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# The effects of capital requirements on good and bad risk-taking

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**Abstract**

We study optimal capital requirement regulation in a dynamic quantitative model in which nonfinancial firms, as well as households, hold deposits. Firms hold deposits for precautionary reasons and to facilitate the acquisition of production inputs. Our theoretical analysis identifies a novel general equilibrium channel that operates through firms' deposits and mitigates the cost of increasing capital requirements. We calibrate our model and find that the optimal capital requirement is 18.7% but only 13.6% in a comparable model in which only households hold deposits. Our novel channel accounts for most of the difference.

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# 1 Introduction

After the 2007–2008 financial crisis, the revision of the regulatory framework of financial intermediaries has become a central topic of discussion by regulators and academics. The Basel III accord has tightened bank regulation with the aim of reducing the likelihood and depth of financial crises. One of the key sets of rules at the center of this debate is capital requirements, namely, limits on the fraction of debt that banks can use to finance their investment. Appealing to the Modigliani and Miller (1958) theorem, Admati and Hellwig (2013) argue that capital requirements should be raised even further to eliminate banks' bad risk-taking, namely, the moral hazard induced by government guarantees and implicit too-big-to-fail subsidies.[1] One argument against tighter capital requirements is that banks are special because their liabilities are valued for their safety and liquidity (DeAngelo and Stulz, 2015). Under this view, raising capital requirements reduces excessive risky lending by banks but at the cost of reducing the supply of valuable bank deposits.

A recent literature analyzes these trade-offs in a quantitative, general equilibrium framework. While most analyses use models in which only households hold deposits (Van den Heuvel, 2008; Davydiuk, 2017; Begenau, 2018), deposits in practice are held not only by households but also by firms.

In this paper, we ask whether and to what extent accounting for the deposits held by nonfinancial firms affects the determination of the optimal capital requirement. We derive a general equilibrium model in which—similar to the literature—government guarantees induce banks to take excessive risks. Capital requirements limit such a risk, but they also reduce the supply of deposits. Crucially, though, the cost of reducing the supply of deposits depends not only on how households value deposits but also on how the lower supply affects firms' behavior.

We find that the optimal capital requirement is substantially higher than in comparable models with only households' deposits. This result arises from a novel general equilibrium effect related to the role played by firms' deposits. Firms are subject to idiosyncratic risk and hold deposits for precautionary reasons. In particular, deposits promote risky but socially valuable production by facilitating the acquisition of production inputs. We refer to the channel by which deposits stimulate firms' activities as *good risk-taking*. If financial regulation is tightened and the availability of deposits decreases, firms will demand fewer inputs. However, in general equilibrium, input prices will decrease, partially offsetting firms' desire to hire fewer inputs. This additional effect mitigates the direct costs of increasing

[1] Some regulators have made a case for similar rules as well; see, for example, the Minneapolis Plan discussed by Kashkari (2016).

capital requirements, thereby raising the optimal requirement relative to other quantitative models that omit firms' deposits.

The impact of our channel is quantitatively relevant. After presenting a baseline model to describe the results, we extend it to include several quantitative features. The optimal capital requirement in the quantitative model is 18.7% and thus substantially higher than in many models in the literature. Importantly, the channel we highlight is large even in the context of our model, in which some features are different from those in many related papers. To make this argument, we solve for the capital requirement that would be chosen under two alternative formulations: one in which all the deposits are held by households, and another one in which both households and firms hold deposits but we shut down our novel general equilibrium channel. When only households hold deposits, the optimal capital requirement is 13.6%, that is, 5.1 percentage points lower than in the full model. Our novel channel accounts for a large part of the difference: the capital requirement that maximizes welfare when both households and firms hold deposits but we shut down our channel is 15.3%.

Aside from our novel approach at modeling the liquidity value of deposits for firms, other aspects of our work build heavily on the existing literature that quantifies optimal capital requirements. We follow the pioneering approach of Van den Heuvel (2008) in embedding the analysis of capital requirements regulation in a dynamic, quantitative, general equilibrium model, and some elements of both our theoretical and quantitative analyses are based on Van den Heuvel (2008), Davydiuk (2017), and Begenau (2018).[2]

The firms' side of our model builds on a framework introduced by Quadrini (2017), in which deposits are held by firms subject to uninsurable idiosyncratic shocks to the productivity of their employees. The wage bill must be paid independently of the realization of the shocks, and thus the productivity risk is borne by the firm. The effect of these shocks is to reduce the firm's labor demand relative to an economy without idiosyncratic shocks. Because deposits are safe, they reduce the volatility of firms' cash flows, so that a high availability of and return on deposits increases firms' willingness to hire workers. We call this channel "good risk-taking" because increasing labor demand is in general socially valuable but not fully exploited because of the idiosyncratic risk. The mechanism by which more cash available to a firm increases its labor demand is in line with the causal evidence in Benmelech, Bergman and Seru (2015), who show that firms with more long-term debt maturing in any given year—and thus likely to have less cash available—reduce their labor force by more

[2]In addition, we abstract from some features that have been studied in other papers, such as the interactions with the shadow banking system (Begenau and Landvoigt, 2017; Dempsey, 2017), the possible optimality of time-varying capital requirements (Davydiuk, 2017; Malherbe, 2017), the effect of legacy assets (Bahaj et al., 2016; Bahaj and Malherbe, 2018), and the interaction with economic growth (Nguyễn, 2014).

than their peers.[3]

Tighter capital requirements reduce firms' labor demand in the model; however, the ultimate impact on welfare depends on what happens to the equilibrium level of employment, which is affected not only by labor demand but also by labor supply. To clarify this point, we analyze an extreme case of our model in which labor is in fixed supply. In this case, a drop in labor demand reduces wages but, because employment is fixed, does not affect the component of welfare that depends on the labor market.[4] Under a proper calibration of the key labor market parameters, tightening capital requirements reduces both wages and employment. Nonetheless, our main message is unaltered because the drop in wages lowers the wage bill of firms, thereby mitigating the welfare cost of the higher capital requirements. That is, a bad idiosyncratic shock does not preclude a firm from financing future projects even if it has fewer deposits.

We argue that government guarantees and capital requirements are important for firms' deposits. Indeed, even if some firms might have high deposit balances, the government has been covering deposits and other bank liabilities well beyond the deposit insurance limit. For instance, Veronesi and Zingales (2010) calculate that Paulson's equity infusion plan implemented during the Columbus Day weekend of October 2008—at the height of the financial crisis—entailed a transfer of \$21-\$44 billion from taxpayers to the holders of liabilities of some of the largest US banks. This is a large number when compared to the \$90 billion borne by the Deposit Insurance Fund between 2007 and 2013 (Davison and Carreon, 2010) and is likely a lower bound on the overall taxpayer-subsidized transfers because of the numerous interventions at that time.

Capital requirements in our model limit the negative impact of subsidized deposit insurance. More generally, though, deposit insurance can also be interpreted as any explicit or implicit government guarantee on bank debt (e.g., the Temporary Liquidity Guarantee Program set up by the Federal Deposit Insurance Corporation in 2008 and the too-big-to-fail guarantee that resulted in the Paulson plan studied by Veronesi and Zingales, 2010). We follow a common approach in the literature that imposes deposit insurance and motivates it with its role in preventing runs, as in Diamond and Dybvig (1983), but does not explicitly include runs nor analyze the optimality of such a policy.[5]

[3] Benmelech, Bergman and Seru (2015) build on the approach of Almeida et al. (2012), that is, on the assumption that cross-sectional variation in long-term debt maturing at any point in time is exogenous to corporate outcomes at that time. Indeed, variations in maturing long-term debt among firms are likely exogenous to market conditions and investment opportunities because the portion of maturing debt was issued prior to the year of maturity.

[4] Total welfare is affected, though, because changing capital requirements alters the bad risk-taking of banks even when labor is in fixed supply.

[5] We note that fully eliminating deposit insurance might not be optimal in our framework because it would

We motivate firms' aversion to idiosyncratic risk with an agency problem, following a literature that has highlighted the importance of these frictions (Panousi and Papanikolaou, 2012; Glover and Levine, 2015, 2017). Firms are owned by households that can fully diversify away their exposure to idiosyncratic risk by holding a well-diversified portfolio of equity. However, each firm is run by a manager who holds only an equity stake in the firm she manages and thus is exposed to the idiosyncratic risk of the firm. As a separate contribution of the paper, we introduce some modeling assumptions that make the model tractable and allow us to ignore managers' consumption when performing welfare analysis, without altering the implications of the agency friction. In addition, even if idiosyncratic shocks create heterogeneity across firms, the equilibrium in our model depends only on aggregate firms' wealth, and other moments of the firm size distribution are irrelevant. As a result, we can easily aggregate firms' behavior, maintaining the main focus on financial regulation and solving the model in general equilibrium. This last feature is particularly important for our novel channel; richer structural corporate finance models with agency frictions, such as Nikolov and Whited (2014), are instead typically solved in partial equilibrium.

Another implication of our model is related to the measurement of the welfare cost of capital requirements. In a model with deposits in the utility function, Van den Heuvel (2008) shows that the welfare cost can be computed using a simple formula that depends only on variables that are easily observable. In particular, the liquidity premium—that is, the spread between deposit rates and rates on similarly low-risk but less liquid investments—plays a prominent role in that formula. We show that an additional key input is required to compute the welfare cost in our model, namely, how firms' input prices respond to changes in regulation. This element is more difficult to quantify in the data without appealing to the structure and simulation of a model. In our theoretical analysis, we emphasize two extreme parameterizations: one in which the deposit premium plays the most prominent role in assessing the welfare cost of capital requirements, as in Van den Heuvel (2008), and one in which it provides no information at all.[6]

# 2 Literature review

A recent and growing literature has embedded the analysis of capital requirements into quantitative general equilibrium models. This literature includes Van den Heuvel (2008), Chris-

make deposits unsafe, thereby increasing rather than reducing the volatility of firms' cash flows. We leave the joint determination of optimal deposit insurance and capital requirement regulation to future research.

[6]In the macro-monetary literature, some papers show that liquidity premia might not be sufficient statistics for policy analysis. For instance, Li, Rocheteau and Weill (2012) show that assets with the same liquidity value can have different liquidity premia.

tiano and Ikeda (2013), Corbae and D'Erasmo (2014), Elenev, Landvoigt and Van Nieuwerburgh (2018), Nguyễn (2014), Gertler, Kiyotaki and Prestipino (2016), Begenau and Landvoigt (2017), Davydiuk (2017), Dempsey (2017), and Begenau (2018). Egan, Hortaçsu and Matvos (2017) develop a structural model of the US banking sector and argue that capital requirements should be at least 18% to avoid bank runs. Most of the literature, however, tends to be qualitative or to abstract from general equilibrium (Thakor, 2014). Indeed, several papers, such as Berger and Bouwman (2013), Mehran and Thakor (2011), and Diamond and Rajan (2001) provide results about the role of bank capital and changes in capital requirements that are identified in the cross section, abstracting from general equilibrium effects.

A related paper by Allen et al. (2018) studies the effect of government guarantees on banks' choices of liquidity and investments in risky projects. Both our paper and that of Allen et al. (2018) point out that higher risk-taking can be a good consequence of financial regulation. In their paper, more risk-taking by banks is associated with greater liquidity provision. In our paper, more risk-taking by firms has a positive impact, in general, on employment and output.

Our approach for modeling firms' risk builds on Quadrini (2017), who also emphasizes the role of bank liabilities for insurance purposes.[7] There are, however, two main differences. First, he focuses mainly on banks' risk-taking and crises, whereas our focus is on the impact of financial regulation on nonfinancial firms' risk-taking.[8] Second, we extend his model so that we can reinterpret the agents subject to idiosyncratic risk as firms run by managers who cannot diversify away idiosyncratic risk because of an agency friction. This extension facilitates the welfare analysis and the comparison of the model with the data, and it represents a separate contribution of our paper. Indeed, the firms' building block of our model can be used to study other questions at the intersection of corporate finance and macroeconomics.

This paper is also related to a literature that studies financial intermediaries as suppliers of safe assets, such as Stein (2012), Magill, Quinzii and Rochet (2016), and Diamond (2016). This literature builds on the ideas of Gorton and Pennacchi (1990) and Dang et al. (2017), in which the debt of banks is riskless to enhance its liquidity value or to overcome an informational friction. Bank debt is valuable in our model for a related but slightly different reason: there is a demand for securities that are uncorrelated with the idiosyncratic risk of firms. Some of these papers also perform policy analyses in models with only households' deposits. While their theoretical results are not affected by our novel channel, the corre-

[7] The approach used by Quadrini (2017) at modeling firms' risk builds on Arellano, Bai and Kehoe (2011).

[8] Dindo, Modena and Pelizzon (2018) derive a demand for banks' liabilities for insurance purposes similar to Quadrini (2017) and ours (although in a continuous-time model), but the regulation of intermediaries that they study always reduces welfare.

sponding quantitative policy stance might need to be tilted by imposing stricter limits on financial intermediaries.

Our paper relates to a large literature on firms' exposure to idiosyncratic risks. Smith and Stulz (1985) and Froot, Scharfstein and Stein (1993) derive theories in which firms do not completely hedge away idiosyncratic risks because external financing is costly. Minton and Schrand (1999) provide empirical evidence that firms that are more exposed to idiosyncratic risk invest less and have higher costs of external financing than other firms, consistent with an inability or unwillingness to completely insure against idiosyncratic shocks. In this setting, idiosyncratic shocks are costly to the firm. In addition, we build on the results of Panousi and Papanikolaou (2012) and Glover and Levine (2015, 2017), and we assume that firms are run by managers that are subject to the idiosyncratic risk of the firm they run. Thus, as pointed out by Panousi and Papanikolaou (2012), risk aversion of managers plays a role in shaping firm decisions. In our model, this implies that deposits provide insurance against the idiosyncratic risk, consistent with the finding of Bates, Kahle and Stulz (2009) of a rising trend in firms' cash holdings since the 1980s, which they attribute in large part to an increasing precautionary motive.

More generally, our work is part of a broader literature that relates financial intermediaries, firms' idiosyncratic risk, and the labor market. Bacchetta, Benhima and Poilly (forthcoming) show a negative relation between corporate cash holdings and employment in the data, which they rationalize with external liquidity shocks to firms. Bigio (2010) and Jermann and Quadrini (2012) study how firms' financial frictions affect the macroeconomy, including labor demand. Donaldson, Piacentino and Thakor (forthcoming) analyze a model in which households borrow from banks and the possibility of default interacts with the firms' output and employment.

# 3 Model

## 3.1 Environment

Time is discrete and infinite. There are four main players in the economy: firms run by managers, banks, households, and the government. There is also a bank-financed production sector, representing the assets in which banks invest, but it will play a minor role. Before presenting the details of the model, we briefly summarize the main structure.

We follow Quadrini (2017) in assuming that firms are subject to idiosyncratic risk and hold deposits for precautionary reasons, but we depart somewhat from his model. In particular, each firm is run by a risk-averse manager who acts in her own interest because of an agency friction. This friction motivates the manager's holding of an undifferentiated stake in the firm she runs, and thus an exposure to firm-specific idiosyncratic risk. In contrast, firms' owners (i.e., households) fully diversify away the idiosyncratic risk by holding equity stakes in all firms. These assumptions are motivated by the results of Panousi and Papanikolaou (2012), who document that managerial compensation affects firms' investments in response to idiosyncratic risk, and Glover and Levine (2015, 2017), who calibrate structural models of firm investment and show that managers respond more to firm-specific shocks in comparison to what shareholders would choose in the absence of agency frictions.

We model firms using a simpler approach than in typical structural corporate finance models with agency frictions, such as Nikolov and Whited (2014), for two reasons. First, our approach allows us to keep the firm side of the model tractable and focus on financial regulation. Second, we can easily solve the model in general equilibrium, which is crucial for our results. Many papers in the corporate finance literature model firms' dynamics in rich partial equilibrium settings, and extending those frameworks to general equilibrium would cloud our message.

Banks collect deposits from firms, invest in a bank-financed sector, and are subject to idiosyncratic shocks that make a fraction of them insolvent. Deposits at insolvent banks are made whole by the government through deposit insurance.

Households consume, supply labor, and own firms and banks. We will impose some parameter restrictions so that the objective of financial regulation will be solely that of maximizing the welfare of households, without any consideration for the welfare of managers.

We first convey our results in a simple model that includes only the main elements. In particular, the simple model has no aggregate risk, linear utility from consumption, exogenous risk of banks' investments, an ad hoc rule to determine firms' dividends, and no deposits held by households. We relax these assumptions in the quantitative model of Section 5.

#### 3.1.1 Firms and managers

There is a continuum of firms that are owned by households. Each firm is run by a manager who behaves in her own interest because of an agency friction and owns an equity stake in the firm.[9]

The role of the manager is to choose the amount of labor $l_t^i$ that is hired every period by the firm. The total output produced by the firm is $z_{t+1}^i l_t^i$, where $z_{t+1}^i$ is the firm's productivity. The productivity $z_{t+1}^i$ is subject to an idiosyncratic shock realized at the beginning of $t+1$.

[9]The contract between the firm and the manager is imposed exogenously, but we could derive it endogenously as the best contract that makes the manager unwilling to divert resources away from the firm for personal use. However, this would complicate the exposition and would not affect the results.

Crucially, $z^i_{t+1}$ is realized after the manager has chosen the labor input $l^i_t$ and has committed to pay the wage bill $w_t l_t$, where $w_t$ is the wage. For future reference, we will denote $\bar{z}$ to be the average realization of the shock: $E_t \left\{ z^i_{t+1} \right\} = \bar{z}$.

