Let us denote the discounted sum of present and future household utility, given a funding program  $(A_t^g, N_t^g, S_t)$ , the premium on public funding  $r_t^g$ , and a shock realization  $\varepsilon_t < 0$  by  $V = V(A_t^g, N_t^g, S_t; r_t^g; \varepsilon_t; \cdot)$ . Given this environment, our objective is to narrow down the policy options that the government should consider under genuine uncertainty. We aim at characterizing two sets of policies: the undominated set, which includes policies that the government should consider, and the dominated set, which includes policies that the government should avoid.

The next step is to bring in more structure into the relationship between the policy program and household welfare,  $V(A_t^g, N_t^g, S_t; r_t^g; \varepsilon_t; \cdot)$ . We assume that the (excess) return on public funds,  $dr_t^g = r_t^g - r_t^d$ , is small enough, compared with the other terms, so that its cross-terms with the shock, which are proportional to  $\varepsilon_t \times dr_t^g$ , can be ignored in the analysis. This assumption allows us to decouple, and analyze separately, the welfare benefits of the program (which are proportional to  $\varepsilon_t$ ) and the welfare losses of the program (which are proportional to  $dr_t^g$ ). This is shown in Appendix B.1, Section B.1.4. See in particular Equation (B.26), which shows where the cross-terms would enter.

On the welfare benefit side of the program, the size of the program  $S_t$ , defined in Equation (26), is a sufficient statistic. All programs  $(A_t^g, N_t^g, S_t)$  which lie on the policy frontier, i.e., satisfy Equation (27), give rise to the same level of stabilization, or enhanced resilience, ( $S_t$ ) in the face of negative macro shock  $\varepsilon_t$ . Hence, the welfare benefits of the program, after a negative shock realization  $\varepsilon_t < 0$ , are proportional to the product  $S_t \varepsilon_t$ . See Equation (25) and the underlying analysis in Appendix B.2. Furthermore, we show in Appendix B.3 that the fiscal costs of the funding program are given by  $FC_t = -BRE_t S_t \varepsilon_t$ , which measures the government's losses from a public funding program of size  $S_t$  if a negative shock  $\varepsilon_t < 0$  hits the economy. If the fiscal costs have to be covered by distortionary taxes, the resulting welfare losses from taxation depend on  $FC_t$ . Hence, the net welfare benefits of the program, net of possible losses from distortionary taxation, are proportional to  $S_t \varepsilon_t$ .

As shown in Appendix B.1, Subsections B.1.2 and B.1.3, the current investments are a sufficient statistic of the social welfare costs arising from the distorting effects of public funding. That is, the distorting effects of the program to all model variables (current and future), are transmitted through current investments,  $I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot)$ . Therefore, the harmful effects of the program on social welfare, given by the value function ( $V$ ), are also transmitted through current investments. If program  $(A_t^g, N_t^g, S_t)$  gives rise to lower (higher) current investments than an alternative program  $(A_t^{g'}, N_t^{g'}, S_t')$ , then program  $(A_t^g, N_t^g, S_t)$  creates larger (smaller) welfare losses than program  $(A_t^{g'}, N_t^{g'}, S_t')$ .

Hence, we can conclude that the mapping from a policy package  $(A_t^g, N_t^g, S_t)$  to social welfare ( $V$ ) has the following structure:

$$V = V(I_t^*(A_t^g dr_t^g, N_t^g dr_t^g, \cdot), S_t \varepsilon_t; \varepsilon_t, \cdot),$$

subject to (27). Our task is to find policies  $(A_t^g, N_t^g, S_t)$  such that there do not exist alternative policies  $(A_t^{g'}, N_t^{g'}, S_t')$  that would dominate  $(A_t^g, N_t^g, S_t)$ . We say that a policy  $(A_t^{g'}, N_t^{g'}, S_t')$  dominates the policy  $(A_t^g, N_t^g, S_t)$  if  $(A_t^{g'}, N_t^{g'}, S_t')$  gives rise to at least as high utility as  $(A_t^g, N_t^g, S_t)$  in all states of the world, and higher utility in some states of the world. Here the different states of the world correspond to different (negative) shocks realizations  $\varepsilon_t < 0$ . More formally, the set of undominated policies  $(A_t^g, N_t^g, S_t)$  is defined as follows:

$$\begin{aligned} & \text{Find } A_t^g \geq 0, N_t^g \geq 0 \text{ and } S_t, \\ & \quad \text{such that } \nexists A_t^{g'}, N_t^{g'}, S_t' \\ & V(I_t^*(A_t^{g'} dr_t^{g'}, N_t^{g'} dr_t^{g'}, \cdot), S_t' \varepsilon_t; \varepsilon_t, \cdot) \geq V(I_t^*(A_t^g dr_t^g, N_t^g dr_t^g, \cdot), \\ & \quad S_t \varepsilon_t; \varepsilon_t, \cdot), \forall \varepsilon_t < 0 \\ & \text{subject to} \\ & BRE_t S_t = N_t^g + BL_t(1 - S_t)A_t^g, \\ & BRE_t S_t' = N_t^{g'} + BL_t(1 - S_t')A_t^{g'}. \end{aligned}$$

Next, recall that  $S_t$  is a sufficient statistic of the social welfare benefits of a program  $(A_t^g, N_t^g, S_t)$ . Likewise,  $S_t'$  is a sufficient statistic of the social welfare benefits of an alternative program  $(A_t^{g'}, N_t^{g'}, S_t')$ . Then if  $S_t'$  is larger (smaller) than  $S_t$ , the program

$(A_t^{g'}, N_t^{g'}, S_t')$  gives rise to larger (smaller) social welfare benefits than  $(A_t^g, N_t^g, S_t)$  after any negative shock realization  $\varepsilon_t < 0$ . If  $S_t' = S_t$ , the programs  $(A_t^{g'}, N_t^{g'}, S_t')$  and  $(A_t^g, N_t^g, S_t)$  give rise to the same social welfare benefits after any negative shock realization  $\varepsilon_t < 0$ . We may say that policy  $(A_t^{g'}, N_t^{g'}, S_t')$  dominates policy  $(A_t^g, N_t^g, S_t)$  if  $S_t' = S_t$  (so that both policies result in the same welfare benefits after any shock realization  $\varepsilon_t < 0$ ) but  $(A_t^{g'}, N_t^{g'}, S_t')$  generates smaller distortions and welfare losses than  $(A_t^g, N_t^g, S_t)$ . Since current investments,  $I_t^*$ , are a sufficient statistic for welfare losses, we can conclude that  $(A_t^{g'}, N_t^{g'}, S_t')$  dominates  $(A_t^g, N_t^g, S_t)$  if and only if  $I_t^*(A_t^{g'} dr_t^g, N_t^{g'} dr_t^g, \cdot) > I_t^*(A_t^g dr_t^g, N_t^g dr_t^g, \cdot)$  and  $S_t' = S_t$ .

We can find the set of undominated policies in the following way. We choose a target level ( $S_t$ ) for the stabilization of the financial system, that is the size of the program. Then we find the structure of the program  $(A_t^g, N_t^g)$  that minimizes distortions or, equivalently, maximizes  $I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot)$  subject to (27). More formally,

$$\max_{\{A_t^g, N_t^g\}} I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot)$$

subject to

$$BRE_t S_t = N_t^g + BL_t(1 - S_t)A_t^g, \quad A_t^g \geq 0, \quad N_t^g \geq 0,$$

where  $S_t$ ,  $BRE_t$ , and  $BL_t$  are taken as given. The corresponding Lagrangian is

$$\begin{aligned} \mathcal{L} = & I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot) + \eta_1 [N_t^g + BL_t(1 - S_t)A_t^g - BRE_t \times S_t] \\ & + \eta_2 A_t^g + \eta_3 N_t^g, \end{aligned}$$

where  $\eta_1$ ,  $\eta_2$ , and  $\eta_3$  are Lagrangian multipliers. The first-order conditions with respect to  $A_t^g$  and  $N_t^g$  are

$$\frac{\partial I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot)}{\partial A_t^g} + \eta_1 BL_t(1 - S_t) + \eta_2 = 0 \tag{B.29}$$

$$\frac{\partial I_t^*(A_t^g dr_t^g, N_t^g dr_t^g; \cdot)}{\partial N_t^g} + \eta_1 + \eta_3 = 0. \tag{B.30}$$

The Kuhn-Tucker conditions associated with the constraints  $A_t^g \geq 0$  and  $N_t^g \geq 0$  are

$$\begin{aligned} \eta_2 = 0 & \text{ if } A_t^g > 0, & \eta_2 > 0 & \text{ if } A_t^g = 0 \\ \eta_3 = 0 & \text{ if } N_t^g > 0, & \eta_3 > 0 & \text{ if } N_t^g = 0. \end{aligned}$$

Next note that Equation (23) implies that in the neighborhood of the steady state

$$\frac{\frac{\partial I_t^*}{\partial A_t^g}}{\frac{\partial I_t^*}{\partial N_t^g}} = \frac{-\frac{\partial I_t}{\partial A_t} dr_t^g}{-\frac{\partial I_t}{\partial N_t} dr_t^g} = \left. \frac{dN}{dA} \right|_I = MRTS.$$

There are three types of solutions, or three regimes:

- (i) If  $A_t^g > 0$  and  $N_t^g = 0$ , we have  $\eta_2 = 0$ ,  $\eta_3 > 0$ . Then dividing (B.30) by (B.29) gives, after some straightforward algebra,

$$\begin{aligned} \frac{1}{MRTS} &= \frac{1}{BL_t(1 - S_t)} + \frac{\eta_3}{\eta_1} \frac{1}{BL_t(1 - S)} \\ &\Rightarrow MRTS < BL_t(1 - S_t), \end{aligned}$$

where the inequality follows, since  $\eta_1 > 0$  and  $\eta_3 > 0$ .

