

NBER WORKING PAPER SERIES

THE SUPPLY AND DEMAND FOR SAFE ASSETS

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Working Paper 18732
<http://www.nber.org/papers/w18732>

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2013

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The Supply and Demand for Safe Assets
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NBER Working Paper No. 18732
January 2013, Revised April 2020
JEL No. E0,E02,E2,E3,E32,E4,E41,G01,G12,G2

ABSTRACT

Safe assets are demanded to smooth consumption across states (both intertemporally and in cross-section). Some of these assets are supplied publicly (government bonds) and some are created and supplied privately (such as mortgagebacked securities and asset-backed securities). Private assets are created endogenously when the supply of government bonds is low. Private assets are used as collateral and come in heterogeneous quality. Financial fragility is the probability that a large amount of private assets are examined, some are found to be of low quality and then some firms cannot get loans. We characterize the government's optimal supply of government bonds when considering their effects on the creation of private assets and on economy-wide fragility. We show that monetary and macroprudential policies cannot be run in isolation. When there are too many private assets the government should operate a Bond Exchange Facility that exchanges private assets for public safe assets.

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1 Introduction

Safe assets play an essential role in the economy. A safe asset is an asset whose real value does not fluctuate in response to different shocks. In other words, the level of consumption that holding a safe asset allows is insulated from potential shocks. In this paper we explore the reasons that safe assets are demanded and we explore the central bank's role in their provision. We show that monetary policy cannot be separated from macroprudential policy.

The demand for safe assets comes from two needs: agents wanting to smooth consumption: over time, *inter-temporal consumption smoothing* and in cross-section across states of nature. For instance, lenders want to equalize consumption over different realizations of productivity, and so a safe asset is demanded as *collateral*. The supply of safe assets comes from two sources: public and private. *Public safe assets* are government bonds, promises that the government can make by relying on its taxation power. *Private safe assets* (such as real estate, mortgage-backed securities, etc) take the form of promises that private agents can make by transforming non-pledgeable and perishable goods into non-perishable and pledgeable assets. As private safe assets may be of heterogeneous quality, their safety (the stability of their real value) depends on information about such quality not being revealed. Thus, private assets are safe as long as they are *information-insensitive*.

Issues surrounding safe assets have become increasingly pressing since the transformation of the financial system from a retail-based banking system to a wholesale banking system, starting in the late 1970s. Gorton, Lewellen, and Metrick (2010) show that as a percentage of the total privately-produced safe debt, demand deposits have fallen from about 80% in the 1950's to 31% now. In contrast, short-term money market instruments rose from 11% to 21% and AAA asset-backed and mortgage-backed securities rose from zero to 18%. More generally, the "shadow banking system," which is the sum of mortgage-backed and asset-backed securities and money-like debt instruments, grew from 11% to 38%, getting larger in levels than demand deposits. This transformation seems to be permanent.

In this new financial landscape, U.S. Treasuries are more important than previously. Krishnamurthy and Vissing-Jorgensen (2012 and 2015) show that Treasuries have a convenience yield, arising from their safety property. Gorton, Lewellen, and Metrick (2010), Xie (2012), and Sunderam (2015) show that the private sector produces more

private safe assets when the supply of Treasuries declines. Private safe assets, however, are not perfect substitutes for public safe assets in terms of safety, as information about their heterogeneous quality can be produced, increasing the likelihood of a financial crisis. This creates a challenge for policies that affect the supply of Treasuries without considering their effect on financial stability. This is clearly the case for the central bank, which uses open market operations to exchange one kind of money, Treasuries, for another kind of money, cash (numeraire in our setting). As we do not address fiscal policy in this paper, we use the terms "central bank" and "government" interchangeably.

The central bank faces a problem when, by implementing a monetary policy, it wants to reduce the supply of Treasuries but does not want to trigger information acquisition about the quality of private collateral, that may trigger a financial crisis as information-insensitive collateral becomes information-sensitive (as in Dang, Gorton, and Holmström (2013)). In this setting, macroprudential policy cannot be separated from monetary policy, contrary to the existing literature, e.g., see Svensson (2018) and Bernanke (2018). The central bank needs another tool. It needs to be able to swap Treasuries for private safe assets in order to cope with two goals.

To build these ideas and identify the role of each element, we proceed in steps. We first explore the roles for safe assets assuming that only the government supplies them by issuing government bonds. We show that the government may face a trade-off: providing bonds to serve as collateral in a given period may distort consumption smoothing across periods. We solve the constrained planner's problem and characterize the optimal amount of bonds that the government should provide to optimize this trade-off. We show that, if the market for bonds is competitive, the optimum is implemented when the return on bonds is zero. This implies that the convenience yield (here, the departure from zero returns) is a good signal that the government can exploit to guide potential mistakes in the supply of bonds. Intuitively, returns on bonds are positive when there is an abundance of bonds (then the government needs to compensate agents to hold those bonds) and reducing the supply would improve intertemporal consumption smoothing. In contrast, if returns are negative (a positive convenience yield) when there is scarcity of bonds. In this case, increasing the supply would optimally provide more collateral.

We then introduce the possibility that agents create private safe assets. At a cost, agents can transform non-pledgeable and perishable goods into pledgeable and non-

perishable assets. Pledgeability allows the private asset to be used as collateral and share consumption across agents in a given period. Non-perishability allows the private asset to be used to move consumption across periods and smooth consumption over time. The possibility of creating private assets optimally reduces the need for the government to provide public safe assets.

But, in contrast to government bonds, private assets can potentially be of heterogeneous quality. This is relevant because information about such quality in credit markets introduces dispersion in investment scale (this is, ex-ante risk). Better collateral can support a larger loan. The possibility of a sudden change in information production about private collateral in credit markets introduces systemic risk; investment projects based on loans against bad collateral may not be undertaken. Production crashes. In other words, information-insensitive collateral (no information is produced) is more beneficial than information-sensitive collateral (information is produced), and a crisis happens when there is a change in regime from the first case to the second, as in Gorton and Ordóñez (2014 and 2018).

We study the incentives that lenders have to investigate private collateral. We show that information acquisition is more likely the scarcer are government bonds relative to the needs for collateral to finance investment, the lower the average quality of private assets and the lower the quality of investments. This shows the interconnection between public and private assets. When public assets are abundant, there is both less use of private assets and less incentives to acquire information about their quality.

We study the dynamics of our environment and make two points. First, we show conditions under which monetary policy cannot be considered in isolation from macro-prudential policy. The constrained optimum specifies an optimal amount of government bonds that implements the right combination of intertemporal smoothing and collateral, *while discouraging information acquisition* about private collateral. Conventional monetary policies that exchanges bonds for cash (numeraire) is just one tool, and may not be able to achieve both goals at the same time. If this is not possible, the government needs a new tool to be able to exchange government bonds for private assets. The new policy tool we discuss here is not like quantitative easing, which exchanges cash for government bonds. Rather the new tool is like the Term Securities Lending Facility (which the Fed opened during the Financial Crisis) which allowed for the exchange of private safe assets for government bonds (not cash); see Fleming, Hrung, and Keane (2009). We will call this new tool the "Bond Exchange Facility"

(BEF), with a plausible implementation as discussed in Gorton and Ordóñez (2020). Conventional monetary policy can implement optimal intertemporal smoothing, but the BEF is needed to guarantee that information production about private collateral is avoided.