In addition, the firm holds deposits $d^i_t$ at time $t$ in the banking system, which earn a return $R^d_t$ at $t+1$. The government provides full deposit insurance, so deposits are safe. At time $t$, the manager takes the deposits $d^i_t$ as predetermined. That is, $d^i_t$ depends on the history of managers' choices and shocks realized before time $t$.

At the beginning of $t+1$, the total wealth available to the firm is given by

$$x^i_{t+1} = \left( z^i_{t+1} - w_t \right) l^i_t + R^d_t d^i_t, \tag{1}$$

where the first term on the right-hand side denotes the profits obtained by hiring workers (which can be negative if the productivity shock $z^i_{t+1}$ is low) and the second term denotes the gross return on deposits. Thus, if the realization of the productivity shock $z^i_{t+1}$ is low—in particular, if it is lower than the wage $w_t$—the firm must tap its deposit balance, $R^d_t d^i_t$, to pay its workers.

A fraction $\alpha$ of the wealth $x^i_{t+1}$ is paid out as dividends, and the remaining fraction $1-\alpha$ is retained by the firm, where $\alpha$ is an exogenous parameter (we will endogenize $\alpha$ in the full model of Section 5). Thus, deposits evolve according to $d^i_{t+1} = (1-\alpha)\, x^i_{t+1}$ or, using (1),

$$d^i_{t+1} = (1-\alpha) \left[ \left( z^i_{t+1} - w_t \right) l^i_t + R^d_t d^i_t \right]. \tag{2}$$

In this simple model in which $\alpha$ is exogenous, all results are unchanged if we make such a parameter time varying and firm specific, but we instead keep it constant to simplify the exposition.[10] Note that $\alpha$ is not chosen by the manager and, in this sense, can be understood as a part of the contract between the manager and the shareholders; we return to this point in Section 5 when we endogenize the choice of $\alpha$.

We emphasize that the manager's choice of labor $l^i_t$ is actually a joint decision of how many workers to hire and how many deposits to hold at $t+1$, subject to equation (2). Indeed, given prices, equation (2) shows that the choice of $l^i_t$ determines deposits at $d^i_{t+1}$.

We parameterize the equity stake of the manager by $\kappa$, so that the manager's dividends are $\alpha\kappa x^i_{t+1}$ and dividends paid to shareholders (i.e., to households) are $\alpha(1-\kappa)x^i_{t+1}$. The

[10] More precisely, we could replace $\alpha$ with $\alpha^i_t$, subject to the restriction that the average value is the same in the cross section, that is, $\int \alpha^i_t di = \alpha$ for all $t$.

manager consumes all her dividends each period,[11] so her consumption $c^i_{t+1}$ is

$$c^i_{t+1} = \alpha\kappa \left[ \left( z^i_{t+1} - w_t \right) l^i_t + R^d_t d^i_t \right], \tag{3}$$

which produces a utility value $\log c^i_{t+1}$. Dividends paid to shareholders (i.e., households) are given by

$$\pi^i_{t+1} = \alpha(1-\kappa) \left[ \left( z^i_{t+1} - w_t \right) l^i_t + R^d_t d^i_t \right]. \tag{4}$$

We can thus formalize the problem of the manager. The manager solves

$$V^m_t \left( d^i_t \right) = \max_{l^i_t, c^i_{t+1}, d^i_{t+1}} \beta^m E_t \left\{ \log c^i_{t+1} + V^m_{t+1} \left( d^i_{t+1} \right) \right\} \tag{5}$$

subject to (2) and (3), and where $\beta^m \in (0,1)$ is the discount factor of the manager and $E_t$ denotes the expectation with respect to the idiosyncratic productivity shock $z^i_{t+1}$.

Since the manager hires workers $l^i_t$ before the realization of the productivity shock $z^i_{t+1}$, and thus chooses the wage bill $w_t l^i_t$ before knowing $z^i_{t+1}$, the manager's consumption fluctuates over time. For any given choice of $l^i_t$, a high value of $z^i_{t+1}$ implies that firms' wealth $x^i_{t+1}$, dividends $(1-\alpha)\, x^i_{t+1}$, and manager's consumption $c^i_{t+1}$ will be high as well, and vice versa.

Crucially, the manager has the ability to control the volatility of her consumption $c^i_{t+1}$ through her choice of $l^i_t$. In particular, her consumption volatility is increasing in labor. In principle, the manager can choose $l^i_t = 0$, which would imply deterministic consumption $c^i_{t+1} = \alpha\kappa R^d_t d^i_t$; however, the manager will find it optimal to hire some workers, $l^i_t > 0$, and thus be exposed to idiosyncratic risk. The return on deposits and the supply of deposits from banks, both of which are related to capital requirements regulation, will affect the manager's desired exposure to such idiosyncratic risk.

The following proposition characterizes the optimal choice of managers. It shows that firm $i$'s labor demand, $l^i_t$, is proportional to its deposits $d^i_t$. Thus, although individual firms will grow and shrink as they receive different sequences of idiosyncratic shocks, we can solve for the equilibrium by easily aggregating the firms' building block of the model because the firm-size distribution does not affect aggregate variables. All proofs are in Appendix A.

**Proposition 1.** *(Managers and firms' labor demand) Manager $i$'s optimal choice of labor is*

$$l^i_t = \phi_t d^i_t, \tag{6}$$

[11] This assumption is without loss of generality because of some parameter restrictions that we will impose in Section 3.3.

*where $\phi_t$ is independent of $d_t^i$ and satisfies the following first-order condition:*

$$0 = E_t \left\{ \frac{z_{t+1}^i - w_t}{\left(z_{t+1}^i - w_t\right) \phi_t + R_t^d} \right\}, \tag{7}$$

The first-order condition (7) governs firms' decisions to hire workers. The firm's labor demand is lower in comparison to what it would be in an economy in which the manager is able to diversify away her exposure to the firms' idiosyncratic risk. That is why we refer to the willingness of firms to hire workers as the "good" risk-taking decision, because any force that creates an incentive for firms to hire more workers brings the economy closer to the first best.

The result of Proposition 1 implies that our model is consistent with some evidence documented by the corporate finance literature. First, as in Benmelech, Bergman and Seru (2015), our model generates a labor demand that is increasing in the safe financial assets held by the firm. Indeed, Benmelech, Bergman and Seru (2015) document a causal, positive effect of cash held by the firm (i.e., safe financial assets) on the firm's labor force. Second, as in Opler et al. (1999), riskier cash flow (i.e., higher variance of $z_{t+1}^i$) implies that the firm is willing to hold more cash. In addition, firms that do well (i.e., firms hit by a sequence of good values of $z_{t+1}^i$) accumulate cash internally, and firms that experience losses (i.e., firms with bad realizations of $z_{t+1}^i$) experience decreases in cash.

We emphasize that the result of Proposition 1 is independent of the equity stake $\kappa$ of the manager, provided that $\kappa > 0$. When solving for the equilibrium, we will exploit this feature to simplify the welfare analysis. In particular, we will impose parametric restrictions which imply that managers' consumption is arbitrarily small and all dividends will be paid to shareholders (i.e., we will assume that $\kappa$ is arbitrarily small) while at the same time preserving the implications of the agency friction on firms' behavior (see Section 3.3).

We will derive our theoretical results under a general specification of the stochastic process for $z_{t+1}^i$. However, in the simulations, we will use the following functional form: $z_{t+1}^i = 1/p_z$ with probability $p_z \in (0, 1)$, and $z_{t+1}^i = 0$ with probability $1 - p_z$. This implies that $\bar{z} \equiv E_t \left\{z_{t+1}^i\right\}$ will be normalized to one.

### 3.1.2 Banks and bank-financed sector

Banks live for a single period: each bank is set up at time $t$ and is liquidated at the beginning of time $t + 1$.[12] Each newly created bank receives an amount $n_t$ of net worth from its

[12]This assumption is made without loss of generality because our model does not include adjustment costs on banks' size nor costs to raise equity.

shareholders (i.e., households). Then, the bank collects deposits $d_t$ and uses the resources $n_t + d_t$ to purchase physical capital $k_t$. In the economy as a whole, capital accumulates endogenously, similar to a standard real business cycle model.

At the beginning of $t + 1$, each bank is hit by an idiosyncratic quality shock $\varepsilon$, with $E\{\varepsilon\} = 1$. This shock captures the fact that some banks experience higher or lower losses on their loans and investments in comparison to the average bank in the economy. Formally, after the shock, the stock of capital held by a particular bank is $\varepsilon k_t$; the total stock of capital in the banking sector as a whole is unchanged because the shock $\varepsilon$ is idiosyncratic. Banks lend the physical capital $\varepsilon k_t$ to a bank-financed sector, which then returns the undepreciated fraction $1-\delta$ of the physical capital plus a return $r_{t+1}$ to the banks. Thus, bank assets can be interpreted as loans to some producers that rely on banks for financing—different from those analyzed in Section 3.1.1—or as loans to other borrowers unrelated to production (e.g., home mortgages). Banks' profits are given by the cash flow $\varepsilon k_t (1 - \delta + r_{t+1})$ net of the repayment $R_t^d d_t$ to depositors, where $R_t^d$ is the gross return on deposits. Profits are bounded below by a limited liability constraint: banks with negative profits pay zero to shareholders and default on their depositors.

Banks face a capital requirement $\zeta$ that limits their ability to raise deposits. That is, their equity ratio $n_t/k_t$ must be weakly larger than the regulatory requirement $\zeta$.

In this simple model, the risk of the idiosyncratic shock $\varepsilon$ is exogenous. However, there is still a sense in which banks can increase their risk-taking to exploit the deposit insurance subsidy: even though the risk per unit of capital is fixed, the total risk-taking of a bank depends on the size $k_t$ of the bank's balance sheet. In the equilibrium of our baseline model, banks take advantage of the deposit insurance subsidy by expanding beyond what would be socially optimal. Thus, deposit insurance increases the total amount of banks' bad risk-taking even though the risk per unit of capital is exogenous. In the quantitative model of Section 5, banks will also be able to increase their level of risk per unit of capital, but the qualitative results will be the same.

We can now formalize the problem of banks. Given $n_t$, the bank's problem is

$$\max_{k_t, d_t} \int \left\{ \varepsilon k_t (1 - \delta + r_{t+1}) - R_t^d d_t \right\}^+ dF(\varepsilon) \tag{8}$$

s.t.

$$k_t = d_t + n_t \tag{9}$$

$$n_t \geq \zeta k_t \tag{10}$$

where (9) is the budget constraint, (10) reflects the capital requirement, $\{\cdot\}^+ = \max\{\cdot, 0\}$ is the positive part of banks profits, and $F(\cdot)$ is the CDF of banks' idiosyncratic productivity shocks. Our theory results hold for a generic $F(\cdot)$, but for our simulations, we will assume that $\varepsilon$ is log-normally distributed with mean $E(\varepsilon) = 1$ and variance $\sigma^2$; that is, $\log \varepsilon \sim \mathbb{N}\left(-\frac{1}{2}\sigma^2, \sigma^2\right)$. The deposits at banks that receive a low value of the productivity shock $\varepsilon$, such that $\varepsilon k_t (1 - \delta + r_{t+1}) < R_t^d d_t$, are fully repaid to depositors thanks to the deposit insurance intervention.

When shareholders invest in banks' equity, they invest in a mutual fund that diversifies its holdings of equity over all banks in the economy. The return on equity $R_{t+1}^n$ is given by

$$R_{t+1}^n = \frac{1}{n_t} \int \left\{\varepsilon k_t (1 - \delta + r_{t+1}) - R_t^d d_t\right\}^+ dF(\varepsilon). \tag{11}$$

Equation (11) implies that $\underline{\varepsilon}_{t+1}$, the highest value of $\varepsilon$ at which banks default on their depositors, is implicitly defined as

$$R_t^d d_t = \underline{\varepsilon}_{t+1} k_t (1 - \delta + r_{t+1}). \tag{12}$$

Subsidized deposit insurance creates an incentive for banks to lower their lending rate $r_{t+1}$, thereby increasing the amount of physical capital in the economy. The logic of this result is the usual combination of limited liability and a lack of responsiveness of the deposit rate $R_t^d$ because of deposit insurance. The overaccumulation of capital arising from the distortion of subsidized deposit insurance entails a welfare loss.

From a mechanical perspective, the problem of banks can be solved as follows. Because in equilibrium the return on deposits will be less than the return on banks' capital, the capital requirement (10) is always binding. As a result, banks' technology is constant returns to scale. Given $n_t$, (10) can be used to compute the size $k_t$ of the banks' assets, and then the budget constraint (9) can be used to solve for deposits $d_t$. Finally, the equilibrium value of $n_t$ is determined such that (12) holds, given the return on equity demanded by banks' shareholders in equilibrium.

To better understand the behavior of banks, we can combine (11), (9), and (10) to obtain

$$\int_{\underline{\varepsilon}_{t+1}}^{\infty} \varepsilon (1 - \delta + r_{t+1}) \, dF(\varepsilon) = \zeta R_{t+1}^n + (1 - \zeta) \Pr\left\{\varepsilon \geq \underline{\varepsilon}_{t+1}\right\} R_t^d. \tag{13}$$

Equation (13) equalizes the benefits and costs of purchasing an extra dollar of physical capital for a bank. The marginal benefit is the gross return $\varepsilon (1 - \delta + r_{t+1})$, only in the states in which the bank is not in default, that is, for $\varepsilon \geq \underline{\varepsilon}_{t+1}$. The marginal cost of financing the purchase corresponds to the cost of raising more deposits and more equity. A fraction $\zeta$ of the purchase requires equity, for which households require a return $R_{t+1}^n$. The remaining fraction $1-\zeta$ can be financed with deposits, which require a return $R_t^d$; the bank internalizes the cost of deposits only in the states of the world in which it remains solvent, which happens with probability $\Pr\left\{\varepsilon \geq \underline{\varepsilon}_{t+1}\right\}$.

We close this section by describing the problem of the bank-financed sector. These players rent capital $k_t$ from banks and use it for production, according to the production function $Ak_t^\gamma$, with $\gamma \in (0,1)$ and $A > 0$. The output can be interpreted as production by bank-financed firms or as housing services, if $k_t$ is interpreted as mortgages. The profits $\pi_{t+1}^{bf}$ (where $bf$ stands for "bank financed") are obtained by maximizing

$$\pi_{t+1}^{bf} = \max_{k_t} Ak_t^\gamma - r_{t+1}k_t, \tag{14}$$

which implies the first-order condition

$$A\gamma k_t^{\gamma-1} = r_{t+1}. \tag{15}$$

The profits $\pi_{t+1}^{bf}$ are positive because bank-financed players use a decreasing returns to scale technology, and they are distributed lump sum to households.

### 3.1.3 Households

Households are infinitely lived agents with linear utility of consumption $c_t$ and convex disutility of labor supply $l_t$. This quasi-linear specification allows us to easily characterize their choices, but we will use a more general utility function in the quantitative model of Section 5. Households supply the labor used by firms and the equity to banks, and they earn the profits generated by the firms run by managers, the banks, and the bank-financed firms.

Households' utility is given by

$$\sum_{t=0}^{\infty} \beta^t u\left(c_t, l_t\right) = \sum_{t=0}^{\infty} \beta^t \left[c_t - \beta\chi \frac{l_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}\right], \tag{16}$$

where $\chi > 0$, $\eta > 0$, and $\beta \in (0,1)$. Households choose labor at time $t$ but do not provide that labor until the beginning of period $t+1$ when production actually occurs; thus we discount the disutility of labor chosen at $t$ with an additional $\beta$ in equation (16).

A household that starts with wealth $a_t$ solves the problem

$$V_t^h\left(a_t\right) = \max_{c_t, l_t, n_t} \; c_t - \beta\chi \frac{l_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \beta V_{t+1}^h\left(a_{t+1}\right)$$

subject to the budget constraint

$$c_t + n_t \leq a_t \tag{17}$$

and to an upper bound on the amount of hours worked, $l_t \leq \bar{l}$. Wealth at $t+1$ is given by

$$a_{t+1} = w_t l_t + n_t R^n_{t+1} + \int \pi^i_{t+1} di + \pi^{bf}_{t+1} - T_{t+1}. \tag{18}$$

At time $t$, the household chooses how to allocate its wealth $a_t$ between consumption $c_t$ and investment in bank equity $n_t$, and it chooses the labor supply $l_t$ taking as given the wage $w_t$. At $t+1$, the wealth is the sum of its labor income $w_t l_t$, the gross return on banks' equity $n_t R^n_{t+1}$, and the profits $\int \pi^i_{t+1} di$ and $\pi^{bf}_{t+1}$ distributed by firms and by the bank-financed sector, net of lump-sum taxes $T_{t+1}$.[13]

The linear utility from consumption implies that households' value function is linear as well, that is, $\left(V^h\right)'(a) = 1$. Thus, their labor supply curve is given by

$$w_t = \chi \left(l_t\right)^{\frac{1}{\eta}}, \tag{19}$$

and the supply of banks' net worth $n_t$ is fully elastic (i.e., they are willing to supply any amount) provided that the return on equity $R^n_{t+1}$ satisfies

$$R^n_{t+1} = \frac{1}{\beta}. \tag{20}$$

Note that households' choice of $n_t$ affects the accumulation of physical capital $k_t$, given firms' deposits $\int d^i_t \, di$ and banks' budget constraint (9).

### 3.1.4 Government

The government taxes households in order to ensure that depositors at failed banks at the beginning of $t+1$ are made whole. The government seizes output at failed banks (who return zero to their equity holders) to partially defray the expenses of paying back depositors.