- (ii) If  $A_t^g = 0$  and  $N_t^g > 0$ , we have  $\eta_2 > 0$ ,  $\eta_3 = 0$ . Dividing (B.29) by (B.30) then gives

$$MRTS = BL_t(1 - S_t) + \frac{\eta_2}{\eta_1} \Rightarrow MRTS > BL_t(1 - S_t),$$

where the inequality follows, since  $\eta_1 > 0$  and  $\eta_2 > 0$ .

- (iii) If  $A_t^g > 0$  and  $N_t^g > 0$ , we have  $\eta_2 = 0$ ,  $\eta_3 = 0$ . Dividing (B.29) by (B.30) then gives

$$MRTS = BL_t(1 - S_t).$$

It is easy to see that this characterization of undominated policies gives us a mapping from the size of the program ( $S_t$ ) to the optimal structure of the program ( $A_t^g, N_t^g$ ). Let us define  $S_t^* = 1 - MRTS/BL_t$ . (i) If  $S_t < S_t^*$  the optimal structure is  $A_t^g = (BRE_t/BL_t)(S_t/(1 - S_t))$ ,  $N_t^g = 0$ . (ii) If  $S_t > S_t^*$  the optimal structure is  $A_t^g = 0$ ,  $N_t^g = BRE_t \times S_t$ . (iii) If  $S_t = S_t^*$ , any structure  $A_t^g \geq 0$ ,  $N_t^g \geq 0$  which satisfies (27) is optimal. Note that (iii) is a knife-edge case, with measure zero.

Finally, all policies ( $A_t^g, N_t^g, S_t$ ) which do not belong to the undominated set are dominated. ■

### B.5 The Threshold Size of a Public Funding Program

In this section, we express the threshold size of a public funding program,  $S^*$ , with the help of the observable data moments used in the calibration of the model. We also examine the sensitivity of the threshold size  $S^*$  to the calibration.

**Expressing  $S^*$  in Terms of Data Moments.** Remember that  $S^* = 1 - MRTS/BL$ . Let us first express the bank leverage accelerator (under laissez-faire),  $BL$ , in terms of the data moments used in calibration (see Section 5 and Appendix C.2). Using (C.2) and (C.3) in Appendix C.2 we get

$$BL = \frac{1 + MRB + r^a CRB}{(1 + r^a) CRB}. \quad (\text{B.31})$$

Note that since  $\left(\frac{1+MRB+r^a CRB}{1+r^a}\right)$  tends to be rather close to unity, we get  $BL \approx CRB^{-1}$ .

Next, plugging Equations (C.5), (C.6), and (C.7) in Appendix C.2 into (18) allows us to express  $MRTS$  in terms of the data moments we use in calibrating the model:

$$MRTS = \frac{(1 + r^n)(r^a CRB + MRB)}{r^n((1 + r^a) CRB + MRB)}, \quad (\text{B.32})$$

where  $MRB$  is a measure of banks' monitoring costs, relative to banks' assets. To gain some further intuition, it is useful to re-express  $MRTS$  as

$$MRTS = \left( \frac{1 + \frac{MRB}{r^a CRB}}{1 + \frac{MRB}{(1+r^a)CRB}} \right) \left( \frac{r^a}{r^n} \right) \left( \frac{1 + r^n}{1 + r^a} \right).$$

Note that the terms  $1 + \frac{MRB}{r^a CRB}$  and  $\left(\frac{r^a}{r^n}\right)$  are potentially quite large (evidently depending on calibration), while the remaining terms  $1 + \frac{MRB}{(1+r^a)CRB}$  and  $\left(\frac{1+r^n}{1+r^a}\right)$  tend to be close to unity. Then

$$MRTS \approx (r^a + MRB/CRB) / r^n.$$

We now turn to the conditions under which  $MRTS < BL$ , so that  $S^* = 1 - \frac{MRTS}{BL} > 0$ . Applying Equations (B.31) and (B.32), one can show that this is the case if and only if

$$\frac{1 + r^n}{r^n} < \left( \frac{1 + r^a CRB + MRB}{r^a CRB + MRB} \right) \left( 1 + \frac{MRB}{(1 + r^a) CRB} \right). \quad (\text{B.33})$$

In Appendix D.3, however, we show that the model has an equilibrium with a meaningful role for financial intermediation if and only if  $r^n > r^a CRB + MRB$  (see condition (D.43)). This condition can be rewritten as

$$\frac{1 + r^n}{r^n} < \frac{1 + r^a CRB + MRB}{r^a CRB + MRB}. \quad (\text{B.34})$$

Note that (B.34) implies (B.33). Hence, if there is an equilibrium where banks intermediate funding and monitor entrepreneurial firms, there exists a threshold value  $S^* > 0$ .

Finally, combining (B.31) and (B.32) yields

$$\begin{aligned} S^* &= 1 - \frac{MRTS}{BL} = 1 - \left( \frac{r^a CRB + MRB}{1 + r^a CRB + MRB} \right) \\ &\quad \left( \frac{(1 + r^n) CRB}{r^n ((1 + r^a) CRB + MRB)} \right) \\ &= 1 - \left( \frac{r^a + \frac{MRB}{CRB}}{CRB^{-1} + r^a + \frac{MRB}{CRB}} \right) \left( \frac{1 + r^n}{r^n (1 + r^a + \frac{MRB}{CRB})} \right). \end{aligned} \quad (\text{B.35})$$

To gain some further intuition, note that  $CRB^{-1} + r^a + \frac{MRB}{CRB} \approx CRB^{-1}$ , while the term  $\frac{1+r^n}{1+r^a+\frac{MRB}{CRB}}$  tends to be rather close to unity (evidently depending on the calibration). Thus, we get

$$S^* \approx 1 - (r^a CRB + MRB) / r^n.$$

These findings are numerically illustrated in Table B.1, which reports the threshold size  $S^*$ , given by (B.35), for different values of the data moments  $r^a$ ,  $CRB$ , and  $MRB$ , while  $r^n = 4.5\%$  follows the baseline calibration.

### B.6 Dominated and Undominated Policies: Example

We assume that the utility function involves internal habit persistence, and the subutility function for consumption is

Table B.1. Threshold Size  $S^*$  with Different Calibrations of the Financial Block (baseline calibration in bold)

		CRB									
		4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	
$r^a = 10\%$											
	0.5	0.81	0.79	0.77	0.74	0.72	0.69	0.67	0.65	0.63	
	1.0	0.74	0.71	0.68	0.66	0.63	0.61	0.58	0.56	0.54	
	1.5	0.68	0.64	0.61	0.58	0.55	0.53	0.50	0.48	0.45	
	2.0	0.63	0.58	0.55	0.52	0.48	0.46	0.43	0.40	0.37	
	2.5	0.58	0.54	0.49	0.46	0.42	0.39	0.36	0.33	0.30	
	3.0	0.55	0.49	0.45	0.40	0.37	0.33	0.30	0.27	0.24	
3.5	0.51	0.45	0.40	0.36	0.32	0.28	0.24	NA	NA		
		CRB									
$r^a = 12\%$											
	0.5	0.80	0.77	0.74	0.71	0.68	0.66	0.63	0.60	0.57	
	1.0	0.72	0.69	0.66	0.63	0.60	0.57	0.54	0.51	0.49	
	1.5	0.66	0.62	0.59	0.55	<b>0.52</b>	0.49	0.46	0.43	0.40	
	2.0	0.61	0.57	0.53	0.49	0.45	0.42	0.39	0.36	0.33	
	2.5	0.57	0.52	0.47	0.43	0.39	0.36	0.32	0.29	0.26	
	3.0	0.53	0.47	0.42	0.38	0.34	0.30	0.26	0.23	0.19	
3.5	0.50	0.44	0.38	0.33	0.29	NA	NA	NA	NA		

(continued)

Table B.1. (Continued)

		CRB									
		4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	
$r^a = 14\%$		0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.55	0.52	
MRB	0.5	0.71	0.67	0.63	0.60	0.57	0.53	0.50	0.47	0.44	
	1.0	0.65	0.60	0.56	0.53	0.49	0.46	0.42	0.39	0.36	
	1.5	0.60	0.55	0.50	0.46	0.42	0.39	0.35	0.32	0.28	
	2.0	0.55	0.50	0.45	0.41	0.36	0.32	0.29	0.25	0.21	
	2.5	0.52	0.46	0.40	0.35	0.31	0.27	0.23	NA	NA	
	3.0	0.49	0.42	0.36	0.31	NA	NA	NA	NA	NA	
	3.5										

**Note:** CRB is the capital ratio of banks (%), MRB is the ratio of banks' monitoring costs to their assets (%), and  $r^a$  is the return on bank equity (%). Following the baseline calibration, we set the return on firm equity  $r^a = 4.5\%$ . NA means that the "no-corner-solution condition" (D.43) in Appendix D.3) is not satisfied. In these cases the suggested calibration is not valid.