Second, a transitory shock that reduces the supply of public bonds available as collateral, induces an increase in the production of private collateral, increasing the incentives to acquire information and financial fragility, as information acquisition of a large volume of private assets suddenly reduces output and welfare, *a crisis*.¹ Only the BEF can prove effective to rapidly take private collateral "out of circulation", hence reducing fragility without distorting consumption smoothing.

There is a large literature on the role that government safe assets play in supplying private agents with collateral or liquidity. In different circumstances, government debt can relieve constraints on the private economy. Examples of this line of research include Woodford (1990), Aiyagari and McGrattan (1998), Holmström and Tirole (1998), and more recently Angeletos, Collard, and Dellas (2016) and Azzimonti and Yared (2019). In contrast to this literature, we focus on the financial stability considerations that arise when private agents produce private safe assets of heterogeneous quality in response to a dearth of public safe assets. The likelihood of a financial crisis is increasing in the ratio of private safe assets to public safe assets. This complicates what would otherwise be the government's optimal policy.

The paper proceeds as follows. In Section 2 we introduce the basic model with no information frictions. We show the two sources of demand for safe assets: consumption smoothing and collateral. We also show the two sources of supply: public bonds and privately-produced safe assets. In Section 3 we introduce information frictions. We show that the privately-produced safe assets are only "safe" as long as no information is produced about their quality. In Section 4 we extend the model to an overlapping generations model and characterize the steady states. In this setting we show the potential need for the BEF to exchange government bonds for privately-produced safe assets and we explore the effects of an unexpected negative supply shock to the supply of government bonds. Section 5 concludes.

¹The global savings glut is an example of such a reduction in the supply of government bonds. See, e.g., Bernanke (2005).

2 Two Period Model Without Information Frictions

In this section we introduce the two sources of demand for safe assets (consumption smoothing and collateral) and the two sources of supply (public and private). First, as a benchmark, we consider a simple setting with public supply (government bonds) and a single role (consumption smoothing). Then, we add the second role (collateral) and show that a government that fails to acknowledge this role may err in different ways in the provision of bonds, depending on the policy misspecification. Such mistakes can be avoided if the government uses information about the convenience yield to guide their bond policy. Finally, we introduce assets that can be produced privately and that are in competition with government bonds. Private assets can also serve both roles. Here we show that this possibility changes the optimal provision of bonds as a function of how costly it is to produce private assets and how well they can serve as collateral.

2.1 Optimal Bond Policy when Bonds are not Collateral

Assume households live for two periods in an endowment economy. Endowment in the first period is Y_1 and endowment in the second period is Y_2 . The consumption of numeraire good gives households utility $U(C)$, which is separable, strictly concave and that satisfies the Inada conditions. The discount between periods is β .

Unconstrained Optimum: The planner's problem (which is the same as the household problem when it can move resources freely across periods) is

$$\max_{C_1, C_2} U(C_1) + \beta U(C_2)$$

subject to

$$C_1 + C_2 \leq Y_1 + Y_2$$

which is simply characterized by the Euler equation

$$U'(C_1) = \beta U'(C_2)$$

Assuming $U(C) = \log C$, for instance, the solution is just given by

$$C_1 = \frac{Y_1 + Y_2}{1 + \beta} \quad \text{and} \quad C_2 = \beta C_1$$

So the planner would perfectly smooth consumption if it has the technology to transfer resources across periods.

Equilibrium and Optimal Implementation: Imagine now households cannot transfer resources across periods but the government has access to a storage technology that can do it. This “time machine” technology is just a shortcut to endow the government with a taxation technology in a more involved setting with different groups (other groups) in which Ricardian Equivalence does not hold.

Ricardian Equivalence might not hold for instance in an overlapping generations environment in which every generation has $Y_1 > 0$ and $Y_2 = 0$. The government could tax the young to give to the old (without altruism considerations that may recover the equivalence (see Barro (1974)).² The way to implement this policy would be to sell bonds to the young and pay them when old with tax revenue from the next young generation. We explore this possibility later in the paper.

Another example in which this “time machine” technology redistributes wealth across periods is by having two coexisting types of households, one with complete access to credit markets, and the other (the one we model here) without access. The government could tax the group with access and give to the group without access to credit. The effect of incomplete markets on the failure of the Ricardian Equivalence has been explored by Aiyagari (1994) and Heathcote (2005) among others.

Finally, a third reason often used to contest Ricardian Equivalence is the distortionary effects of taxation (see Auerbach and Kotlikoff (1987) and McGrattan (1994)). Here we show a very reduced-form version of this logic. To operate this “time machine” the government can offer to sell (or buy) Treasury bonds B in the first period at a price P , which can be positive (buy) or negative (sell).

Consider agents buying bonds. If the government’s promise in the second period exceeds what the government collects in the first period (this is $B > PB$), the difference has to be raised by taxing second-period households’ endowments, Y_2 . We assume

²Several empirical studies (Altonji, Hayashi, and Kotlikoff (1992, 1996 and 1997)) find that households are not altruistically-linked in a way consistent with Ricardian Equivalence.

that taxing endowments is distortionary, as it destroys χ units of endowment per unit of tax. Furthermore, in case the government promises in the second period less than collected in the first (this is $B < PB$), we assume the extra resources are “thrown into the ocean”.

The household problem in this economy becomes

$$\max_{C_1, C_2, B} U(C_1) + \beta U(C_2)$$

subject to

$$\begin{aligned} C_1 + PB &\leq Y_1 \\ C_2 &\leq Y_2 + B - T \\ T &= (1 + \chi) \max\{0, (1 - P)B\}. \end{aligned}$$

Plugging taxes into the second-period households’ budget constraint, the maximization problem becomes:

$$\begin{aligned} C_1 + PB &\leq Y_1 \\ C_2 &\leq Y_2 + Bm. \end{aligned}$$

with the distortion formally defined as

$$m = \min\{1, 1 - (1 + \chi)(1 - P)\}. \quad (1)$$

The Euler equation is

$$PU'(C_1) = \beta m U'(C_2)$$

and the unconstrained optimum is implemented when $P = m$, which implies $P = 1$.

To fix ideas, from the Euler equation and the resource constraints we can obtain the demand for Treasury bonds. Take the log case, as before,

$$P \frac{1}{Y_1 - PB} = \beta \frac{m}{Y_2 + Bm} \implies B = \frac{\beta Y_1 - \frac{P}{m} Y_2}{(1 + \beta)P},$$

decreasing in the price P . Notice that the social planner wants to choose the supply

of bonds B_S such that $\frac{P}{m} = 1$, this is,

$$B_S^* = \frac{\beta Y_1 - Y_2}{(1 + \beta)}, \quad (2)$$

where the optimal supply of bonds increases with Y_1 and decreases with Y_2 . If $\beta Y_1 > Y_2$ the government would like to sell bonds in the first period (in exchange for numeraire) to implement the unconstrained optimum by reducing the consumption of households in the first period and increasing it in the second period. If $\beta Y_1 < Y_2$ the government would like to buy bonds from households in the first period to implement the unconstrained optimum, this time by increasing consumption in the first period with resources coming from the second period (or from another unmodelled group in the same period).

