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Private Money Creation, Liquidity Crises, and Government Interventions

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Abstract

The joint supply of public and private liquidity is examined when financial intermediaries issue both riskless and risky debt and the economy is vulnerable to liquidity crises. Government interventions in the form of asset purchases and deposit insurance are equivalent (in the sense that they sustain the same equilibrium allocations), increase welfare, and, if fiscal capacity is sufficiently large, eliminate liquidity crises. In contrast, restricting intermediaries to investing in low-risk projects always eliminates liquidity crises but reduces welfare. Under some conditions, deposit insurance gives rise to an equilibrium in which intermediaries that issue insured debt (i.e., traditional banks) coexist with others that issue uninsured debt (i.e., shadow banks), despite the two being ex ante identical.

Public and private liquidity; Financial crises; Deposit insurance; Asset Purchases; Financial Regulation.

G01, G28, E44

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1 Introduction

The 2007-2008 financial crisis has highlighted the existence of two main classes of money-like securities that can provide liquidity services. The first class includes safe financial assets such as Treasury securities, whereas the second class includes several types of liabilities of the so-called shadow banking system. The securities in this second group of securities were not completely safe because of a lack of appropriate backing on intermediaries' balance sheets. At the height of the crisis, these securities lost not only their value but also their ability to provide liquidity services.

In response to these events, the U.S. government increased the direct supply of public liquidity as well as the support and backing of the liquidity supplied by private intermediaries. These interventions included the asset purchase programs of the Federal Reserve, the increase in the deposit insurance limit, and the Temporary Liquidity Guarantee Program offered by the Federal Deposit Insurance Corporation (FDIC). In addition, after the crisis, the regulation of financial intermediaries was made more stringent with the objective of making private intermediaries' debt safe and reducing the likelihood and depth of future crises.

Motivated by these events, this paper uses a general equilibrium model to provide a unifying analysis of the interaction between private and public liquidity and of three key policies implemented in response to the 2007-2008 financial crisis: the central bank's asset purchases and expansion of the public liquidity provision, government guarantees of private money, and regulation of financial intermediaries.

We focus on three main questions. First, we study whether liquid assets should be supplied by the government or by private financial intermediaries—a classic question in macroeconomics (Sargent, 2011). Second, if a positive supply of government liquidity is optimal, should such assets be backed by taxes or by a portfolio of private securities held by the central bank? Third, if a positive supply of private money by financial intermediaries is optimal, should the intermediaries be subject to regulation, such as deposit insurance or restrictions on the riskiness of their investments?

To clarify the forces behind our results, some stark assumptions are made to keep the model simple and tractable. In the model, a financial friction forces agents to use debt securities for transaction purposes. In line with the historical evidence in Gorton (2017), riskless debt in our model (which we refer to as safe assets) always provides liquidity, whereas risky debt does so only in normal times, that is, when it is not defaulted on. This feature is a key distinction from the approach commonly used in the literature. Motivated by Gorton and Pennacchi (1990), some closely related papers use models in which only risk-free securities provide liquidity (see, e.g., Angeletos, Collard, and Dellas, 2016; Greenwood, Hanson, and Stein, 2015; Magill, Quinzii, and Rochet, 2016; Stein, 2012).

In the *laissez-faire* equilibrium, liquidity crises happen when risky private securities are defaulted on and thereby lose their liquidity value. The possibility of these crises opens up a role for government interventions, and our simple framework gives rise to a rich set of predictions.

If fiscal capacity is limited, the best policies are those in which public and private liquidity complement each other. Two such policies are studied: asset purchases (i.e., a large supply of public liquidity backed by the central bank's purchases of private securities) and deposit insurance. The two policies are equivalent, in the sense that they allow the economy to achieve the same allocation and thus the same welfare. This is because the consolidated balance sheet of all the agents that supply liquidity (i.e., government and financial intermediaries) is identical under the two policies. It is thus irrelevant, in the sense of Wallace (1981), whether the government supports liquidity with central bank interventions or with deposit insurance. An additional result that arises under deposit insurance is that the equilibrium is characterized by a coexistence of insured and uninsured intermediaries that invest in the same type of risky assets. This resembles the coexistence of traditional banks and shadow banks in practice and arises endogenously in our model.

With respect to the regulation of intermediaries' risk taking, it is studied a policy that forces all intermediaries to invest in low-risk, low-productive projects in order to avoid default. This policy eliminates liquidity crises but reduces welfare because it forces intermediaries to forgo projects that, albeit risky, have a higher expected return.

Financial intermediaries in our model can supply liquid assets by investing in risky or safe projects. Investment in risky projects allows intermediaries to offer risky assets, whereas investment in safe projects allows intermediaries to offer safe assets. However, safe projects are more costly because a fraction of the investment is lost; we motivate this cost with the need to screen and monitor projects to make sure that they are indeed safe. As a result, issuing risky debt that is subject to default allows financial intermediaries to save on such monitoring costs. The logic is similar to that in Geanakoplos (1997, 2003) in which the possibility of default is a way to economize on scarce and costly collateral.

The monitoring cost creates an incentive for intermediaries to supply risky assets. In bad states, these securities default, and therefore there is a shortage of liquidity. In addition, depending on the policy and parameters, some safe debt might also be supplied. This debt is always liquid and thus trades at a premium because of the shortage of liquidity in bad states.

Our results are first derived in a simple model in which risky debt fully defaults in crisis times, but we then show that the same results can be obtained in a richer model. In particular, one of the extensions considers adverse selection problems in the market of risky securities, in line with the narrative of the 2007-2008 financial crisis (Gorton, 2009) and with a large literature that has emphasized the role of this friction (Bolton, Santos, and Scheinkman, 2009, 2011; Gorton and Ordoñez, 2013, 2014, 2019; Malherbe, 2014).

Our analysis complements a recent literature that has studied the role of liquidity in macro models with financial intermediaries. Examples include Bianchi and Bigio (2016), Bigio (2015), Gertler and Kiyotaki (2010), Moreira and Savov (2016), and Quadrini (2014). With respect to this literature, the novelty of our paper is to analyze the coexistence between private and public liquidity and the advantage of one form of liquidity over the other in terms of efficiency. In this sense, our work is related to the classic debate in macroeconomics about the supply of private versus public liquidity (see Aguirre and Infantino, 2013, and Sargent, 2011, for a summary). The lack of policy interventions in the *laissez-faire* equilibrium can be reinterpreted as the suggestion of supporters of the free-banking theory, such as Hayek (1976), which emphasize the benefits of deregulation. The large supply of public liquidity backed by taxes or by a portfolio of private securities is related to the proposals of Friedman (1960), which instead argue that liquidity should be controlled by the government. The regulation that forces intermediaries to invest in safe projects is akin to the real-bills theory, according to which intermediaries should invest only in risk-free assets.

Some papers in the New Monetarist literature study the role of private money and its interaction with public liquidity by allowing physical capital to be used for transactions. However, they mostly focus on models with no aggregate risk, and either with only safe assets (Geromichalos, Licari, Suárez-Lledó, 2007; Lagos and Rocheteau, 2008) or, if multiple types of assets are included, with an exogenous supply of such assets (Rocheteau, 2011).

The banking literature is rich with models that analyze liquidity creation in the spirit of the seminal contribution of Gorton and Pennacchi (1990). The papers closest to ours are Greenwood, Hanson, and Stein (2015) and Magill, Quinzii, and Rochet (2016). These works assume that liquidity services are provided only by risk-free securities, whereas in our framework, risky securities can also be liquid. As a result, our model can study the determination of the liquidity and risk properties of private debt jointly as a function of the characteristics of financial intermediaries and the policy environment. In addition, the above two papers have some other important differences relative to our paper.

In Magill, Quinzii, and Rochet (2016), only private debt can provide liquidity services, and therefore the focus of their analysis is to study how government policies can enhance the supply of private liquidity. In our model, instead, government debt also has liquidity value. Despite these differences, both models predict that the central bank can achieve the first best by issuing safe securities and backing them by purchasing risky assets. In our model, this is a consequence of the direct liquidity role of public debt, whereas in their context, it is a way to increase the funds channeled to investments.

In Greenwood, Hanson, and Stein (2015), the policy analysis focuses on the optimal maturity structure of government debt. Short-term debt is more liquid but entails higher refinancing risk in comparison to long-term debt. In addition, the liquid short-term debt crowds out excessive money creation by financial intermediaries, limiting the negative effects of a fire-sale externality similar to that of Lorenzoni (2008) and Stein (2012). Our policy focus is instead on a different and broader set of government interventions.

Angeletos, Collard, and Dellas (2016) consider an environment in which privately issued, risk-free debt serves as collateral, but such debt is scarce because agents can pledge only a fraction of their future income. Therefore, they study how public liquidity and the government's commitment to raise more taxes in the future can ease this financial friction. In contrast, privately issued assets in our model include not only risk-free debt but also risky debt, which leads to policy conclusions that emphasize different features, namely, the interaction between government interventions and the supply of risky securities.

In a recent work, Brunnermeier and Niepelt (2019) have shown equivalence results in swaps between public and private money for the equilibrium allocations. In our model, private and public liquidity are not perfectly substitutable because of the cost of issuing private safe securities and the full default of risky securities in the low state of nature. Moreover, we also impose limitations on the government's ability to supply safe liquidity.

The rest of this paper is organized as follows. Section 2 presents the model. Sections 3 and 4 discuss the equilibrium with costless and costly monitoring of safe investments, respectively. Section 5 discusses the effects of government intervention. Section 6 presents our robustness analyses. Section 7 concludes.

2 Model

We present a simple two-period ($t = 0, 1$) general equilibrium model in which we show all our results analytically. The economy features three sets of actors: households, financial intermediaries, and the government.

Aggregate risk is introduced by assuming that there are two states of nature at $t = 1$, high and low. The high state is denoted by h and occurs with probability $1 - \pi$, with $0 < \pi < 1$. The low state is denoted by l and occurs with probability π. The key mechanism in our model is that the realization of the low state triggers defaults in the intermediary sector, which in turn give rise to a liquidity crunch.

At $t = 0$, households can invest their wealth in three types of securities: safe, riskless private debt issued by intermediaries that invest in safe projects, risky private debt issued by intermediaries that invest in risky projects, and government debt. Riskless debt is backed by safe investments and thus is never defaulted on. Risky debt is instead backed by risky investments that completely lose their value in the low state, and thus it is fully defaulted on in that state. Government debt is always repaid and therefore always safe.

At $t = 1$, part of the consumption expenditure of households must be financed with debt securities. That is, households are subject to a liquidity constraint, and liquidity services are provided by the debt securities purchased at $t = 0$. Since risky securities are fully defaulted on in the low state, they do not provide any liquidity service in that state.

The assumptions that there are only two types of privately issued securities and that all the risky debt issued by financial intermediaries is worth zero in the low state might look extreme. However, in Section 6 and in the Appendix, we show that the model can be enriched to relax these assumptions without altering any of the results.

2.1 Environment

The model has two periods, $t = 0, 1$. Time $t = 1$ is divided into two subperiods. Households have the following preferences:

$$X + (1 - \pi)\left[\ln C_h + X_h\right] + \pi\left[\ln C_l + X_l\right], \tag{1}$$

where X denotes consumption at $t = 0$, C_h and C_l denote consumption in the first subperiod at $t = 1$ in state h and l, respectively, and X_h and X_l denote consumption in the second subperiod of $t = 1$ in state h and l, respectively. Without loss of generality, the discount factor between $t = 0$ and $t = 1$ is normalized to one. The functional form of (1) allows us to derive simple and stark results. Nonetheless, we show in Section 6 and in the Appendix that the key results are unchanged if households have a more general utility function, although the derivation becomes more complicated.

The resource constraint of the economy is described to characterize the first-best allocation. Then we introduce financial frictions and describe the problem of households, government, and financial intermediaries.

At $t = 0$, there is an endowment of goods $\bar{Y}$, which can be consumed or transformed into two types of capital: safe capital K^S and risky capital K^D. The two types of capital have the same average productivity at $t = 1$, but the safe capital requires an extra investment τ for each unit of capital at $t = 0$. The cost τ can be interpreted as a monitoring cost to control the safety of capital, motivated by Diamond (1984). Thus, the aggregate resource constraint at $t = 0$ is

$$X + (1 + \tau)K^S + K^D \leq \bar{Y}. \tag{2}$$

At $t = 1$, each unit of safe capital K^S produces one unit of output in both states h and l. In contrast, each unit of risky capital K^D produces $A_h > 1$ unit of output in state h and zero units in state l. The assumption of equal average productivity of the two types of capital at $t = 1$ can be formalized as $(1 - \pi)A_h = 1$.