The total amount of tax to be collected is

$$T_{t+1} = \int_{-\infty}^{\varepsilon_{t+1}} \Bigg[ \underbrace{R^d_t d_t}_{\text{owed to depositors}} - \underbrace{\varepsilon k_t \left(1 - \delta + r_{t+1}\right)}_{\text{collected from banks}} \Bigg] dF(\varepsilon), \tag{21}$$

[13] Note that we allow households to choose only investments in banks' equity claims because that is a key element of our model. In principle, we could enrich households' portfolio choice by allowing them to trade claims on firms' dividends; however, that would not change any of the results and would simply add more notation because of our representative household assumption.

where $R_t^d d_t$ is the amount owed to depositors, and $\varepsilon k_t\left(1-\delta+r_{t+1}\right)$ for $\varepsilon<\underline{\varepsilon}_{t+1}$ denotes the assets of failed banks.

## 3.2 Equilibrium definition and aggregation of firms' decisions

Given initial conditions $d_0^i$ for all $i$ and $a_0$, and exogenous stochastic processes for $\left\{z_t^i\right\}$ and $\{\varepsilon\}$, an equilibrium is a collection of firm policies, bank policies, household policies, and government taxes such that

1. Firms' deposits $d_t^i$, managers' consumption $c_t^i$, and managers' choice for labor demand $l_t^i$ solve (5);
2. Banks' choices for capital $k_t$ and deposits $d_t$ solve their problem (8);
3. Households' choices for supply of labor $l_t$ and net worth $n_t$ maximize their utility (16);
4. The government taxes households lump-sum and uses the proceeds to pay depositors at failed banks according to equation (21);
5. The wage $w_t$ and the return on deposits $R_t^d$ clear the labor and deposit markets, respectively.

The aggregate resource constraint will hold by Walras' law. Nonetheless, we state it to clarify the mechanics of the model:

$$c_t+k_t-(1-\delta)k_{t-1}\leq \bar{z}l_{t-1}+Ak_{t-1}^{\gamma},$$

where $l_{t-1}=\int l_{t-1}^i\,di$ is total labor. The resources produced each period are the output $\bar{z}l_{t-1}$ of manager-run firms and the output $Ak_{t-1}^{\gamma}$ of the bank-financed sector; recall that the output of manager-run firms depends on labor choices made at $t-1$. These resources are used for consumption $c_t$ or to invest in the stock of capital $k_t$, net of the undepreciated stock $(1-\delta)k_{t-1}$ from the previous period, as in the standard growth model.

When computing the equilibrium, we must aggregate the firms' building block of the model. However, as noted in Section 3.1.1, firms' labor demand does not depend on the distribution of deposits across firms, a result that simplifies the analysis considerably. Thus, total labor demand $l_t$ is

$$\begin{aligned} l_t &= \int l_t^i\,di \\ &= \phi_t d_t\,, \end{aligned} \tag{22}$$

where the second line uses the result $l_t^i = \phi_t d_t^i$ from Proposition 1 and defines $d_t$ to be total deposits across firms, $d_t = \int d_t^i \, di$. Similarly, we can easily aggregate over firms' law of motion for deposits. To do so, we first impose the restriction

$$\alpha = 1 - \beta. \tag{23}$$

The restriction in (23) can be justified in either of two ways. First, (23) arises endogenously in the nonstochastic steady state of the full model of Section 5, in which we endogenize firms' dividend policy. Second, as an alternative justification, we note that (23) is necessary and sufficient to obtain a benchmark result in which Modigliani-Miller holds for banks if we shut down deposit insurance (see Appendix B). Then, using (2) and (23), the law of motion of aggregate deposits $d_t$ is

$$d_{t+1} = \beta \left[ \left( \bar{z} - w_t \right) l_t + R_t^d d_t \right], \tag{24}$$

where $\bar{z}$ denotes the mean of the idiosyncratic firm productivity $z_{t+1}^i$.

## 3.3 Welfare

When computing optimal capital requirements, we should, in principle, account for the welfare of both households and managers. However, to do so we must take a stand on the weight to be assigned to households and managers in the welfare function—a task that would significantly complicate the analysis. To address this issue, we note that, in practice, the fraction of managers in the population is small relative to households, and their compensation is small relative to firms' profits. Thus, in this section we formalize the notion that total consumption and total welfare are well approximated by households' consumption and welfare, respectively, so that we can compute the optimal capital requirement by looking solely at the welfare of households.

We define the welfare function $W$ to be the sum of households' welfare and managers' welfare:

$$W = V_0^h(a_0) + \theta \int V_0^m(d_0^i) \, di, \tag{25}$$

where $\theta > 0$ is a Pareto weight that defines managers' contribution to total welfare in comparison to households. The welfare analysis depends, in principle, on the Pareto weight $\theta$ and the fraction $\kappa$ of dividends paid to managers. However, we discipline these two parameters in such a way that (i) welfare depends only on households' utility, $W = V_0^h(a_0)$; (ii) the implication of the agency friction and the easy aggregation of the firms' building block of the model, derived in Proposition 1, continue to hold; and (iii) aggregate consumption depends only on households' consumption.

To discipline $\theta$, we note that the fraction of managers in the population is, in practice, small. As a result, we consider $\theta$ to be arbitrarily small so that the economy-wide welfare depends only on households' utility: $W = V_0^h(a_0)$. In Appendix C, we provide a simple extension of the model in which we formalize the measure of managers relative to households, take the limit of such measure to zero, and show that $W = V_0^h(a_0)$ even if we set the Pareto weight $\theta$ to one (i.e., even if each manager has the same Pareto weight as each household).

To discipline $\kappa$, we note that managers' compensations are small relative to the overall dividends paid by firms. As a result, we choose $\kappa$ to be arbitrarily small, which implies that all dividends are paid to households.[14]

We summarize the implications for choosing $\theta$ and $\kappa$ to be arbitrarily small in the following proposition.

**Proposition 2.** *(Parameter restrictions and welfare) If $\kappa \to 0$ and $\theta \to 0$ (with $\theta/\kappa$ constant along the limiting sequence), manager $i$'s optimal choice in Proposition 1 is not affected, manager $i$'s consumption converges to $c_{t+1}^i \to 0$, profits distributed to households, defined in (4), become*

$$\pi_{t+1}^i \to \alpha \left[ \left( z_{t+1}^i - w_t \right) \phi_t + R_t^d \right] d_t^i,$$

*and the economy-wide welfare function $W$ becomes equal to the value function of households, $W \to V_0^h(a_0)$.*

The key result of Proposition 2 is that the importance of managers vanishes for welfare purposes (i.e., their consumption converges to zero) without affecting the key first-order condition that governs their labor demand, (7). The implication of Proposition 2 is that we can just focus on the welfare of households when evaluating financial regulation, even though the model exhibits a behavior driven by an agency friction.

# 4 Theoretical results

This section derives the main theoretical results of the paper. We begin by showing that our model generates a liquidity premium on deposits (Section 4.1). Then, we study the effects of capital requirements on firms' good risk-taking (Section 4.2), and we examine the welfare implications of ignoring our novel channel when setting the capital requirement (Section 4.3). Because what we call the "bad risk-taking" channel is a standard mechanism in the literature

[14] Setting an arbitrarily small $\kappa$ drives managers' consumption to zero. However, we show in Appendix C that when we formalize the measures of managers and take the limit as this measure goes to zero, managers' consumption remains positive and well defined even if $\kappa \to 0$.

(Van den Heuvel, 2008; Begenau, 2018), we defer discussion of how banks' bad risk-taking interacts with firms' deposits to Appendix D.

Throughout this section, we illustrate the theory with numerical examples to highlight how good risk-taking and bad risk-taking are traded off in the determination of the optimal capital requirements. In Section 5, we calibrate a quantitative model to better estimate the magnitudes of the effects we describe in this section.

## 4.1 Liquidity premium on deposits

We begin by showing that our model generates a premium on the return on deposits that is equal to their marginal private value (i.e., the marginal value from the firms' point of view). We focus on the steady state, as we do for most of our theoretical analysis, and denote steady-state values by dropping the time subscript.

**Proposition 3.** *(Deposit premium) Assume that* $Var\left(z_{t+1}^i\right) > 0$. *In steady state, the deposit premium is*

$$\begin{aligned} 0 < \frac{1}{\beta} - R^d &= \int \left[ \left( E_t \left\{ z_{t+1}^i \right\} - w \right) \left. \frac{\partial l_t^i}{\partial d_t^i} \right|_{w \text{ fixed}} \right] di \\ &= \left( \bar{z} - w \right) \phi, \end{aligned} \tag{26}$$

*where the right-hand side of (26) denotes the marginal private value of deposits.*

The deposit premium is positive because deposits provide insurance to firms' managers against the exposure to idiosyncratic risk. Such a premium is then equal to the marginal private value of deposits (i.e., the right-hand side of equation (26)). To understand this expression, consider the following. If each firm began time $t$ with an additional \$1 of deposits, managers would take on more risk (i.e., hire more workers) and firm $i$ would earn a profit $z_{t+1}^i - w_t$ per additional worker hired. Such profits would then be valued by households according to their constant unitary marginal utility of consumption.

Crucially, the marginal private value of deposits is computed by taking the wage $w$ as given. In the next sections, we show that the optimal capital requirement should instead be set by taking into account the response of the wage. This consideration gives rise to a wedge between the private value of deposits (i.e., the value of deposits from the firms' point of view) and the social value (i.e., the value of deposits for the regulator), which then reduces the welfare cost of increasing capital requirements.

Proposition 3 also provides a direct link between labor market outcomes and the deposit premium. Indeed, equation (26) shows that the deposit premium is related to the wage $w$,

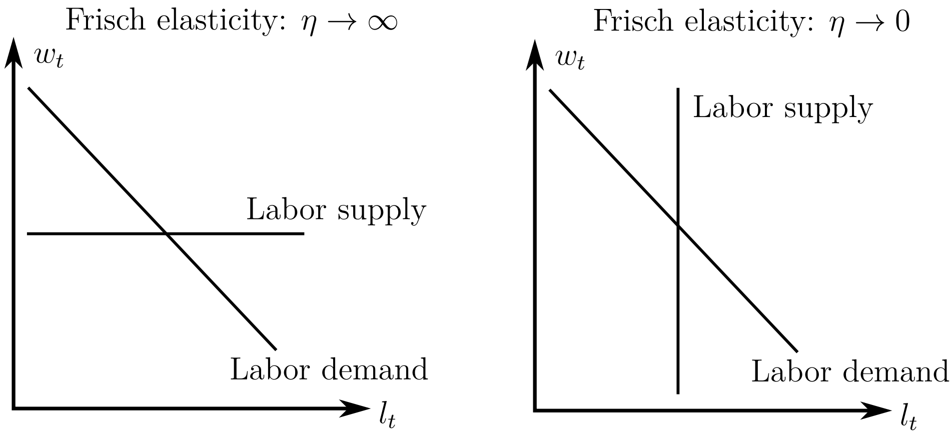


**Figure 1.** Equilibrium in the labor market. Left panel: the labor supply curve is infinitely elastic and thus pins down the wage. Right panel: the labor supply curve is inelastic and thus pins down the equilibrium value of employment.

which in turn is affected by the utility parameter $\chi$. In Section 5, we will use this result to calibrate $\chi$ to match the deposit premium in the data.

## 4.2 Capital requirements and good risk-taking

This section presents the main result about the interaction between capital requirements and firms' good risk-taking. The effects of modifying capital requirements differ dramatically depending on how firms' input prices—in our model, wages—adjust in response to the policy change.

In this simple model, we show next that the equilibrium response of wages to policy changes depends on the *Frisch elasticity of labor supply*. This elasticity is defined as the percentage change in households' labor supply in response to a 1% change in the wage, keeping consumption constant. Using the first-order condition of households (19), we obtain that

$$\text{Frisch elasticity of labor supply} = \eta$$

(recall that $\eta$ is one of the parameters that affects the disutility of labor).

To further clarify the role of the Frisch elasticity of labor supply, Figure 1 plots the demand and supply in the labor market in two extreme cases. In the left panel, the Frisch elasticity of labor supply is $\eta \to \infty$ (i.e., labor supply is fully elastic and households have linear disutility from labor). In this case, the wage is essentially fixed because the households' first-order condition (19) implies $w_t = \chi$. Thus, if firms demand more inputs in response to policy changes, the wage does not change, and the effect of financial regulation on employment is maximal. The right panel plots the other extreme case, in which the Frisch elasticity is $\eta \to 0$ (i.e., labor supply is fixed). In this case, financial regulation produces an impact only on wages $w_t$ and has no effect on employment $l_t$.

In the rest of this section, we formalize the above results and then provide an illustrative example. We maintain our focus on the two extreme cases with fully elastic labor supply (i.e., $\eta \to \infty$) and fixed labor supply (i.e., $\eta \to 0$).

Tightening capital requirements reduces deposits, which in turn makes it harder for firms to self-insure against idiosyncratic risk.[15] In response, firms reduce labor demand. The extent to which this change in labor demand affects equilibrium labor $l_t$ depends on the Frisch elasticity of labor supply, $\eta$. If $\eta \to \infty$ (i.e., labor supply is fully elastic), any change in labor demand is transmitted one-for-one into changes in the equilibrium value of labor, $l_t$. If $\eta \to 0$ (i.e., labor supply is fixed), changes in labor demand produce only changes in the wage, $w_t$, but no changes in employment. We summarize this result in the next proposition, focusing on a comparison across steady states and denoting the steady-state value of endogenous variables by dropping the time subscript.

**Proposition 4.** *(Capital requirements and good risk-taking) Assume that there exists a steady-state equilibrium with $l > 0$. Then:*

- *If the Frisch elasticity of labor supply is $\eta \in (0, \infty)$, then $\partial w/\partial \zeta < 0$ and $\partial l/\partial \zeta < 0$;*
- *If the Frisch elasticity of labor supply is $\eta \to \infty$, then $\partial w/\partial \zeta = 0$ and $\partial l/\partial \zeta < 0$;*
- *If the Frisch elasticity of labor supply is $\eta \to 0$, then $\partial w/\partial \zeta < 0$ and $\partial l/\partial \zeta = 0$.*

The first implication of Proposition 4 is that the marginal social value of deposits differs from the marginal private value for all $\eta < \infty$.[16] The marginal private value of deposits from the point of view of each firm is implicitly computed by taking the wage as given, but the social value accounts for the fact that the wage may adjust in general equilibrium as the supply of deposits changes. To clarify this point, consider the limiting case in which the labor supply is fixed (i.e., $\eta \to 0$). In this case, an increase in the availability of deposits—arising from, for instance, lower capital requirements—triggers an increase in the wage that exactly offsets the private benefits of the additional deposits. As a result, changing capital requirements does not affect firms' good risk-taking or the equilibrium value of output

[15] Lemma 6 in Appendix A shows that the steady-state level of deposits, denoted by $d$, satisfies $\partial d/\partial \zeta < 0$ for all $\eta \in (0, \infty)$ as well as in the limit as $\eta$ goes to either zero or infinity.

[16] This reasoning requires deposits to be above a certain threshold, which depends on parameters, so that firms hire workers in equilibrium; hence, we require $l > 0$ as an assumption of the proposition. If the quantity of deposits is too small, firms cannot insure against idiosyncratic risk, and thus they might decide not to hire any workers.

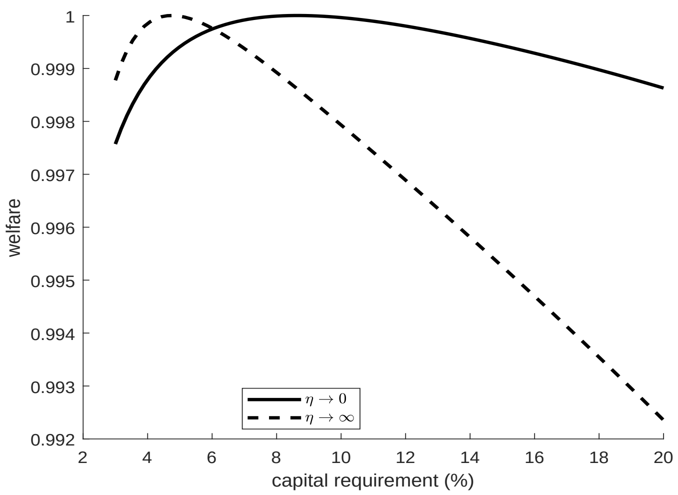


**Figure 2.** The figure plots total welfare $W(\zeta)$ for values of the capital requirement $\zeta$ ranging from 3% to 20%, starting from an initial steady-state where $\zeta = 8\%$. Parameter values are $\beta = 0.95$, $p_z = 0.952$, $\delta = 0.1$, $A = 0.52$, $\sigma = 0.063$, $\chi = 0.96$, and $\gamma = 0.3$. We choose $A$, $\sigma$, and $\chi$ to induce a deposit premium of 2%, a default probability of 10%, and an equilibrium consumption value of 1. The dotted line assumes a fully elastic labor supply (i.e., $\eta \to \infty$); the solid line assumes a fixed labor supply (i.e., $\eta \to 0$), where labor supply is fixed at $\bar{l} = 0.555$. Details on these calculations are in Appendix E.

produced by firms. This is not to say that capital requirements do not produce any effect at all. As we discuss in Appendix D, even with fixed labor supply, capital requirements affect banks' bad risk-taking and the size of the banking sector.