Notice that if bonds are abundant and $P < 1$, then $\frac{P}{m} = \frac{P}{P-\chi(1-P)} > 1$,³ which implies that the government has to distort consumption in the second period with taxes, forcing it to also inefficiently reduce consumption in the first period. At the other extreme, if bonds are scarce, and $P > 1$, then $\frac{P}{m} = \frac{P}{1} > 1$, which implies that the government extracts more in the first period than what it can deliver in the second period, wasting resources and reducing consumption excessively. Notice also that, in the case where taxation is not distortionary (this is $\chi = 0$), $m = 1$ and any price $P \leq 1$ is consistent with optimal implementation, a version of Ricardian Equivalence in our setting.

Relation with Monetary Policy: The planner's optimal $P \equiv \frac{1}{1+r} = 1$ can be implemented by a monetary authority that uses Treasury bonds to conduct open market operations and sets $1 + r = 1$ (a Friedman rule, given our assumption that creating bonds is costless for the government). If the central bank expects Y_2 to be very low with respect to Y_1 it would like to increase the interest rate to "cool down" the economy by reducing consumption and aggregate demand. An increase of interest rates is the same as reducing the price of government bonds. Alternatively the central bank could sell Treasury bonds (increase B_S) in exchange for money (numeraire) (an increase in $1 + r$). The opposite happens when Y_2 is expected to be large relative to Y_1 and the central bank would like to reduce rates, by buying Treasury bonds, to "stimulate" the economy by increasing consumption and aggregate demand. The amount of bonds given in equation (2) is what implements the optimal level of consumption in the economy.

³When $\chi > \frac{P}{1-P}$, then $\frac{P}{m} < 0$, which also distorts consumption.

Convenience Yield: Notice that a shortage of Treasuries introduces a convenience yield for government bonds. From market clearing, when $B = B_S$:

$$P = \frac{\beta Y_1}{(1 + \beta)B_S + Y_2}.$$

As the supply of Treasuries, B_S , decreases, its price increases. Taking the optimal price as 1, the convenience yield can be written as $P - 1$, or

$$CY \equiv P - 1 = \frac{(\beta Y_1 - Y_2) - (1 + \beta)B_S}{(1 + \beta)B_S + Y_2}. \quad (3)$$

The convenience yield is zero only when $B_S = B_S^*$ from equation (2), and the optimal amount of bonds is provided to perfectly smooth consumption.

2.2 Optimal Bond Policy with Bonds as Collateral

Now we extend the endowment setting to include production with credit needs. More specifically, a fraction x of households have an investment opportunity at the beginning of the second period, after the endowment Y_2 is obtained but before consumption takes place. This investment opportunity transforms l unit of endowment good per household into Al^α units of endowment good. The rest of the households $1 - x$ do not have any investment opportunities. Whether a household is productive or not is realized at the beginning of the second period.

The unconstrained optimal scale of production for each productive household is given by $\max_l [Al^\alpha - l]$, or $l^* = [\alpha A]^{\frac{1}{1-\alpha}}$. To simplify the cases in terms of feasibility, in what follows, we assume that $Y_2 < l^* < \frac{Y_2}{x}$. In other words, the endowment of each household is not enough to finance production at optimal scale, but the endowments of all households is sufficient.

Constrained Optimum: Now, we solve for the constrained optimum, in which the planner still possesses the technology to transfer resources across periods, but cannot impose a transfer between productive and unproductive agents within the second period. This implies that, i) projects can only be operated by productive agents with own endowments (either current or saved from the first period) and ii) there is no cross-insurance of consumption between productive and non-productive agents.

This constrained problem is then:

$$\max_{C_1, C_{p,2}, C_{np,2}, l} U(C_1) + \beta[xU(C_{p,2}) + (1 - x)U(C_{np,2})]$$

subject to

$$\begin{aligned} C_1 + C_{p,2} &\leq Y_1 + Y_2 + \hat{Y}_2 \\ C_1 + C_{np,2} &\leq Y_1 + Y_2 \\ \hat{Y}_2 &= [Al^\alpha - l] \\ l &\leq Y_2 + (Y_1 - C_1). \end{aligned}$$

Denoting by μ the Lagrange multiplier of this last, credit constraint, the first order conditions are:

$$\begin{aligned} \{C_1\} &: U'(C_1) = \lambda_{p,2} + \lambda_{np,2} + \mu \\ \{C_{p,2}\} &: \beta x U'(C_{p,2}) = \lambda_{p,2} \\ \{C_{np,2}\} &: \beta(1 - x) U'(C_{np,2}) = \lambda_{np,2} \\ \{l\} &: \lambda_{p,2}(\alpha Al^{\alpha-1} - 1) = \mu \end{aligned}$$

Defining the marginal return of the project as

$$R(l) = \alpha Al^{\alpha-1} - 1,$$

with $R(l) > 0$ and $R'(l) < 0$ in equilibrium, and $R(l^*) = 0$. Combining these conditions

$$U'(C_1) - \beta \mathbb{E}(U'(C_2)) = \beta x U'(C_{p,2}) R(l). \quad (4)$$

This equation highlights the main trade-off that the planner faces given that he is constrained from moving resources between agents with different investment opportunities. The planner equalizes the intertemporal smoothing distortions (the difference between $U'(C_1)$ and $\beta \mathbb{E}(U'(C_2))$) with the increase in extra second period's production obtained by moving resources to the second period (x productive agents will be able to produce an extra numeraire $R(l)$, which they value at $\beta U'(C_{p,2})$ at the margin).⁴

⁴If there are enough resources such that the planner implements l^* , then $R(l^*) = 0$ and the planner does not need to introduce intertemporal distortions.

Intuitively, when there are no productive opportunities, the planner would simply equalize marginal utilities in both periods (as in the previous setting). When investment opportunities exist, however, there is an extra gain from moving resources to the second period to sustain investment that is restricted by second-period endowments. This leads the planner to distort consumption smoothing by consuming less in the first period in order to be able to produce and consume more in the second period.

Equilibrium and Optimum Implementation: Now we consider an equilibrium in which the government would like to implement the planner's allocation by providing government bonds in the first period.

To capture the credit friction that prevents agents with different investment opportunities from exchanging numeraire in the second period, and even though the output of investment is deterministic, we assume that such output is non-pledgeable. We assume, however, that government bonds are pledgeable (households can abscond with numeraire but not with government bonds). Hence, productive agents can borrow numeraire from non-productive agents using bonds as collateral in order to overcome the credit friction.

The household problem in the first period, knowing that in the second period it may become a productive agent with probability x , is:

$$\max_{C_1, C_{p,2}, C_{np,2}, l, B} U(C_1) + \beta[xU(C_{p,2}) + (1 - x)U(C_{np,2})]$$

subject to

$$\begin{aligned} C_1 + PB &\leq Y_1 \\ C_{p,2} &\leq Y_2 + Bm + \hat{Y}_2 \\ C_{np,2} &\leq Y_2 + Bm \\ \hat{Y}_2 &= [Al^\alpha - l] \\ l &\leq Y_2 + Bm. \end{aligned}$$

where m is the bond consumption after taxation distortions from equation (1). The

first-order conditions are

$$\begin{aligned}
\{C_1\} & : U'(C_1) = \lambda \\
\{C_{p,2}\} & : \beta x U'(C_{p,2}) = \lambda_{p,2} \\
\{C_{np,2}\} & : \beta(1-x)U'(C_{p,2}) = \lambda_{np,2} \\
\{l\} & : \lambda_{p,2}(\alpha Al^{\alpha-1} - 1) = \mu \\
\{B\} & : P\lambda - (\lambda_{p,2} + \lambda_{np,2})m = \mu m.
\end{aligned}$$

Combining these conditions we obtain the condition that determines the demand for bonds in equilibrium,

$$PU'(C_1) - \beta m \mathbb{E}(U'(C_2)) = \beta mxU'(C_{p,2})R(l). \quad (5)$$

The constrained optimum can be implemented if and only if $P = m = 1$. To obtain the supply of government bonds that implements such a price, we need to equalize the supply with the demand of bonds from equation (5) at $P = 1$.