At $t = 1$, there is another endowment of goods that can possibly be state-contingent and is denoted by $\bar{Y}_h$ and $\bar{Y}_l$ in the high and low state, respectively, with $\bar{Y}_l \leq \bar{Y}_h$. The time-1 endowment and output are available in the first subperiod of $t = 1$, but they can be used for consumption in both subperiods. Thus, the aggregate resource constraints in state h and l at $t = 1$ are

$$C_h + X_h \leq \bar{Y}_h + K^S + A_h K^D, \tag{3}$$

$$C_l + X_l \leq \bar{Y}_l + K^S. \tag{4}$$

The endowments $\bar{Y}_h$ and $\bar{Y}_l$ are interpreted as the resources produced by a sector of the economy for which financial intermediation does not play a key role, such as large firms that have access to the equity and bonds market, and thus we take these endowments as given.

In this environment, the key condition that characterizes the first best is the equality between the marginal utilities of consumption in the two subperiods at time $t = 1$:

$$\frac{1}{C_h} = 1, \quad \frac{1}{C_l} = 1. \tag{5}$$

Without any further assumption, and provided that endowments are sufficiently large, households could achieve an allocation that implements (5) without any role for financial intermediation, government intervention, or both.

Next, financial frictions are introduced that limit the ability of households to consume in the first subperiod. These frictions give rise to a role for intermediaries and the government as suppliers of liquid assets.

We follow Lucas and Stokey (1987) by assuming that each household is composed of a shopper and a seller, and the shopper must purchase the consumption goods C_h and C_l from sellers of other households. In addition, the purchases must be paid immediately with some financial instrument. Formally, this is equivalent to assuming that households lack the commitment that would allow them to purchase C_h and C_l with credit (i.e., to repay in the second subperiod). If instead households could pledge the resources that they have available in the second subperiod of $t = 1$ (such as any unsold endowment or the proceeds from selling goods in the first subperiod), they could overcome this financial friction. In other words, these resources are non-contractible.

Financial intermediaries and the government can both supply the securities that households need to purchase goods C_h and C_l.

A financial intermediary can issue either safe (risk-free) securities S and invest in safe capital K^S or issue risky securities D and invest in risky capital K^D. These securities are modelled as zero-coupon debt with a face value of one. That is, S has a unitary payoff at $t = 1$ in both states, and D has a payoff of one in state h and zero in state l. Different from households, intermediaries can commit to repaying the securities issued at $t = 0$ using any resources that they have available at $t = 1$, namely, the payoff of capital. However, despite the commitment, the lack of resources available to risky intermediaries in state l gives rise to a limited liability constraint. As a result, risky intermediaries fully default on their debt in state l.[1]

The government can also commit and thus issue securities that households can use as payment instruments at $t = 1$ together with S and D. Government debt is always repaid and thus is a safe asset, as we explain in Section 2.4. We assume that households are endowed at time $t = 0$ with an amount of government debt $\bar{B}$, which is repaid in the second subperiod of $t = 1$ by raising taxes.[2] In the policy analysis of Section 5, we allow for a richer set of interventions, and we show that the amount of taxes that the government can levy determines the level of public liquidity.

Having introduced the financial friction in the model, we now discuss the behavior of households, financial intermediaries, and the government.

2.2 Households

At time 0, households face the following budget constraint:

$$Q^B B + Q^S S + Q^D D + X \leq \bar{Y} + Q^B \bar{B}. \tag{6}$$

They begin time $t = 0$ with an endowment $\bar{Y}$ of goods and with government bonds $\bar{B}$, and the latter can be traded at price Q^B. They can use these resources to consume X or to invest in a portfolio of securities which includes government bonds B traded at price Q^B, safe private securities S issued by the intermediaries at price Q^S, and risky private securities D issued by intermediaries at price Q^D.

We model the debt of government and financial intermediaries as zero-coupon securities with a face value of one. Government debt and private safe securities are risk-free and thus always pay one unit in both the high and low state. Risky private debt, however, has a payoff of one in state h and zero in state l because it is fully defaulted on in state l. In Section 6 and in the Appendix, we show that our results are unchanged in two frameworks with a richer modeling of risky securities. The first framework considers also risky securities that are partially defaulted but instead are liquid in the low state. In the second framework, risky securities have idiosyncratic payoff, and some of them are fully repaid in the low state; however, they do not provide liquidity because of an adverse selection problem.

At time 1, consumption C_h and C_l must be financed with the debt securities purchased at $t = 0$. Safe debt always provides liquidity services, whereas risky debt provides these services only in state h. Therefore, purchases of C_h and C_l are subject to the following liquidity constraints:

$$C_h \leq B + S + D \tag{7}$$

$$C_l \leq B + S. \tag{8}$$

In state h, consumption C_h can be financed with B, S, and D because all three securities are fully repaid. In state l,

[1] The limited liability constraint could in turn be motivated by the lack of commitment of households to make any payment at $t = 1$. That is, even if households make a promise, at $t = 0$, to recapitalize any insolvent intermediary at $t = 1$, they would then default on that promise because of their lack of commitment.

[2] Without loss of generality, we have assumed that households are endowed with $\bar{B}$, although we could reformulate the model to allow the government to issue this debt at $t = 0$.

consumption C_l can be financed only with B and S because securities D are fully defaulted on. Consumption of goods X_h and X_l in period 1 is subject to the following budget constraints:

$$X_h \leq \bar{Y}_h + B + S + D + \Pi_h - C_h - T_h \tag{9}$$
$$X_l \leq \bar{Y}_l + B + S + \Pi_l - C_l - T_l, \tag{10}$$

in which T_h and T_l are state-contingent lump-sum taxes and Π_h, Π_l are state-contingent intermediaries' aggregate profits.

It is worth emphasizing that constraints (7) and (8) capture the special properties that some debt securities have in the modern financial system because of the liquidity services they provide. These securities have been broadly labeled "safe assets," and a recent literature has modeled them as riskless (see, among others, Caballero and Farhi, 2017; Diamond, 2016; Li, 2017; Magill, Quinzii, and Rochet, 2016; Stein, 2012; Woodford, 2016). However, as discussed by Gorton (2017), the historical evidence shows that debt securities that provide liquidity services are not necessarily risk-free. In some countries, such as the U.S. and the U.K., these risky and liquid securities have been issued by private intermediaries, whereas government debt has been essentially risk-free. Moreover, throughout the history of financial systems, these private debt securities have taken the form of goldsmith notes, bills of exchange, bank notes, demand deposits, certificates of deposit, commercial paper, money market mutual fund shares, and securitized AAA debt.

Consumption and portfolio choices follow from the maximization of (1) under the constraints (6), (7), (8), (9), and (10). The optimal consumption of C_h and C_l is given by

$$C_h = \frac{1}{1+\mu_h} \qquad C_l = \frac{1}{1+\mu_l}, \tag{11}$$

respectively, where μ_h and μ_l are the Lagrange multipliers associated with the liquidity constraints (7) and (8). Since $\mu_h, \mu_l \geq 0$, it follows that $C_h, C_l \leq 1$ and, thus, $C_h = C_l = 1$ at the first best.

To conclude the characterization of the household's problem, we derive the demand for government debt and intermediaries' debt. This demand is affected by the liquidity value provided by these assets, captured by the Lagrange multiplier μ :

$$Q^B = Q^S = 1 + (1-\pi)\mu_h + \pi\mu_l, \tag{12}$$
$$Q^D = (1-\pi)(1+\mu_h). \tag{13}$$

Private debt D provides liquidity services only in state h when it is not defaulted on. An implication of (12) and (13) is that $Q^B = Q^S \geq Q^D$. Crucially, liquidity services provide benefits not only to households but also to the issuer of the debt security because they lower borrowing costs. We return to this point later in the analysis.

2.3 Financial intermediaries

There is an infinite number of small financial intermediaries that can choose the type of capital (safe capital, K^S, or risky capital, K^D) in which to invest and therefore the type of debt security to supply, safe or risky. Since intermediaries are small and thus marginal with respect to the supply of each market, they take prices Q^S and Q^D as given. We assume that each intermediary can supply only one type of security, although a given security can be supplied by infinitely many intermediaries. In Section 6, we show that our results are unchanged in the case that each intermediary can invest in both types of capital.

Intermediaries have limited liability in period 1. As a result, they default on their own debt if the payoff of capital is not sufficient to cover the debt obligations.

We begin with the analysis of intermediaries that issue safe debt S. At time $t = 0$, they invest in riskless capital K^S subject to the budget constraint

$$(1+\tau)K^S = Q^S S. \tag{14}$$

As previously discussed, we interpret τ as a cost of monitoring the safe capital. At time $t = 1$, their profits are not contingent on the realized state of nature and are given by

$$\Pi_h^S = \Pi_l^S = K^S - S. \tag{15}$$

Substituting K^S from the budget constraint (14) into (15), the optimal supply of safe debt is non-negative insofar as

$$Q^S \geq (1+\tau), \tag{16}$$

and it is zero otherwise.

Intermediaries issuing risky securities D invest in the risky capital at $t = 0$ subject to the budget constraint

$$K^D = Q^D D. \tag{17}$$

At $t = 1$, profits in state h are given by

$$\Pi_h^D = A_h K^D - D, \tag{18}$$

whereas profits in state l are zero because the payoff of risky capital is zero and debt is fully defaulted on, following the limited liability assumption. As a consequence, the supply of risky debt is non-negative insofar as

$$Q^D \geq 1 - \pi \tag{19}$$

and is zero otherwise.

Intermediaries are free to choose in which security market to enter, and they take this decision according to the maximum profits that they can obtain. That is, they enter the market of safe securities if the expected profits in that market are higher than those of risky securities, and vice versa.

2.4 Government

In the baseline analysis, we consider the simple case in which the balance sheet of the government is composed of only liabilities, that is, zero-coupon bonds $\bar{B}$. These bonds can be interpreted as Treasury debt or the central bank's reserves. In Section 5, we extend the analysis by allowing the government to issue more debt at $t = 0$, to purchase privately issued securities, possibly through the central bank, and to guarantee the debt issued by private intermediaries.

Recall that households are endowed, at $t = 0$, with government debt $\bar{B}$. These government liabilities are free of risk because the government raises enough taxes to back them, namely, T_h and T_l in the high and low state of $t = 1$ with

$$T_h = T_l = \bar{B}. \tag{20}$$

An alternative interpretation of the ability of the government to fully repay its debt can be given if we extend the analysis to a monetary economy with a constant price level in which government debt is backed by the central bank's liabilities. Indeed, the central bank's liabilities define the unit of account for the monetary system and are thus free of risk by definition; that is, the central bank can repay its liabilities by "printing" new reserves. In the policy analysis of Section 5, we will impose some restrictions on the ability of the government to increase taxes T_h and T_l.

3 Equilibrium with no monitoring costs

We now solve for the equilibrium in the benchmark scenario in which there are no monitoring costs to invest in risk-free projects, that is, $\tau = 0$. Despite the liquidity constraint, the first best can be achieved through either private or public liquidity.

To solve for the equilibrium, we first note that free entry abates to zero all profits and implies that the supply of safe and risky debt is non-negative at their respective prices:

$$Q^S = 1 + \tau, \tag{21}$$

$$Q^D = 1 - \pi. \tag{22}$$

The next proposition shows that in equilibrium, safe securities are supplied in a sufficient quantity to satiate the demand for liquidity.

Proposition 1 *In the model with no monitoring costs ($\tau = 0$), there is complete satiation of liquidity, $\mu_h = \mu_l = 0$, and consumption is at the first best, $C_h = C_l = 1$. The quantity of financial intermediaries' safe debt is given by*

$$S \geq \max\left(1 - \bar{B}, 0\right), \tag{23}$$

which is issued at the price $Q^S = 1$.

The economy achieves the first best because the supply of safe assets is sufficiently large. This can be achieved in two ways. If $\bar{B} \geq 1$, the government achieves the first best by supplying a large quantity of public liquidity, which can be interpreted as a way to implement the Friedman rule. If instead $\bar{B} < 1$, private money issued by intermediaries is crucial to complement the supply of public liquidity and achieve the first best. We elaborate more on the second case.