The second takeaway from Proposition 4 is that the existence of a deposit premium in the data is not sufficient to conclude that deposits have a positive marginal social value. In our model, deposits display a positive premium (i.e., $1/\beta - R^d > 0$, as shown in Proposition 3) even if they have a zero marginal social value. This is because the return on deposits $R^d$ is determined by the firms' first-order conditions, which account only for private marginal values.

The last and key implication of Proposition 4 is that the existence of a wedge between the marginal and social values of deposits has crucial implications for determining the optimal capital requirement. If deposits' marginal social value is indeed less than private values, the availability of an additional dollar of deposits is not very important. As a result, capital requirements can be set at a somewhat high level to limit the negative effects of subsidized deposit insurance on banks' bad risk-taking.

To illustrate this final point, we compare two numerical examples, where the Frisch elasticity is $\eta \to \infty$ or $\eta \to 0$. We consider an economy that is initialized at a steady state with a capital requirement $\zeta = 8\%$ and where, at $t = 0$, the regulator permanently changes the capital requirement to a different $\zeta$. We then compute welfare $W(\zeta)$ as the economy transitions and reaches the new steady state.[17] Figure 2 plots $W(\zeta)$ for capital requirements ranging from 3% to 20%. We stress that we have constructed the examples so that both economies with $\eta \to \infty$ and $\eta \to 0$ have the same deposit premium of 2% in the initial steady state with an 8% capital requirement.

The optimal capital requirement differs substantially between the two extreme cases for the Frisch elasticity $\eta$. With $\eta \to \infty$ (i.e., fully elastic labor supply), the private and social values of deposits are equalized, and the optimal capital requirement is 4.8%. With $\eta \to 0$ (i.e., fixed labor supply), the marginal social value of deposits is zero, and the optimal capital requirement is much higher, at 8.7%. In addition, the sensitivity of welfare to changes in capital requirements is much lower in the second case. In Appendix D, we explain why the optimal capital requirement under a fixed labor supply is not too high despite the zero marginal social value of deposits.[18]

## 4.3 Capital requirements and welfare

The previous analysis has compared economies with different Frisch elasticities of labor supply. We now discuss how to compute the effect of our novel channel in a given economy. Indeed, in the quantitative analysis of Section 5, we want to quantify the importance of including firms' deposits and the good risk-taking channel on the determination of the optimal capital requirement.

We consider two approaches to compute the importance of firms' deposits and the good risk-taking channel. The first approach is to compare the optimal capital requirement with that of another model in which deposits are held by households only, rather than firms. Since this comparison is conceptually simple, we will undertake it directly in the quantitative model of Section 5. In this section, we explore a second approach that illustrates the magnitude of our channel without resorting to a different model. Specifically, we compute the optimal capital requirement obtained by shutting down our novel channel that operates through wages and which is described in Proposition 4. To do so, we replace the path for wages that arises after changing the capital requirement with the one that would arise if the capital requirement had not changed, compute counterfactual paths for consumption and labor, and calculate an alternative measure of welfare, which we denote as $\widehat{W}(\zeta)$. Crucially, we

[17] Welfare $W(\zeta)$ is equal to the value function of households (see Proposition 2); we emphasize its dependence on the capital requirement $\zeta$ chosen at $t = 0$ by the regulator.

[18] The logic of this result is similar to that in Begenau (2018), who shows that tighter capital requirements have two opposite effects on bank lending. These two forces generate a trade-off even if changes in capital requirements have no effect on welfare through the supply of deposits. See Appendix D for more details.

compute $\widehat{W}(\zeta)$ by shutting down only our novel channel in the context of the labor market, without altering the way capital requirements affect banks' bad risk-taking.[19]

We consider an economy that is initially in a steady state with a capital requirement $\zeta_{-1}$, and we solve for the equilibrium as the regulator changes the capital requirement to some different $\zeta$ at $t = 0$. We then compute the welfare that arises under the new capital requirement $\zeta$, denoted by $W(\zeta)$, and the welfare $\widehat{W}(\zeta)$ that does not account for our novel channel. We next describe how we compute $\widehat{W}(\zeta)$.

To compute the welfare $\widehat{W}(\zeta)$ that does not include our new channel, we construct a fictitious path for consumption and labor, $\{\hat{c}_t(\zeta), \hat{l}_t(\zeta)\}_{t=0}^{\infty}$, that would arise had wages not adjusted in response to the new capital requirement. More precisely, we limit the effect of this experiment on employment, without affecting the way capital requirements affect banks' bad risk-taking. Thus, our fictitious consumption and labor $\{\hat{c}_t(\zeta), \hat{l}_t(\zeta)\}_{t=0}^{\infty}$ are constructed as follows:

- We compute firms' labor demand $\hat{l}_t$ given (i) the correct equilibrium paths of firms' deposits $\{d_t(\zeta)\}_{t=0}^{\infty}$ and the return on deposits $\{R_t^d(\zeta)\}_{t=0}^{\infty}$ that arise under the new capital requirement, but (ii) assuming that firms face the wage $\hat{w}_t(\zeta) = w_{-1}$ for all $t$, that is, the wage that would prevail if the capital requirement had remained constant;
- We compute consumption $\hat{c}_t$ that would arise using (i) the correct equilibrium value of the output of the bank-financed sector and (ii) the output produced by firms if they had employed the fictitious amount of workers $\hat{l}_t$, rather than the true equilibrium amount $l_t$.

We then evaluate the utility of households at the path of consumption and labor $\{\hat{c}_t(\zeta), \hat{l}_t(\zeta)\}_{t=0}^{\infty}$, which gives us the welfare measure $\widehat{W}(\zeta)$ (see Section 3.3 for the link between welfare and households' utility). With this approach, we are able to isolate the effect of our channel on welfare through the labor market, without contaminating our measure with the way capital requirements affect banks.

Figure 3 illustrates the result of this section for an economy with a Frisch elasticity of labor supply $\eta = 1$.[20] The solid line in Figure 3 plots the correct welfare $W(\zeta)$. The optimal capital requirement in this economy is $\zeta^* = 6.8\%$; we normalize $W(\zeta)$ to one at such a value.[21] The dashed line in Figure 3 plots the welfare $\widehat{W}(\zeta)$ that does not include our novel

[19] In the quantitative model of Section 5, we show that the two approaches described here—using a model with only households' deposits versus shutting down our channel that acts through wages—deliver approximately the same optimal capital requirement, well below the true optimum.

[20] This is in line with standard values employed in macro-labor models and, for our purposes, is the most conservative value that is in line with the empirical evidence of Chetty et al. (2011).

[21] In this simple model, welfare is measured in units of consumption because of the linearity of the utility function in $c_t$.

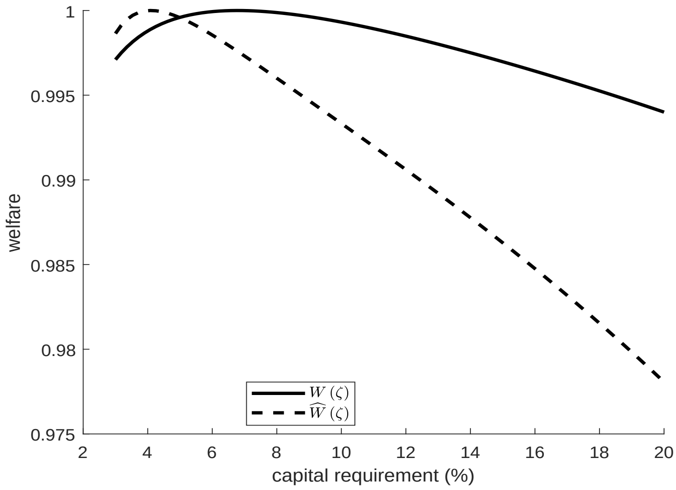


**Figure 3.** The solid line plots the full welfare $W(\zeta)$ for values of the capital requirement $\zeta$ ranging from 3% to 20%, starting from an initial steady state where $\zeta_{-1} = 8\%$. The dashed line plots the welfare $\widehat{W}(\zeta)$ that does not include the effects of our novel channel operating through the labor market and wages. Parameter values are $\beta = 0.95$, $p_z = 0.95$, $\delta = 0.1$, $A = 0.52$, $\sigma = 0.063$, $\chi = 0.96$, $\gamma = 0.3$, and $\eta = 1$.

channel. The welfare measure $\widehat{W}(\zeta)$ peaks at $\hat{\zeta} = 4.1\%$, which is significantly lower than the correct capital requirement $\zeta^* = 6.8\%$. Because our novel channel reduces the cost of increasing capital requirements, the optimal capital requirement is much higher than the one that maximizes the component of welfare that does not include our effect. In addition, a welfare analysis based on $\widehat{W}(\zeta)$ overestimates the losses of setting capital requirements too high. All the qualitative results derived here will also hold in the quantitative model of Section 5.

# 5 Quantitative model

In this section, we extend the theoretical model with the objective of performing a quantitative analysis. In particular, we undertake two main exercises. First, we solve for the optimal capital requirement in a quantitative version of the model. Second, we quantify the contribution of our novel channel by computing the optimal capital requirement that abstracts away from changes in wages or deposits held by firms. In particular, we follow two approaches to quantify our contribution: we compute (i) the capital requirement that would be chosen if we shut down the effects of our novel channel that operates in the labor market, similar to Section 4.3; and (ii) the capital requirement that would be chosen in a comparable model in which only households hold deposits.

We find that the optimal capital requirement in the full quantitative model is 18.7%, the capital requirement that would be chosen in the full model absent our novel channel is 15.3%, and the capital requirement that maximizes welfare if all deposits are held by households is 13.6%. Thus, the main reason why the optimal regulation is tighter in our model is related to our novel channel acting through wages in general equilibrium, rather than who holds the deposits.

We extend the baseline model along five dimensions: (i) we endogenize firms' dividend policy, rather than setting it exogenously; (ii) we introduce aggregate risk; (iii) we allow banks to risk-shift by giving them access to a technology that increases their idiosyncratic risk, subject to a cost; (iv) we give households a constant relative risk aversion (CRRA) utility from consumption, rather than linear utility; and (v) we give households utility from holding deposits.[22] We briefly describe these features and then present the calibration and results.

We solve the model using nonlinear global projection methods that allow for rich dynamics and occasionally binding constraints. We use this approach to match some key features of the time series of bank default rates, which are low in normal times but spike during crises. Our quantitative model allows banks to endogenously engage in more "bad risk-taking" by making riskier and less productive loans, but they do so less than half of the time in the calibrated model. Thus, a solution approach based on standard perturbation methods would not adequately capture this key feature of the data.

One realistic feature we do not include in the quantitative model are firms' holdings of other safe assets, such as government bonds. Such a feature would substantially complicate the analysis but would not change the main results, so long as the supply of such assets is not systematically correlated with changes in capital requirements; this assumption is used, for instance, in Begenau (2018). Our claim is based on two arguments. First, firms' holdings of other safe assets are small in comparison to deposits (see Appendix F). This statement is based on data from the Flow of Funds and, thus, accounts for privately held firms; using statistics that account for private firms is the right approach for our purposes because we use a general equilibrium model of the whole economy, and privately held firms in the United States account for about two-thirds of aggregate employment (Dinlersoz et al., 2018). Second, and more importantly, the fact that firms hold additional safe assets does not alter our main results as long as the model is calibrated to match the deposit premium in the data. As shown in Proposition 3, the deposit premium is equal to firms' marginal

[22]We have explored simpler quantitative versions of the model in which households do not hold deposits, and as expected, the optimal capital requirement in those models is even higher than what we document here.

value of banks' deposits, and thus it captures firms' willingness to hire out of an extra dollar of deposits. Thus, the labor market effects of a change in capital requirements that modifies the supply of deposits depend on (i) the liquidity premium and (ii) how wages adjust in equilibrium. Inframarginal holdings of other safe assets will not affect the response of firms' hiring decisions to a change in capital requirements, so long as the liquidity premium is calibrated to match the data.

## 5.1 Extended model

**Firms' dividend policy.** We endogenize firms' dividend policy by allowing firms' shareholders (i.e., households) to choose optimally the amount of dividends to be paid every period, thereby relaxing (23). The choice of letting households rather than managers choose dividends is motivated by the results of La Porta et al. (2000)—who find that firms in countries with good legal protections for shareholders choose dividend policies that are consistent with shareholders' rather than managers' preferences—and the fact that we calibrate the model to the US economy. In practice, shareholders can easily monitor firms' cash, and in common-law countries such as the United States (where all shareholders—including minority ones—enjoy a high level of legal protection), they can influence dividend payments. For instance, for public firms, activist investors are likely to take actions if cash and dividends are managed in a way that hurts shareholders. To prevent such actions, managers might follow policies that are most beneficial for shareholders in the first place. In contrast, monitoring the optimality of firms' core management decisions—including those related to the firms' labor force—is more difficult. Thus, core management decisions are more likely to be subject to agency frictions, as in our model. From a modeling perspective, letting households choose the dividend policy implies that the agency friction affects only firms' hiring policies, thereby making the effects of such a friction more transparent.

The fraction of firms' wealth paid out as dividends is now possibly time varying and firm specific and thus denoted by $\alpha_t^i$, rather than $\alpha$. The optimal $\alpha_t^i$ is chosen so that the stream of dividends maximizes the value of the firm from the households' point of view (i.e., using the household discount factor).[23] The next proposition shows that the dividend policy implies the same $\alpha_t^i$ at all firms, and thus $\alpha_t^i = \alpha_t$ for all $i$. This follows from the simple structure of our model, which allows an easy aggregation across firms. The proposition also describes the equilibrium condition that pins down $\alpha_t$. The inability of the manager to differentiate away firms' idiosyncratic risk is unchanged, and so is the first-order condition (7).

[23] The value of $\alpha_t^i$ can still be understood as part of the contract between shareholders and the manager.

**Proposition 5.** *The optimal dividend policy from the point of view of households implies that $\alpha_t^i = \alpha_t$ for all $i$, and $\alpha_t$ is chosen so that*

$$1 = E_t \left\{ \beta \left( \frac{\Lambda_{t+1}}{\Lambda_t} \right) \left[ (\bar{z} - w_t) \phi_t + R_t^d \right] \right\}, \tag{27}$$

*where $\Lambda_t$ is households' marginal utility of consumption.*

The choice of $\alpha_t$ can depend on aggregate shocks or changes in capital requirements realized at time $t$. This implies that deposits $d_t$ can vary in response to aggregate shocks or changes in capital requirements. This is in contrast to the baseline model, in which (23) implied that firms' deposits were essentially predetermined at $t-1$. In addition, we note that the optimal dividend policy in Proposition 5 collapses to $\alpha = 1 - \beta$ in the nonstochastic steady state, which is the same condition as (23).

Because $\alpha_t$ is in general time varying, the law of motion for deposits (24) is replaced by

$$d_{t+1}^f = (1 - \alpha_{t+1}) \left[ (\bar{z} - w_t) \phi_t + R_t^d \right] d_t^f,$$

where $d_t^f$ denotes the total amount of deposits held by firms. We will continue to denote $d_t$ to be the deposits of banks, and we will denote $d_t^h$ to be the deposits held by households.

**Aggregate risk.** We introduce aggregate risk by assuming that the productivity of the bank-financed sector, now denoted by $A_{t+1}$, follows an AR(1) process in logs. The law of motion of $A_{t+1}$ is

$$\log A_{t+1} = (1 - \rho) \log \bar{A} + \rho \log A_t + \sigma_A \varepsilon_{t+1}^A,$$

where $\bar{A}, \sigma_A > 0$ and $\varepsilon_{t+1}^A \sim \mathbb{N}(0, 1)$. We replace $A$ in equations (14) and (15) with $A_{t+1}$.

**Banks' risk choice.** We allow banks to increase their idiosyncratic volatility by paying a convex cost, similar to Van den Heuvel (2008) and Begenau (2018). Limited liability and the deposit insurance intervention together imply that bankers will avail themselves of this technology, although it is socially suboptimal. Specifically, we assume that banks can choose a probability $p_t \geq 0$ such that their idiosyncratic shock is $\varepsilon = 0$ with probability $p_t$ and $\varepsilon/(1-p_t)$ with probability $1-p_t$, where $\varepsilon$ is drawn from the same distribution $F(\varepsilon)$ as in the baseline model. Without a convex cost of choosing $p_t$, bankers would let $p_t$ get arbitrarily close to 1; we assume that bankers pay a cost $\lambda(p_t) d_t$, where $\lambda(\cdot)$ is an increasing and convex function, specified below. The banker's problem becomes

$$\max_{k_t,d_t,p_t} \quad (1-p_t)\,E_t \int \left\{ \frac{\varepsilon}{1-p_t} k_t\,(1-\delta+r_{t+1}) - R_t^d d_t - \lambda\,(p_t)\,d_t \right\}^+ dF\,(\varepsilon) \tag{28}$$

subject to $p_t \geq 0$ and to the same budget and capital requirement constraints as before, (9) and (10). For failed banks, the cost $\lambda\,(p_t)\,d_t$ reduces the value of assets seized by the government to partially defray the expenses of paying back depositors and, thus, increases the taxes that must be collected to fund deposit insurance. Formally, we include $\lambda\,(p_t)\,d_t$ on the right-hand side of equation (21).[24]

The endogenous risk chosen by banks affects welfare and the optimal regulation through two channels. First, the cost $\lambda\,(p_t)\,d_t$ reduces total output and ultimately households' consumption. Second, the ability to choose $p_t > 0$ increases the private value of physical capital $k_t$ to banks and therefore exacerbates the overinvestment induced by deposit insurance. Both channels increase the social value of increasing capital requirements, and higher capital requirements will lead banks to choose a lower value of $p_t$.