To compare with the initial benchmark, take the case of log utilities, such that equation (5) becomes

$$\begin{aligned}
P \frac{1}{Y_1 - PB} - \beta m \left[\frac{x}{A(Y_2 + Bm)^\alpha} + \frac{1-x}{Y_2 + Bm} \right] &= \beta m \frac{x}{A(Y_2 + Bm)^\alpha} (\alpha A(Y_2 + Bm)^{\alpha-1} - 1) \\
P \frac{1}{Y_1 - PB} &= \beta m \left[\frac{x\alpha}{Y_2 + Bm} + \frac{1-x}{Y_2 + Bm} \right]
\end{aligned}$$

or, defining $\hat{\beta} \equiv \beta(1 - x(1 - \alpha)) < \beta$

$$P \frac{1}{Y_1 - PB} = \hat{\beta} \frac{m}{Y_2 + Bm} \quad \Rightarrow \quad B = \frac{\hat{\beta} Y_1 - \frac{P}{m} Y_2}{(1 + \hat{\beta})P}. \quad (6)$$

The extra use of bonds as collateral raises production in the second period and induces a reduction of the second period's marginal utility of consumption. Hence, the use of bonds as collateral acts as an effective reduction of households' patience because it increases consumption in the future. That is, compared to the setting in which bonds are not used as collateral there is a marginally lower demand for bonds, and the optimum is implemented by choosing the supply of bonds B_S such that $P = 1$.

This is

$$B_S^* = \frac{\widehat{\beta}Y_1 - Y_2}{(1 + \widehat{\beta})} \quad \text{with } \widehat{\beta} = \beta(1 - x(1 - \alpha)).$$

This seems counterintuitive. If bonds are more valuable, why is the demand for them lower? Consider the case in which there is a demand for bonds, and now bonds suddenly allow for an increase in consumption in the second period by even more. In such a case, households would rather reduce the demand for bond a bit to move some of that extra consumption from the second to the first period.

Misspecified Policies: We can compare the optimal level of bonds when the government acknowledges their use as collateral vis-a-vis policies that do not consider bonds as collateral. There are several ways in which the government may misspecify its bond policy.

A *pessimistic misspecification* is one in which the government believes that bonds *cannot* be used as collateral to finance projects, and that production in the second period can only be sustained by second period endowments. Then the government believes that the demand for bonds is given by

$$P \frac{1}{Y_1 - PB} = \beta m \left[\frac{x}{AY_2^\alpha + Bm} + \frac{1-x}{Y_2 + Bm} \right].$$

As the government expects a lower consumption in the second period than the consumption households really expect from using bonds as collateral, the right-hand side (expected marginal utility in the second period) is higher than that from the correctly specified demand function (6). This implies that the government expects a higher demand for bonds, and trying to implement a price $P = 1$ it would supply more bonds than optimal, inducing indeed an excess supply. Forcing the bond market to clear at $P < 1$, introduces inefficiencies by forcing the government to resort to distortionary taxation in the second period (as $\frac{P}{m} > 1$).

An *optimistic misspecification* policy is one in which the government believes that bonds *are not needed* as collateral to finance the project. In other words, the government believes that output of the project is pledgeable and then the optimal production \widehat{Y}_2^* can be implemented without using collateral. Then the government believes that the

demand for bonds is given by

$$P \frac{1}{Y_1 - PB} = \beta m \left[\frac{x}{\widehat{Y}_2^* + Bm} + \frac{1-x}{Y_2 + Bm} \right].$$

As the government expects higher consumption in the second period than the consumption households really expect from being subject to credit frictions, the right-hand side (expected marginal utility in the second period) is lower than that determined by the correctly specified demand function (6). This implies that the government expects a lower demand for bonds, and tries to implement a price of $P = 1$ by supplying fewer bonds than is optimal, inducing an excess demand and $P > 1$ (a positive convenience yield) and also a misallocation of resources as some will be “thrown to the ocean”.

As can be seen, the price of government bonds is informative about the government’s misspecification in terms of the importance of bonds as collateral. It is also informative about the degree of financial frictions (or the degree of pledgeability of the project’s outcome) in the economy, as the production would range between AY_2^α and \widehat{Y}_2^* . In short, the convenience yield depends on the gap between the government’s perception about the use of collateral in the economy, and the real use of collateral in the economy.

2.3 Optimal Bond Policy with Production of Private Assets

We have previously assumed that only government bonds provide a vehicle to move consumption intertemporally and to act as pledgeable promises to sustain credit and production in the economy. Here, we add that agents can produce a private asset that can also move consumption intertemporally and that can also be used as collateral, but only partially (a unit of private asset sustains ϕ units of collateral). We assume that, using first period endowment, households can produce Z private assets at a cost of Z^γ in terms of numeraire, where $\gamma > 1$. First, we compute the planner’s problem and then we discuss the policy implementation in this extended setting in which households can generate their own “time machine” and pledgeable assets.

Constrained Optimum: We solve for a planner’s optimum when the planner cannot impose a transfer of resources between productive and non-productive agents, but

has a technology to create assets that transfer resources intertemporally. This constrained problem is:

$$\max_{C_1, C_{p,2}, C_{np,2}, l, Z} U(C_1) + \beta[xU(C_{p,2}) + (1 - x)U(C_{np,2})]$$

subject to

$$\begin{aligned} C_1 + C_{p,2} + Z^\gamma &\leq Y_1 + Y_2 + Z + \hat{Y}_2 \\ C_1 + C_{np,2} + Z^\gamma &\leq Y_1 + Y_2 + Z \\ \hat{Y}_2 &= [Al^\alpha - l] \\ l &\leq Y_2 + (Y_1 - C_1 - Z^\gamma) + \phi Z. \end{aligned}$$

First order conditions are

$$\begin{aligned} \{C_1\} &: U'(C_1) = \lambda_{p,2} + \lambda_{np,2} + \mu \\ \{C_{p,2}\} &: \beta x U'(C_{p,2}) = \lambda_{p,2} \\ \{C_{np,2}\} &: \beta(1 - x) U'(C_{np,2}) = \lambda_{np,2} \\ \{l\} &: \lambda_{p,2}(\alpha Al^{\alpha-1} - 1) = \mu \\ \{Z\} &: (\lambda_{p,2} + \lambda_{np,2})(\gamma Z^{\gamma-1} - 1) + \mu \cdot \gamma Z^{\gamma-1} = \phi \mu \end{aligned}$$

Combining these conditions, the planner's optimal choice on how to allocate consumption across periods is given by

$$U'(C_1) - \beta \mathbb{E}(U'(C_2)) = \beta x U'(C_{p,2}) R(l), \quad (7)$$

and the planner's optimal choice of asset production is given by:

$$\gamma Z^{\gamma-1} U'(C_1) - \beta \mathbb{E}(U'(C_2)) = \beta x \phi U'(C_{p,2}) R(l) \quad (8)$$

Equations (7) and (8) characterize the optimal choice for the planner between delaying consumption and generating assets. Both alternatives smooth consumption intertemporally and increase collateral and production in the second period. Equation (7) is the already discussed trade-off of delaying consumption. The benefit is having more resources to invest in the second period (weighted by the expected return of the project evaluated at the marginal utility of consumption in the second period). The

cost is distorting consumption (measured by the difference between marginal utilities across periods). Equation (8) displays a similar trade-off of producing assets. The benefit is also that there are more resources to invest in the second period, but scaled down by $\phi < 1$. The cost is that consumption is distorted (measured by the difference between marginal utilities across periods) but with a marginal cost in terms of numeraire in the first period of $\gamma Z^{\gamma-1}$.