When $\bar{B} < 1$, the efficiency result of Proposition 1 is a direct implication of the competition mechanism of the model, which allows financial intermediaries to decide the type of debt to supply. To understand this point and prove the proposition, suppose by contradiction that there is no supply of safe debt. Instead, assume that intermediaries only provide risky assets. As a result, in the low state, risky securities default, and thus consumption can be financed with public liquidity only. Using (8) and (11), the Lagrange multiplier of the liquidity constraint in the low state is positive,

$$\mu_l = \frac{1}{\bar{B}} - 1 > 0, \tag{24}$$

and thus there is a shortage of liquidity in that state. In contrast, equilibrium in the market of risky securities, which require both (13) and (22) to hold, implies that the Lagrange multiplier of the liquidity constraint is zero in the high state, $\mu_h = 0$. That is, the supply of risky securities is large enough to satiate liquidity needs in the high state, and thus there is no shortage of liquidity in that state. Now consider a generic intermediary deciding which security to issue. Suppose that the intermediary chooses to issue safe debt, which never defaults. Consumers attach a high value to safe securities because the liquidity premium in the low state is positive; this high value is reflected in the price $Q^S = (1 + \pi\mu_l)$ that they are willing to pay. The high Q^S implies that the intermediary can borrow at a lower cost and, thus, its profits are positive in both states: $\Pi_h^S = \Pi_l^S = \pi\mu_l > 0$. Thus, issuing safe securities S is profitable. This result contradicts the initial conjecture that an equilibrium exists in which safe debt is not supplied by any intermediary.

To sum up, intermediaries supply safe private securities up to the point at which the liquidity premium is driven to zero in all states, $\mu_h = \mu_l = 0$. That is, free entry into the market ensures that all rents are eliminated. The supply of safe securities is enough to complement the amount of public liquidity (as described by (23)) and reach the first best, $C_h = C_l = 1$. Moreover, the supply of risky securities can be positive in equilibrium, and their price is just given by the present discounted value of their expected payoffs. However, the supply of these assets is irrelevant for welfare.

This section is closed by comparing Proposition 1 with some related literature that studies liquidity. In versions of the Lagos and Wright (2005) model in which physical capital can be used for payment (e.g., Geromichalos, Licari, and Suárez-Lledó, 2007; and Lagos and Rocheteau, 2008), a sufficiently large supply of capital satiates the demand for liquidity. The result of Proposition 1 is similar in spirit. Even though capital does not provide liquidity directly in our model, it is used by intermediaries to back their supply of private money. In addition, given $\tau = 0$, intermediaries choose to hold safe capital as backing. Thus, the key difference with this literature is that intermediaries endogenously choose the amount and riskiness of capital that is used as backing and thus the riskiness of private money. This result reflects the similarities between our approach and that of Geanakoplos and Zame (2002, 2014) because the physical capital held by intermediaries in our model serves the same role as collateral in their model.

4 Equilibrium in the full model with monitoring costs

We now turn to the analysis of the full model in which intermediaries face a positive monitoring cost to invest in risk-free projects, $\tau > 0$. The main result of this more general framework is that risky securities—those that default and lose liquidity in the low state—are now supplied by intermediaries, and thus the amount of privately issued liquidity is lower than in the baseline model with no monitoring costs. In addition, depending on policies and parameters, risky and safe debt can coexist in equilibrium; when that is the case, some intermediaries supply risky debt, whereas others supply safe debt, even though these intermediaries are ex ante identical.

We present the results in two steps. First it is shown that the equilibrium must be characterized by a positive supply of risky assets, and then the full equilibrium is characterized.

Proposition 2 *Assume that financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital. If an equilibrium exists in which intermediaries supply debt securities, then there must be a positive supply of risky debt securities, that is, $D > 0$.*

If an equilibrium exists in which intermediaries are active and issue debt, three scenarios are possible: either all intermediaries issue safe debt, or all intermediaries issue risky debt, or some intermediaries issue safe debt and some others issue risky debt. Thus, we can prove Proposition 2 by showing that the scenario in which all intermediaries issue only safe debt S is not an equilibrium. We proceed by contradiction. Suppose that all intermediaries issue safe debt in equilibrium. In this case, equating demand (12) and supply (21), it follows that $\mu_h = \mu_l = \tau > 0$. To offset the monitoring cost, the liquidity premium on safe debt must be positive; if the liquidity premium were zero, intermediaries would make negative profits because of the cost τ. Note that a positive liquidity premium is associated with a level of consumption below the first best in some state. Furthermore, the fact that there are only safe securities that are equally liquid in both states implies that consumption is equalized across states. Therefore, $C_h = C_l < 1$; in particular, $C_h < 1$ and (11) imply that the Lagrange multiplier of the liquidity constraint in state h is also positive: $\mu_h > 0$. We can now identify a profitable deviation that leads us to conclude that the scenario with only safe debt cannot be an equilibrium. Given $\mu_h > 0$, households are willing to pay a liquidity premium on a security that relaxes the liquidity constraint (7) in the high state. Now consider an intermediary that issues risky debt D. This intermediary earns positive profits in the high state (and zero profits in the low state) because risky securities include a liquidity premium:

$$\Pi_h^D = \mu_h D > 0. \tag{25}$$

Thus, the intermediary has an incentive to deviate and issue risky debt.

More generally, the previous analysis can be extended to show that any scenario in which $\mu_h > 0$ cannot be an equilibrium because there would exist profitable deviations to increase the supply of risky securities. Thus, the Lagrange multiplier in the high state must be zero in equilibrium, $\mu_h = 0$.

We now characterize the full equilibrium. We focus on the case in which the government issues a limited amount of public liquidity (i.e., $\bar{B} < 1$), and we return to the analysis of government policy in Section 5.

Proposition 3 *If financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital and the government issues debt $\bar{B} < 1$, then:*
1) In the high state, there is full satiation of liquidity, and thus $C_h = 1$ and $\mu_h = 0$, whereas in the low state,

$$C_l = \max\left\{\frac{\pi}{\pi+\tau}, \bar{B}\right\} < 1 \quad \text{and} \quad \mu_l = \min\left\{\frac{\tau}{\pi}, \frac{1}{\bar{B}} - 1\right\}. \tag{26}$$

2) The price and supply of safe securities are

$$Q^S = (1 + \pi\mu_l) > 1, \quad S = \max\left(\frac{\pi}{\pi+\tau} - \bar{B}, 0\right), \tag{27}$$

and the price and supply of risky securities are

$$Q^D = (1 - \pi) < 1, \quad D \geq 1 - \bar{B} - S > 0. \tag{28}$$

3) The government imposes taxes $T_h = T_l = \bar{B}$ at $t = 1$.

The proposition can be proven by noting that the allocation in the proposition is optimal for all private agents given prices, is feasible for the government, and is consistent with market clearing. That is, the allocation and prices (i) satisfy feasibility and optimality for households, (6)-(13), (ii) satisfy feasibility and optimality for intermediaries, (14)-(19), (iii) satisfy the government state-contingent budget constraints at $t = 1$, (20), and (iv) satisfy market clearing for securities D, S, and B at $t = 0$, and for goods at $t = 0$ and in each state at $t = 1$.

As an implication of Proposition 2, the equilibrium displays a positive supply of risky securities. Note, however, that there is room for safe debt to be supplied in equilibrium, in addition to risky debt. Indeed, with risky debt, liquidity is lower in the low state in comparison to the high state. As a result, securities that provide liquidity in the low state will trade at a premium. If this premium is large enough to cover the cost τ, intermediaries issue safe securities. Whether the premium on safe intermediaries' debt is large or not depends in turn on the amount of public liquidity. A large supply of public liquidity implies a low liquidity premium on safe debt (recall that public liquidity is risk-free); thus, issuing safe debt is not profitable for intermediaries. That is, a sufficiently high level of public debt crowds out the production of privately issued safe money by influencing the liquidity premium on default-free obligations. In contrast, a low supply of public liquidity creates a profitable opportunity for intermediaries to issue some safe debt.

The proposition shows that the price of safe debt S is greater than one; that is, securities S are issued above par and pay a negative return. This result follows from the fact that we have normalized the discount factor between $t = 0$ and $t = 1$ to one and that securities S include a liquidity premium. If we instead extend the model to allow for a discount factor $\beta < 1$, households' required return on non-liquid assets would be $1/\beta > 1$. Thus, the price of the liquid securities S would be $Q^S > \beta$ and, possibly, less than one.

Proposition 3 has implications for characterizing how a liquidity crunch occurs in our model. This happens in the low state because risky securities do not have appropriate backing in that state and, thus, lose their liquidity value.

Since there is a shortage of the only assets that are liquid in the low state (i.e., safe assets), the demand for goods C_l drops because of the liquidity constraint (8), and thus consumption C_l decreases too.

We conclude with a brief comparison with the literature that studies the liquidity of private money and crises. In contrast to many papers in which private money is risk-free, we allow for intermediaries' default on debt and, thus, risk associated with the payoff of private money. The literature includes works expounding the idea of safe assets following Gorton and Pennacchi (1990) (e.g., Stein, 2012), papers cast in the New Monetarist framework following Lagos and Wright (2005) (e.g., Williamson, 2012), and analyses of public finance (e.g., Angeletos, Collard, and Dellas, 2016). Allowing for the possibility of debt default is crucial not only because it better captures the narrative of the 2007-2008 financial crisis, but especially because it lays the foundations for novel policy results. For instance, questions related to the role of government deposit insurance can naturally be studied only if default arises in equilibrium. In addition, we include aggregate risk, which allows us to derive policy implications such as the role of fiscal capacity in crisis times.

5 Government intervention

The possibility of liquidity crisis that arises in the *laissez-faire* equilibrium opens up a possible role for government intervention. The amount of liquidity is large enough only in the high state, whereas the economy experiences a liquidity crunch in the low state.

We study general government policies related to debt issuance, the active management of the balance sheet of the central bank, and the regulation of financial intermediaries.

As a first step, we consider a large supply of public liquidity backed by higher taxes at all times. This intervention entirely crowds out the production of safe private debt but nonetheless achieves the first best. Two policies are presented that implement the first best even if the government faces a limit on average taxation: asset purchases by the central bank and actuarially fair deposit insurance. These policies exploit the backing provided by intermediaries in good times and, thus, require government backing only in bad times. Crucially, asset purchases and deposit insurance are equivalent, in the spirit of Wallace (1981). The taxes required under the two policies are identical in all contingencies because the consolidated balance sheet of the government and private intermediaries (i.e., of the agents that supply liquidity) is identical under the two policies.

Under a more stringent limit on taxes in low states, government policies do not implement the first best, but they nonetheless improve welfare. The equivalence between asset purchases and deposit insurance extends to this case. In particular, with deposit insurance, the equilibrium is characterized by the coexistence of three types of privately issued securities. In addition to safe debt S and risky debt D, some intermediaries issue insured debt, which we denote $\hat{D}$. All the intermediaries are ex ante identical, and each of them chooses to issue S, D, or $\hat{D}$. Moreover, intermediaries issuing $\hat{D}$ and D invest in the same type of risky capital. The coexistence of insured and uninsured intermediaries in the model resembles the coexistence of regulated commercial banks and unregulated shadow banks in practice.

Finally, we study a regulation that forces all intermediaries to invest in safe projects. This policy reduces welfare because issuing risky securities backed by investments in risky projects allows intermediaries to economize on monitoring costs.

5.1 Optimal government policy with no limit on taxes

This section characterizes the optimal government policy when there is no limit on the ability to raise lump-sum taxes. We amend the model by allowing the government to increase the supply of public debt to $B \geq \bar{B}$ at $t = 0$. We still assume that the government repays the debt with taxes T_h and T_l at $t = 1$. The details of this extension are provided in the online Appendix.

The optimal policy requires that the government issues a large supply of public debt B and, thus, imposes large taxes T_h and T_l at $t = 1$ to back the debt. As a result, households can attain the first-best level of consumption using public liquidity only. The next proposition formalizes this result.

Proposition 4 *If financial intermediaries face a per-unit cost $\tau > 0$ of monitoring safe capital, the optimal government policy is to set $B \geq 1$, achieving the first best.*

The optimal policy requires the government to satiate the economy with public liquidity, which is backed by a large amount of taxes imposed on households at $t = 1$. With no limit on lump-sum taxes, the government has an advantage in supplying liquidity. The reason is that intermediaries' safe debt, S, is costly because it requires monitoring, whereas the government money has no costs associated with backing through taxes. Moreover, optimal issuance of public liquidity entirely crowds out the supply of privately issued safe assets.