We parameterize the cost of increasing $p_t$ above zero using the function

$$\lambda\,(p) = \lambda p \frac{1}{(1-p)^{1+\nu}}, \tag{29}$$

where $\lambda$ and $\nu$ are parameters. This cost function has two advantages over a more traditional one, such as a quadratic function. First, because banks will default in equilibrium, what matters to them is their expected cost, which is proportional to $(1-p_t)\,\lambda\,(p_t)$, using (28). If $\lambda\,(p_t)$ were lacking a $(1-p_t)^{-1}$ term, the expected marginal cost of increasing $p_t$ would be nonmonotone, and the total expected cost would vanish as $p_t \to 1$. In contrast, the formulation in (29) guarantees that the expected marginal cost of increasing $p_t$ is monotone and goes to infinity as $p_t \to 1$. Thus, (29) ensures that we avoid multiple equilibria or implausibly high choices of $p_t$. Second, as we describe below, equation (29) will imply that banks optimally set $p_t = 0$ in many states of the world, allowing for rich, nonlinear dynamics. As a result, bank default will be highly nonlinear, replicating the large variations observed in the data between normal times and crises. We will return to the mechanics of banks' choices of $p_t$ when we describe the calibration of the parameters $\lambda$ and $\nu$.

**Households' utility and households' deposits.** We give households a CRRA utility from consumption and utility from holding deposits $d_t^h$. We follow the literature by inter-

[24] The cost $\lambda\,(p_t)\,d_t$ can be interpreted as an obligation undertaken by the bank at time $t$, such as the cost to manage loans to riskier borrowers, which must be paid to recover the value of the loans $\varepsilon k_t\,(1-\delta+r_{t+1})$.

preting the utility from deposits as arising from their use in transactions, owing to their high liquidity.[25]

Thus, the value function of households becomes

$$V_t^h(a_t) = \max_{c_t,l_t,n_t} \frac{c_t^{1-\gamma_c}-1}{1-\gamma_c} + \psi \frac{\left(d_t^h/c_t\right)^{(1-\gamma_d)}}{1-\gamma_d} - \beta\chi \frac{l_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \beta E_t\left\{V_{t+1}^h(a_{t+1})\right\}. \tag{30}$$

The parameter $\gamma_c$ is households' coefficient of relative risk aversion, $\gamma_d$ governs the elasticity of deposits demand, and $\psi$ governs the level of deposits demand. The budget constraint of households is now given by $c_t + n_t + d_t^h \leq a_t$, and the law of motion of wealth is

$$a_{t+1} = w_t l_t + n_t R_{t+1}^n + d_t^h R_t^d + \int \pi_{t+1}^i di + \pi_{t+1}^{bf} - T_{t+1}. \tag{31}$$

The specification in equation (30) for how deposits enter households' utility is similar to that in Begenau (2018).

## 5.2 Calibration and simulation

We calibrate the model under an 8% capital requirement and then study the welfare effect of changing the requirement. We divide the parameters into two groups. The first set of parameters, reported in Panel A of Table 1, includes parameters that are normalized (i.e., $\bar{z}$ and $\bar{A}$ are normalized to one) and others that are set to values in line with the related literature. The second set, reported in Panel B, is calibrated toward the indicated data moments.

Panel A of Table 1 reports the fixed parameters for which we do not have a calibration target. The model is calibrated at an annual frequency, and thus we set the discount factor $\beta$ to 0.95. Standard values are also used for the depreciation rate of capital ($\delta = 0.1$), the Cobb-Douglas coefficient of capital ($\gamma = 0.3$), households' risk aversion ($\gamma_c = 1$, that is, log utility), and the autocorrelation of productivity shocks ($\rho = 0.95$). A key parameter is the Frisch elasticity of labor supply, $\eta$, which we set to 1, in line with the standard approach in the macro-labor literature; this is also the most conservative value according to the estimates of Chetty et al. (2011).

Panel B of Table 1 reports parameters that we calibrate toward the indicated data moments. Because the model is nonlinear and we solve it globally, we do not exactly match all

[25] In principle, it is possible to think about the effect of deposits in providing insurance against idiosyncratic risk to households, as we do for firms. However, we abstract from this channel here and leave it for future research.

| Panel A: Set Parameters | | | | | |
|---|---|---|---|---|---|
| Parameter | Value | Parameter | Value | Parameter | Value |
| $\eta$ | 1 | $\gamma$ | 0.3 | $\bar{A}$ | 1 |
| $\beta$ | 0.95 | $\gamma_c$ | 1 | $\bar{z}$ | 1 |
| $\delta$ | 0.1 | $\rho$ | 0.95 | $z^i$ | $\{1/p_z, 0\}$ |

| Panel B: Calibrated Parameters | | | | |
|---|---|---|---|---|
| Parameter | Value | Target | Value (data) | Value (model) |
| $\chi$ | 1.439 | Deposit premium $R^f - R^d$ | 1.92% | 1.92% |
| $p_z$ | 0.944 | Continuers employment growth | 2.50% | 2.51% |
| $\sigma$ | 0.03125 | Avg. bank default probability | 0.76% | 0.76% |
| $\nu$ | 0.14 | Std. dev. bank default probability | 1.05% | 1.04% |
| $\lambda$ | 1.03409 | $p90$ bank default probability | 2.26% | 2.27% |
| $\psi$ | 0.0229 | Deposits held by firms | 33.3% | 33.2% |
| $\gamma_d$ | 1.03 | Deposit volatility $\frac{Std(d/c)}{Std(\log GDP)}$ | 1.27 | 1.27 |
| $\sigma_A$ | 0.0062 | Volatility $\log$ GDP | 1.77% | 1.78% |

**Table 1.** Calibrated Parameter Values

moments. In addition, each parameter affects all moments, but Panel B of Table 1 indicates target moments that are particularly affected by each parameter.

We choose the disutility of labor, $\chi$, to match the average deposit premium in the data, exploiting the results of Proposition 3. There, we show that the deposit premium is decreasing in the wage and increasing in the managers' risk-taking decision $\phi_t$ introduced in Proposition 1. Increasing $\chi$ both raises the wage and reduces $\phi_t$, and thus $\chi$ has a direct effect on the average deposit premium. We choose a deposit premium target of 1.92%, which is the midpoint of the 3.16% deposit premium measured by Van den Heuvel (2008) and the 0.68% deposit premium of Davydiuk (2017).

We set the parameter that governs firms' idiosyncratic shocks, $p_z$, to match the average employment growth rate of firms that expand their labor force, corresponding to firms that receive the high value of $z^i_{t+1}$ in the model. This average employment growth rate is defined as

$$g^i_{t+1} \equiv \frac{\widehat{l}^i_{t+1} - l^i_t}{\frac{1}{2}\left(\widehat{l}^i_{t+1} + l^i_t\right)},$$

where $l_t^i = \phi_t d_t^i$ (as in Proposition 1) and

$$\begin{aligned}\widehat{l}_{t+1}^i &= \phi_{t+1} d_{t+1}^i \Big|_{z_{t+1}^i > 0} \\ &= \phi_{t+1} \left(1 - \alpha_{t+1}\right) \left[\left(\frac{1}{p_z} - w_t\right) \phi_t + R_t^d\right] d_t^i.\end{aligned}$$

Haltiwanger, Jarmin and Miranda (2013) show that for all but the youngest firms, this growth rate is around 2.5%.

We calibrate $\sigma$, $\nu$, and $\lambda$ to match three moments of the time-series variation in the default probability of banks. We measure bank default probabilities using the FDIC's Historical Statistics on Banking from 1975 to 2016. We define the default probability of banks as the number of bank failures in a given year reported by the FDIC, divided by the total number of banks covered by the FDIC. This yields an average default probability of 0.76%, as in Davydiuk (2017), which is mostly affected by $\sigma$. We also target the standard deviation and the 90th percentile of the time-series distribution of the bank default probability; these two moments are mostly affected by $\nu$ and $\lambda$, respectively.

To clarify the calibration of $\sigma$, $\nu$, and $\lambda$, consider the first-order condition of banks with respect to the choice of $p_t$. Denoting $\xi_t$ to be the Lagrange multiplier of the nonnegativity constraint $p_t \geq 0$, we have

$$R_t^d + \xi_t = \lambda \frac{1 + (\nu - 1)\, p_t}{\left(1 - p_t\right)^{1+\nu}}. \tag{32}$$

At $p_t = 0$ and $\xi_t = 0$, the marginal cost of increasing $p_t$ is $\lambda$. Thus, $\lambda$ represents the lowest level of $R_t^d$ at which banks choose to increase $p_t$ above zero. We can thus calibrate $\lambda$ so that, most of the time, $R_t^d < \lambda$ and thus banks choose $p_t = 0$, allowing the model to replicate low default probabilities in normal times. In particular, our choice of $\lambda$ implies that 72.5% of the time, banks choose $p_t = 0$.[26] Once $p_t > 0$, its elasticity with respect to $R_t^d$ is then determined by the parameter $\nu$.[27] By varying $\sigma$, $\lambda$, and $\nu$ jointly, we are able to match the average, standard deviation, and 90th percentile of bank default probability that we observe in the data.

We calibrate the parameters that govern how deposits enter households' utility, $\psi$ and $\gamma_d$, to match the average fraction of deposits held by firms and the volatility of the deposit-consumption ratio, respectively. As described in Appendix F, we find that firms hold about one-third of the total deposits held jointly by households and firms (i.e., we exclude deposits held by governments, foreigners, nonprofits, and the financial sector). To derive this statistic,

[26]The fact that $p_t$ is often 0 is what allows the parameter $\sigma$ to primarily affect the average default probability, though of course $\sigma$, $\lambda$, and $\nu$ all jointly affect this moment.

[27]In particular, the elasticity is negatively related to $\nu$, so that a lower value of $\nu$ raises $p_t$, given $R_t^d$.

we use data from the Flow of Funds (FF) and the Survey of Consumer Finances (SCF).[28] In addition, we compare the total deposits from the FF and SCF with data on deposits from the FDIC and the National Credit Union Administration, and the two measures are consistent with each other. We then set $\gamma_d$ to match the volatility of $d/c$, as in Begenau (2018). To estimate this volatility in the data, we use the HP-filtered ratio of total deposits at FDIC-insured banks to consumption expenditures for nondurable goods and services, for the period 1981-2017. We choose data starting from 1981 to maximize the length of the data sample while, at the same time, focusing on a period of time in which banks were allowed to pay interest at least on some deposit instruments.[29]

Finally, we choose the standard deviation of the productivity process, $\sigma_A$, to match the volatility of the HP-filtered log of GDP. We focus on the 1981-2017 period for consistency with the other macro data used to calibrate the household utility parameter $\gamma_d$.

## 5.3 Results

To compute the welfare effects of changing capital requirements, we begin by simulating an economy with an 8% capital requirement, a value in between the 7.26% used by Davydiuk (2017) and the 9.25% used by Begenau (2018). We then change the capital requirement to a new level, $\zeta$, and compute the welfare as the economy transitions to the new stochastic steady state.

To put our results in context, we then compute two additional results: the welfare that arises in a comparable model in which only households hold deposits, and the welfare that arises in our full model if we shut down our novel channel that acts through wages. This second approach generalizes Section 4.3 by computing counterfactual paths for consumption and labor, holding the wage fixed at the path that would arise without any change in regulation. The main takeaway is that our novel channel accounts for a large fraction of the difference between the results of our full model and those of a model with only households' deposits.

The solid line in Figure 4 reports welfare in consumption-equivalent percentage units for our benchmark quantitative model for capital requirements ranging from 7% to 30%, assuming that the economy begins with an 8% capital requirement. The optimal capital requirement in this economy is 18.7%. This is much higher than the average capital requirement of 6% found by Davydiuk (2017) and the 12.4% optimal capital requirement computed

[28]As noted before, the FF accounts for privately held firms and thus produces results that might differ from those based on Compustat.

[29]Our data target is slightly different from Begenau (2018) because we calibrate the model to an annual frequency, whereas Begenau (2018) uses a quarterly frequency.

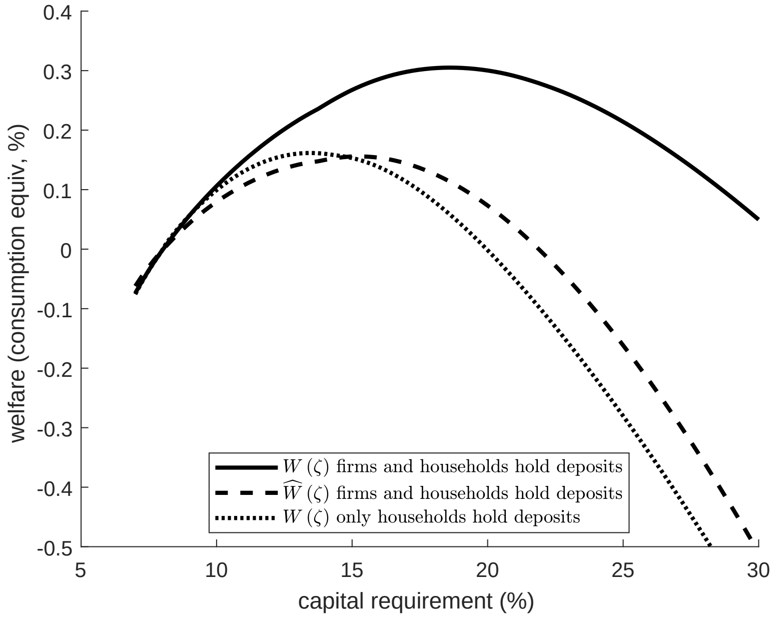


**Figure 4.** The solid line plots welfare $W(\zeta)$, the dashed line plots the welfare $\widehat{W}(\zeta)$ obtained by shutting down our novel general equilibrium effect that acts through wages, and the dotted line plots the welfare in an economy in which deposits are held only by households. Parameter values for the full model used to compute $W(\zeta)$ and $\widehat{W}(\zeta)$ are in Table 1, and parameter values for the model with household deposits only are in Appendix E.4. Welfare is defined in consumption-equivalent units. We compute welfare by averaging across 1,000 simulated economies for 500 periods each, where each of the 1,000 simulations is initialized by drawing a point in the state space of the ergodic distribution of the $\zeta = 8\%$ economy.

by Begenau (2018), and slightly higher than the 17% of Begenau and Landvoigt (2017) and the 18% required to eliminate runs in Egan, Hortaçsu and Matvos (2017).[30]

The dotted line in Figure 4 plots the welfare in a comparable model in which only households hold deposits. We calibrate this model to the same moments in Panel B of Table 1, which requires adjusting some parameters, and so that deposits at banks in the initial steady state are the same as those of the full model (see Appendix E.4 for more details). The optimal capital requirement in this model is 13.6%. This is substantially lower than the optimal requirements in our full model when firms hold deposits (i.e., 5.1 percentage points lower), but in line with the 12.4% derived by Begenau (2018) in her model with only households' deposits and endogenous banks' risk-taking, and the Basel III "fully-phased in" level of 14%–15% (Basel Committee on Banking Supervision, 2017). We also note two

[30]Although Egan, Hortaçsu and Matvos (2017) find that the optimal capital requirement is 39%, they prefer to focus on the 18% requirement that eliminates major welfare losses due to runs.

additional results that arise if one analyzes welfare through the lens of a model with only households' deposits, which are both captured by the difference between the dotted and solid lines in Figure 4. First, using a model with only households' deposits overstates the welfare losses of setting capital requirements too high. Second, this approach understates the welfare benefit of setting capital requirements optimally; that is, the welfare gain to transitioning to the optimal capital requirement in the full model in which firms hold deposits is about twice as high as in the model with only household deposits.

To investigate the source of the difference between welfare in our full model and that in the model with only households deposits, we perform an exercise along the lines of Section 4.3. That is, we compute the welfare $\widehat{W}(\zeta)$ that would arise in our full model with both households' and firms' deposits if we shut down our novel general equilibrium effect that acts through wages. This is constructed similar to Section 4.3 and is represented by the dashed line in Figure 4 (see Appendix E.4 for more details).

The welfare $\widehat{W}(\zeta)$ that does not include our novel channel closely tracks the welfare of the model with only households' deposits. This implies that, absent our novel channel, accounting for firms' deposits alone would not alter the welfare analysis of capital requirement regulation very much. Because of the channel we identify, however, accounting for firms' deposits has important implications for financial regulation. In response to a higher capital requirement, input prices (in our model, the wage) decrease, partially offsetting the costs of the tighter requirement and driving the wedge between the dashed and solid lines in Figure 4. The welfare $\widehat{W}(\zeta)$ peaks at the capital requirement $\zeta = 15.3\%$ and, thus, our channel accounts for about two-thirds of the difference between the 18.7% optimal requirement in the full model and the 13.6% in the model with only households' deposits. In addition, our channel accounts almost entirely for the difference in the welfare gains from regulating capital requirements optimally (i.e., the difference between the maximum values of the solid and dotted lines). In other words, ignoring firms' deposit holdings and our novel channel understates both the optimal capital requirement and the welfare gains of the optimal financial regulation.

# 6 Conclusion

We have presented a model to study capital requirement regulation in which both households and firms hold deposits. Our analysis differs from most of the existing literature, which focuses on households' deposits. Because of a novel general equilibrium effect related to firms' deposits, the optimal capital requirement is substantially higher than in comparable models that only allow households to hold deposits.