Notice that as the marginal benefit of assets is smaller than those of delaying consumption (a superior collateral), in equilibrium $\gamma Z^{\gamma-1} < 1$, and there is less production of assets in the economy than there would be the case of the absence of using bonds and assets as collateral. Further, as the difference between delaying consumption and assets is given by ϕ , in a situation in which ϕ (for some reason) declines exogenously, there is lower than optimal production of assets, not only to smooth consumption (given that the lower production in the second period implies that $\mathbb{E}(U'(C_2))$ rises) but also to replace assets as collateral.

Combining these two equations gives us the combination between delayed consumption and production of assets that the planner would like to achieve to smooth consumption and increase production. Subtracting (8) from (7), the constrained optimal Z^* satisfies

$$\gamma(Z^*)^{\gamma-1} = 1 - (1 - \phi) \frac{x\beta U'(C_{p,2})R(l)}{U'(C_1)}. \quad (9)$$

Implementation: Now we solve for the equilibrium and for the implementation of the constrained optimal amount of government bonds. The households' problem is:

$$\max_{C_1, C_{p,2}, C_{np,2}, l, B, Z} U(C_1) + \beta[xU(C_{p,2}) + (1 - x)U(C_{np,2})]$$

subject to

$$\begin{aligned} C_1 + PB + Z^\gamma &\leq Y_1 \\ C_{p,2} &\leq Y_2 + Bm + Z + \hat{Y}_2 \\ C_{np,2} &\leq Y_2 + Bm + Z \\ \hat{Y}_2 &= [Al^\alpha - l] \\ l &\leq Y_2 + Bm + \phi Z \end{aligned}$$

The first order conditions are

$$\begin{aligned}
\{C_1\} & : U'(C_1) = \lambda \\
\{C_{p,2}\} & : \beta x U'(C_{p,2}) = \lambda_{p,2} \\
\{C_{np,2}\} & : \beta(1-x)U'(C_{p,2}) = \lambda_{np,2} \\
\{l\} & : \lambda_{p,2}(\alpha Al^{\alpha-1} - 1) = \mu \\
\{B\} & : P\lambda - m(\lambda_{p,2} + \lambda_{np,2}) = \mu m \\
\{Z\} & : \gamma Z^{\gamma-1}\lambda - \lambda_{p,2} - \lambda_{np,2} = \mu\phi.
\end{aligned}$$

From the first order condition for bonds,

$$PU'(C_1) - \beta m \mathbb{E}(U'(C_2)) = \beta mxU'(C_{p,2})R(l) \quad (10)$$

and from the first order condition for private assets,

$$\gamma Z^{\gamma-1}U'(C_1) - \beta \mathbb{E}(U'(C_2)) = \beta x\phi U'(C_{p,2})R(l). \quad (11)$$

From conditions (10) and (11), the equilibrium production of private assets is:

$$\gamma(Z^{eq})^{\gamma-1} = \frac{P}{m} - (1-\phi)\frac{x\beta U'(C_{p,2})R(l)}{U'(C_1)}. \quad (12)$$

Notice that even when the agents have the possibility of buying bonds to smooth consumption and to use as collateral, they would still produce some private assets since their production function is convex, and the marginal cost of production is zero at $Z = 0$. Agents' production of private assets is increasing in P and, comparing with equation (9), it is clear that the optimal implementation requires $P = m = 1$.

Just for comparison purposes with previous subsections assume log preferences and $\phi = 1$ (with $\phi < 1$ there is no closed-form solution of the optimal bond supply, but the logic remains). The demand for bonds is given by:

$$P \frac{1}{Y_1 - PB - (Z^{eq})^\gamma} = \beta m \left[\frac{x(1 + \alpha Al^{\alpha-1} - 1)}{Y_2 + Bm + Z^{eq} + Al^\alpha - l} + \frac{1-x}{Y_2 + Bm + Z^{eq}} \right]$$

where $l = Y_2 + Bm + Z^{eq}$, and from equation (12), $Z^{eq} = \left[\frac{P}{\gamma m} \right]^{\frac{1}{\gamma-1}}$. Then,

$$B = \frac{\widehat{\beta}Y_1 - \frac{P}{m}Y_2 - (\widehat{\beta} + \gamma) \left[\frac{P}{\gamma m} \right]^{\frac{\gamma}{\gamma-1}}}{(1 + \widehat{\beta})P},$$

where, as in the previous section, $\widehat{\beta} = \beta(1 - x(1 - \alpha))$. The demand for bonds decreases with the bonds' price, and it is higher without a technology that creates private assets.

The optimum is implemented with $P = m = 1$, which can be done by providing bonds B_S^* such that,

$$B_S^* = \frac{\widehat{\beta}Y_1 - Y_2 - (\widehat{\beta} + \gamma) \left[\frac{1}{\gamma} \right]^{\frac{\gamma}{\gamma-1}}}{(1 + \widehat{\beta})},$$

which is lower than the supply of bonds needed in the absence of private assets.

3 Two Period Model With Information Frictions

Now we assume that private assets come in two qualities, which determine their effective value κZ . The quality can be good (with $\kappa_G > 0$) with probability \bar{p} or bad (with $\kappa_B = 0$), otherwise, with $\bar{p}\kappa_G = 1$. We also assume that collateral and consumption depends on the expected quality of the asset, which we will endogenize later using an overlapping generation structure.

3.1 The Role of Information

In what follows we compare two informational alternatives, with and without information about private assets, and show that the economy's welfare is higher when information is not revealed.

When information about private assets' quality never gets revealed the expected quality of private assets is $\bar{p}\kappa_G = 1$, and this situation is exactly the same as in the previous section, with allocations characterized by equations (10) and (11).

When information gets revealed at the beginning of the second period, there are two sources of risk. One is the "productivity shock" (also present above and which we

assumed non-insurable). This shock determines whether the agent has access to an investment opportunity or not, which we denote by $i \in \{p, np\}$, with $q_p = x$ and $\widehat{Y}_{np,2} = 0$. The other, which is a new source of risk that is introduced by information revelation, is a “private collateral shock” that determines whether the private asset is good or bad, which we denote by $j \in \{G, B\}$, with $q_G = \bar{p}$ and $Z_B = 0$.