The result of Proposition 4 is well known and in line with Friedman's proposal (Friedman, 1960). In the context of the analysis of public versus private money, a similar result is also obtained by Rocheteau (2011).

It is worth emphasizing that Proposition 4 relies on two critical assumptions. First, the government is benevolent. Second, the government does not face any limit on raising taxes. Nonetheless, even with a limit on taxes, we argue in Sections 5.2-5.4 that other policy interventions allow the government to avoid or at least mitigate liquidity crises.

5.2 Optimal government policy with a limit on average taxes: asset purchases by the central

We now turn to the analysis of the supply of public liquidity when the government faces a limit on average taxes that it can collect at $t = 1$, where average taxes are $(1-\pi)T_h + \pi T_l$. To keep the analysis simple and without loss of generality, we assume that the limit on average taxes is

$$(1-\pi)\, T_h + \pi T_l \leq \bar{B} < 1. \tag{29}$$

The bound in (29) implies that the government is restricted to keeping average taxes at or below the no-intervention level. To see this, note that $(1-\pi)\, T_h + \pi T_l = \bar{B}$ in the equilibrium of Proposition 3.

Notwithstanding the limit in (29), we show that an appropriate policy of asset purchases allows the economy to achieve the first best, $C_h = C_l = 1$. Our approach follows Magill, Quinzii, and Rochet (2016), although public debt has no liquidity value in their model and thus the way this policy intervention achieves the first best is somehow different, as we discuss at the end of this section. Under the asset purchase policy, the government supplies a large amount of public money, $B > \bar{B}$, and purchases private intermediaries' risky debt through the central bank. The risky debt held by the central bank pays a return in the high state, allowing the government to reduce taxes in that contingency. Instead, in the low state, the private risky securities are defaulted on, and thus government debt requires backing through taxes. This policy is related to the second proposal of Friedman (1960), who suggested backing the supply of interest-bearing reserves (in our model, B) through the portfolio of assets held by the central bank (in our model, private intermediaries' risky debt).[3]

At $t = 0$, the central bank purchases the quantity D^c of risky securities and finances these purchases by increasing the outstanding debt from the initial level $\bar{B}$ to B (i.e., the net debt issuance at $t = 0$ is $B - \bar{B}$). Thus, the budget constraint of the government is

$$Q^D D^c \leq Q^B \left(B - \bar{B}\right). \tag{30}$$

At $t = 1$, the government repays its debt B using the proceeds earned by holding the assets D^c, if not in default, and taxes:

$$B = T_h + D^c \tag{31}$$

$$B = T_l \tag{32}$$

in the high and low state, respectively.

To achieve the first best, the government must issue an amount $B = 1$ of public money. If the government is indeed able to implement the first best, the households' first-order conditions imply that the pricing of public money and risky securities is $Q^B = 1$ and $Q^D = 1 - \pi$. Given these results, the budget constraint at $t = 0$, equation (30), implies that the government can purchase private risky debt in the amount of

$$D^c = \frac{(1-\bar{B})}{(1-\pi)} > 0. \tag{33}$$

Given this result, the state-contingent budget constraints at $t = 1$, equations (31) and (32), imply that taxes are

$$T_h = 1 - \frac{1-\bar{B}}{1-\pi} \tag{34}$$

$$T_l = 1, \tag{35}$$

and thus average taxes are $(1-\pi)T_h + \pi T_l = \bar{B}$. That is, the limit in (29) is satisfied.

The next proposition summarizes this result.

[3]Even though our policy proposal is related to that of Friedman (1960), it is slightly different because the original proposal considered only the possibility of investing in safe securities.

Proposition 5 *Assume that financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital and the government follows a state-contingent tax rule T_h and T_l in the high and low state, respectively, subject to the limit in (29). The government can achieve the first best by supplying public money $B = 1$, purchasing the amount of risky securities D^c in (33), and setting taxes T_h and T_l to (34) and (35), respectively.*

The proposition shows that the government can achieve the first best even if there is a limit on average taxes. In the high state, risky assets are fully repaid and thus provide a backing for public liquidity B. In the low state, however, they are defaulted on and thus provide an insufficient backing for public liquidity. Therefore, taxes T_l must be increased to back public liquidity.

The requirement that taxes should be increased during a crisis can be relaxed if we extend the model to an infinite horizon and allow government debt and taxes to vary over time. In this case, however, the present-discounted value of taxes must be raised during a crisis, even though the taxes collected during a crisis do not have to increase. In such an infinite-horizon formulation, the government can increase debt to $B > 1$ in the event of a crisis to keep taxes low at that time and repay the higher debt by increasing future taxes when the economy recovers from the crisis.

The solution proposed in this section has policy-relevant implications given the unconventional asset purchases undertaken by many central banks around the world. The rationale and duration for these purchases have been subject to an extensive debate. Our analysis underlines that, even during normal times, central banks should continue to hold private securities for the purpose of fulfilling the liquidity needs of the economy and reducing the tax burden. This view is in contrast to the conventional one that prescribes that central banks should hold Treasury bills; under this approach, no reduction in the tax burden would be possible. In a different framework, Magill, Quinzii, and Rochet (2016) also argue for the continuation of unconventional asset purchases to normal times as a way to achieve efficiency, which in their case is related to the increase in the funds channeled to investments.

Next, we discuss the robustness of Proposition 5. Even if the result of Proposition 5 might not be identical in some extensions of our model, we argue that the spirit of the exercise is preserved. For instance, if intermediaries' default is costly (i.e., deadweight losses are associated with bankruptcy processes), it might be optimal for the government to have a lower demand for D^c to avoid too many losses when intermediaries go bankrupt. As a result, the optimal supply of public liquidity might be smaller and the allocation $C_h = C_l = 1$ would not be optimal. Nonetheless, the spirit of Proposition 5 would be unchanged. The main implication of Proposition 5 is that the government should actively engage in the supply of public money using privately issued intermediaries' debt D^c as partial backing. The optimal holding of D^c is most likely not zero for reasonable extensions of our model.

Another constraint that could limit the purchases of private risky debt arises if we separate the central bank from the Treasury. By purchasing risky securities, the central bank faces income losses in the low state, where the risky assets default, while still having to pay interest on reserves. Therefore, the central bank needs to be recapitalized by the Treasury. If the Treasury's support is not automatic, an additional trade-off between maintaining price stability and achieving the efficient supply of liquidity could emerge.

5.3 Optimal government policy with a limit on average taxes: deposit insurance and government guarantee programs

In this section, we propose an alternative government policy that allows the economy to achieve the first best even if the government is subject to the limit on taxes in equation (29). We refer to this policy as deposit insurance, even though it can be interpreted, more generally, as any program that guarantees the liabilities of financial intermediaries. First, the policy is studied in the context of the model and then some limitations and extensions are investigated.

Consider a deposit insurance scheme that is actuarially fair. The government charges intermediaries a fee for the insurance and, on average, the policy does not provide any subsidy to intermediaries.

Debt of insured intermediaries that invest in risky projects is denoted as $\hat{D}$ to distinguish it from the risky debt D that arises in the equilibrium of Proposition 3. Under deposit insurance, intermediaries' debt $\hat{D}$ is safe from the point of view of households and therefore always provides liquidity services, even though intermediaries invest in risky projects. In the low state at $t = 1$, when the payoff of intermediaries' investments is zero, the government provides the insurance payment with a transfer to intermediaries, which in turn is used to repay the debt to households in full. In the high state at $t = 1$, when intermediaries' projects produce a positive output, the government charges a proportional fee to intermediaries.

Under the assumption that the only limit faced by the government is on average taxes, we conjecture (and later verify) that the only type of debt that is issued by intermediaries is insured debt $\hat{D}$. At $t = 0$, the budget constraint of intermediaries that invest in risky projects is similar to (17), but now $\hat{D}$ replaces D:

$$K^{\hat{D}} = Q^{\hat{D}}\hat{D}, \tag{36}$$

where $K^{\hat{D}}$ denotes the investment in risky projects and $Q^{\hat{D}}$ is the price of insured debt. Households' demand for $\hat{D}$ implies that the price of $\hat{D}$ is $Q^{\hat{D}} = Q^S = Q^B$ because insured debt is riskless and thus a perfect substitute for the debt of safe intermediaries and the government.

At $t = 1$, intermediaries' profits are

$$\Pi_h^{\hat{D}} = \max\left\{0,\ K^{\hat{D}}(A - \lambda_h) - \hat{D}\right\} \tag{37}$$

$$\Pi_l^{\hat{D}} = \max\left\{0,\ K^{\hat{D}}(0 - \lambda_l) - \hat{D}\right\}, \tag{38}$$

where $\lambda_h > 0$ and $\lambda_l < 0$ denote the proportional fee and transfer from the government in the high and low state, respectively, while the lower bound on profits follows from limited liability.

We focus on the case in which the government does not alter the supply of public debt with respect to the initial level, and thus $B = \bar{B}$. The budget constraint at $t = 1$ is

$$\bar{B} = T_h + \lambda_h K^{\hat{D}} \tag{39}$$

$$\bar{B} = T_l + \lambda_l K^{\hat{D}} \tag{40}$$

in the high and low state, respectively. Note that the government increases taxes in the low state, T_l, to fulfill its guarantee of intermediaries' debt.

The equilibrium under deposit insurance can be characterized as an equivalence proposition, in the spirit of Wallace (1981). If an equilibrium exists under the asset purchase policy of Proposition 5, the same consumption allocation and prices can be sustained under a policy of deposit insurance with the same taxes. The logic of the proof is based on the fact that the consolidated balance sheet of the government and private intermediaries—that is, of the agents that supply liquidity in the economy—is the same under both policies.

To solve for the equilibrium, consider the government that collects the same taxes T_h and T_l as under the asset-purchase policy studied in Section 5.2, which are given by equations (34) and (35). We can use (39) and (40) to solve for the values of the fee and transfer to intermediaries:

$$\lambda_h = \frac{1 - \bar{B}}{K^{\hat{D}}}\frac{\pi}{1 - \pi} \tag{41}$$

$$\lambda_l = -\frac{1 - \bar{B}}{K^{\hat{D}}}. \tag{42}$$

Note that the average payment to intermediaries, which is defined by $(1 - \pi)\lambda_h + \pi\lambda_l$, is zero, and thus on average, the government does not provide any subsidy to intermediaries.

We can then show that the total amount of liquidity in the economy, $\bar{B} + \hat{D}$, allows the economy to achieve the first best. To do so, we plug the value λ_l into the expression for profits in the low state, (38), and we set profits equal to zero because of free entry, obtaining $\bar{B} + \hat{D} = 1$. Note that both public liquidity $\bar{B}$ and insured private debt $\hat{D}$ provide liquidity in both states, and thus households can achieve the first-best level of consumption $C_h = C_l = 1$. Profits in the high state, (37), and the budget constraint of intermediaries at $t = 0$, (36), can be used to solve for the equilibrium value of $K^{\hat{D}}$ and $\hat{D}$.

Crucially, since we are using the same taxes that the government imposes under asset purchases, the limit on average taxes in (29) is satisfied even under deposit insurance. The next proposition summarizes this result.

Proposition 6 *Assume that a policy of taxes T_h and T_l, asset holdings of the central bank D^c, bond supply $B = 1$, and consumption $C_h = 1$ and $C_l = 1$ are part of an equilibrium. There exist state-contingent proportional taxes on intermediaries λ_h in state h and λ_l in state l that sustain the same equilibrium with the same state-contingent taxes T_h and T_l and a lower supply of public liquidity $\bar{B} < 1$ and no supply of safe or risky debt, that is, $S = D = 0$. Under the tax scheme λ_h and λ_l, the debt of intermediaries that invest in risky projects is riskless.*

In practice, deposit insurance is typically up to a limit. Nonetheless, during the acute phase of the 2008 crisis, the deposit insurance limit was increased in several countries, and other forms of government guarantees were introduced.

In the U.S., the insurance limit was increased from \$100,000 to \$250,000. Moreover, the Federal Deposit Insurance Corporation (FDIC) set up the Temporary Liquidity Guarantee Program with the objective of bringing stability to financial markets and the banking industry. The program provided a full guarantee of non-interest-bearing transaction accounts and of the senior unsecured debt issued by a participating entity for about a year. Taken together, these two measures dramatically increased the fraction of liabilities of U.S. financial institutions that were guaranteed by the government. Similar policies were adopted in other countries, including some cases in which the coverage was unlimited, such as in Germany.