$u(C_t, C_{t-1}) = ((C_t - bC_{t-1})^{1-\sigma}) / (1-\sigma)$ , where the habit parameter is set to  $b = 0.8$ . In our simple model, financial frictions introduce a wedge on the consumption/investment margin only. Habit persistence provides a simple way to amplify the welfare effects of the friction while introducing a minimal departure from the basic model.

To keep the illustrative example as simple as possible, we consider a case with two possible shock realizations: the small shock is  $\varepsilon_t = -0.005$  while the large shock is  $\varepsilon_t = -0.03$ . For illustrative simplicity, we assume that there are also two possible funding program sizes. The size of a small program is 0.3 and the size of a large program is 0.8. The premium or the penalty rate that the government charges is  $r^g = 0.1$ . All welfare gains and losses (measured as changes in the household's value function) are expressed as a percentage of (per-period) steady-state consumption.

**Welfare Gain from Stabilization.** Note that welfare gain does not depend on the structure of the program.

	Small Shock	Large Shock
Small Program	0.36%	2.15%
Large Program	0.95%	5.71%

**Welfare Loss from Distortions.** Note that welfare loss from distortions does not depend on the shock realization.

	Banks	Firms
Small Program	0.25%	0.38%
Large Program	2.57%	1.01%

**Net Welfare Gain.** Net welfare gain is equal to welfare gain from stabilization minus welfare loss from distortions.

	Small Program		Large Program	
	Banks	Firms	Banks	Firms
Small Shock	<b>0.11%</b>	-0.02%	-1.62%	<b>-0.06%</b>
Large Shock	<b>1.90%</b>	1.77%	3.14%	<b>4.70%</b>

**Interpreting the Results.** We assume that there is genuine uncertainty. When choosing the policy, the government does not know which shock (small or large) will realize, and it cannot even assign a probability distribution. However, our results narrow the options that a benevolent government should consider under genuine uncertainty. A small funding program targeting firms and a large program targeting banks are *dominated*. The government should never choose either of these programs. A small program targeting banks and a large program targeting firms belong to the set of *undominated* policies. The government should choose its policy from this set (in bold).

### *B.7 Non-optimal Structure of Public Funding and Excess Welfare Losses*

How important is it to get the structure of the public funding program right? How significant are the (excess) welfare losses resulting from a non-optimal structure? In this section, we address this question from two slightly different, but complementary, angles. First, we benchmark the non-optimally structured program with an optimally structured program with the same size (and the same social benefits from resilience), and compare the welfare losses from distortions. Second, within the set of undominated policies (characterized by Proposition 2) we choose a benchmark program which gives rise to the same level distortions as the non-optimal candidate program, but has a bigger size and hence brings about greater social benefits in terms of enhanced resilience.

#### *B.7.1 Benchmarking to an Optimally Structured Program with the Same Size*

If the government chooses to fund nonfinancial firms, the amount  $N^g = BRE \times S$  of public funding is needed, and the welfare losses from distortions ( $WL$ ) are proportional to  $WL(A^g = 0, N^g = BRE \times S) \propto S$ . If the government chooses to capitalize banks, fewer funds are needed  $A^g = \left(\frac{BRE}{BL}\right) \left(\frac{S}{1-S}\right) \leq BRE \times S$ , but since each unit of public funding creates  $MRTS$  times more distortions when placed in banks than when placed in firms, the

resulting welfare losses are proportional to  $WL(A^g = (\frac{BRE}{BL}) (\frac{S}{1-S}), N^g = 0) \propto (\frac{S}{1-S}) (\frac{MRTS}{BL}) = S (\frac{1-S^*}{1-S})$ . It is easy to see that the minimum welfare loss ( $WL^{\min}$ ), corresponding to the optimal structure of the funding program (see Proposition 2) is (proportional to)  $WL^{\min} \propto S \times \min \left\{ 1, \frac{1-S^*}{1-S} \right\}$ , while the maximum welfare loss that arises if the government funds nonfinancial firms with a small program ( $S < S^*$ ) and banks with a large program ( $S > S^*$ ) is (proportional to)  $WL^{\max} \propto S \times \max \left\{ 1, \frac{1-S^*}{1-S} \right\}$ . Denote the *excess welfare loss* resulting from a non-optimal structure of the program by  $\Delta WL$ . It is easy to conclude that

$$\Delta WL \leq WL^{\max} - WL^{\min} \propto \frac{S}{1-S} |S - S^*|. \quad (\text{B.36})$$

The expression on the right-hand side of the inequality (B.36) gives the maximum value of the excess welfare loss. This maximum excess welfare loss is realized if only nonfinancial firms are funded when bank capitalization would be optimal (and vice versa). If, instead, the government implements some form of mixed program and funds both banks and nonfinancial firms, the excess welfare loss is given by the expression

$$\Delta WL \propto \frac{M^g}{1-S} |S - S^*|, \quad (\text{B.37})$$

where

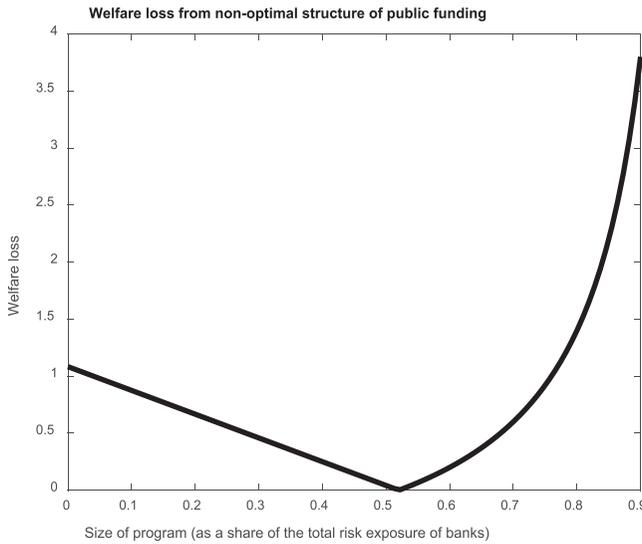
$$M^g = \begin{cases} N^g/BRE & \text{if } S < S^* \\ BL(1-S)A^g/BRE & \text{if } S > S^* \end{cases} \quad (\text{B.38})$$

denotes the misallocation of public funding.

In order to further analyze how important the choice of the program structure is, it useful to compare the excess welfare loss, due to a non-optimal structure, with the minimum welfare loss when the structure is chosen optimally. If the government funds only banks or only firms with the wrong amount, relative excess welfare loss  $\Delta \widehat{WL} = \Delta WL / WL^{\min}$  can be expressed as follows:

$$\Delta \widehat{WL} = \frac{\Delta WL}{WL^{\min}} = \max \left\{ \frac{S^* - S}{1 - S^*}, \frac{S - S^*}{1 - S} \right\}. \quad (\text{B.39})$$

**Figure B.1. Welfare Loss from Non-optimal Structure of Public Funding**



If the government implements a mixed program,

$$\Delta \widehat{WL} = \frac{M^g}{S} \max \left\{ \frac{S^* - S}{1 - S^*}, \frac{S - S^*}{1 - S} \right\}. \tag{B.40}$$

Figure B.1 shows how the (maximum) relative excess welfare loss (the right-hand side of (B.39)) depends on the size of the program with our baseline calibration. The figure indicates that choosing the optimal structure of the program is important if the program is either very small or very large (since in these cases the maximum relative excess welfare loss is large), while it is less important for medium-sized programs. Indeed when the size is the program approaches the threshold value  $S^*$  (from either side), the maximum excess relative welfare loss approaches zero.