Using this, more general, notation the households' problem can be written as:

$$\max_{C_1, C_{ij,2}, l_j, B, Z} U(C_1) + \beta \sum_{i,j} q_i q_j U(C_{ij,2})$$

subject to

$$\begin{aligned} C_1 + PB + Z^\gamma &\leq Y_1 \\ C_{ij,2} &\leq Y_2 + Bm + \kappa_j Z + \widehat{Y}_{ij,2} \quad \forall i, j \\ \widehat{Y}_{pj,2} &= [Al_j^\alpha - l_j] \\ l_j &\leq Y_2 + Bm + \phi \kappa_j Z \quad \forall j. \end{aligned}$$

The first order conditions are:

$$\begin{aligned} \{C_1\} &: U'(C_1) = \lambda \\ \{C_{ij,2}\} &: \beta q_i q_j U'(C_{ij,2}) = \lambda_{ij,2} \\ \{l_j\} &: \lambda_{pj,2} (\alpha A l_j^{\alpha-1} - 1) = \mu_j \\ \{B\} &: P\lambda - m \sum_{i,j} \lambda_{ij,2} = m \sum_j \mu_j \\ \{Z\} &: \gamma Z^{\gamma-1} \lambda - \sum_{i,j} \kappa_j \lambda_{ij,2} = \sum_j \phi \kappa_j \mu_j. \end{aligned}$$

Notice that $\sum_{i,j} \lambda_{ij,2} = \beta \mathbb{E}(U'(C_{ij,2}))$. There is more risk than in the case with a single collateral type as the return on the project, $R_j \equiv (\alpha A l_j^{\alpha-1} - 1)$ is stochastic.

The demand for bonds equalizes their cost and benefits,

$$P U'(C_1) - \beta m \mathbb{E}(U'(C_{ij,2})) = \beta mx \sum_j q_j U'(C_{pj,2}) R_j, \quad (13)$$

which is also the case for creation of private assets,

$$\gamma Z^{\gamma-1}U'(C_1) - \beta \mathbb{E}(\kappa_j U'(C_{ij,2})) = \beta x\phi \sum_j q_j \kappa_j U'(C_{pj,2}) R_j. \quad (14)$$

Notice that the benefits of private assets are smaller than the benefits of government bonds for two reasons. First, the heterogeneity in the quality of private assets reduces their value for intertemporal smoothing as it introduces more risk in the second period (i.e., $\beta \mathbb{E}(\kappa_j U'(C_{ij,2})) < \beta \mathbb{E}(U'(C_{ij,2}))$). Second, private assets are worse collateral (not only because of $\phi < 1$) but also because of the extra risk generated by their heterogeneity (this is, $\sum_j q_j \kappa_j U'(C_{pj,2}) R_j < \sum_j q_j U'(C_{pj,2}) R_j$).

There are three messages that arise from comparing these different information environments. First, fixing the amounts of bonds and private assets in the economy, welfare is lower with information simply because agents face higher utility uncertainty. Second, from comparing no information-equations (10) and (11) with information-equations (13) and (14), the benefits of bonds and private assets increase when information is not revealed. This comes from applying Jensen's inequality, given risk aversion (concavity of the utility function) and decreasing marginal returns (concavity of the production function). Formally, $\mathbb{E}(U'(C_{ij,2})R(Z_j)) > U'(\mathbb{E}C_{ij,2})R(\mathbb{E}Z_j)$.

Finally, information increases the benefits of bonds more than it increases the benefits of private assets. This comes from comparing information-equations (13) with (14). The reason is that private assets are scarcer in states of the world in which they are more valuable, both because they provide low consumption and make poor collateral and then low production. More formally, $\mathbb{E}(U'(C_{ij,2})R(Z_j)) > \mathbb{E}(\kappa_j U'(C_{ij,2})R(Z_j))$.

Once accounting for this distortion in the creation of bonds and private assets, there is a second reason why information reduces welfare: higher investments in bonds and private assets in the first period distorts the allocation of resources, reducing excessively the consumption in the first period to partly compensate for the higher risk in the second.

This comparison highlights the pervasive role of information about heterogeneous collateral in credit markets. If there is no information, all productive agents obtain a loan for a collateral of expected value $\hat{\kappa}_G Z = Z$. If there is information, some productive agents would obtain a larger loan based on collateral $\kappa_G Z$ (potentially having excessive collateral once the loan implements the optimal scale l^*) while some

others would not get to produce. With risk aversion and decreasing marginal returns this risk reduces welfare, intuitively because information destroys the cross-insurance that ignorance can provide. In other words, ignorance transforms assets into “safe collateral,” which is beneficial in terms of total consumption in the economy.

3.2 Information Acquisition

Now we add two extensions to the previous setting, so we can study the conditions under which the economy will be in the first situation (with information revealed before lending takes place) or the second situation (with information revealed after production happens).

In contrast to the previous setting, in which the project outcome was assumed deterministic, now we want to study the possibility that a lender (a non-productive agent in our setting) ends up with the asset in case of default, and as such may want to privately acquire information about its quality. First, we assume the project fails with probability d . Second, we assume that a lender can acquire information about the quality of a private asset at the beginning of the second period, at a *utility cost* of ψ .

We have to be more explicit now about the credit protocol. We assume there is random matching between a lender and a borrower and that $x > 1/2$, such that the borrower has all the bargaining power. The possibility of default not only adds another source of risk for the borrower (who is the residual claimant on the project, as the borrower keeps the surplus) but also exposes the lender to the risk of receiving private collateral of low quality in the case of default.

In a match between agents, negotiating a loan of size l , the part that is not covered by bonds and needs to be covered by private assets is $l - Y_2 - Bm$. Assuming the borrower has private asset of perceived quality p_b , then the expected value of his private asset is $p_b \kappa_G Z$. This implies that the borrower has to finance a fraction $f = \frac{l - Y_2 - Bm}{p_b \kappa_G Z} \leq 1$ of the asset to get a loan l . Naturally, $f = 1$ as long as $R(l) > 0$ in equilibrium (there is not enough collateral in the economy to reach l^*).

The larger the loan, or the less likely the asset is of good quality, the larger is the fraction of private assets that the borrower puts at stake when obtaining credit. This is relevant because, in principle, the higher the lender’s exposure to the borrower’s private asset, the higher is the incentive to acquire information about that asset.

Under what conditions can the information-insensitivity of collateral (superior in terms of welfare) be sustained in equilibrium? This happens when the lender's expected utility from acquiring information (net of the cost) is larger than the lender's utility from not acquiring information. This is, when,

$$\mathbb{E}U(C_{np,2}^I) - U(C_{np,2}^U) \leq \psi.$$

In the evaluation of these utilities, note that consumption in the absence of information production is:

$$C_{np,2}^U = Y_2 + Bm + p_l \kappa_G Z$$

where p_l is the quality of the private asset owned by the lender, and the lender always recovers the loan at the end of the period. In other words, the lender breaks even and consumes as if there were no loan at all.