We emphasize again that the deposit insurance scheme provided by the government is actuarially fair because the average tax imposed on intermediaries is zero: $(1-\pi)\lambda_h + \pi\lambda_l = 0$. As long as the government runs a correctly priced deposit insurance program, it should be able to avoid any moral hazard that might instead arise when the insurance is subsidized. In this sense, our results suggest that regulatory agencies such as the FDIC should link the deposit insurance premium to each intermediary's risk of default. This approach would not only reduce or avoid moral hazard but also support the adequate level of liquidity in the economy.

Finally, we point out that our model provides a role for deposit insurance that is different from, although complementary to, the standard motivation related to bank runs. Following Diamond and Dybvig (1983), the bank runs literature highlights the importance of deposit insurance as a tool to eliminate bad equilibria driven by panics. In our model, crises are driven by fundamental shocks, and deposit insurance plays a key role in reducing the negative impact of such shocks.

5.4 Optimal government policy with a state-contingent limit on taxes

In Sections 5.2 and 5.3, we limited the action of the government by imposing a constraint on average taxes. Despite the limit, the government is able to implement policies that achieve the first best. These policies, though, require setting high taxes in the low state to offset the lack of private backing with government backing.

In this section, we take the policy analysis one step further by imposing an additional limit on government actions. In addition to the limit on average taxes in (29), we assume that the government has to satisfy a state-contingent limit on taxation, that is, $T_h, T_l \leq \bar{T}$, where $\bar{T}$ satisfies $\bar{B} < \bar{T} < 1$. As the analyses in Sections 5.2 and 5.3 show, the state-contingent limit is binding in the low state, and thus we simply reformulate the limit as $T_l \leq \bar{T}$.

Under the limit $T_l \leq \bar{T}$, the first best cannot be achieved by government policy. Nonetheless, we show that asset purchases and deposit insurance are still optimal, and the equivalence between these two policies shown by Proposition 6 is robust to the extension of this section.

We begin with the analysis of asset purchases. The budget constraints of the government at $t=0$ and $t=1$ are the same as in Section 5.2 (i.e. (30)-(32)). At $t=0$, the government increases the supply of public debt from the initial level $\bar{B}$ to $B > \bar{B}$ and purchases an amount D^c of risky securities. At $t=0$, the government repays its debt B using the proceeds of D^c, if not in default, and taxes. The key difference with Section 5.2 is that we now consider asset purchases that satisfy $D^c < (1-\bar{B})/(1-\pi)$ and $B < 1$ to keep taxes in the low state within the limit $\bar{T}_l \leq T$.

The next proposition characterizes the optimal asset purchase policy and the respective equilibrium. The result looks similar to that of Proposition 3, but the government is able to increase the supply of public debt using asset purchases.

Proposition 7 *Assume that financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital and the government faces a limit (29) on averages taxes and $T_l \leq \bar{T}$. The optimal asset purchase policy is a supply of debt $B = \bar{T} > \bar{B}$ and a purchase of risky securities:*

$$D^c = \begin{cases} \frac{1+\tau}{1-\pi}\left(\bar{T}-\bar{B}\right) & \text{if } \bar{T} < \frac{\pi}{\pi+\tau} \\ \frac{1+\pi\left(1/\bar{T}-1\right)}{1-\pi}\left(\bar{T}-\bar{B}\right) & \text{if } \bar{T} \geq \frac{\pi}{\pi+\tau}, \end{cases} \tag{43}$$

which implies the following equilibrium.

1) In the high state, there is full satiation of liquidity, and thus $C_h = 1$ and $\mu_h = 0$, whereas in the low state,

$$C_l = \max\left\{\frac{\pi}{\pi+\tau}, \bar{T}\right\} < 1 \quad \text{and} \quad \mu_l = \min\left\{\frac{\tau}{\pi}, \frac{1}{\bar{T}} - 1\right\}. \tag{44}$$

2) The price and supply of safe securities are

$$Q^S = (1+\pi\mu_l) > 1, \quad S = \max\left(\frac{\pi}{\pi+\tau} - \bar{T}, 0\right), \tag{45}$$

and the price and supply of risky securities are

$$Q^D = (1-\pi) < 1, \quad D \geq 1 - \bar{T} - S > 0. \tag{46}$$

3) The government imposes taxes at $t = 1$:

$$T_h = \bar{B} - \frac{\pi}{1-\pi}(1+\mu_l)\left(\bar{T} - \bar{B}\right) \tag{47}$$

$$T_l = \bar{T}, \tag{48}$$

and average taxes satisfy $(1-\pi)T_h + \pi T_l < \bar{B}$.

The proposition can be proven in three steps. First, and similar to the proof of Proposition 3, one can show that the allocation stated in the proposition is optimal for households and intermediaries, given prices, and is consistent with market clearing. Second, the government budget constraints at $t = 0$ and $t = 1$, given by (30)-(32), are satisfied. Third, we prove the optimality of the policy. Note that any feasible policy must satisfy $B \leq \bar{T}$; otherwise, using (32), the constraint $T_l \leq \bar{T}$ would be violated. If the limit on taxes in state l is in the range $\bar{T} \in (\pi/(\pi+\tau), 1)$, any policy with $B < \bar{T}$ would imply a lower value of liquidity in the low state in comparison to the policy with $B = \bar{T}$, making the liquidity constraint even more binding in the low state and reducing C_l further away from the first best. If the limit on taxes is $\bar{T} \leq \pi/(\pi+\tau)$, any policy with $B < \bar{T}$ would not change the amount of liquidity; however, supplying government debt $B < \bar{T}$ rather than $B = \bar{T}$ increases the supply of safe debt in equilibrium, which reduces the resources available for consumption at $t = 0$ because of the monitoring cost. Therefore, it is optimal to set $B = \bar{T}$.

We now turn to the analysis of deposit insurance. We show that the level of consumption $C_h = 1$ and $C_l = \max\left\{\pi/(\pi+\tau), \bar{T}\right\}$ obtained in Proposition 7 can be achieved with the same level of taxation if the government offers deposit insurance, thereby generalizing the results of Proposition 6 to the case in which the government cannot implement the first best.

Similar to Section 5.3, we use $\hat{D}$ to denote the debt of insured intermediaries that invest in risky projects, and we continue to use D to denote uninsured debt of intermediaries that invest in risky projects. This distinction is now critical because securities $\hat{D}$ and D coexist in the deposit insurance equilibrium of this section. Deposit insurance allows the economy to achieve the same consumption allocation obtained with asset purchases if the supply of insured debt is $\hat{D} = \bar{T} - \bar{B}$ and the supply of uninsured debt is $D = 1 - \bar{B} - \hat{D} - S$, where safe debt S is the same as in Proposition 3.

As discussed in Section 5.3, the price of insured private debt is equal to the price of safe assets, and thus $Q^{\hat{D}} = 1+\pi\mu_l$, where now this debt has a premium because consumption in the low state is not at the first best. As a result, the budget constraint (36) implies that insured intermediaries invest an amount $K^{\hat{D}} = (1+\pi\mu_l)(\bar{T} - \bar{B})$ in risky projects.

Plugging the values of $\hat{D}$ and $K^{\hat{D}}$ into the zero-profit condition of intermediaries in the low state (i.e., into (38) evaluated at $\Pi_l^{\hat{D}} = 0$), it follows that the proportional transfer to intermediaries in the low state is

$$\lambda_l = -\frac{1}{1+\pi\mu_l}. \tag{49}$$

Similarly, we can use the zero-profit condition in the high state, the price of insured debt $Q^{\hat{D}}$, and the budget constraint of insured intermediaries (36) to solve for the proportional fee charged in the high state:

$$\lambda_h = \frac{\pi}{1-\pi}\frac{1+\mu_l}{1+\pi\mu_l}. \tag{50}$$

We can compute the taxes by plugging λ_h and λ_l into (39) and (40) and rearranging to obtain that they are the same as in the asset-purchase case.

We can then summarize the equivalence between asset purchases and deposit insurance with the following proposition.

Proposition 8 *Assume that a policy of taxes T_h and T_l, asset holdings of the central bank $D^c \in \Big[0, (1-\bar{B})/(1-\pi)\Big)$, and bond supply B are part of an equilibrium. There exist state-contingent, proportional taxes on intermediaries λ_h in state h and λ_l in state l that sustain the same equilibrium with the same taxes T_h and T_l and a lower supply of public liquidity, $\bar{B} < B$. Under the second policy, insured, safe debt issued by intermediaries that invest in risky projects coexists with uninsured debt issued by other intermediaries that invest in the same type of risky projects, along with public liquidity and possibly safe private debt.*

We want to emphasize that the results in this section capture some stylized facts of the modern financial system.

Under asset purchases, the central bank buys risky securities, and the consolidated fiscal-monetary authority faces losses if these securities are defaulted on. In practice, central banks that have purchased assets backed by private investments have targeted securities with no default risk; for instance, the Federal Reserve purchased agency mortgage-backed securities (MBS). However, these securities have no default risk because they are guaranteed by government-sponsored enterprises (i.e., Fannie Mae and Freddie Mac), which in turn are backed by the Treasury. If many of the mortgages underlying the MBS held by the Federal Reserve had defaulted, the consolidated Treasury-Federal Reserve balance sheet would have faced losses, as in our model, because of the Treasury guarantee.

Under deposit insurance, insured and uninsured debt coexist in the equilibrium of the model, resembling the co-existence, in practice, of insured commercial bank deposits and uninsured shadow banks. Intermediaries in the model are ex ante identical, and those that invest in risky projects endogenously decide whether to operate under the deposit insurance scheme or in the unregulated shadow banking system.

5.5 Regulation of intermediaries' investments

We now turn our attention to a policy that restricts the type of investments of private intermediaries and, in particular, forces them to invest only in riskless projects. As a result, all intermediaries issue safe assets without the need for the government to provide deposit insurance.

Forcing all intermediaries to invest in riskless projects reduces welfare. This result is the mirror image of the fact that the *laissez-faire* equilibrium is constrained efficient, as we show below.

Restricting intermediaries' investments is fundamentally different from the policies studied in Sections 5.1-5.4. Government provision of liquidity and deposit insurance requires an adequate fiscal backing in the low state, even if the government buys assets through the balance sheet of the central bank. These policies primarily work by complementing the insufficient private backing of liquidity with public backing. In contrast, the regulation that we now study directly affects the private backing of securities issued by intermediaries without requiring any fiscal capacity.

To understand why this policy reduces welfare, recall the result of the unregulated equilibrium. Some intermediaries invest in the risky technology to economize on the monitoring cost, and thus they issue risky debt that defaults in the low state. The argument is similar to that in Geanakoplos (1997, 2003), in which default is desirable in order to economize on scarce collateral and the equilibrium is constrained efficient. As a result, forcing all intermediaries to invest in safe projects eliminates liquidity crises but requires intermediaries to waste a large amount of resources to pay monitoring costs.

Proposition 9 *Assume that financial intermediaries face a monitoring cost $\tau > 0$ and $\bar{B} < 1$. If the government forces all intermediaries to invest in safe projects, welfare is lower in comparison to the laissez-faire equilibrium.*

We prove the proposition by showing that the *laissez-faire* equilibrium of Proposition 3 is constrained efficient. Thus, regulations imposed on financial intermediaries to force them to invest in safe projects cannot improve welfare in the economy.

To show that the *laissez-faire* equilibrium is constrained efficient, we consider a planner with limited abilities—more precisely, a planner that is subject to two restrictions. First, the planner takes government policy as given (i.e., takes as given public liquidity $\bar{B}$ and taxes $T_h = T_l = \bar{B}$). Second, the planner chooses intermediaries' assets and debt issuance but has no ability to either affect households' demand for debt nor influence the way securities and goods are traded in markets. That is, the planner takes as given households' demand for safe and risky securities (i.e., (12) and (13)), and the way such securities are traded by households at $t = 1$ to purchase consumption goods.