*B.7.2 Benchmarking to an Optimally Structured Program with a Larger Size*

**Pure Programs with the Wrong Structure.** (i) Consider a small program, with  $S < S^*$ . Assume that the program is

(non-optimally) implemented by public funding to nonfinancial firms. Hence  $N^g = BRE \times S$ , and the welfare losses from distorted investments are (proportional to)  $WL \propto S$ . Next, assume that the government capitalizes banks instead. Since each unit of public stakes distorts the economy  $MRTS$  times more when allocated to banks than when placed in firms,  $A^{g'} = \frac{BRE}{MRTS} \times S$  gives rise to the same welfare losses from distortions as the original program. Denote the size of the alternative program, targeting banks, by  $S'$ . The size  $S'$  can be solved from Equation (27). That is,

$$BRE \times S' = BL(1 - S') \frac{BRE}{MRTS} \times S.$$

This gives

$$\frac{S'}{1 - S'} = \frac{S}{1 - S^*}$$

or

$$S' = \frac{S}{1 + S - S^*}. \quad (\text{B.41})$$

Clearly  $S' > S$ , when  $S < S^*$ . Also note that  $S' < S^*$  when  $S < S^*$ . Hence, the program of size  $S'$  is indeed optimally implemented by bank capitalization.

(ii) Consider next a large program, with  $S > S^*$ . Assume that the program is (non-optimally) implemented by public bank capitalization. Hence,  $A^g = \frac{BRE}{BL} \left( \frac{S}{1-S} \right)$ , and the welfare losses from distorted investments are (proportional to)  $WL \propto \frac{MRTS}{BL} \frac{S}{1-S} = \left( \frac{1-S^*}{1-S} \right) S$ . Next assume that the government funds nonfinancial firms instead. Since each unit of public stakes distorts the economy  $MRTS$  times more when allocated to banks than when placed in firms,  $N^{g'} = BRE \left( \frac{MRTS}{BL} \right) \left( \frac{S}{1-S} \right) = BRE \left( \frac{1-S^*}{1-S} \right) S$  gives rise to the same welfare losses from distortions as the original program. Denote the size of the alternative program, targeting firms, by  $S'$ . The size  $S'$  can be solved from Equation (27). That is,

$$BRE \times S' = BRE \left( \frac{1 - S^*}{1 - S} \right) S.$$

This gives

$$S' = \left( \frac{1 - S^*}{1 - S} \right) S. \quad (\text{B.42})$$

Clearly  $S' > S$ , when  $S > S^*$ .

Note that (B.42) is only valid if  $S' \leq S^{\max} = 1 - \frac{1}{BL}$ , or  $S \leq \frac{S^{\max}}{1 + S^{\max} - S^*}$ . If  $S > \frac{S^{\max}}{1 + S^{\max} - S^*}$ , we choose as the (optimally structured) benchmark a program with the maximum size. This benchmark, which targets nonfinancial firms only, gives rise to distortion-related welfare losses which are proportional to

$$WL' \propto S^{\max}.$$

Since  $\frac{S}{1-S} > \frac{S^{\max}}{1-S^*}$ , it is easy to conclude that  $WL' < WL$  (where  $WL \propto \left( \frac{1-S^*}{1-S} \right) S$ ).

**Mixed Programs.** Let us next consider mixed funding programs, with  $A^g > 0$  and  $N^g > 0$ . The welfare loss due to distorted incentives is (proportional to)

$$WL \propto MRTS \times A^g + N^g,$$

while the size of the program is

$$S = \frac{BL \times A^g + N^g}{BRE + BL}. \quad (\text{B.43})$$

(To get this result solve  $BRE \times S = BL(1 - S)A^g + N^g$  for  $S$ .)

- (i') First assume that the program is (relatively) small, i.e.,  $S < S^*$ . Further assume that, instead of implementing the (non-optimal) candidate program, the government (only) capitalizes banks. Public stakes  $A^{g'}$  placed in banks give rise to the same level of distortions and welfare losses as the candidate program. Hence,  $A^{g'}$  can be solved from the equation

$$MRTS \times A^{g'} = MRTS \times A^g + N^g$$

and

$$A^{g'} = A^g + \frac{N^g}{MRTS}. \quad (\text{B.44})$$

The size of the alternative program,  $S'$ , can be solved from Equation (27). Hence, we get

$$\frac{S'}{1 - S'} = \frac{BL}{BRE} A^{g'} = \frac{BL}{BRE} \left( A^g + \frac{N^g}{MRTS} \right), \quad (\text{B.45})$$

where the last form is derived using (B.44). Next, it is useful to re-express Equation (B.45) in terms of  $S$  (the size of the non-optimal candidate program) and  $M^g = N^g/BRE$  (the misallocation of public funding under the non-optimal program). Using (B.43) one can re-express (B.45) as

$$\frac{S'}{1 - S'} = \left( \frac{S}{1 - S} \right) \left[ 1 + \left( \frac{S^* - S}{1 - S^*} \right) \frac{M^g}{S} \right]. \quad (\text{B.46})$$

Finally, Equation (B.46) can be solved for  $S'$

$$S' = \left( \frac{1 - S^* + (S^* - S) \frac{M^g}{S}}{1 - S^* + S(S^* - S) \frac{M^g}{S}} \right) S. \quad (\text{B.47})$$

Note that when  $M^g = S$  (and the government funds only nonfinancial firms in the non-optimal candidate program), Equation (B.47) boils down to (B.41).

- (ii') Assume now that the program is (relatively) large, i.e.,  $S > S^*$ . Further assume that, instead of implementing the (non-optimal) candidate program, the government (only) targets nonfinancial. Public stakes

$$N^{g'} = MRTS \times A^g + N^g$$

in nonfinancial firms give rise to the same level of welfare losses from distorted incentives as the (non-optimally structured) candidate program. The size of the alternative program,  $S'$ , can be solved from Equation (27). Hence, we get

$$S' = \frac{N^{g'}}{BRE} = \frac{MRTS \times A^g + N^g}{BRE}. \quad (\text{B.48})$$

Next, it is useful to re-express Equation (B.48) in terms of  $S$  (the size of the non-optimal candidate program) and

$M^g = BL(1 - S)A^g/BRE$  (the misallocation of public funding under the non-optimal program). Using (B.43) one can re-express (B.48) as

$$S' = \left(1 + \left(\frac{S - S^*}{1 - S}\right) \frac{M^g}{S}\right) S. \tag{B.49}$$

Note that when  $M^g = S$  (and the government funds only banks in the non-optimal candidate program), Equation (B.49) boils down to (B.42). Finally, note that Equation (B.49) is only valid if  $S' \leq S^{\max} = 1 - \frac{1}{BL}$  or, equivalently,  $S \leq S^{**}$ , where

$$S^{**} = \frac{1 + S^{\max} - \widehat{M}S^* - \sqrt{\left(1 + S^{\max} - \widehat{M}S^*\right)^2 - 4\left(1 - \widehat{M}\right)S^{\max}}}{2\left(1 - \widehat{M}\right)} \tag{B.50}$$

and  $\widehat{M} = M^g/S$ . When  $\widehat{M} \rightarrow 1, S^{**} \rightarrow \frac{S^{\max}}{1 + S^{\max} - S^*}$ . If  $S > S^{**}$ , we have  $S' = S^{\max}$ .

**Assessing the Welfare Losses from a Non-optimal Structure.** Remember that the welfare gains from enhanced stability are (approximately) proportional to the size of the program (see Equation (25) in the main text; see also Appendix B.2). The difference between the size of the optimally structured benchmark program ( $S'$ ) and the candidate program ( $S$ ) is a measure of the welfare losses due to the non-optimal structure

$$\Delta WL^* \propto \Delta S = S' - S \leq \begin{cases} \left(\frac{S^* - S}{1 + S - S^*}\right) S & \text{if } S < S^* \\ \left(\frac{S - S^*}{1 - S}\right) S & \text{if } S^* > S. \end{cases}$$

To further assess the magnitude of these welfare losses, it is useful to divide  $\Delta S$  by  $S$  (since the social welfare benefits from enhanced resilience of the candidate program are proportional to  $S$ ). If the government funds only banks or only firms with the wrong amount, we obtain

$$\Delta \widehat{WL}^* = \frac{\Delta S}{S} = \begin{cases} \frac{S^* - S}{1 + S - S^*} & \text{if } S < S^* \\ \frac{S - S^*}{1 - S} & \text{if } S > S^*. \end{cases} \tag{B.51}$$

If the government implements a mixed program, we get

$$\Delta \widehat{WL}^* = \frac{\Delta S}{S} = \begin{cases} \frac{(S^* - S)(1 - S) \frac{M^g}{S}}{1 - S^* + S(S^* - S) \frac{M^g}{S}} & \text{if } S < S^* \\ \left(\frac{S - S^*}{1 - S}\right) \frac{M^g}{S} & \text{if } S > S^*, \end{cases} \tag{B.52}$$

where  $M^g$  (the misallocation of public funding under a mixed program) is given by (B.38). Note that Equations (B.51) and (B.52) are only valid if  $S' \leq S^{\max} = 1 - 1/BL$  or, equivalently,  $S \leq S^{**}$ , where  $S^{**}$  is defined in (B.50). If  $S > S^{**}$ , we have  $\Delta \widehat{WL}^* = \Delta S/S = S^{\max}/S - 1$ .