In case of acquiring information about the collateral posted by the borrower, the lender does not lend in case the collateral is bad quality (with probability $1 - p_b$) and lends in case the collateral is good quality (with probability p_b), and obtains the repayment specified in the "information-insensitive loan contract" in case the project succeeds (this is with probability $1 - d$), as information acquisition was assumed private knowledge. In this case, consumption is the same as $C_{np,2}^U$. Then, the only potential gain from information accrues when the lender finds out the collateral is good quality, signs the presumed information-insensitive contract and the project fails. In this case, with probability dp_b the lender obtains

$$\begin{aligned} C_{np,2}^I &= Y_2 + Bm + p_l \kappa_G Z - l + Y_2 + Bm + f \kappa_G Z \\ &= Y_2 + Bm + p_l \kappa_G Z + f(1 - p_b) \kappa_G Z \\ &= Y_2 + Bm + p_l \kappa_G Z + \frac{(1 - p_b)}{p_b} (l - Y_2 - Bm). \end{aligned}$$

Then, no information is a sustainable equilibrium if and only if

$$dp_b [U(C_{np,2}^I) - U(C_{np,2}^U)] \leq \psi. \quad (15)$$

Note that if agents were risk neutral this condition would boil down to subtracting

$C_{np,2}^U$ from $C_{np,2}^I$ and the condition would become

$$l \leq \frac{\psi}{d(1-p_b)} + Y_2 + Bm,$$

which are similar to the conditions in Gorton and Ordóñez (2014 and 2018), but considering the use of government bonds and own funds in obtaining the loan.

The next proposition shows comparative statics for information acquisition.

Proposition 1 *The incentives to acquire information about private assets used as collateral increase with the size of the loan sustained by private collateral (l given B) and decrease with the amount of bonds used as collateral (B given l). The incentives also increase with the probability of default (d) and decrease with the probability the asset is of good quality (p_b) and with the cost of information production (ψ).*

Proof Denote the net incentives to acquire information as

$$\Pi = dp_b[U(C_{np,2}^I) - U(C_{np,2}^U)] - \psi$$

Then

$$\frac{\partial \Pi}{\partial l} = d(1-p_b)U'(C_{np,2}^I) > 0$$

and

$$\frac{\partial \Pi}{\partial B} = dm p_b [U'(C_{np,2}^I) - U'(C_{np,2}^U)] - dm(1-p_b)U'(C_{np,2}^I) < 0.$$

There are two reasons why the incentives to acquire information decrease with B . The first argument shows that, fixing the use of collateral (that is, fixing $l - Y_2 - Bm$), the lender is “relatively richer” and has fewer incentives to explore such collateral. The second argument shows that, fixing the size of the loan (i.e., fixing l), the use of private collateral declines and as such so do the incentives to explore it.

$$\frac{\partial \Pi}{\partial d} = p_b[U(C_{np,2}^I) - U(C_{np,2}^U)] > 0$$

$$\frac{\partial \Pi}{\partial \psi} = -1 < 0$$

Finally,

$$\frac{\partial \Pi}{\partial p_b} = d[U(C_{np,2}^I) - U(C_{np,2}^U)] - \frac{d}{p_b}U'(C_{np,2}^I)(l - Y_2 - B) < 0$$

The sign is trivial when agents are risk-neutral. For more general utility functions, define $C^+ \equiv \frac{(1-p_b)}{p_b}(l - Y_2 - B)$ the difference in consumption (this is, $C_{np,2}^I - C_{np,2}^U$), and divide by C^+ ,

$$\frac{\frac{\partial\Pi}{\partial p_b}}{C^+} = d \frac{[U(C_{np,2}^U + C^+) - U(C_{np,2}^U)]}{C^+} - \frac{d}{p_b} \frac{U'(C_{np,2}^U + C^+)}{C^+} (l - Y_2 - B).$$

Taking the limit as C^+ goes to 0,

$$\lim_{C^+ \rightarrow 0} \frac{\frac{\partial\Pi}{\partial p_b}}{C^+} = dU'(C_{np,2}^U) - \frac{d}{1-p_b}U'(C_{np,2}^U) = -\frac{dp_b}{1-p_b}U'(C_{np,2}^U) < 0.$$

Q.E.D.

This proposition shows that a heavy use of bonds to sustain a given loan size discourages lenders from acquiring information about private collateral. To see this, notice that the incentives to acquire information increase in dp_b and $\frac{(1-p_b)}{p_b}(l - Y_2 - Bm)$. It also shows that in case that the government does not implement the first best by supplying excessive bonds, $m < 1$ and an increase in taxation distortions (this is, and increase in χ) also increases fragility.

Even though it is clear that a higher default probability, d , increases the incentives to acquire information, the effect of p_b is a bit more intricate. While an increase in p_b increases the likelihood of finding private collateral of good quality, it reduces the value of doing it. The second effect always dominates, at least locally for general utility functions.

4 Dynamics in OLG and the Bond Exchange Facility

Above we used a two-period model to highlight the importance of keeping track of convenience yields to design policies that involve the supply of government bonds. This is particularly relevant when agents can privately create imperfect private substitutes that are fragile in that information about their heterogeneous quality may be suddenly generated. Having fewer bonds increases the reliance on private assets and induces inefficient information production about their quality.

Here we propose an overlapping-generation (OLG) extension to follow the dynamics of private asset creation in response to government bond changes. We highlight two

messages. First, the optimal policy in steady state may require combining conventional and unconventional (BEF) policies. Second, a transitory decline in government bonds (that may be driven by external demands, or by other federal government considerations) may have long-term consequences in terms of financial fragility, which again can be corrected by resorting to the use of a BEF.

4.1 Environment

Each generation lives for two periods. In each calendar period $t \in \{0, 1, \dots\}$ there coexists a young generation and an old one. An agent is born young at date t with endowment Y_1 units of numeraire. At the beginning of the period she invests in private assets, which now we denote as a flow z_t that adds to the stock Z_t . Then the agent buys a one-period maturity bond, B_t . At the end of its youth the agent randomly matches with an old individual, who sells their private asset at its perceived fundamental value $p\kappa_G(1 - \delta)Z_t$, where δ is the depreciation rate of private assets, independent of their quality, and p is the probability that such particular asset is good. The buyer's previous investment, z_t , inherits the quality of the asset purchased.⁵

To fix ideas about the investment quality, consider the following example. At the beginning of their youth, agents invest in infrastructure z_t and at the end of their youth they buy a depreciated building of size $(1 - \delta)Z_t$ that is located on a specific acre of land. The total size of the building will then be $Z_{t+1} = (1 - \delta)Z_t + z_t$. The acre where the building is located can be of good quality (in the sense that it boosts the value of the building by κ_G) or bad quality (the land is in such a bad location that the value of the whole building on that acre is 0). In this sense the investment of an agent inherits the quality of the asset he buys.

During the transition from period t to $t + 1$, a fraction $1 - \lambda$ of land (the foundations of the building in the previous example) experiences an idiosyncratic shock that resets the quality, which can be good with probability \bar{p} . This implies that there is depreciation of information about the quality of an asset at a rate $1 - \lambda$ (in case information is not replenished in the economy). Note that the actual amounts of good and bad quality assets do not change.

⁵The particular timing in which young households first invest and buy bonds and then buy assets imply that investments and portfolios are not conditional on the quality of traded assets. Reversing the timing (first buying the assets and then investing and buying bonds) would just introduce additional sources of heterogeneity across agents but would not affect aggregate results and dynamics.

This process generates three possible beliefs about the quality of private assets, $p = 0$ (the asset is known to be bad), $p = 1$ (the asset is known to be good) and $p = \bar{p}$ (the asset is of unknown quality). We denote a *crisis* to be a situation in which a large fraction of assets of unknown quality are investigated (and their quality discovered) before credit is negotiated. More generally, the possible beliefs about purchased assets are $k \in \{0, \bar{p}, 1\}$, which can transition to $j \in \{0, \bar{p}, 1\}$ when traded, according to the process of idiosyncratic shocks between periods and information acquisition in credit markets.