Under these assumptions, the planner maximizes households' utility (1) subject to the resource constraints (2)-(4), the liquidity constraints (7) and (8), households' demand for debt (12) and (13), banks' budget constraints (14) and (17), and the limited liability constraints of financial intermediaries, which imply $S = K^S$ and $D = A_h K^D$. Using the normalization $(1-\pi)A_h = 1$ introduced in Section 2, the problem of the planner simplifies to

$$\max_{K^S, K^D} \quad (1-\pi)\ln\left(\bar{B} + K^S + \frac{K^D}{1-\pi}\right) + \pi \ln\left(\bar{B} + K^S\right) - (1+\tau)K^S - K^D, \tag{51}$$

where we have omitted the constant terms that are independent of the choice variables. After solving for K^S and K^D, the other variables—such as the supply of safe and risky debt—can be computed using the structure of the model.

Assuming $\bar{B} < 1$, the first-order condition with respect to K^D implies $C_h = 1$, and the first-order condition with respect to K^S implies $C_l = \max(\pi/(\pi+\tau), \bar{B})$. This is exactly the allocation that is implemented by the *laissez-faire* equilibrium of Proposition 3, which is thus constrained efficient. Therefore, the allocation in the regulated economy of Proposition 9 cannot improve upon it.

5.6 Discussion

We now discuss more broadly the policy implications of our model in comparison with three classic views on the role of private and public liquidity, namely, the free-banking theory of Hayek (1976), the narrow banking theory of Friedman (1960), and the real-bills doctrine. We also provide some comparison with the recent regulation of financial intermediaries based on Basel III.

We argue that the results of the model with costless monitoring ($\tau = 0$) and no limit on taxes are in line with the views of both Hayek (1976) and Friedman (1960). However, the results of the full model with costly monitoring ($\tau > 0$) and limits on taxes suggest that the optimal policies represent a mix of the two views.

In Hayek (1976), the process of competition leads the private sector to supply a sufficiently large quantity of the best available type of liquid assets, namely, safe assets. The competitive market structure in our model is indeed in the spirit of Hayek's (1976, p. 43). If $\tau = 0$ and safe securities were not provided, households would attach a premium to them because such securities relax the liquidity constraint during crises (i.e., when the low state in the model realizes). Therefore, intermediaries would find it convenient to supply safe debt because the premium paid by households reduces intermediaries' financing costs. Free entry then ensures that there are enough safe securities so that the households' liquidity constraint is never binding. As a result, the interest of households is perfectly aligned with that of financial intermediaries. Indeed, the premium on safe assets, which reflects a lack of liquidity from society's point of view, creates incentives for profit-maximizing intermediaries to supply safe securities. With $\tau = 0$, unfettered competition achieves the first best without any regulation because intermediaries optimally choose to hold safe investments.

Friedman (1960)'s proposal can also achieve the first best. According to this view, the government should have monopoly power in the supply of liquidity. This objective can be reached under a narrow banking system; that is, intermediaries are forced to satisfy a 100% reserve requirement. In the context of our model, intermediaries would buy government safe debt B instead of capital, so the budget constraint (14) would be replaced by $Q^B B = Q^S S$. If this were the case, private intermediaries would not perform any liquidity creation because their debt would be backed by liquid government reserves instead of illiquid capital. As a result, the overall supply of liquid assets in the economy would be determined solely by the amount of government debt. Note that in turn the government has to back its debt and interest payments, which is achieved by collecting taxes. Nevertheless, a benevolent government that implements a narrow banking system and faces no limit on taxes can achieve the first best by supplying government debt in the amount $B \geq 1$, as shown by Proposition 4.

In the more general model with monitoring cost ($\tau > 0$) and limits on taxes, neither the private sector nor the government alone can satiate the demand for liquidity. The mechanism of private money creation supported by Hayek (1976) leads to an equilibrium that does not implement the first best (i.e., Proposition 3). Friedman's proposal of a narrow banking system does not implement the first best because of the costs or limits on taxes. Our results show that government interventions are welfare improving, but they should be complemented by some supply of private securities.

Finally, we comment on Proposition 9, that warns about the possible negative consequences of policies that force intermediaries to invest in safer but lower productive assets. Historically, these policies can be reconducted to the prescription of the real-bills doctrine, which requires intermediaries to hold essentially risk-free assets (Sargent, 2011). More recently, Basel III has increased the risk weights related to capital requirements. These modifications and the even tighter requirements suggested by Admati and Hellwig (2013) and Kashkari (2016) might force or give incentive to intermediaries to hold safer, lower return assets. Even if these policies reduce or eliminate liquidity crises, their impact on welfare could be negative.

6 Robustness analyses

In this section, three robustness exercises are discussed. We present here the key elements and results, details are left to the online Appendix.

Despite our model being simple and stylized, we show that our results are very general and unchanged in these richer frameworks. The first two robustness analyses generalize the results to economies in which private risky securities have a much richer payoff structure in comparison to what we have used so far. The third analysis shows that the results are unchanged under a more general utility function.

6.1 Multiple private securities

In the first extension, each intermediary can invest a fraction of its resources in the safe capital K^S and the remaining fraction in the risky capital K^D. Intermediaries issuing debt securities partially backed by riskless capital need to pay the monitoring cost τ in proportion to the investment in safe capital. In the low state, these securities will be partially defaulted on but can nonetheless be used to finance the purchase of consumption C_l.

The security D of the baseline model, which fully defaults in the low state and thus does not provide any liquidity, is the one in which an intermediary does not make any investment in safe capital. The possibility of issuing this security plays a key role even in the extension. Consumption must be at the first best in the high state; otherwise, intermediaries would earn positive profits by issuing D. This result is essentially the same as that derived in Proposition 2.

The result of Proposition 3 extends to the model with multiple private securities as well. Even if intermediaries can issue multiple types of debt securities, their overall investments in safe and risky capital, K^S and K^D, are unchanged. As a result, the overall liquidity supplied by private intermediaries is unchanged because it depends only on its backing through capital K^S and K^D. In addition, the fact that consumption in the low state is not at the first best gives rise to a liquidity premium for securities that are not fully defaulted on in that state. This liquidity premium compensates intermediaries for the monitoring cost required to invest a fraction of their resources in the safe capital.

6.2 Private securities with idiosyncratic payoff and asymmetric information

Another stark feature of the benchmark analysis is that all risky debt D pays zero in the low state; that is, *all* risky intermediaries *fully default* in that state. To relax this assumption, we allow risky capital to have idiosyncratic payoff in the low state; in particular, the payoff of capital is zero with probability $\kappa > 0$ and a positive amount with probability $1 - \kappa$. As a result, only a fraction κ of risky intermediaries fully defaults and pays nothing in the low state.

This framework is equivalent to that of the main text once we introduce asymmetric information about risky securities, which in turn gives rise to a classic adverse selection problem (Akerlof, 1970). The adverse selection problem arises only in the low state when some risky securities are defaulted on, whereas it does not arise in the high state because all risky securities are fully repaid.

We assume that each households can fully differentiate its purchases of risky securities at $t = 0$. Thus, in the low state of time $t = 1$, buyers of goods hold a fraction κ of risky securities that pays zero and the remaining fraction $1 - \kappa$ that pays one, and they have full information about the quality (i.e., the payoff) of their own securities. In contrast, the sellers of goods cannot distinguish the quality of the risky securities.[4]

Sellers of consumption goods are aware of their lack of information and do not want to incur losses if they are paid with risky securities. As a result, the purchasing power of risky securities reflects the average quality of the securities that buyers of goods bring to market. In equilibrium, buyers of goods do not have any incentive to use high-quality risky securities (i.e., non-defaulted risky securities) because sellers would accept them only at a discount. Thus, keeping these securities until the second subperiod to consume X_l would be more convenient. As a result, the only equilibrium is one in which the buyers of goods bring only "bad" securities with zero value, and thus no liquidity is provided by risky securities.

This model with asymmetric information exactly replicates the implications of the benchmark model and reinforces the interpretation of the switch to state l as a liquidity crisis event. Indeed, it is sufficient to have a small probability κ of a "bad" payoff for risky securities to make them unacceptable for goods exchange at time 1.

This extension captures a key stylized fact of the 2007-2008 financial crisis. In the years leading to the crisis, mortgage-backed securities were liquid and traded in markets and thereby were essentially indistinguishable from Treasury bonds from the point of view of their liquidity value. This facts corresponds to the high state in our model. When the crisis exploded in 2007, small losses related to mortgage-backed securities were sufficient to dry up trading in all markets and produce a liquidity crunch (Gorton, 2009). These events occurred even if the losses associated with mortgage-backed securities were small and largely in line with their ratings, as documented by Ospina and Uhlig (2018). Indeed, a liquidity crisis arises in our model even if agents fully and correctly anticipate the probability of its occurrence.

6.3 General utility

The last extension that we consider is to allow for a general utility of the form

$$X + (1 - \pi)U(C_h, X_h) + \pi U(C_l, X_l), \tag{52}$$

[4] Seller of consumption goods can only distinguish safe and government securities from risky securities, but they cannot identify the risky securities issued by the fraction κ of intermediaries that fully default on their debt.

which is now non-separable across the two goods at time 1. The results of the benchmark model extend to this more general context. The marginal utility with respect to consumption C will be at the unitary value in state h, $U_c(C_h, X_h) = 1$, and above one in state l, $U_c(C_l, X_l) > 1$, reflecting lower consumption in that state. With appropriate bounds on the value of the endowments at time 1, the liquidity constraint is binding in the low state and not binding in the high state, as in the benchmark model. The role of these bounds is to limit the volatility of endowments. As a result, we can restrict attention to liquidity crises in the low state generated by financial frictions, abstracting from crises driven by large fundamental shocks.

7 Conclusion

A framework to study private money creation is presented in a model in which both public and private liquidity play a role for transactions. If creating private, safe assets is relatively cheap, the efficient level of liquidity is supplied without any need for government regulation. If producing safe assets is costly, however, the demand for liquidity is satiated only in good times, whereas in times of economic distress, the economy is subject to liquidity shortages and crises.

Within this framework, we have explored several policies to improve welfare. The main message is that policies in which public and private liquidity complement each other, such as a government guarantee of private debt or a large supply of public liquidity backed by a portfolio of private risky securities, are desirable. In contrast, forcing intermediaries to take costly action to reduce their default probability negatively affects welfare.

Our results emphasize the importance of taking into account limitations in the government's ability to intervene in liquidity markets. Future research could explore how such constraints arise, for example due to issues of timing, lack of resources, or the political process. The tighter these constraints are, the less feasible it is for the government to complement public liquidity and offset liquidity crises.

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Online Appendix

Private Money Creation, Liquidity Crises and Government Interventions

Pierpaolo Benigno and Roberto Robatto

A Government policy with no limit on taxes

In this appendix, we present the details of the model in which the government can increase the supply of public debt with no limit on taxes, and we prove Proposition 4.

At $t = 0$, the government can change the supply of public debt from $\bar{B}$ to B. Its budget constraint is

$$\bar{B} - B = T,$$

where T are lump-sum taxes (or transfers if $T < 0$) imposed on households at $t = 0$.

The household budget constraint, (6), is replaced by

$$Q^B B + Q^S S + Q^D D + X \leq \bar{Y} + Q^B \bar{B} - T.$$

If $B = \bar{B}$, then $T = 0$ and the equilibrium is the same as in Proposition 3. If instead the government changes B, the optimal policy is to set $B \geq 1$, as stated in Proposition 4. The equilibrium has $C_h = C_l = 1$ (which corresponds to the first best), which is feasible because the liquidity constraints (7) and (8) are not binding. The supply of risky debt is $D \geq 0$, and its price is $Q^D = 1 - \pi$, consistent with the optimality of both households, equation (13), and intermediaries, equation (19). The supply of safe debt is $S = 0$, and its price is $Q^S \in [1, 1 + \tau]$, which is also consistent with households' and intermediaries' optimization.

B Robustness analyses

We discuss in detail the three robustness analyses of Section 6.

B.1 Multiple private securities

In the main text, we have assumed that two different types of capital are available and that intermediaries can choose only one type of capital in which to invest. We now depart from this assumption and allow intermediaries to build a portfolio that combines risky and safe capital. Intermediaries can build a generic portfolio of capital of type α, with $0 \leq \alpha \leq 1$, which is a linear combination of a safe capital having a unitary payoff in each state of nature and risky capital paying $A_h > 1$ in state h and 0 in state l. Capital of type α requires an additional investment of $\alpha\tau$ units to produce the safe payoff. Therefore, intermediaries investing in capital of type α have the following balance sheet at time 0:

$$[\alpha(1 + \tau) + (1 - \alpha)]K^\alpha = Q^\alpha D^\alpha, \tag{B.1}$$

where K^α, Q^α, and D^α denote the investments by an intermediary that builds capital of type α, the price of its debt, and the amount of its debt, respectively (i.e., the subscript α refers to type of capital).