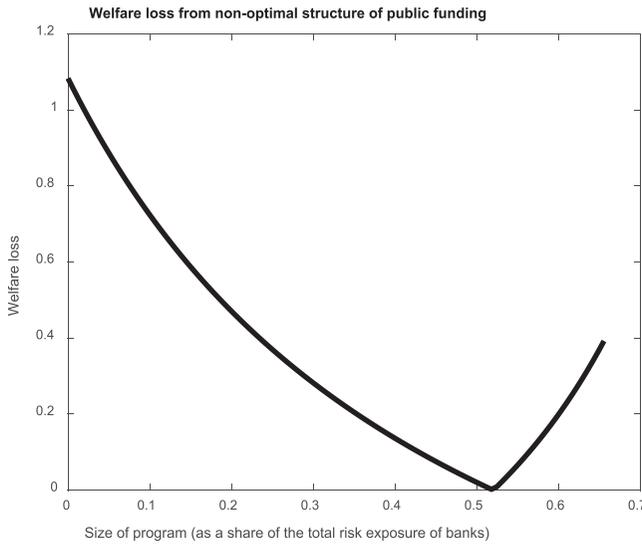
Figure B.2 shows how the maximum relative welfare loss (the right-hand side of (B.51)) depends on the size of the program under our baseline calibration for  $S \in (0, S^{**})$ , where  $S^{**} = \frac{S^{\max}}{1 + S^{\max} - S^*}$ ; under our baseline calibration,  $S^{**} = 0.66$ . The figure essentially indicates that if the program size  $S$  is around the threshold value  $S^*$ , it does not matter much whether the government allocates funds to banks, firms, or both. However, the larger the gap between  $S^*$  and  $S$ , the larger are the excess welfare losses from a non-optimal structure. Indeed, for (very) small programs,  $\Delta \widehat{WL}^* = \Delta S/S \approx 1$ , meaning that in this case the (excess) welfare loss from a non-optimal structure (funding firms when one should fund banks) is of the same order of magnitude as the stabilization-related welfare benefits from the candidate program. Overall, we get the same results as above in Appendix B.7.1 when using the welfare loss measure  $\Delta \widehat{WL}$  (see expression (B.39) and Figure B.1).

### B.8 Robustly Optimal Public Funding of Both Banks and Firms

**First Example: The Government Does Not Know the Threshold  $S^*$ .** According to Proposition 2, the threshold size of public funding is  $S^* = 1 - MRTS/BL$ . Assume the government does not know  $MRTS$  (which tells how much more distorting it is to fund banks rather than nonfinancial firms), but believes with sufficient certainty that  $MRTS$  lies somewhere between  $MRTS_1$  and  $MRTS_2$ , where  $MRTS_2 < MRTS_1$ . This implies that the threshold size  $S^* \in [S_1^*, S_2^*]$ , where

$$S_i^* = 1 - \frac{MRTS_i}{BL}, \quad i \in \{1, 2\}.$$

**Figure B.2. Welfare Loss from Non-optimal Structure of Public Funding**



If the size of the program the government wants to implement ( $S$ ) is either smaller than  $S_1^*$  or larger than  $S_2^*$ , the situation is unproblematic: the government should capitalize banks (if  $S < S_1^*$ ), or fund nonfinancial firms (if  $S > S_2^*$ ). However, if  $S \in (S_1^*, S_2^*)$ , the government faces a dilemma: it may incur an excess welfare loss as large as  $\Delta WL \propto S \left( \frac{MRTS_1}{BL(1-S)} - 1 \right) = \frac{S}{1-S} (S - S_1^*)$  if it targets banks (but funding nonfinancial firms would be the optimal strategy) or as large as  $\Delta WL \propto S \left( 1 - \frac{MRTS_2}{BL(1-S)} \right) = \frac{S}{1-S} (S_2^* - S)$  if it targets nonfinancial firms (but capitalizing banks would be the optimal strategy). In such a situation, the government may want to choose, for example, a robust strategy that aims to minimizing the maximum (excess) welfare losses due to the misallocation of public funds. Such a strategy would involve targeting both banks and firms. Note that the welfare losses due to a mixed package are proportional to  $WL(A^g, N^g) \propto MRTS \times A^g + N^g$ .

A robust min-max strategy solves the following problem:

$$\min_{A^g, N^g} \max_{i \in \{1, 2\}} MRTS_i A^g + N^g,$$

subject to  $BRE \times S = BL(1 - S)A^g + N^g$ . One can show that such a strategy would give rise to the mixed policy package

$$N^g = BRE \times S \left( \frac{MRTS_1 - BL(1 - S)}{MRTS_1 - MRTS_2} \right) = BRE \times S \left( \frac{S - S_1^*}{S_2^* - S_1^*} \right)$$

and

$$\begin{aligned} A^g &= \left( \frac{BRE \times S}{BL(1 - S)} \right) \left( \frac{BL(1 - S) - MRTS_2}{MRTS_1 - MRTS_2} \right) \\ &= \left( \frac{BRE}{BL} \right) \left( \frac{S}{1 - S} \right) \left( \frac{S_2^* - S}{S_2^* - S_1^*} \right), \end{aligned}$$

where the government targets both banks and firms as long as  $S \in (S_1^*, S_2^*)$ . Quite intuitively, the share of funds allocated to nonfinancial firms (banks) increases (decreases) with the size of the program  $S$ .

**Second Example: Staggered Program.** Assume that the government knows the threshold value  $S^*$ , but it does not know if, in the end, it wants to implement a small program  $S_1 < S^*$  or a large program  $S_2 > S^*$ . Given Proposition 2, the small program  $S_1$  would be optimally implemented by capitalizing banks, while the larger program  $S_2$  would be optimally implemented by targeting nonfinancial firms.

We assume that the government first implements the smaller policy package  $S_1$ , and subsequently decides whether or not it wants to expand the size of the program to  $S_2$ . Let  $A_1^g$  and  $N_1^g$  denote the government funding allocated to banks and firms, respectively, under policy package  $S_1$ , while  $A_2^g$  and  $N_2^g$  denote the government funding allocated to banks and firms, respectively, when policy package  $S_2$  is in place. We further assume that

$$A_2^g \geq A_1^g, \quad N_2^g \geq N_1^g.$$

In words, if a certain amount of public funding is allocated to banks (firms) in the initial policy package  $S_1$ , this money cannot be taken back if the program is expanded to  $S_2$ . When designing the (robustly) optimal structure of policy package  $S_1$ , the government takes these constraints into account.

A robustly optimal strategy aims at minimizing the maximum (excess) welfare losses due to the misallocation of public funds. A robustly optimal strategy solves the problem

$$\min_{A_1^g, N_1^g, A_2^g, N_2^g} \max_{i \in \{1,2\}} MRTS \times A_i^g + N_i^g,$$

subject to

$$BRE \times S_i = BL(1 - S_i) A_i^g + N_i^g \text{ for } i \in \{1, 2\}$$

$$A_2^g \geq A_1^g, \quad N_2^g \geq N_1^g.$$

One can show that the robustly optimal structure of policy package  $S_1$  is given by the equations

$$N_1^g = BRE \times S_1 \left( \frac{\frac{1}{BL_2^*} - \frac{1}{MRTS}}{\frac{1}{BL_2^*} - \frac{1}{BL_1^*}} \right)$$

$$= BRE \times S_1 \left( \frac{1 - S_1}{1 - S^*} \right) \left( \frac{S_2 - S^*}{S_2 - S_1} \right)$$

and

$$A_1^g = \frac{BRE \times S_1 - N_1^g}{BL_1^*} = \frac{BRE \times S_1^*}{BL_1^*} \left( \frac{\frac{1}{MRTS} - \frac{1}{BL_1^*}}{\frac{1}{BL_2^*} - \frac{1}{BL_1^*}} \right)$$

$$= \frac{BRE \times S_1}{BL} \left( \frac{1 - S_1}{1 - S^*} \right) \left( \frac{S^* - S_1}{S_2 - S_1} \right).$$

The robustly optimal structure of policy package  $S_2$  is given by the equations

$$A_2^g = A_1^g$$

and

$$N_2^g = BRE \times S_2 - BL_2^* A_2^g$$

$$= BRE \times \left[ S_2 - S_1 \left( \frac{BL_2^*}{BL_1^*} \right) \left( \frac{\frac{1}{MRTS} - \frac{1}{BL_1^*}}{\frac{1}{BL_2^*} - \frac{1}{BL_1^*}} \right) \right]$$

$$= BRE \times S_2 - \frac{BRE \times S_1}{BL} \left( \frac{1 - S_2}{1 - S^*} \right) \left( \frac{S^* - S_1}{S_2 - S_1} \right).$$

One can show that the share of public funds allocated to nonfinancial firms (both  $N_1^g$  and  $N_2^g$ ) increases with  $S_1$  and  $S_2$ , while the share of public funds allocated to banks decreases with  $S_1$  and  $S_2$ .