This paper opens up several directions for future research. First, depending on how firms' idiosyncratic productivities evolve over time, the value of deposits to firms might be time varying. This effect might give rise to important implications for the analysis of time-varying regulation above and beyond those analyzed by Davydiuk (2017) and Malherbe (2017), in which the value of deposits is constant over time and time variation in optimal capital requirements comes from time variation in banks' overinvestment. Second, we have followed the literature in assuming complete deposit insurance, but Egan, Hortaçsu and Matvos (2017) show that only about half of all deposits in the United States are in fact FDIC insured. Our model can be employed to study the optimal degree of deposit insurance. In our model, eliminating deposit insurance altogether increases firms' cash-flow volatility, and thus the optimal outcome is likely to be partial deposit insurance.

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# Appendix

## A Proofs

*Proof of Proposition 1.* We conjecture and later verify that the value function has the form

$$V_t^m\left(d_t^i\right) = \frac{\beta^m}{1-\beta^m}\log\left(d_t^i\right) + \Xi_t, \tag{33}$$

where $\Xi_t$ is independent of $d_t^i$. Then, the problem of the manager implies the first-order condition (7). Since $l_t^i$ is independent of $d_t^i$, the conjecture about the value function can be verified, obtaining

$$\Xi_t = \frac{\beta^m}{1-\beta^m}\left\{\log\left(\kappa\alpha\right) + \frac{\beta^m}{1-\beta^m}\log\left(1-\alpha\right) + \frac{1}{1-\beta^m}E_t\log\left[\left(z_{t+1}^i - w_t\right)\phi_t + R_t^d\right]\right\}. \tag{34}$$

$\square$

*Proof of Proposition 2.* When taking the limit as $\kappa \to 0$ and $\theta \to 0$, we have: (i) Proposition 1 is not affected because (7) is independent of $\kappa$ and $\theta$; (ii) the results about $c_t^i$ and $\pi_{t+1}^i$ follow from (3) and (4); (iii) to show that $W \to V_0^h\left(a_0\right)$, we use the results in the proof of Proposition 1 to obtain $\theta V_0^m\left(d_0^i\right) \to 0$. In particular, the last result uses the fact that $\theta\Xi_t \to 0$ as both $\theta$ and $\kappa$ tend to zero (keeping $\theta/\kappa$ constant), given the definition of $\Xi_t$ in (34). $\square$

*Proof of Proposition 3.* To show $R^d < 1/\beta$, we first establish that $w < E_t\left\{z_{t+1}^i\right\}$. First, note that $w \leq E_t\left\{z_{t+1}^i\right\}$, otherwise firms would make negative profits on average and thus will not hire any workers, and the labor market will not clear. Next, assume by contradiction that $w = E_t\left\{z_{t+1}^i\right\}$. Equation (7) and the assumption that $Var(z_{t+1}^i) > 0$ imply that $\phi = 0$ and thus firms will not hire any workers, and the labor market will not clear. Thus, the only possible case is $w < E_t\left\{z_{t+1}^i\right\}$. This result and equation (24) evaluated in steady state imply $R^d < 1/\beta$ and $1/\beta - R^d = (\bar{z} - w)\phi$. Finally, the right-hand side of (26) can be computed using $l_t^i = \phi d_t^i$ and $E_t\{z_{t+1}^i\} = \bar{z}$, establishing the result. $\square$

To prove Propositions 4 and 8, we first state and prove the following intermediate lemma.

**Lemma 6.** *If there exists a steady-state equilibrium with $l > 0$, we have*

$$\frac{\partial d}{\partial \zeta} < 0,\ \frac{\partial R^d}{\partial \zeta} < 0,\ \frac{\partial w}{\partial \zeta} < 0,\ \frac{\partial \phi}{\partial \zeta} > 0,\ \frac{\partial l}{\partial \zeta} < 0,$$

*for all $\eta \in (0,1)$. Moreover, the sign of $\partial d/\partial \zeta$ is also preserved in the limit as $\eta \to 0$ and $\eta \to \infty$, whereas $\partial R^d/\partial \zeta < 0$ as $\eta \to 0$ but $\partial R^d/\partial \zeta \to 0$ as $\eta \to \infty$.*

*Proof of Lemma 6.* We totally differentiate (7), the law of motion of deposits (2) evaluated in steady state and integrated over $i$, the labor demand equation $l = \phi d$, and the first-order condition of banks (13). Thus, we obtain a system of four equations in four unknowns, where the unknowns are $\partial w/\partial \zeta$, $\partial \phi/\partial \zeta$, $\partial R^d/\partial \zeta$, and $\partial d/\partial \zeta$. To derive the results, it is useful to define the following variables:

$$\begin{aligned}
\mathbb{A} &\equiv E\left\{\frac{R^d}{\left[\phi\left(z'-w\right)+R^d\right]^2}\right\} > 0 \\
\mathbb{B} &\equiv E\left\{\frac{\left(z'-w\right)^2}{\left[\phi\left(z'-w\right)+R^d\right]^2}\right\} > 0 \\
\mathbb{C} &\equiv E\left\{-\frac{\left(z'-w\right)}{\left[\phi\left(z'-w\right)+R^d\right]^2}\right\} > 0 \\
\mathbb{D} &\equiv E\left\{\frac{1}{\phi(z'-w)+R^d}\right\} > 0.
\end{aligned}$$

The signs of $\mathbb{A}$, $\mathbb{B}$, and $\mathbb{D}$ hold because the argument of the expectation is positive for all states. The sign of $\mathbb{C}$ follows from three remarks. First, $\mathbb{C}$ is a cross-partial derivative of the manager's objective function with respect to $R^d$ and $\phi$, that is,

$$\frac{\partial}{\partial R^d}\frac{\partial\,(\text{manager's objective function})}{\partial \phi} = \mathbb{C},$$

where

$$(\text{manager's objective function}) = \beta^m E_t\left\{\theta \log c_{t+1}^i + V_{t+1}^m\left(d_{t+1}^i\right)\right\}.$$

Second, since the objective function of the manager is concave in $\phi$ (i.e., the first-order condition with respect to $\phi$ pins down a maximum), then its derivative with respect to $\phi$ is locally decreasing in $\phi$. Third, (7) implies a constant ratio $\phi/R^d$, and thus a marginal increase in $R^d$ implies an increase in $\phi$. Thus, $\mathbb{C}$ must be positive when evaluated at equilibrium values.

We can then solve the system of four equations in four unknowns described before. For deposits, we obtain

$$\frac{\partial d}{\partial \zeta}=-\frac{\left(\frac{1}{\beta}-R^{d}\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)+\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{1-\gamma}\right)(1-\zeta)^{\gamma-1}}\right)\left(d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right)}{\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{2-\gamma}\right)(1-\zeta)^{\gamma-1}}\left[d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right]+(1-\zeta)\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)\phi\left[\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right]}<0,$$

where the inequality follows from the fact that both the numerator and the denominator on the right-hand side are positive, using $R^d < 1/\beta$ and $w < \bar{z}$ (which must both hold, otherwise firms would make negative profits) and the signs of $\mathbb{A}$, $\mathbb{B}$, $\mathbb{C}$, and $\mathbb{D}$ established before. The sign of the derivative is preserved in the limit as $\eta \to 0$ and $\eta \to \infty$, using the labor supply equation (19).

Similarly, for the return on deposits, we obtain

$$\frac{\partial R^{d}}{\partial \zeta}=-\frac{\phi\left(\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right)\left(\frac{1}{\beta}-R^{d}\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)+\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{1-\gamma}\right)(1-\zeta)^{\gamma-1}}\right)}{\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{2-\gamma}\right)(1-\zeta)^{\gamma-1}}\left(d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right)+(1-\zeta)\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)\phi\left[\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right]}<0,$$

and taking the limit as $\eta$ goes to zero or $\infty$, we can establish the respective result.

For the wage, we obtain

$$\frac{\partial w}{\partial \zeta}=-\frac{\phi\left(\mathbb{B}+\mathbb{C}\left(\bar{z}-w\right)\right)\left(\frac{1}{\beta}-R^{d}\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)+\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{1-\gamma}\right)(1-\zeta)^{\gamma}}\right)}{\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{2-\gamma}\right)(1-\zeta)^{\gamma-1}}\left(d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right)+(1-\zeta)\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)\phi\left[\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right]}<0,$$

and for the manager's risk-taking choice $\phi$ we obtain

$$\frac{\partial \phi}{\partial \zeta}=\frac{\phi\mathbb{D}\left(\frac{1}{\beta}-R^{d}\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)+\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{1-\gamma}\right)(1-\zeta)^{\gamma}}\right)}{\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{2-\gamma}\right)(1-\zeta)^{\gamma-1}}\left(d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right)+(1-\zeta)\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)\phi\left[\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right]}>0.$$

Finally, using $l = \phi d$, totally differentiating with respect to $\zeta$, and using the previous results, we obtain

$$\frac{\partial l}{\partial \zeta}=-\frac{\left(\frac{1}{\beta}-R^{d}\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)+\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{1-\gamma}\right)(1-\zeta)^{\gamma}}\right)\left[\phi\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right]}{\frac{A(1-\gamma)\gamma\int_{\underline{\varepsilon}}^{\infty}\varepsilon dF(\varepsilon)}{\left(d^{2-\gamma}\right)(1-\zeta)^{\gamma-1}}\left(d\mathbb{D}+\frac{\eta\left(\mathbb{B}+\mathbb{C}(\bar{z}-w)\right)}{w^{1-\eta}\chi^{\eta}}\right)+(1-\zeta)\int_{\underline{\varepsilon}}^{\infty}dF\left(\varepsilon\right)\phi\left[\mathbb{A}\left(\bar{z}-w\right)+\mathbb{B}\phi\right]}<0.$$

□

*Proof of Proposition 4.* For $\eta \in (0, \infty)$, the results are shown in Lemma 6. For the case $\eta \to \infty$ and $\eta \to 0$, the results follow as corollaries of the proof of Lemma 6, using the labor supply (19) and taking the appropriate limits with respect to $\eta$. □

*Proof of Proposition 5.* Define the value of the firm before dividends as $V_t^f\left(x_t^i\right)$, from the point of view of shareholders. This value corresponds to the present discounted stream of dividends, discounted using the stochastic discount factor of households, and where the choice of dividends is made optimally to maximize households' utility. Let $\alpha_t^i$ be the fraction of firm $i$ wealth paid out as dividends. Then,

$$V_t^f\left(x_t^i\right) = \max_{\alpha_t^i} \ \alpha_t^i x_t^i + \beta E_t \left\{ \left(\frac{\Lambda_{t+1}}{\Lambda_t}\right) V_{t+1}^f\left(x_{t+1}^i\right) \right\},$$

where $\Lambda_t$ is the households' marginal utility of consumption and

$$\begin{aligned} x_{t+1}^i &= \left(z_{t+1}^i - w_t\right) l_t + R_t^d d_t \\ &= \left[\left(z_{t+1}^i - w_t\right)\phi_t + R_t^d\right] d_t \\ &= \left[\left(z_{t+1}^i - w_t\right)\phi_t + R_t^d\right]\left(1-\alpha_t^i\right) x_t^i, \end{aligned}$$

and the last line uses $d_t = \left(1-\alpha_t^i\right) x_t^i$. Note that $\phi_t$ is taken as given because it is chosen by the manager.

The first-order condition with respect to $\alpha_t^i$ implies

$$1 = \beta E_t \left\{ \left(\frac{\Lambda_{t+1}}{\Lambda_t}\right) \left[\left(z_{t+1}^i - w_t\right)\phi_t + R_t^d\right] \left(V_{t+1}^f\right)'\left(x_{t+1}^i\right) \right\} \tag{35}$$

where the marginal value of the firm can be computed recursively using the envelope condition

$$\left(V_t^f\right)'\left(x_t^i\right) = \alpha_t^i + \beta E_t \left\{ \left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)\left(1-\alpha_t^i\right)\left[\left(z_{t+1}^i - w_t\right)\phi_t + R_t^d\right]\left(V_{t+1}^f\right)'\left(x_{t+1}^i\right) \right\}.$$

The previous two equations imply $\left(V_t^f\right)'\left(x_t^i\right) = 1$ for all $t$, and thus (35) simplifies to

$$1 = \beta E_t \left\{ \left( \frac{\Lambda_{t+1}}{\Lambda_t} \right) \left[ \left( z_{t+1}^i - w_t \right) \phi_t + R_t^d \right] \right\}.$$

We then note that $z_{t+1}^i$ is i.i.d. and independent of all other endogenous variables at $t+1$, and thus it can be replaced with its expectation $\bar{z}$, obtaining (27). In addition, the condition that pins down $\alpha_t^i$ is the same for all firms, and thus $\alpha_t^i = \alpha_t$ for all $i$. □

# B Benchmark with no shocks: Modigliani-Miller

This appendix characterizes the equilibrium in a version of the model in which we shut down all shocks—the idiosyncratic shocks on firms and those on banks. The objective is to establish a benchmark that can be used as a comparison for the analyses that follow.

An implication of shutting down the shocks to banks is that there is *de facto* no deposit insurance. This is because banks' profits are fully deterministic and thus no bank fails in equilibrium, implying that deposit insurance disbursements are zero.

In this benchmark scenario, Modigliani-Miller holds in the sense that the equilibrium is independent of how banks' assets are financed. We view this result as a "check" that our framework allows for the Modigliani-Miller theorem to hold once we shut down deposit insurance and the uninsurable idiosyncratic risk of firms. The restriction on $\alpha$ imposed in (27) is essential to obtain such a result.

To overcome the indeterminacy of Modigliani-Miller, we assume that capital requirements are imposed anyway by the regulator, even though there is no deposit insurance disbursement, and that they are satisfied with equality: $n_t/k_t = \zeta$.

**Proposition 7.** *(Benchmark equilibrium without any shock) Suppose* $z_{t+1}^i \equiv 1$ *and* $\varepsilon \equiv 1$. *Given* $\zeta$*, the equilibrium is characterized by prices* $R^d = R^n = 1/\beta$, $w = 1$; *banking variables* $k = \left[ \left( \frac{1}{\beta} - (1-\delta) \right) \frac{1}{A\gamma} \right]^{-\frac{1}{1-\gamma}}$, $d = k(1-\zeta)$, *and* $n = \zeta k$; *labor* $l = \left(1/\chi\right)^{\eta}$; *taxes* $T = 0$; *and consumption of households* $c = \left(1/\chi\right)^{\eta} + Ak^{\gamma} - \delta k$.

*Proof.* Since there are no idiosyncratic shocks to firms, the first-order condition (7) implies $w = 1$, which in turn implies the equilibrium value of labor stated in the proposition, using (19). The law of motion of deposits, (2), evaluated in steady state (i.e., at $d_t^i = d_{t+1}^i$) and using the restriction on $\alpha$ in (23), implies $R^d = 1/\beta$. Given this result, and since no bank fails in equilibrium because shocks are shut down, equation (13) implies $1 - \delta + r = 1/\beta$ which, together with the first-order condition of bank-financed players, (15), implies the value of capital $k$ stated in the proposition. The value of deposits and equity follows from the bank's budget and capital requirement constraints, (9) and (10). Taxes $T = 0$ follow from the fact that no bank fails in equilibrium, and consumption follows from Walras' law. □

# C Formalizing the measure of managers in the economy

In this appendix, we provide a simple extension to the baseline model in which we formalize the measure of managers in the economy, and we show that, when taking such measure to be small, the social welfare function includes only households' welfare, as in Proposition 2. Crucially, this is the case even if the Pareto weight on managers and households is the same.

Our objective is to formalize the idea that (i) each firm has a different manager, (ii) managers' compensations are small relative to firms' total dividends, and (iii) managers are a small fraction of the population. At the same time, we also want to (iv) avoid the problem of the baseline model that managers' consumption is driven to zero as $\kappa \to 0$. Formalizing these concepts in a tractable manner presents some challenges, which we discuss briefly. In the baseline model of Section 3, the measure of firms is (implicitly) normalized to one. There, the measure of managers is one as well, so that each firm has a different manager, but then we run into the problem that the size of households (also normalized to one) is the same as that of managers. If we instead try to reduce the measure of managers to make it small relative to households, we run into the problem of not having "enough" managers to run all the firms in the economy. Formally, these problems arise because of the need to work with a continuum of agents for tractability reasons.

To overcome these issues, we proceed as follows. We now assume that each manager is part of a family with $\mu$ members (e.g., if $\mu = 2$, you can think of each manager as having a spouse that is not part of the labor force). Since the compensation paid by firm $i$ to the manager is a fraction $\kappa$ of the dividends $\pi^i_{t+1}$, each member of the family receives an equal share $\kappa\pi^i_{t+1}/\mu$ of it. We denote $c^i_{t+1}$ to be the consumption of each member of the family. As a result, total consumption $\mu c^i_{t+1}$ of the family is financed each period with the total compensation $\kappa\pi^i_{t+1}$, so that equation (3) is replaced by[31]

$$\mu c^i_{t+1} = \kappa\pi^i_{t+1}, \tag{36}$$

and the total utility of the family is $\mu \log c^i_{t+1}$.

[31] Recall that we do not allow managers to save.

With this structure, we can now redefine the problem of the manager, (5). We now denote $V_t^m\left(d_t^i\right)$ to be the utility of the whole manager's family, which is given by

$$V_t^m\left(d_t^i\right) = \max_{l_t^i, c_{t+1}^i, d_{t+1}^i} \beta^m E_t \left\{\mu \log c_{t+1}^i + V_{t+1}^m\left(d_{t+1}^i\right)\right\}$$

subject to (2) and (36). We can then show that the first-order condition (7) is unchanged using the same approach employed in the proof of Proposition 1, that is, conjecturing and then verifying that the value function has the form

$$V_t^m\left(d_t^i\right) = \mu \frac{\beta^m}{1-\beta^m} \log\left(d_t^i\right) + \mu \Xi_t, \tag{37}$$

where $\Xi_t$ is defined in equation (34).