At $t = 1$, capital of type α has a per-unit payoff $\alpha + (1 - \alpha)A_h$ in state h and α in state l. Therefore, the expected payoff is unitary,

$$(1 - \pi)[(1 - \alpha)A_h + \alpha] + \pi\alpha = 1,$$

under the assumption $(1-\pi)A_h = 1$. The profits of an intermediary investing in capital of type α are

$$\begin{aligned}\Pi_h^\alpha &= [(1-\alpha)A_h + \alpha]K^\alpha - D^\alpha,\\ \Pi_l^\alpha &= \alpha K^\alpha - (1-\chi^\alpha)D^\alpha.\end{aligned}$$

The limited liability constraint implies that $\Pi_h^\alpha, \Pi_l^\alpha \geq 0$. This constraint binds in state l and implies that the default rate is

$$\chi^\alpha = 1 - \alpha\frac{K^\alpha}{D^\alpha}. \tag{B.2}$$

Expected profits can be written as

$$\begin{aligned}E(\Pi^\alpha) &= K^\alpha - (1-\pi)D^\alpha - \pi(1-\chi^\alpha)D^\alpha = \\ &\frac{Q^\alpha D^\alpha}{[\alpha(1+\tau)+(1-\alpha)]} - (1-\pi)D^\alpha - \pi(1-\chi^\alpha)D^\alpha,\end{aligned}$$

where the second line uses (B.1) to substitute for K^α. Therefore, the supply of debt of type α is non-negative provided that

$$Q^\alpha \geq [\alpha(1+\tau)+(1-\alpha)][(1-\pi)+\pi(1-\chi^\alpha)].$$

Competition in the market abates all rents, and therefore the equilibrium supply price is

$$Q^\alpha = [\alpha(1+\tau)+(1-\alpha)][(1-\pi)+\pi(1-\chi^\alpha)]. \tag{B.3}$$

We can combine (B.1), (B.2), and (B.3) to determine the equilibrium default rate as

$$\chi^\alpha = \frac{1-\alpha}{1-\alpha\pi}.$$

The default rate is decreasing with α and it reaches the maximum, $\chi^\alpha = 1$, when $\alpha = 0$ and the minimum, $\chi^\alpha = 0$, when $\alpha = 1$.

On the demand side, the debt of type α is always liquid even if it is partially defaulted on. We indeed assume that the liquidity constraint is of the form

$$C_h \leq B + \int_0^1 D^\alpha d\alpha,$$

and

$$C_l \leq B + \int_0^1 (1-\chi^\alpha)D^\alpha d\alpha,$$

in the respective states. Therefore, the demand of debt for type α is positive insofar as the price is

$$Q^\alpha = [(1-\pi)(1+\mu_h) + \pi(1-\chi^\alpha)(1+\mu_l)].$$

In this environment, we can state a proposition that is similar to Proposition 3.

Proposition 10 *Assume that financial intermediaries can invest in any linear combination of safe and risky capital with weights α and $1-\alpha$ (denoted as the capital of type α), with $0 \leq \alpha \leq 1$, they face a per-unit cost $\tau > 0$ to monitor safe capital, and the government issues debt $\bar{B} < 1$. Then:*

1. *In the high state, there is full satiation of liquidity, and thus $C_h = 1$ and $\mu_h = 0$, whereas in the low state ,*

$$C_l = \max\left\{\frac{\pi}{\pi+\tau}, \bar{B}\right\} < 1 \quad \textit{and} \quad \mu_l = \min\left\{\frac{\tau}{\pi}, \frac{1}{\bar{B}} - 1\right\}.$$

2. *The price and supply of securities of type* $0 < \alpha \leq 1$ *are*

$$Q^{\alpha} = (1+\pi\mu_l) > 1, \quad \int_{\alpha>0}^{1} (1-\chi^{\alpha}) D^{\alpha} d\alpha = \max\left(\frac{\pi}{\pi+\tau} - \bar{B}, 0\right),$$

and the price and supply of securities of type $\alpha = 0$ *are*

$$Q^{\alpha=0} = (1-\pi) < 1, \quad D^{\alpha=0} \geq 1 - \bar{B} - \int_{\alpha>0}^{1} D^{\alpha} d\alpha > 0.$$

3. *The government imposes taxes* $T_h = T_l = \bar{B}$ *at* $t = 1$.

First, we prove that $\mu_h = 0$. By contradiction, if $\mu_h > 0$, the portfolio of type $\alpha = 0$ would have a price $Q^{\alpha=0} = (1-\pi)(1+\mu_h)$ and give positive expected profits $E(\Pi^{\alpha=0}) = (1-\pi)\mu_h D^{\alpha=0} > 0$. This cannot be an equilibrium with free entry. Since $\mu_h = 0$, we now equate the demand and supply price of each security α, with $\alpha > 0$, and get

$$(1-\pi)\alpha\tau + \pi(1-\chi^{\alpha})[\alpha\tau - \mu_l] = 0,$$

which can be solved for μ_l to obtain

$$\mu_l = \alpha\tau \frac{(1-\pi) + \pi(1-\chi^{\alpha})}{\pi(1-\chi^{\alpha})}.$$

After substituting in (B.2), we get $\mu_l = \tau/\pi$. This is true for each security of type α, with $\alpha > 0$. Note that if $\mu_l < \tau/\pi$ because public debt is relatively high (i.e., if $\mu_l = 1/\bar{B} - 1$), all the securities of type $\alpha > 0$ are not supplied in equilibrium. The only security supplied is the one backed by a portfolio of capital of type $\alpha = 0$, that is, risky capital.

B.2 Private securities with idiosyncratic payoff and asymmetric information

We extend our framework to consider an adverse selection problem affecting risky securities. We modify the payoff of risky capital, and we introduce asymmetric information about risky debt D issued by private intermediaries.

The payoff of risky capital in the high state is $A_h > 1$, but we now assume that the payoff in the low state is subject to an idiosyncratic shock. For each intermediary that invests in risky capital, the payoff in the low state is A_l with probability $1-\kappa$ and zero with probability κ. We assume that the law of large number holds, and thus the output produced by risky capital K^D in the low state is $(1-\kappa)A_l K^D$. Without loss of generality, we assume that $A_l = A_h$, and we impose the normalization $(1-\pi)A_h + \pi(1-\kappa)A_l = 1$. The baseline model of the main text is the special case in which $\kappa = 1$.

Intermediaries in the market of risky securities issue debt D at a price Q^D. In state h, the payoff of each risky security D issued by an intermediary is one. In state l, the payoff is one with probability $1-\kappa$ and zero with probability κ.

We maintain the assumption of Lucas and Stokey (1987) that each household is composed of a shopper and a seller. The shopper (i.e., the buyer of consumption goods) holds the securities D at $t = 1$, and we now assume that the shopper has full information about the payoff of each security. However, the seller of consumption goods only knows that a fraction $1-\kappa$ of the risky securities in the economy is fully repaid; that is, the seller cannot distinguish the good securities from the "lemons," that is, from the securities that pay zero.

The utility of households is still given by (1), and the budget constraint at $t = 0$ is unchanged and given by (6). The liquidity constraint at time 1 in state h is also unchanged and given by (7), but the liquidity constraint in state l is given by

$$C_l \leq B + S + p\left[q^H + q^L\right] D,$$

where

$$\begin{aligned} 0 &\leq q^H \leq 1-\kappa \\ 0 &\leq q^L \leq \kappa \end{aligned}$$

To understand these constraints, consider that a buyer of consumption goods C_l can use B and S as in the baseline model but can, in principle, use D as well. The buyer of goods enters the first subperiod of $t=1$ with a measure $(1-\kappa)D$ of securities with payoff one and the remaining measure κD of securities with payoff zero. The buyer has full information about the payoff of each security (i.e., whether each security pays one or zero) and decides to use an amount q^H of the securities with payoff one and an amount q^L of the securities with payoff zero to purchase consumption goods. In contrast, the seller of consumption goods does not have information about the payoff of securities D and cannot distinguish them. The variable p is the relative price of risky securities in state l; that is, one unit of risky securities can be exchanged for p units of consumption goods.

The budget constraint in the second subperiod of $t=1$ is the same as in (9) in the state h; however, in state l, the constraint is

$$\begin{aligned} X_l &\leq \bar{Y}_l + B + S - C_l - T_l \\ &\quad + (1-\kappa) D + [\theta(p) - p] D_l^{seller} + [(p-1)q^H + pq^L]D. \end{aligned}$$

This constraint has three additional elements in comparison to the baseline model. The first is $(1-\kappa) D$, which captures the fact that a fraction $1-\kappa$ of risky securities is fully repaid even in the low state. The second element is $[\theta(p) - p] D_l^{seller}$. The function $\theta(\cdot)$ represents the beliefs, formed by each seller of consumption goods, about the average quality (i.e., the average payoff) of the risky securities that are traded on the market, and D_l^{seller} is the quantity of risky debt accepted by the seller as a payment instrument in the low state. Thus, $[\theta(p) - p] D_l^{seller}$ are the profits (or losses if negative) that sellers make by accepting D_l^{seller} securities at price p, under the expectation that the average payoff of the securities is $\theta(p)$. The last term, $[(p-1)q^H + pq^L]$, denotes the profits (or losses if negative) that the buyer of goods makes by using risky securities in the market. If the buyer used an amount q^H of securities with payoff one in the first subperiod, the buyer earns profits $(p-1)$ per unit of security because each security has a value p in the first subperiod and 1 in the second subperiod. If the buyer used an amount q^L of securities with payoff zero, the profits are instead p per unit because these securities are worthless in the second subperiod.

We now characterize the household's first-order conditions with respect to S, D, and B, which are given by

$$Q^S = (1-\pi)(1+\mu_h) + \pi(1+\mu_l),$$

$$Q^B = (1-\pi)(1+\mu_h) + \pi(1+\mu_l),$$

$$Q^D = (1-\pi)(1+\mu_h) + \pi\{1-\kappa + [(p-1)q^H + pq^L] + \mu_l p(q^H + q^L)\}. \tag{B.4}$$

The first-order conditions with respect to C_h and C_l are given by

$$\frac{1}{C_h} = 1 + \mu_h$$

$$\frac{1}{C_l} = 1 + \mu_l.$$

The first-order condition with respect to D_l^{seller} implies that

$$\theta(p) - p = 0. \tag{B.5}$$

The first-order conditions with respect to q^H and q^L are

$$[p\mu_l + (p-1)]\, D = \overline{\zeta}^H - \underline{\zeta}^H, \tag{B.6}$$

$$[p\mu_l + p]\, D = \overline{\zeta}^L - \underline{\zeta}^L, \tag{B.7}$$

where $\overline{\zeta}^H$ and $\underline{\zeta}^H$ are the Lagrange multipliers on the constraints $q^H \leq 1-\kappa$ and $q^H \geq 0$, respectively, while $\overline{\zeta}^L$ and $\underline{\zeta}^L$ are the Lagrange multipliers on the constraints $q^L \leq \kappa$ and $q^L \geq 0$.

We now analyze the intermediary's problem. Nothing changes for those issuing safe securities, in comparison to the baseline model. For intermediaries that issue risky securities, the budget constraint at $t = 0$ is also unchanged, but profits in state h are given by

$$\Pi_h^D = A_h K^D - D,$$

and profits in state l are

$$\Pi_l^D = \begin{cases} A_l K^D - D & \text{with probability } 1-\kappa \\ 0 & \text{with probability } \kappa \end{cases}$$

because, with probability κ, the payoff of risky capital is zero and debt is fully defaulted, following the limited liability assumption. As a consequence, the supply of risky debt is non-negative insofar as the price satisfies

$$Q^D = (1-\pi) + \pi(1-\kappa). \tag{B.8}$$

We now describe the equilibrium concept. In the main part of the paper, the equilibrium requires that households maximize their utility, financial intermediaries maximize profits, and markets for goods and securities clear. In this appendix, we closely follow the equilibrium concept used by Akerlof (1970), and thus we impose the additional requirement that households' beliefs about the quality of securities, $\theta(p)$, must be rational for all p. Since $\theta(p)$ represents the average payoff of securities traded in exchange for consumption in the low state, and since any risky security in the low state has a payoff of either zero or one, we have

$$\theta(p) = \frac{q^H}{q^L + q^H}. \tag{B.9}$$

As a preliminary step, we show that the price p at which risky debt is accepted for transactions cannot be strictly positive.