## Appendix C. Calibration

### *C.1 Data Moments and Calibration*

In calibrating the real sector of the model, we follow the RBC literature. A period is one year. We calibrate the household's utility function parameters to involve relatively modest risk aversion and a fairly inelastic labor supply:  $\sigma = 2$ ,  $\phi = 0.5$ , and  $\xi = 2$ , and set the discount factor  $\beta$  to 0.98, which approximately corresponds to an annual real interest rate of 2 percent. We assign the depreciation rate  $\delta$  to 0.10, a typical value in the literature. The capital share in the final goods sector,  $\alpha$ , is set to the often-used value of  $1/3$ . The output shares of investment and consumption are roughly 20 percent and 80 percent, respectively.

Calibration of the parameters of the financial block, while less standard, only requires values for excess returns to banks' and entrepreneurial firms' capital, their capital ratios, and bankers' monitoring costs (see Appendix C.2.1). To parameterize the steady-state (excess) rate of return on entrepreneurial capital,  $r^n$ , we first take the value of 6.5 percent, commonly used in the RBC literature, as the average return to capital in the economy, and then subtract a riskless rate of 2 percent, yielding  $r^n = 4.5\%$  (see, for example, Fama and French 2002). As to the value for the entrepreneurial firms' steady-state capital ratio,  $N/I$ , the literature suggests substantial intertemporal and cross-section variation (e.g., Rajan and Zingales 1995; De Jong, Kabir, and Nguyen 2008; Graham and Leary 2011; and Graham, Leary, and Roberts 2015). We choose the value of 0.45, which is close to the post-1990 estimate for the U.S. by Graham, Leary, and Roberts (2015).

The steady-state (excess) rate of return on bank capital,  $r^a$ , is calibrated based on Albertazzi and Gambacorta (2009), who find the average after-tax return on bank equity in 1999–2003 to vary from 7 percent in the euro area to 14–15 percent in the U.K. and the U.S. (Hirtle and Stiroh 2007 report similar magnitudes

for U.S. retail banks), and on Haldane and Alessandri (2009), who find the pretax return on bank equity in the U.K. to be around 20 percent on average over the recent decades. We set  $r^a$  to 12 percent, which lies in the midrange of these estimates.

The bank's steady-state capital ratio is given by  $A/(A + D - mI) = A/(I - N)$  (see Appendix D.2). Since the banks in our model have a stake in the projects they fund, the closest empirical counterpart for our bank capital is tier 1 capital, which includes banks' common stocks and retained earnings. Typical estimates (e.g., Acharya and Steffen 2014) of tier 1 capital to (non-risk-adjusted) assets vary between 4 percent and 8 percent. Our model focuses on firm loans, abstracting from other bank assets. We set  $A/(I - N) = 0.08$  to account for the riskiness of corporate lending. This magnitude also corresponds to the precrisis tier 1 equity-to-asset ratio in the aggregate bank balance sheet calculated by the Federal Deposit Insurance Corporation (FDIC).

Finding an estimate for monitoring costs is not easy. Based on the estimations of Albertazzi and Gambacorta (2009) and Philippon (2015), the unit cost of financial intermediation could be 1–4 percent of a bank's total assets. As their unit cost measures include activities in addition to monitoring, that estimate provides an upper bound for the ratio of monitoring costs to assets. However, corporate lending involves more intense monitoring than many other asset classes in a bank's balance sheet. Furthermore, in our model the total operating costs of a bank are equal to the monitoring costs (since in the model there are no other operating costs). This suggests that the empirical counterpart could include (some) costs of financial intermediation not (directly) related to monitoring. Based on these observations, we choose a monitoring-cost-to-asset ratio ( $mI/(I - N)$ ) of 1.5 percent.

## *C.2 Parameters of the Financial Block*

### *C.2.1 Data Moments and Steady-State Values of Model Variables*

We now define the observable financial data moments in terms of the steady state of the model variables in the financial block

(see Appendix D.2). The calibration of the parameters of the financial block of the model is based on the following observables:

- *Excess* rates of return on bank capital  $r^a$ , and on entrepreneurial capital  $r^n$ . In each period, bankers earn the gross rate of return  $(1+r)(1+r^a)$  and entrepreneurs earn the rate of return  $(1+r)(1+r^n)$ , where  $1+r = 1/\beta$  is the real interest rate earned by workers in the steady state.
- Nonfinancial firms' capital ratio

$$CRF = \frac{N}{I}. \quad (\text{C.1})$$

- Banks' capital ratio

$$CRB = \frac{A}{A+D-mI} = \frac{A}{I-N}. \quad (\text{C.2})$$

In the denominator, we subtract the banks' monitoring costs  $mI$  from the total amount of funds  $A+D$  to obtain the amount of the banks' assets allocated to the investment projects. Note the difference between the balance sheets of nonfinancial firms and banks. The balance sheets of nonfinancial firms include funds from bankers and depositors, as well as the entrepreneurs' own capital. The grand total is  $I$ . Banks have bankers' own capital and funds from depositors, and the aggregate amount of funds is  $I-N$ .

- Banks' monitoring costs as a ratio of banks' assets

$$MRB = \frac{mI}{I-N}. \quad (\text{C.3})$$

- Finally, it is useful to express the ratio of monitoring costs to output ( $mI/Y$ ) with the help of these data moments, and the investment share of output  $\iota = I/Y$

$$\frac{mI}{Y} = MRB(1-CRF)\iota. \quad (\text{C.4})$$

*C.2.2 Equations Linking Data Moments and Parameters of the Financial Block*

Based on the equations from the main text, Appendix C.2.1 above, and the analytical solution of the steady state, given in Appendix D.2, we present equations linking the parameters of the financial block to the data moments. The calibrated financial block parameters are as follows:

- The exit rate of bankers  $\lambda^b$ . Equation (D.12) in Appendix D.2 implies that

$$\lambda^b = \frac{\beta}{1+r^a} = \frac{1}{(1+r^a)(1+r)}. \quad (\text{C.5})$$

- The exit rate of entrepreneurs  $\lambda^e$ . Equation (D.13) in Appendix D.2 implies that

$$\lambda^e = \frac{\beta}{1+r^n} = \frac{1}{(1+r^n)(1+r)}. \quad (\text{C.6})$$

- The (relative) difference in the success probabilities of good and bad projects  $\Delta p/p_H$ .

Using the banker's incentive constraint (4b) and participation constraint (4d), together with the aggregation equation (9), all evaluated at the steady state, yields  $\Delta p/p_H = mI/((1+r^a)A)$ . Applying Equations (C.2) and (C.3) gives

$$\frac{\Delta p}{p_H} = \frac{MRB}{CRB(1+r^a)}. \quad (\text{C.7})$$

- The elasticity of the monitoring function  $\gamma/(1-\gamma)$ . Inserting (C.5), (C.6), and (C.7) in (16), and recalling that  $\nu = A/N$ , yields  $\gamma/(1-\gamma) = A(r^a + MRB/CRB)/(r^n N)$ . Then using (C.1) and (C.2) gives

$$\frac{\gamma}{1-\gamma} = \frac{r^a CRB + MRB}{r^n \frac{CRF}{1-CRF}}. \quad (\text{C.8})$$

Note that  $CRF/(1-CRF) = N/(I-N)$  is the ratio of entrepreneurial capital to non-entrepreneurial capital in

nonfinancial firms' balance sheets. Applying (C.2) and (C.3),  $\gamma/(1-\gamma)$  can be re-expressed in yet another way:

$$\begin{aligned} \frac{\gamma}{1-\gamma} &= \frac{r^a A + mI}{r^n N} \\ &= \frac{\text{banks' profits} + \text{banks' monitoring costs}}{\text{entrepreneurs' profits}}. \end{aligned}$$

- Parameter of the monitoring function  $\Gamma$ .