As a final step, we show that if the fraction of dividends paid to managers is small (i.e., $\kappa \to 0$) and managers are small in comparison to households (i.e., if the size of each manager's family $\mu \to 0$), we recover the result that total welfare depends only on households' welfare: $W \to V_0^h(a_0)$. The welfare function is given by (25) and, different from the analysis in Section 3.3, we now do not take a stand on the Pareto weight $\theta$. This means, for instance, that $\theta$ could be set to one to have an equal weight on households and managers.

We consider the limit as $\kappa \to 0$ and $\mu \to 0$, with $\kappa/\mu$ constant along the limiting sequence. Then, equation (36) implies that consumption $c_{t+1}^i$ of each manager's family member is not affected by the limit—indeed, (36) implies $c_{t+1}^i = \left(\kappa/\mu\right)\pi_{t+1}^i$, and $\kappa/\mu$ is constant along the limiting sequence. We also note, using (37), that the utility value per member of the family, $V_t^m\left(d_t^i\right)/\mu$, is not affected by the limits, and the total value $V_t^m\left(d_t^i\right)$ of each family goes to zero as $\kappa \to 0$ and $\mu \to 0$. This last result allows us to establish our main result, namely, that the welfare function (25) depends only on households' utility in the limit. Formally,

$$W \to V_0^h(a_0) \text{ for any Pareto weight } \theta > 0$$

as $\kappa \to 0$ and $\mu \to 0$.

# D Capital requirements and bad risk-taking

In this appendix, we clarify the effects of capital requirements on banks' choices. First, we highlight that higher capital requirements can either increase or decrease bank lending. This result is essentially the same as in Begenau (2018), but it interacts with firms' good risk-taking in our model. Second, we explain why a capital requirement that is too high

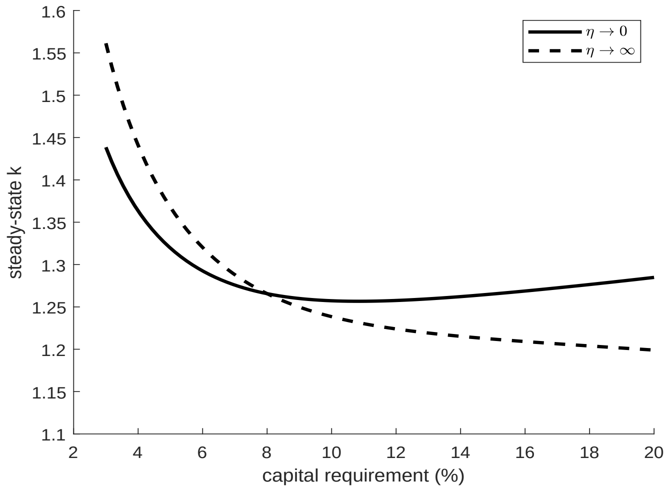


**Figure 5.** Both lines in the figure plot the steady-state level of physical capital $k$ for values of the capital requirement $\zeta$ ranging from 3% to 20%. Parameter values are $\beta = 0.95$, $p_z = 0.952$, $\delta = 0.1$, $A = 0.52$, $\sigma = 0.063$, $\chi = 0.96$, and $\gamma = 0.3$. We choose $A$, $\sigma$, and $\chi$ to induce a deposit premium of 2%, a default probability of 10%, and an equilibrium consumption value of 1. The dotted line assumes a fully elastic labor supply (i.e., $\eta \to \infty$); the solid line assumes a fixed labor supply (i.e., $\eta \to 0$), where labor supply is fixed at $\bar{l} = 0.555$. Details on these calculations are in Appendix E.

is not optimal even if the marginal social value of deposits is zero. Finally, we link all these theoretical results with some empirical evidence that supports the existence of a wedge between the private and social value of deposits.

Tightening capital requirements produces two effects on the amount of bank lending $k$, which we label the *leverage effect* and the *funding effect.* The leverage effect forces banks to be financed proportionally more with equity (i.e., to reduce their leverage). Since equity is more expensive than deposits, banks react by reducing total lending $k$. The funding effect is related to how the deposit rate changes in response to a modification of capital requirements, as noted by Begenau (2018). As tighter capital requirements make deposits more scarce, depositors might be willing to accept a lower return $R^d$. Such a lower return *reduces* the cost for banks to fund an additional dollar of loans, *increasing* $k$.

The leverage and funding effects are also related to the Frisch elasticity of labor supply, $\eta$. Recall that firms hold deposits to insure against the need to pay wages in the event of a bad productivity shock. Since wages are affected by the Frisch elasticity $\eta$, firms' demand for deposits is tied to this elasticity as well. When the Frisch elasticity is $\eta < \infty$, both the leverage and funding effects are at work. If instead the Frisch elasticity is $\eta \to \infty$ (i.e., if labor demand is fully elastic), only the leverage effect operates; in this case, wages do not respond to changes in capital requirements, and neither do the private benefits of holding deposits.

We summarize these points in the following proposition.

**Proposition 8.** *(Capital requirements and bad risk-taking) If $\eta < \infty$, increasing the capital requirement $\zeta$ produces two effects:*

- Leverage effect. *Fixing $R^d$, banks' debt-to-equity ratio $d/n$ decreases and banks' lending rate $r$ increases; this effect reduces the equilibrium value of physical capital $k$ and thus reduces the size of the banking sector;*

- Funding effect. *The deposit rate $R^d$ decreases; this puts downward pressure on the banks' lending rate $r$, generating an increase in the equilibrium value of physical capital $k$ and thus increasing the size of the banking sector.*

*If instead $\eta = \infty$, only the leverage effect operates.*

*Proof.* Combining (15), (20), and (13) evaluated at the nonstochastic steady state, we obtain

$$\int_{\underline{\varepsilon}}^{\infty} \varepsilon \left(1 - \delta + A\gamma k^{\gamma-1}\right) dF(\varepsilon) = \zeta \frac{1}{\beta} + (1-\zeta) R^d \int_{\underline{\varepsilon}}^{\infty} dF(\varepsilon)$$

Totally differentiating with respect to $\zeta$, we have

$$\int_{\underline{\varepsilon}}^{\infty} \varepsilon \left(A\gamma(\gamma-1)k^{\gamma-2}\frac{\partial k}{\partial \zeta}\right) dF(\varepsilon) = \left[\frac{1}{\beta} - R^d \int_{\underline{\varepsilon}}^{\infty} dF(\varepsilon)\right] + (1-\zeta)\frac{\partial R^d}{\partial \zeta} \int_{\underline{\varepsilon}}^{\infty} dF(\varepsilon).$$

Fixing $R^d$, and since the term in square brackets on the right-hand side is positive (because $R^d < 1/\beta$ in equilibrium), then capital $k$ drops when $\zeta$ marginally increases (leverage effect).

The funding effect follows from the fact that $R^d$ weakly decreases, as established in Lemma 6 (see Appendix A). □

An implication of Proposition 8 is that the effect of increasing capital requirements on total bank lending $k$ is ambiguous if $\eta < \infty$. If instead $\eta \to \infty$, bank lending $k$ unambiguously decreases. Figure 5 illustrates these results with a numerical example. The figure plots the steady-state value of bank assets $k$ for various values of capital requirement $\zeta$ and for the two extreme cases of $\eta \to \infty$ and $\eta \to 0$.

When $\eta \to \infty$ (i.e., dotted line in Figure 5), higher capital requirements always reduce $k$ because only the leverage effect is at work. When $\eta \to 0$ (i.e., solid line), both the leverage and funding effect are at work. In this case, lending by banks (i.e., capital $k$) decreases for levels of the capital requirement up to 11.4%. However, as the capital requirement is increased above 11.4%, banks' lending $k$ goes up. This is because the leverage effect dominates for values of $\zeta$ below 11.4%, whereas the funding effect dominates as $\zeta$ is pushed above 11.4%.

The existence of the leverage effect explains why the optimal capital requirement is not too high even when the marginal social value of deposits is zero. In such a case, the objective of the capital requirement is solely that of offsetting the negative effects of subsidized deposit insurance, with no consideration for the effects on deposits. In particular, in this simple model, deposit insurance gives rise to an incentive for banks to lend too much. In the numerical example in Figure 5, the best way to offset deposit insurance is to target the minimum level of $k$ that can be achieved, corresponding to a 11.4% capital requirement. However, the optimal capital requirement (computed in Figure 2) is 8.7% because it accounts for the transition from the old to the new steady state.

When mapping the theory to the data, Begenau (2018) notes that the return on deposits $R^d$ responds to changes in the quantity of deposits. In both her model and ours, this feature gives rise to the funding effect, which runs counter to the conventional intuition that tighter capital requirements reduce bank lending. Crucially, in our model, the existence of a funding effect is associated with a Frisch elasticity of labor supply $\eta < \infty$, which in turn produces a wedge between the marginal and private value of deposits, as shown in Proposition 4. This wedge lowers the cost of increasing capital requirements, as we describe in Section 4.3.

# E Solution method

In this section we describe the numerical method for solving the numerical examples in Section 4 and Appendix D, and the quantitative model in Section 5. We take all parameters as given and constant.

## E.1 Steady state of the baseline model of Section 3

We describe how we solve for the steady state of the baseline model of Section 3. We use this method to generate initial conditions to perform the policy experiments represented in Figures 2 and 3, and to produce Figure 5. We denote steady-state variables by dropping all time subscripts.

First, because the deposit premium is positive, as shown by Proposition 3, the capital constraint always binds. Thus, equations (9) and (10) together imply that

$$n = \zeta k \tag{38}$$

$$d = (1-\zeta)\, k. \tag{39}$$

Equation (15) can be used to solve for $k$,

$$k = \left[\frac{\gamma A}{r}\right]^{\frac{1}{1-\gamma}}, \tag{40}$$

and equation (24) implies that

$$R^d = \frac{1}{\beta} - (\bar{z} - w)\,\phi. \tag{41}$$

To solve for the steady state, we guess a value for $w$. Given this value for $w$, we solve equation (7) for $\phi$, noting that since $z_{t+1}^i$ can only take the two values of 0 and $1/p_z$, we have $\phi_t$ in closed form:

$$\phi_t = R_t^d \frac{1-w_t}{w_t\left(\frac{1}{p_z} - w_t\right)}. \tag{42}$$

We then have $R^d$ from equation (41). We then plug (12), (20), and (39) into (13) and, using the value of $R^d$ just computed, we solve for $r$. In particular, since $\varepsilon$ is log-normal with mean 1, we have

$$\int_{\underline{\varepsilon}}^{\infty} \varepsilon dF(\varepsilon) = 1 - \Phi\left\{\frac{1}{\sigma}\log\underline{\varepsilon} - \frac{1}{2}\sigma\right\},$$

$$\Pr\{\varepsilon \geq \underline{\varepsilon}\} = 1 - \Phi\left\{\frac{1}{\sigma}\log\underline{\varepsilon} + \frac{1}{2}\sigma\right\},$$

where $\Phi\{\cdot\}$ denotes the standard normal CDF. Given $r$, we can find $n$, $d$, and $k$ from equations (38)-(40). Finally, we search over values of $w \in (0, \bar{z})$ to satisfiy equation (19), given $l = \phi d$ (from Proposition 1) computed using the implied values of $d$ and $\phi$.

## E.2 Changing capital requirements at $t = 0$: numerical examples of Section 4

We now describe how we solve the model to compute the welfare plotted in Figures 2 and 3. We perform the following policy experiment. Given the economy in steady state with an 8%

capital requirement, we vary the capital requirement to a new level, ranging from $\zeta = 3\%$ to $\zeta = 20\%$. For each new level of $\zeta$ in this range, we solve for the equilibrium transition path to the new steady state. We then compute welfare over this path, $W(\zeta)$, which is equal to the value function of households $V_0^h(a_0)$, as discussed in Section 3.3.[32]

Assume the economy is in steady state at $t = 0$. At the start of $t = 1$, a new capital requirement $\zeta$ is announced.[33] Deposits $d_t$ are predetermined at time $t-1$ from equation (24). Thus, $d_1 = d_0$.

We solve the model at each $t$ recursively. Suppose we know $d_t$. Then (9) and (10) imply $k_t = \frac{d_t}{1-\zeta_t}$, and $r_{t+1}$ comes directly from equation (15). We then plug equation (12) into equation (13) and solve numerically for $R_t^d$. Given $R_t^d$, we plug equation (19) into equation (7) and solve numerically for $\phi_t$ (and then recover $w_t$). Then, given $\phi_t$, $w_t$, and $R_t^d$, we use equation (24) to compute $d_{t+1}$, and we move to the next $t$.

Consumption at $t+1$ can be computed using the resource constraint of the economy. The amount of resources available at the beginning of $t+1$ is given by the output produced by firms, $\bar{z}l_t$, plus the output produced by the bank-financed sector, $Ak_t^\gamma$, and is used for consumption $c_{t+1}$ and investments. Since investments can be expressed as $k_{t+1} - (1-\delta)k_t$, we have

$$\begin{aligned} c_{t+1} &= \bar{z}l_t + Ak_t^\gamma - \left[k_{t+1} - (1-\delta)k_t\right] \\ &= \bar{z}\phi_t d_t + Ak_t^\gamma - \delta k_t - (k_{t+1} - k_t), \end{aligned} \tag{43}$$

where the second line uses $l_t = \phi_t d_t$ from Proposition 1 and rearranges.

To compute the welfare $\widehat{W}(\zeta)$ that does not include our novel channel, we proceed as follows. Let $\{R_t^d(\zeta), d_t(\zeta), k_t(\zeta)\}_{t=0}^\infty$ be the equilibrium value of the return on deposits, deposits, and capital obtained by changing the capital requirement to $\zeta$ at $t = 0$. As a first step, we compute the level of firms' risk taking $\hat{\phi}_t(\zeta)$ that would be chosen by a firm that faces the correct return on deposits $R_t^d(\zeta)$ and the "wrong" wage $w_{-1}$ (i.e., the wage that would arise if the capital requirement had not changed). To do so, we solve for $\hat{\phi}_t(\zeta)$ using (7) evaluated at $w_t = w_{-1}$ and $R_t^d = R_t^d(\zeta)$. Second, we compute the labor demand $\hat{l}_t(\zeta)$ using $\hat{\phi}_t(\zeta)$ and the correct equilibrium value of deposits: $\hat{l}_t(\zeta) = \hat{\phi}_t(\zeta)d_t(\zeta)$. Third, we solve for the consumption $\hat{c}_t(\zeta)$ that would arise if employment is $\hat{l}_t(\zeta)$, using (43) evaluated at

[32] Although the economy only approaches the new steady state asymptotically, we find that 1,000 time periods is sufficient for welfare to converge.

[33] Although we assume that the capital requirement is changed once and for all at $t = 0$, this solution method in this simple model with quasi-linear utility works if $\zeta$ is time varying and follows any deterministic path.

$l_t = \hat{l}_t(\zeta)$ and at the correct equilibrium value of capital $k_t(\zeta)$:

$$\hat{c}_{t+1}(\zeta) = \bar{z}\hat{l}_t(\zeta) + Ak_t(\zeta)^\gamma - \left[k_{t+1}(\zeta) - (1-\delta)\, k_t(\zeta)\right].$$

We then compute welfare $\widehat{W}(\zeta)$ by evaluating households' utility at $\{\hat{c}_t(\zeta), \hat{l}_t(\zeta)\}_{t=0}^{\infty}$.

## E.3 Quantitative model

**Households' and banks' problems.** The first-order conditions for $l_t$ and $n_t$ for problem (30), after plugging in the budget constraint, are

$$w_t E_t \{\Lambda_{t+1}\} = \chi\,(l_t)^{1/\eta} \tag{44}$$

$$1 = E_t\left\{\beta\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right) R^n_{t+1}\right\} \tag{45}$$

where $\Lambda_t$ is the marginal utility of consumption, given by

$$\Lambda_t = c_t^{-\gamma_c}\left[1 - \psi\left(\frac{d_t^h}{c_t}\right)^{1-\gamma_d}\frac{1}{c_t^{1-\gamma_c}}\right].$$

Equation (44) would be a standard labor supply curve if it were not for the expectation on the left-hand side. This expectation appears in (44) because wages are earned at $t+1$ but labor is chosen at $t$. The expected return condition for bank equity (45) is standard.

The first-order condition for households' deposits is

$$\frac{\psi\left(\frac{d_t^h}{c_t}\right)^{-\gamma_d}}{c_t^{1-\gamma_c} - \psi\left(\frac{d_t^h}{c_t}\right)^{1-\gamma_d}} = E_t\left\{\beta\frac{\Lambda_{t+1}}{\Lambda_t}\right\}\left(R_t^f - R_t^d\right) \tag{46}$$

where $R_t^f \equiv \left[E_t\left\{\beta\frac{\Lambda_{t+1}}{\Lambda_t}\right\}\right]^{-1}$. The left-hand side is the marginal benefit of an additional \$1 of deposits for households—additional utility from deposits—while the right-hand side is the marginal cost—deposits earn less than the risk-free rate. In this sense, $\psi$ is the "intercept" of households' deposit demand, and $\gamma_d$ controls the slope of their demand curve.