Lemma 11 *Any $p > 0$ cannot be part of an equilibrium with a positive supply of risky securities, $D > 0$.*

Before proving the lemma, we provide some preliminary calculations. The first-order condition with respect to q^L, (B.7), implies that $q^L = \kappa$, and thus $\theta(p)$ in (B.9) is well defined for any $q^H \in [0, 1-\kappa]$. Given (B.9) and the first-order condition of sellers, (B.5), it follows that

$$p = \frac{q^H}{q^H + q^L}, \tag{B.10}$$

and thus $p < 1$. Combining (B.10) with the demand and supply for risky debt, (B.4) and (B.8), we obtain

$$(1-\pi)\,\mu_h + \mu_l q^H = 0. \tag{B.11}$$

To prove the lemma, we assume by contradiction that an equilibrium exists with $p > 0$. If this is the case, (B.11) and the fact that the Lagrange multipliers must be non-negative imply that $\mu_h = 0$ and $\mu_l = 0$; in particular, the result $\mu_l = 0$ follows from the fact that (B.10) and the assumption $p > 0$ imply that $q^H > 0$. However, (B.6) evaluated at $\mu_l = 0$ becomes

$$(p-1)\, D = \overline{\zeta}^H - \underline{\zeta}^H.$$

This result implies that $\overline{\zeta}^H = 0$ and $\underline{\zeta}^H > 0$ because $p < 1$, and thus $q^H = 0$. However, this result leads to a contradiction because $q^H = 0$ implies that $p = 0$, using (B.10).

We are now ready to state the main result of this model with asymmetric information. The equilibrium is essentially the same as that in the main part of the paper. Here, because of the lemon problem, risky securities are not accepted for transactions in the low state, in the sense that the equilibrium value of p is zero. Thus, the liquidity constraint in the l state endogenously collapses to (8).

Proposition 12 *If financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital and the government issues debt $\bar{B} < 1$, then:*

1. *In the high state, there is full satiation of liquidity, and thus $C_h = 1$ and $\mu_h = 0$, whereas in the low state,*

$$C_l = \max\left\{\frac{\pi}{\pi+\tau}, \bar{B}\right\} < 1 \quad \text{and} \quad \mu_l = \min\left\{\frac{\tau}{\pi}, \frac{1}{\bar{B}} - 1\right\}.$$

2. *The price and supply of safe securities are*

$$Q^S = (1 + \pi\mu_l) > 1, \quad S = \max\left(\frac{\pi}{\pi+\tau} - \bar{B}, 0\right),$$

and the price and supply of risky securities are

$$Q^D = (1-\pi) + \pi\,(1-\kappa) < 1, \quad D \geq 1 - \bar{B} - S > 0,$$

with $p = 0$, $q^H = 0$, and $q^L \in (0, \kappa]$.

3. *The government imposes taxes $T_h = T_l = \bar{B}$ at $t = 1$.*

To prove the proposition, we verify that $p = 0$, $q^H = 0$, and $q^L \in (0, \kappa]$ satisfy the first-order conditions (B.6) and (B.7). Moreover, from (B.11) it follows that $\mu_h = 0$. The price Q^D can be obtain from (B.4). All the other results follow using the same approach as in the proof of Proposition 3.

B.3 General utility

In this extension, we consider a more general utility of the form

$$X + (1-\pi)U(C_h, X_h) + \pi U(C_l, X_l), \tag{B.12}$$

which is non-separable in the consumption of the two goods at time 1.

The first-order condition for C in (11) is replaced by

$$U_c(C_h, X_h) = \mu_h + U_x(C_h, X_h),$$

$$U_c(C_l, X_l) = \mu_l + U_x(C_l, X_l),$$

where $U_c(\cdot,\cdot)$ and $U_x(\cdot,\cdot)$ are the partial derivatives of $U(\cdot,\cdot)$ with respect to its first and second argument, respectively, and μ_h and μ_l are the Lagrange multipliers of (7) and (8).

The first-order conditions with respect to government bonds and intermediaries' safe debt holdings are

$$\begin{aligned} Q^B &= Q^S = (1-\pi)\left[\mu_h + U_x(C_h, X_h)\right] + \pi[\mu_l + U_x(C_l, X_l)] \\ &= (1-\pi)\, U_c(C_h, X_h) + \pi U_c(C_l, X_l) \end{aligned} \tag{B.13}$$

whereas that with respect to risky securities is

$$Q^D = (1-\pi)\left[\mu_h + U_x(C_h, X_h)\right] = (1-\pi)\, U_c(C_h, X_h). \tag{B.14}$$

The problem of the intermediary is to maximize expected profits. Intermediaries investing in safe securities maximize

$$(1-\pi)\, U_x(C_h, X_h)\Pi_h^S + \pi U_x(C_l, X_l)\Pi_l^S,$$

where profits are evaluated, in each state, using the marginal utility of households in the second subperiod. The budget constraint and the profits at $t=1$ are the same as in the baseline model. Thus, their supply is non-negative if $Q^S \geq (1+\tau)$ and, taking into account the zero-rent condition in the market, if

$$Q^S = (1+\tau). \tag{B.15}$$

Similarly, intermediaries issuing risky securities maximize

$$(1-\pi)\, U_x(C_h, X_h)\Pi_h^D + \pi U_x(C_l, X_l)\Pi_l^D,$$

and the budget constraint at $t=0$ and profits at $t=1$ are also the same. Taking into account the zero-rent condition, their supply is non-negative at the price

$$Q^D = (1-\pi)\,. \tag{B.16}$$

Before generalizing Proposition 3, we specify the properties that we require for the general utility function $U(C,X)$.

Assumption 13 *The utility function $U(C,X)$ is strictly increasing, strictly concave in C, and concave in X (i.e., $U_c > 0$, $U_x > 0$, $U_{cc} < 0$, $U_{xx} \leq 0$), continuously differentiable, and satisfies the following restrictions: i) $U_x(\bar{B} + \tilde{K}^S + A\tilde{K}^D, Y_h - \bar{B}) \geq 1$; ii) $U_x(\tilde{K}^S + \bar{B}, \bar{Y}_l - \bar{B}) < (\pi+\tau)/\pi$; iii) $U_{xc}(\cdot,\cdot) \geq 0$ in which $\tilde{K}^S$ and $\tilde{K}^D$ are determined, together with $\tilde{X}_h$, by the following set of equations:*

$$\begin{aligned} U_c(\bar{B} + \tilde{K}^S, \bar{Y}_l - \bar{B}) &= \min\left\{\frac{\pi+\tau}{\pi}, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\} \\ U_c(Y_h + \tilde{K}^S + A_h\tilde{K}^D - \tilde{X}_h, \tilde{X}_h) &= 1 \\ U_c(\bar{Y}_h + \tilde{K}^S + A_h\tilde{K}^D - \tilde{X}_h, \tilde{X}_h) &= U_x(\bar{Y}_h + \tilde{K}^S + A_h\tilde{K}^D - \tilde{X}_h, \tilde{X}_h). \end{aligned}$$

One way to interpret the above conditions is to consider that they impose some bounds on the endowments in the two states of nature.[5] Condition *i*) avoids that the endowment $\bar{Y}_h$ is so large that the liquidity constraint becomes binding in state h, and condition *ii*) prevents that $\bar{Y}_l$ is too low so that the liquidity constraint in state l is never binding. It

[5]This can be seen more easily if the utility function is separable in its arguments.

should be noted that the benchmark case considered in the main text satisfies the above conditions. Indeed, $U_x(\cdot,\cdot) = 1$ and $U_{xc}(\cdot,\cdot) = 0$.

We now generalize Proposition 3.

Proposition 14 *If financial intermediaries face a per-unit cost $\tau > 0$ to monitor safe capital and $\bar{B}$ such that $U_c(\bar{B}, \bar{Y}_l - \bar{B}) > 1$, then:*

1. *In the high state, consumptions C_h and X_h are such that $U_c(C_h, X_h) = 1$, $C_h = \bar{Y}_h + K^S + A_h K^D - X_h$ and $\mu_h = 0$, whereas in the low state,*

$$U_c(C_l, X_l) = \min\left\{\frac{\pi+\tau}{\pi}, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\} > 1$$

   and $\mu_l > 0$;

2. *The price of safe securities is*

$$Q^S = 1 + \pi(U_c(C_l, X_l) - 1) > 1,$$

   while the supply is implicitly defined by

$$U_c(S + \bar{B}, \bar{Y}_l - \bar{B}) = \min\left\{\frac{\pi+\tau}{\pi}, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\},$$

   and the price and supply of risky securities are

$$Q^D = (1-\pi) < 1, \quad D = C_h - \bar{B} - S > 0.$$

3. *The government imposes taxes $T_h = T_l = \bar{B}$ at $t = 1$.*

To prove the proposition, first note that combining (B.14) and (B.16), we get $U_c(C_h, X_h) = 1$. Moreover, using this result and combining it with (B.13) and (B.15), we can obtain that $U_c(C_l, X_l) = (\pi + \tau)/\pi$. If the supply of public debt is such that $U_c(\bar{B}, \bar{Y}_l - \bar{B}) > (\pi + \tau)/\pi$, safe securities are not supplied in equilibrium and $U_c(C_l, X_l) = U_c(\bar{B}, \bar{Y}_l - \bar{B})$.

We now prove that the liquidity constraint is binding in the low state and not in the high state. Note that

$$U_c(C_h, X_h) = \mu_h + U_x(C_h, X_h) = 1.$$

For μ_h to be equal to zero, it should be that $U_x(C_h, X_h) = 1$. Suppose by contradiction that $U_x(C_h, X_h) < 1$, then $C_h = \bar{B} + K^S + AK^D$ and $X_h = \bar{Y}_h - \bar{B}$ in which we have incorporated the intermediary and government budget constraints into the consumer's budget constraint. Therefore, $U_x(\bar{B} + K^S + AK^D, \bar{Y}_h - \bar{B}) < 1$, which violates item *i*) in Assumption 13 given the equilibrium values of K^S and K^D. Now consider the result that $U_c(C_l, X_l) = \min\left\{(\pi + \tau)/\pi, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\}$, which implies that

$$U_c(C_l, X_l) = \mu_l + U_x(C_l, X_l) = \min\left\{\frac{\pi+\tau}{\pi}, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\}.$$

If, by contradiction, $\mu_l = 0$, then it should be the case that $U_c(C_l, X_l) = U_x(C_l, X_l) = \min\left\{(\pi + \tau)/\pi, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\}$ and

$$U_x(C_l, \bar{Y}_l + K^S - C_l) = \min\left\{\frac{\pi+\tau}{\pi}, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\},$$

where we have used the second subperiod budget constraint. Now, since $C_l \leq K^S + \bar{B}$, then $U_x(K^S + \bar{B}, \bar{Y}_l - \bar{B}) = U_c(K^S + \bar{B}, \bar{Y}_l - \bar{B}) \geq \min\left\{(\pi + \tau)/\pi, U_c(\bar{B}, \bar{Y}_l - \bar{B})\right\}$, which violates item *ii*) in Assumption 13, given item *iii*). Note also that if $U_c(\bar{B}, \bar{Y}_l - \bar{B}) > (\pi + \tau)/\pi$, the equilibrium value of safe capital is zero, that is, $K^S = 0$.

The price of safe securities is given by (B.13), which can be written as $Q^S = 1 + \pi(U_c(C_l, X_l) - 1)$. The price of risky securities is given by (B.16).

The supply of safe securities is positive insofar as $U_c(\bar{B}, \bar{Y}_l - \bar{B}) > (\pi + \tau)/\pi$ and is implicitly given by $U_c(S + \bar{B}, \bar{Y}_l - \bar{B}) = (\pi + \tau)/\pi$. The supply of risky securities follows from the liquidity constraint in state h and is given by $D \geq C_h - \bar{B} - S > 0$. Note that D should be greater than zero, otherwise, $U_c(S + \bar{B}, \bar{Y}_h - \bar{B}) \geq U_c(S + \bar{B}, \bar{Y}_l - \bar{B}) > 1$ given $\bar{Y}_h \geq \bar{Y}_l$ and item $iii)$ in Assumption 13, and therefore intermediaries would earn rents by issuing risky securities.