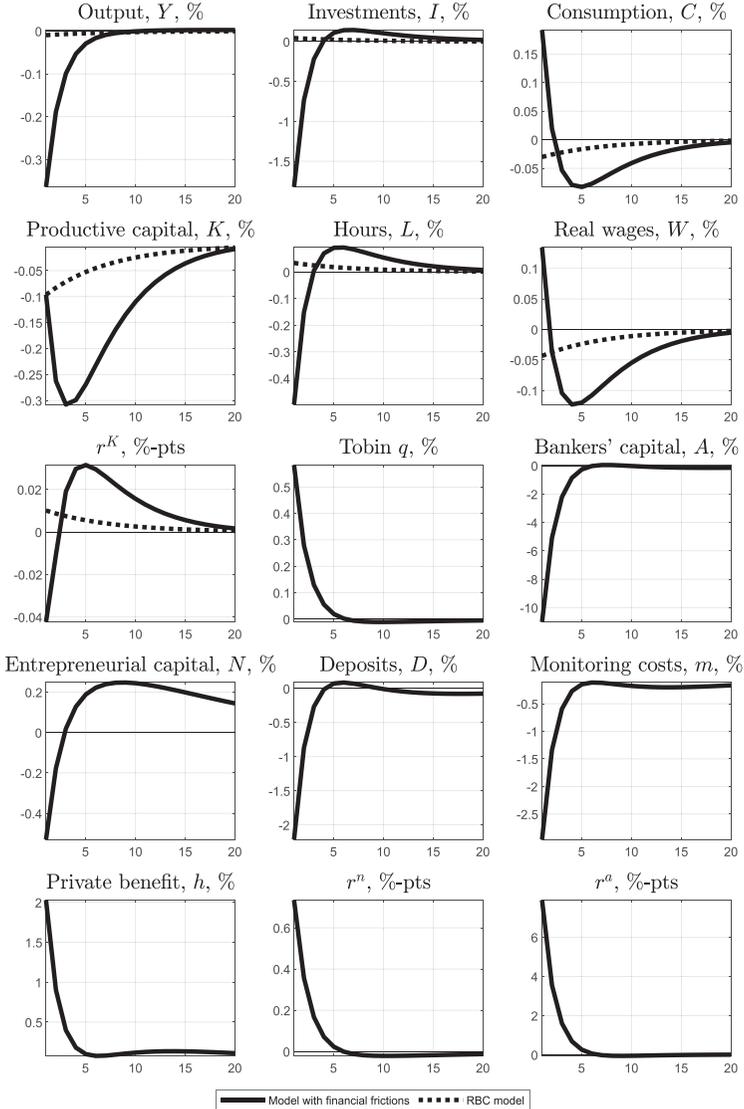
$$\Gamma = \left( \frac{1+r^n}{1+r^a} \right) \left( \frac{CRF}{CRB} \right) (1-CRF)^{\frac{\gamma}{1-\gamma}} MRB^{\frac{1}{1-\gamma}}, \quad (\text{C.9})$$

where  $\gamma$  is given by (C.8). The derivation of (C.9) involves the following steps. In Appendix A.4 we define  $G_t = (A_t + N_t)/I_t$ . Applying (C.1) and (C.2), the steady-state version of this equation can be rewritten as  $G = CRB(1-CRF) + CRF$ . Using Equations (D.15), (D.25), and (D.26) in Appendix D.2, the measure  $G$  can be expressed in terms of  $\nu$  and the parameters of the financial block (including  $\Gamma$ ). Finally, applying (16), (C.5), (C.6), and (C.7), we get (C.9).

### C.3 Impulse Responses

Figure C.1 portrays the impulse responses of key real- and financial-sector variables to a negative investment shock. As a benchmark, we also show the real-sector impulse responses in a standard RBC model which corresponds to our model with the exception of financial intermediation and associated frictions.

**Figure C.1. Impulse Responses to a Negative Investment Shock (1 percentage point decrease in success probabilities)**



## Appendix D. Technical Appendix

### D.1 Equilibrium

The equilibrium of the model, reproduced here for the reader's convenience, is a sequence

$$\{K_{t+1}, L_t, Y_t, r_{t+1}, W_t, r_t^K, C_t, I_t, q_t, \rho_t, r_t^a, r_t^n, m_t, h_t, A_{t+1}, N_{t+1}, D_t\}_{t=0}^{\infty}$$

that satisfies Equations (2), (3), (10), (11), (12), (13), (14), (15a,b), and

$$1 + r_{t+1} = \frac{r_{t+1}^K + q_{t+1}(1 - \delta)}{q_t}, \quad (\text{D.1})$$

$$\xi L_t^\phi C_t^\sigma = W_t, \quad (\text{D.2})$$

$$Y_t = K_t^\alpha L_t^{1-\alpha}, \quad (\text{D.3})$$

$$W_t = (1 - \alpha) \frac{Y_t}{L_t}, \quad (\text{D.4})$$

$$r_t^K = \alpha \frac{Y_t}{K_t}, \quad (\text{D.5})$$

$$Y_t = C_t + I_t, \quad (\text{D.6})$$

$$D_t = (1 + m_t) I_t - (A_t + N_t), \quad (\text{D.7})$$

$$\rho_t = q_t - 1. \quad (\text{D.8})$$

### D.2 Steady State

We present the steady state of the model in three parts. In part A, we solve for the steady-state values of the prices and the ratios of quantities (such as  $\nu = A/N$ ) in the financial block. In addition, we solve for the steady-state values of the moral-hazard-related variables ( $h$  and  $m$ ). In part B, we solve the steady state of the real (RBC) block. Finally, in part C, we solve for the steady-state values of the quantities (levels) in the financial block.

**Part A.** We derive the steady-state values of financial variables in four steps:

1. The law of motion of  $A_t$  is

$$A_{t+1} = \lambda^b (1 + r_{t+1}) (1 + r_t^a) A_t \quad (\text{D.9})$$

and the law of motion of  $N_t$  is

$$N_{t+1} = \lambda^b (1 + r_{t+1}) (1 + r_t^n) N_t. \quad (\text{D.10})$$

Since the household's Euler equation (3) implies that in steady state

$$1 + r = \frac{1}{\beta}, \quad (\text{D.11})$$

the steady-state versions of Equations (D.9) and (D.10) immediately yield

$$1 + r^a = \frac{\beta}{\lambda^b} \quad (\text{D.12})$$

and

$$1 + r^n = \frac{\beta}{\lambda^e}. \quad (\text{D.13})$$

Furthermore, the steady-state versions of (D.9) and (D.10) give

$$\frac{A}{N} \equiv \nu = \frac{\lambda^b R^b}{\lambda^e R^e} = \frac{\lambda^b m}{\lambda^e h}, \quad (\text{D.14})$$

where the last form follows since  $R^b = m/(q\Delta p)$  and  $R^e = h/(q\Delta p)$ .

2. Denote

$$J_t = A_t + N_t$$

and recall from Appendix A.4 the definition  $G_t = (A_t + N_t)/I_t = J_t/I_t$ . Combining these with (D.9) and (D.10), we get

$$J_{t+1} = (1 + r_{t+1}) p_H q_t \frac{J_t}{G_t} (\lambda^b R_t^b + \lambda^e R_t^e)$$

(since  $I_t = J_t/G_t$ ). Thus, in steady state

$$1 = (1 + r) p_H q \frac{1}{G} (\lambda^b R^b + \lambda^e R^e).$$

Combine

$$R^b = m / (q\Delta p), \quad R^e = h / (q\Delta p),$$

and (D.11) with above to obtain

$$G = \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e h). \quad (\text{D.15})$$

3. Use the equilibrium relations

$$m_t = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho_t + \frac{A_t}{I_t} \right) = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} (\gamma \rho_t + \mu_t G_t) \quad (\text{D.16})$$

and

$$\begin{aligned} m_t &= \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho_t + \frac{N_t}{I_t} \right) \quad (\text{D.17}) \\ &= \frac{\Delta p}{p_H} ((1 - \gamma) \rho_t + (1 - \mu_t) G_t), \end{aligned}$$

where

$$\mu_t = \frac{A_t}{A_t + N_t} = \frac{\nu_t}{1 + \nu_t}.$$

Plug (D.15) into (D.16) and (D.17). In steady state we then have

$$m = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho + \frac{\nu}{1 + \nu} \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e h) \right) \quad (\text{D.18})$$

and

$$h = \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho + \frac{1}{1 + \nu} \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e h) \right). \quad (\text{D.19})$$

From (D.14) we get

$$m = \frac{\lambda^e}{\lambda^b} \nu h \quad (\text{D.20})$$

and plugging this into (D.18) and (D.19) yields

$$\frac{\lambda^e}{\lambda^b} \nu h = \frac{\frac{\Delta p}{p_H}}{1 + \frac{\Delta p}{p_H}} \left( \gamma \rho + \nu \frac{1}{\beta} \frac{p_H}{\Delta p} \lambda^e h \right)$$

and

$$h = \frac{\Delta p}{p_H} \left( (1 - \gamma) \rho + \frac{1}{\beta} \frac{p_H}{\Delta p} \lambda^e h \right). \tag{D.21}$$

Solving  $\rho$  from (D.21) yields

$$\rho = \frac{p_H}{\Delta p} \left( 1 - \frac{\lambda^e}{\beta} \right) \left( \frac{h}{1 - \gamma} \right). \tag{D.22}$$

Plugging (D.22) into (D.18) gives

$$\frac{\lambda^e}{\lambda^b} \nu h = \frac{1}{1 + \frac{\Delta p}{p_H}} \left( \left( 1 - \frac{\lambda^e}{\beta} \right) \frac{\gamma}{1 - \gamma} + \nu \frac{\lambda^e}{\beta} \right) h. \tag{D.23}$$