The bank's problem (28), after plugging in equation (29) and the constraints and rearranging, becomes

$$\max_{p_t}\; E_t\int\left\{\varepsilon\,(1-\delta+r_{t+1}) - (1-p_t)\,R_t^d\,(1-\zeta) - \frac{\lambda p_t}{(1-p_t)^\nu}\,(1-\zeta)\right\}^+ dF(\varepsilon)$$

for which the first-order condition is equation (32), which we solve numerically for $p_t$. Notice also that the default threshold $\underline{\varepsilon}_{t+1}$ becomes

$$\underline{\varepsilon}_{t+1} = (1 - p_t)(1 - \zeta)\frac{R_t^d + \lambda(p_t)}{1 - \delta + r_{t+1}}.$$

The left-hand-side of equation (32) is the marginal benefit of increasing $p_t$, while the right-hand side is the marginal cost. The marginal cost is $\lambda$ at $p_t = \xi_t = 0$ and rises to infinity as $p_t \to 1$, so if $R_t^d > \lambda$, $\xi_t = 0$ and there is a single solution to equation (32) for $p_t$; otherwise $\xi_t = \lambda - R_t^d$ and the optimal $p_t = 0$.

**Numerical solution method.** In this economy there is a single exogenous state variable, $A_t$, and two endogenous state variables, which we denote $Y_t$ and $X_t$. The variable $Y_t$ is total output available for consumption and future investment. The variable $X_t$ is total wealth held by firms before they make dividend payments. That is,

$$\begin{aligned}
Y_t &\equiv \phi_{t-1} d_{t-1}^f + A_t k_{t-1}^\gamma + (1 - \delta) k_{t-1} - \lambda \frac{p_{t-1}}{(1 - p_{t-1})^{1+\nu}} \left(d_{t-1}^h + d_{t-1}^f\right) \\
X_t &\equiv \left[(\bar{z} - w_{t-1})\phi_{t-1} + R_{t-1}^d\right] d_{t-1}^f.
\end{aligned}$$

Notice that $X_t$ is predetermined at $t - 1$, much like $d_t$ was predetermined at $t - 1$ in the model of Section 3. However, in this model $\alpha_t$ is a choice variable of firms, so that $d_t^f$ satisfies

$$d_t^f = (1 - \alpha_t) X_t,$$

where the dependence of $d_t^f$ on the state at $t$ comes from its dependence on $\alpha_t$. The bank's capital constraint (10) becomes

$$\begin{aligned}
n_t &\geq \zeta k_t \\
&= \zeta \left(n_t + d_t^h + d_t^f\right).
\end{aligned}$$

We solve the model globally on a grid of values for the state variables. Instead of using $Y_t$ and $X_t$, however, we define

$$\omega_t \equiv \log X_t - \psi_0 - \psi_1 \log Y_t,$$

where $\psi_0$ and $\psi_1$ are constants, and we solve the model over $\log Y_t$ and $\omega_t$. Solving the model on a grid for $\omega_t$ rather than $\log X_t$ is more accurate because $\log Y_t$ and $\log X_t$ are correlated in equilibrium, so that solving on a grid of $\log Y$ and $\log X$ would include node points that occur with extremely low probabilities in the ergodic distribution. In addition, instead of using equation (46) to solve for households' deposits directly, it is more convenient to instead solve for

$$\Upsilon_t \equiv \psi \left(\frac{d_t^h}{c_t}\right)^{1-\gamma_d} \frac{1}{c_t^{1-\gamma_c}}.$$

Given $c_t$, there are simple one-to-one mappings between $\Upsilon_t$, $\Lambda_t$, $d_t^h$, and $d_t^h/c_t$. However, in practice $\Upsilon_t$ is easier to interpolate between node points, which we must do to compute expectations of $\Lambda_{t+1}/\Lambda_t$, as described below. In a similar vein, for fixed values of the right-hand side of equation (46), the left-hand side is monotonically decreasing in $d_t^h/c_t$, so we solve it in $d_t^h/c_t$ and back out the implied values of $d_t^h$ and $\Upsilon_t$ at each node point. For the model to be sensible, we require $\Upsilon_t \in (0,1)$. To enforce this, rather than interpolate $\Upsilon$ as a Chebyshev polynomial, we instead interpolate $\hat{\Upsilon}$, where

$$\hat{\Upsilon} \equiv \log\left(\frac{\Upsilon}{1-\Upsilon}\right).$$

This ensures $\hat{\Upsilon}$ can range between $-\infty$ and $\infty$ even as $\Upsilon$ remains in $(0,1)$, not only on the node points but between them as well.

We choose six points for $\log A_t$ using the method of Rouwenhorst (1995), and for each $\log A_t$ point we approximate $\alpha_t$, $R_t^d$, $w_t$, $\phi_t$, $\hat{\Upsilon}_t$, and $\log c_t$ as fifth-order Chebyshev polynomials on a grid of 36 points for $\log Y_t$ and $\omega_t$. In particular, at each of the $6 \times 36 = 216$ node points, we solve equations (7) and (44) for $w_t$ and $\phi_t$, given $d_t^f$ and $R_t^d$, and equations (27) and (45) for $R_t^d$ and $\alpha_t$, given $p_t$, $\phi_t$, and $w_t$. Consumption $c_t$ comes from the household's budget constraint

$$\begin{aligned} c_t &= Y_t - k_t \\ &= Y_t - \frac{1-\alpha_t}{1-\zeta_t} X_t, \end{aligned}$$

which we then use to solve equation (46) for $\hat{\Upsilon}_t$. We then solve equation (32) for the optimal $p_t$, setting $p_t = 0$ if $R_t^d < \lambda$.

This procedure requires a guess for $\left(\alpha_t, R_t^d\right)$ to solve for $(\phi_t, w_t)$ and a guess for $(\phi_t, w_t, p_t)$ to solve for $\left(\alpha_t, R_t^d, d_t^h\right)$, in addition to expectations of $\Lambda_{t+1}$, at each node point. Given $R_t^d$, we solve for $(w_t, \phi_t)$ by searching over values of $w_t$ to satisfy equation (19) after plugging in equation (42).

We solve equations (27) and (45) for $\left(\alpha_t, R_t^d\right)$, given $(w_t, \phi_t)$ and using a guess for the interpolated $\log c$ and $\hat{\Upsilon}$ functions of the state (i.e., evaluated at any state) that allows us to compute expectations of $\Lambda_{t+1}$ at time $t$ for each node point. We then solve equation (46) for $d_t^h/c_t$ given our solution for $\left(\alpha_t, R_t^d\right)$ and using the guess for $p_t$. Interpolating $\log c$ and $\hat{\Upsilon}$ on the grid rather than $c$ and $d^h$ allows us to ensure that consumption and the marginal utility of consumption are always positive, not just at the node points but at every point between them as well.

After solving for $R_t^d$ at each node point, we update the value of $p_t$ by inverting equation (32) to get $p_t = p\left(R_t^d\right)$, which we linearly interpolate on a grid of 1,000 points for $R_t^d$ from $\lambda$ to 1.06. We have $p_t = 0$ whenever $R_t^d < \lambda$. This "kink" at $R_t^d = \lambda$ is why we do not interpolate $p_t$ using Chebyshev polynomials at the node points, as we do for the other endogenous state variables; instead we compute $p_t = p\left(R_t^d\right)$ dynamically during simulations, since this function depends only on parameters and $R_t^d$.

We start with a guess for the value of each variable at each node point from the quasi-linear utility model and iterate until the maximum percentage change across the six endogenous variables $\left\{R^d, \phi, w, \alpha, p, d^h\right\}$ from iteration to iteration is zero to four decimal places in absolute value. We use level changes (not percentages) for $p$ since $p$ is zero at some node points.

After solving the model equations, we simulate 2,500 economies for 700 periods each in order to verify that the model remains within the assumed bounds for the endogenous state variables. Each simulation starts at the steady state of the quasi-linear utility model. To estimate the implied moments of the model, we compute averages over time and over the 2,500 simulated economies, throwing away the first 200 observations of each simulation to reduce dependence on the initial state. We simulate the model using the full Gaussian distribution for $\log A$, linearly interpolating Chebyshev polynomials between the node points in the Markov chain, rather than simulating the Markov chain approximation of $\log A$ itself.

To compute welfare for a change to $\zeta$, we simulate 1,000 economies, using the $\zeta = 8\%$ model, for 400 periods. We then take the 2,500 points in the final period as the initial point for each value of $\zeta$ we consider; that is, we discard the first 399 points and assume that at $t = 401$, the new capital requirement is $\zeta$. This implies no change to $A$, $\log Y$, or $\omega$, but it does change the endogenous policy functions $\alpha$, $\phi$, $w$, and $R^d$ as a function of the state. We then simulate 1,000 economies of 500 periods each for 100 values of $\zeta$ between 0.07 and 0.3 to compute welfare.

For the model parameters reported in Table 1, we use $\psi_0 = 0.35$ and $\psi_1 = -0.22$. For these values of $\psi_0$ and $\psi_1$, we find that for values of $\zeta$ ranging from 7% to 30% we can solve the model on a grid of $(1.3, 1.7)$ for $\log Y$ and $(-0.15, 0.15)$ for $\omega$. For the higher values of

$\zeta$ in the full model, we need to decrease the lower bound for $\omega$ a bit, to -0.169.

## E.4 Additional Welfare Calculations

This section describes the computation of welfare in the model with only households' deposits (i.e., the dotted line in Figure 4) and the computation of welfare in the full model when shutting down the novel channel that acts through wages (i.e., the dashed line in Figure 4).

To compute the dotted line in Figure 4, we solve a version of the model without firm deposits and calibrate it to the same moments as in Table 1. To do so, we assume that $p_z = 1$, so that firms face no idiosyncratic risk. As a result, equation (7) simplifies to $w_t = 1$, and equation (44) pins down the level of labor $l_t$. To calibrate the model, we use the same fixed parameters in Panel A of Table 1, and we target the same moments of Panel B of Table 1, albeit with two differences. First, because we set $p_z = 1$, we ignore the continuers employment growth target. Second, because firms do not hold deposits in this model, we now set $\psi$ to match the deposit premium and $\chi$ to match the average quantity of labor as in the full model. Notice that, by construction, this implies that the two models will have the same average quantity of deposits as well. This calibration implies $\chi = 0.324$, $\sigma = 0.0311$, $\nu = 0.1435$, $\lambda = 1.03404$, $\psi = 0.0815$, $\gamma_d = 2.43$, and $\sigma_A = 0.00635$.

The model with only households' deposits has only a single endogenous state, $Y_t$. However, for consistency, we solve it on the same grid for $\log Y$ on which we solve the full model (i.e., 6 Chebyshev zeroes in $[1.3, 1.7]$). Apart from the lower dimension, we solve this model exactly as we solve the full model, that is, as described in Appendix E.3.

To compute the welfare $\widehat{W}(\zeta)$, which is represented by the dashed line in Figure 4, we follow an approach similar to that of Section 4.3. The complication is that the full quantitative model includes aggregate risk and, thus, the wage $w_t$ in the baseline scenario—in which the capital requirement remains unchanged at the 8% level—is not constant over time. More precisely, the path of $\{w_t\}$ depends on the path of the exogenous productivity $\{A_t\}$. Nonetheless, we can follow the approach of Section 4.3 as long as we "integrate over" all the possible paths of $A_t$. First, note that when we change the capital requirement from 8% to $\zeta \in [7\%, 30\%]$, we draw 1,000 exogenous paths of $A_t$, denoted by $\left\{A_t^{(j)}\right\}$ for $j = 1, \ldots, 1,000$, and then we compute the overall welfare by averaging out across the welfare in each path.[34] To compute $\widehat{W}(\zeta)$, we follow the procedure described in Section 4.3 for each path $j$, and then we average out the results. That is, for any given $j$, we use the exogenous path $\left\{A_t^{(j)}\right\}$ to compute the path of the wages $\left\{w_t^{(j)}\right\}$ that would arise if we keep the capital requirement unchanged at 8%. Then, for each $t$, we compute $\hat{\phi}_t^{(j)}$ using equation (42) evaluated at $w_t^{(j)}$

[34]More precisely, we use the same 1,000 paths of $A_t$ for all values of $\zeta$.

and at the correct return on deposits. We then use $\hat{\phi}_t^{(j)}$ to derive the counterfactual paths of labor and consumption, $\hat{l}_t^{(j)}$ and $\hat{c}_t^{(j)}$, which we use to compute welfare along the exogenous path $j$. Finally, we average out across $j$'s, obtaining $\widehat{W}(\zeta)$.

# F Deposits held by firms and households

To gather data about households' holdings of deposits, we use the Survey of Consumer Finances (SCF).[35] We measure deposits as the sum of transaction accounts and certificates of deposit. Transaction accounts include savings, checking, and money market deposit accounts, money market funds, and call or cash accounts at brokerages. Prepaid debit cards are included starting in 2016. The SCF is administered every three years. We use the data from the last survey, 2016, but we also analyze the previous waves starting in 1989.[36]

For firms, we use data from the Flow of Funds (FF). For comparison with the SCF, we use data for the third quarter of the years in which the SCF is administered because the majority of the SCF data is collected between May and December. We consider nonfinancial noncorporate and corporate holdings of checkable deposits and currency, total time and savings deposits, and money market fund shares. In our baseline calculations, we include money market fund shares to make the results comparable with the households' transaction accounts in the SCF. However, as described below, we compute a robustness check in which we exclude money market fund shares for both households and firms, and the results are virtually unchanged.

In 2016, firms' deposits as a fraction of deposits held by both firms and households is about 1/3 (33.88%), and households' deposits is 2/3. The result is virtually identical in 2013 (33.95%). As shown in Figure 6, the share of firms' deposits has increased over time, in line with the results of the literature that documents the increase in firms' cash holdings (Bates, Kahle and Stulz (2009)). In levels, firms held \$2.86 trillion and households held \$5.58 trillion. If we remove money market funds, the 1/3 versus 2/3 number is essentially unchanged. In 2016, firms' holdings of money market funds are \$0.58 trillion (FF), and retail money market funds are \$0.89 trillion (Cipriani and La Spada (2017)). Assuming that retail funds are held by households, the shares of firms' and households' deposits become 32.72% and 67.28%, respectively.[37]

[35] We do not use the Flow of Funds data to measure households' deposits because estimates for this sector are largely residuals and are derived from data for other sectors.

[36] The SCF is also available before 1989, but the sample design and the core of the SCF questionnaire have only changed in minor ways since 1989.

[37] As noted by Cipriani and La Spada (2017), this number is computed using data on a subset of money market funds that covers about 90% of the total net assets. Thus, our estimate is slightly conservative.

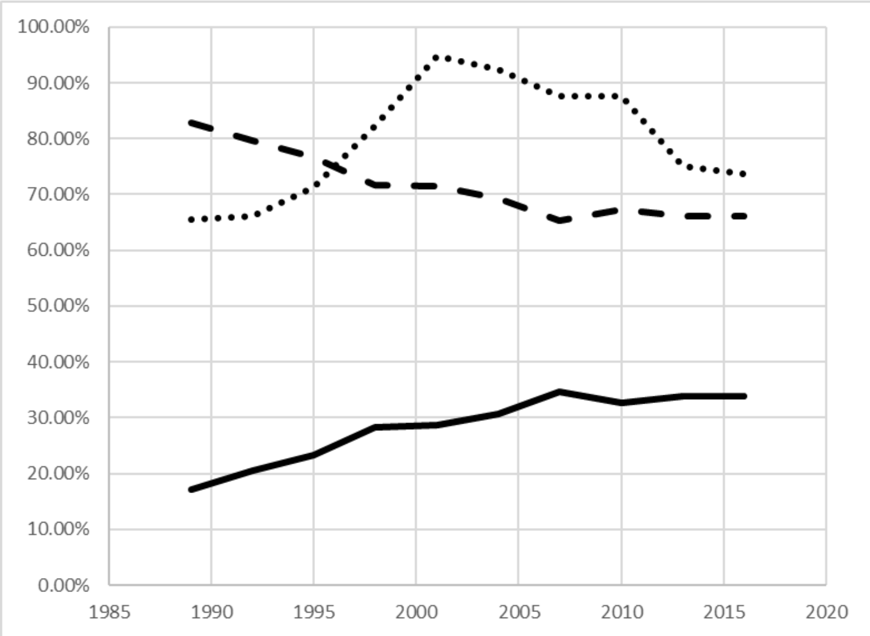


**Figure 6.** The solid line plots firms' deposits as a fraction of deposits held by firms and households. The dashed line plots households' deposits as a fraction of deposits held by firms and households. The dotted line plots firms' and households' deposits as a fraction of deposits at FDIC-insured banks.

For completeness, we also note that deposits are held not only by households and firms. In the FF data, other holders include state and federal governments, the nonprofit sector, non-US holdings, and the financial sector itself. Because these agents either do not hold deposits in our model or are not even modeled, we do not consider their holdings of deposits.

We also compare the data we have used from the SCF and the FF with total deposits at FDIC-insured banks, as reported by the FDIC. The share of deposits held jointly by households and firms as a fraction of total deposits at FDIC-insured banks is 73.66% in 2016; as shown by the dotted line in Figure 6, this share was lower in 1989 and reached its peak in 2001. While other agents hold deposits in practice, as noted above, firms' and households' deposits account for a very large fraction of deposits at FDIC-insured banks. In addition, even if deposits at FDIC-insured banks do not represent the universe of deposits, they do account for most of them. In 2016, deposits at FDIC-insured banks are $11.46 trillion, whereas deposits at federally insured credit unions are $1.1 trillion (National Credit Union Administration data) and assets managed by money market mutual funds are slightly less than $3 trillion (Cipriani and La Spada, 2017).

Finally, we note that firms' holdings of cash-like securities are mostly in deposits at banks. For instance, in 2016, investments in commercial paper are $0.15 trillion and those in Treasury securities $0.11 trillion.

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