Evidently,  $h$  cancels out from (D.23), and the equation can be solved for  $\nu$ :

$$\nu = \frac{\lambda^b}{\lambda^e} \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}} \right) \left( \frac{\gamma}{1 - \gamma} \right), \tag{D.24}$$

4. Using the relation (D.20) together with the monitoring technology

$$h = \Gamma m^{-\frac{\gamma}{1-\gamma}} \Leftrightarrow m^\gamma b^{1-\gamma} = \Gamma^{1-\gamma}$$

we get

$$h = \left( \frac{\lambda^b}{\lambda^e} \right)^\gamma \frac{\Gamma^{1-\gamma}}{\nu^\gamma} \tag{D.25}$$

and

$$m = \left( \frac{\lambda^e}{\lambda^b} \right)^{1-\gamma} \Gamma^{1-\gamma} \nu^{1-\gamma}. \tag{D.26}$$

Given steps 1–4, we can express the steady state of prices and ratios as well as moral-hazard-related variables in the financial block in a recursive form. Real interest rate, Equation (D.11):

$$1 + r = \frac{1}{\beta}.$$

Rate of return to bank capital, Equation (D.12):

$$1 + r^a = \frac{\beta}{\lambda^b}.$$

Rate of return to entrepreneurial capital, Equation (D.13):

$$1 + r^n = \frac{\beta}{\lambda^e}.$$

Ratio of informed capital, Equation (D.24):

$$\nu = \frac{\lambda^b}{\lambda^e} \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta}} \right) \left( \frac{\gamma}{1 - \gamma} \right).$$

Nonverifiable revenue from a “bad” investment project, Equation (D.25):

$$h = \left( \frac{\lambda^b}{\lambda^e} \right)^\gamma \frac{\Gamma^{1-\gamma}}{\nu^\gamma}.$$

Monitoring intensity, Equation (D.26):

$$m = \left( \frac{\lambda^e}{\lambda^b} \right)^{1-\gamma} \Gamma^{1-\gamma} \nu^{1-\gamma}.$$

Ratio of informed capital and investment, Equation (D.15):

$$G = \frac{1}{\beta} \frac{p_H}{\Delta p} (\lambda^b m + \lambda^e h).$$

The net rate of return to the investment projects, Equation (D.22):

$$\rho = \frac{p_H}{\Delta p} \left( 1 - \frac{\lambda^e}{\beta} \right) \left( \frac{h}{1 - \gamma} \right).$$

The net rate of return to the investment project,  $\rho$ , can be further expressed as

$$\rho = \Gamma \frac{p_H}{\Delta p} \left( \frac{1 - \frac{\lambda^b}{\beta} + \frac{\Delta p}{p_H}}{\gamma} \right)^\gamma \left( \frac{1 - \frac{\lambda^e}{\beta}}{1 - \gamma} \right)^{1-\gamma}. \tag{D.27}$$

**Part B.** We now turn to the variables in the real (or RBC) block of the model. The steady state of the real block is linked to the steady state of the financial block (solved in part A above) through the price of capital,  $q$ . The steady-state version of (D.8) implies that the steady-state price of capital is given by

$$q = 1 + \rho. \tag{D.28}$$

Then the steady-state version of Equation (D.1) implies that, in steady state, the rental rate of capital is

$$r^K = q(r + \delta). \tag{D.29}$$

Next, applying the steady-state versions of Equations (2), (D.2), (D.3), (D.4), (D.5), and (D.6) allows us to solve the steady-state values of the remaining variables in the real block: Real wage,

$$W = (1 - \alpha) \left( \frac{r^K}{\alpha} \right)^{-\frac{\alpha}{1-\alpha}}, \tag{D.30}$$

physical capital stock,

$$K = \left[ \left( \frac{1 - \alpha}{\xi} \right) \left( \frac{r^K}{\alpha} \right)^{-\frac{\alpha+\phi}{1-\alpha}} \left( \frac{r^K}{\alpha} - \delta \right)^{-\sigma} \right]^{\frac{1}{\phi+\sigma}}, \tag{D.31}$$

hours worked,

$$L = K \left( \frac{r^K}{\alpha} \right)^{\frac{1}{1-\alpha}}, \tag{D.32}$$

output,

$$Y = \frac{r^K K}{\alpha}, \tag{D.33}$$

investments,

$$I = \delta K, \quad (\text{D.34})$$

and consumption,

$$C = Y - I. \quad (\text{D.35})$$

**Part C.** Finally, we solve for the steady-state values of the quantities in the financial block. Using  $\nu = A/N$  and  $A + N = GI$  gives the steady-state values of bank capital

$$A = \frac{\nu}{1 + \nu} GI \quad (\text{D.36})$$

and entrepreneurial capital

$$N = \frac{1}{1 + \nu} GI. \quad (\text{D.37})$$

Finally, applying the steady-state version of (D.7) gives the steady-state value of deposits

$$D = (1 + m - G)I. \quad (\text{D.38})$$

### *D.3 Ruling Out the Corner Solution*

In this section, we study the conditions under which the no-monitoring corner solution,  $m_t = 0$ ,  $h(m_t) = \bar{h}$ , can be ruled out. Assume that a firm chooses *not* to be monitored:  $m_t = 0$ . One may, for example, think that the firm raises outside funding directly from households, without financial intermediation by banks. Then (4a) implies that  $R_t^e = \bar{h}/(\Delta p q_t)$ . Furthermore, according to Equations (5a) and (5b), the maximum leverage,  $i_t/n_t$ , the firm can obtain is given by

$$\frac{i_t}{n_t} = \frac{1}{g(r_t^a, q_t; m_t = 0, h_t = \bar{h})} = \frac{1}{\frac{p_H}{\Delta p} \bar{h} - \rho_t}.$$

Hence, the expected rate of return on entrepreneurial capital,  $1 + \hat{r}_t^n$ , is given by

$$1 + \hat{r}_t^n = \frac{p_H q_t R_t^e}{g(r_t^a, q_t; m_t = 0, h_t = \bar{h})} = \frac{\frac{p_H}{\Delta p} \bar{h}}{\frac{p_H}{\Delta p} \bar{h} - \rho_t}.$$

To rule out the corner solution, we must have

$$\widehat{r}_t^n < r_t^n, \quad (\text{D.39})$$

where  $r_t^n$  is the expected rate of return on entrepreneurial capital if the entrepreneur chooses the interior solution that involves monitoring. In particular, the condition (D.39) should apply in the steady state, so that we get the condition

$$\bar{h} > \frac{\Delta p}{p_H} \frac{1+r^n}{r^n} \rho. \quad (\text{D.40})$$

In addition, we seek a condition that guarantees that it is socially optimal to choose the “good” project rather than the “bad” project with the maximum level of private payoffs  $\bar{h}$ . For this condition to hold in the steady state, we must have

$$p_H q R > p_L q R + \bar{h} \Leftrightarrow \bar{h} < \frac{\Delta p}{p_H} q. \quad (\text{D.41})$$

When deriving the latter form of the inequality, recall the normalization  $p_H R = 1$ . It is possible to rule out a corner solution if and only if there exist a value  $\bar{h}$  that satisfies both (D.40) and (D.41). Such a value  $\bar{h}$  exists if and only if  $\left(\frac{1+r^n}{r^n}\right) \rho < q = 1 + \rho$  or, equivalently,

$$r^n > \rho. \quad (\text{D.42})$$

In Appendix D.4, we show that

$$\rho = r^n CRF + (r^a CRB + MRB)(1 - CRF),$$

where the data moments  $r^n$ ,  $r^a$ ,  $CRF$ ,  $CRB$ , and  $MRB$  are defined in Section 5, or alternatively in Appendix C.2. Then one can rewrite the condition (D.42) in such a way that it only includes data moments we match,

$$r^n > r^a CRB + MRB. \quad (\text{D.43})$$

Our baseline calibration satisfies this condition.

#### D.4 Expressing $\rho$ in Terms of Data Moments

In this section, we show that

$$\rho = r^n CRF + (r^a CRB + MRB)(1 - CRF), \quad (\text{D.44})$$

where  $\rho$  is the net return on the investment projects in steady state, while the data moments  $r^n$ ,  $r^a$ ,  $CRF$ ,  $CRB$ , and  $MRB$  are defined in Section 5, or alternatively in Appendix C.2. To derive (D.44), first apply Equations (16), (D.20), and (D.22) to get

$$\rho = \left( \frac{p_H}{\Delta p} \right) \left( 1 + \frac{\Delta p}{p_H} - \frac{\lambda^b}{\beta} \right) \left( \frac{m}{\gamma} \right). \quad (\text{D.45})$$

Next note that

$$m = \left( \frac{mI}{I - N} \right) \left( \frac{I - N}{I} \right) = MRB(1 - CRF), \quad (\text{D.46})$$

where the last form is derived using definitions (C.1) and (C.3) in Appendix C.2. Finally, plugging (C.5), (C.7), (C.8), and (D.46) into (D.45) yields (D.44).

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