When the agent gets old, he receives an endowment of Y_2 and draws a productivity (whether he has an investment opportunity or not). Each productive old agent borrows funds from an unproductive old agent using his bonds and private assets as collateral. When used to obtain credit the value of the private asset is $\hat{Z}_{t+1} = p\kappa_G Z_{t+1}$, where $Z_{t+1} = (1 - \delta)Z_t + z_t$ and p is either \bar{p} if quality is unknown, 0 if known to be bad or 1 if known to be good.

At the end of the period, project outcomes are realized, loan contracts are fulfilled, and the old agents redeem their bonds and sell their private asset at the price determined by information (or lack thereof) about the private asset during the credit stage. Furthermore, we allow all agents to obtain an additional endowment for consumption at the end of the period, X . As will become clear, without this extra consumption, and given that the project can fail, no productive agent would borrow up to the constraint for fear of defaulting and consuming 0. In other words, the Inada conditions would prevent collateral constraints from binding. We will go on to assume that X is large enough such that the borrowers would like to use all his available assets at the beginning of the period as collateral.

In this extended setting, the government can access resources from future generations. Since we assume one-period bonds, if at the calendar period $t - 1$ the government promises a generation B_{t-1} when old and sells those bonds at a price $P_{t-1} < 1$, the extra resources are obtained from the next generation, which then will have a lower endowment when young of $Y_1 - (1 - P_{t-1})B_{t-1}$.

We define as the welfare criterion consumption smoothing over the lifetime of each generation and not across generations. Also, as we have discussed, acquisition of information about private assets introduces additional sources of risk and then welfare is maximized when there is no information.

4.2 Characterization

The problem of an individual born in calendar period t depends on the stock of capital accumulated in the economy up to t . In contrast to previous cases, here in case of being productive, the agent suffers the additional risk of project failure. We denote $A_s \in \{A, 0\}$ with $s \in \{\text{success}, \text{failure}\}$ and $\Pr(\text{failure}) = d$.

$$\max_{C_{k,1t}, C_{ijs,2t+1}, l_{j,t+1}, B_t, z_t} \sum_k q_k U(C_{k,1t}) + \beta \sum_{i,j,s} q_i q_j q_s U(C_{ijs,2t+1})$$

subject to

$$\begin{aligned} C_{k,1t} + z_t^\gamma + P_t B_t + p_k \kappa_G (1 - \delta) Z_t &\leq Y_1 - (1 - P_{t-1}) B_{t-1} \\ C_{ijs,2t+1} &\leq Y_2 + B_t + \widehat{Z}_{j,t+1} + \widehat{Y}_{ijs,2t+1} + X \\ \widehat{Z}_{j,t+1} &= p_j \kappa_G [(1 - \delta) Z_t + z_t] \\ \widehat{Y}_{ijs,2t+1} &= [A_s l_{j,t+1}^\alpha - l_{j,t+1}] \\ l_{j,t+1} &\leq Y_2 + B_t + \phi \widehat{Z}_{j,t+1}. \end{aligned}$$

First order conditions are

$$\begin{aligned} \{C_{k,1t}\} &: q_k U'(C_{k,1t}) = \lambda_{k,t} \\ \{C_{ijs,2t+1}\} &: \beta q_i q_j q_s U'(C_{ijs,2t+1}) = \lambda_{ijs,2t+1} \\ \{l_{j,t+1}\} &: \sum_s \lambda_{ijs,2t+1} (\alpha A_s l_{j,t+1}^{\alpha-1} - 1) = \mu_{j,t+1} \\ \{B_t\} &: P_t \sum_k \lambda_{k,t} - \sum_{i,j,s} \lambda_{ijs,2t+1} = \sum_j \mu_{j,t+1} \\ \{z_t\} &: \gamma z_t^{\gamma-1} \sum_k \lambda_{k,t} - \sum_{i,j,s} p_j \kappa_G \lambda_{ijs,2t+1} = \sum_j \phi p_j \kappa_G \cdot \mu_{j,t+1} \end{aligned}$$

Notice that, beyond the explicit reference to the calendar period, the first-order conditions are the same as those that characterize the solution in the two-period model with heterogeneous private collateral and probability of default. As we discussed, we assume throughout that collateral constraints bind, or $\mu_{j,t+1} > 0$, which implies that

$$(1 - d) U'(C_{pj,2t+1}^{\text{success}}) R_{j,t+1} > d U'(C_{pj,2t+1}^{\text{failure}})$$

which is just a technical condition on the size of X (should be large enough).

The demand for bonds is characterized by,

$$P_t \mathbb{E}_{k,t}(U'(C_{k,1t})) = \beta \mathbb{E}_{ijs,t+1}(U'(C_{ijs,2t+1})) + \beta q_p \mathbb{E}_{js,t+1}[U'(C_{pjs,2t+1})R_{js,t+1}], \quad (16)$$

where $R_{js,t+1} = \alpha A_s l_{j,t+1}^{\alpha-1} - 1$ is the realized return of the project.

The creation of private assets is characterized by,

$$\gamma z_t^{\gamma-1} \mathbb{E}_{k,t}(U'(C_{k,1t})) = \beta \mathbb{E}_{ijs,t+1}(p_j \kappa_G U'(C_{ijs,2t+1})) + \beta q_p \phi \mathbb{E}_{js,t+1}[p_j \kappa_G U'(C_{pjs,2t+1})R_{js,t+1}]. \quad (17)$$

The main difference between the two-period setting and this overlapping generation structure is given by the links across periods. There are three links. The first is given by the law of motion of the *volume of private assets* in the economy. This link, of course, would be eliminated by assuming $\delta = 1$ (all private assets have to be created every period). The second link is given by the evolution of the *belief distribution about private assets quality*, which is driven both by information acquisition in credit markets and by the process of idiosyncratic shocks. This link would be eliminated by assuming $\lambda = 0$ (this is all private assets are good with probability \bar{p} every period).⁶ The third link is the one imposed by the government budget constraint and depends on the government's bond policy. This link would be eliminated if $P_t = 1$ in all t , which is indeed the case under the implementation of the optimum, as we explain next.

In what follows we characterize the steady state of this economy. Then we discuss the effect of policy shocks and departures on financial stability.

4.3 Steady State

Assume a constant provision of bonds, B_{SS} . In steady state we can eliminate the calendar period notation. From bonds condition (16),

$$P \mathbb{E}_k(U'(C_{k,1})) = \beta \mathbb{E}_{ijs}(U'(C_{ijs,2})) + \beta q_p \mathbb{E}_{js}[U'(C_{pjs,2})R_{js}],$$

⁶Another, minor, difference between this setting and the two-period one is that agents buy some private assets. Since the matching seller is of random quality, consumption in the first period is also stochastic.

and from investment condition (17),

$$\gamma z^{\gamma-1} \mathbb{E}_k(U'(Ck, 1)) = \beta \mathbb{E}_{ijs}(p_j \kappa_G U'(C_{ijs,2})) + \beta q_p \phi \mathbb{E}_{js}[p_j \kappa_G U'(C_{pjs,2}) R_{js}].$$

In steady state the volume of private assets should be constant, this is

$$(1 - \delta)Z + z = Z \quad \Rightarrow \quad z = \delta Z$$

and the distribution of the quality of private assets is also constant. With regard to a steady state, there are two possibilities. The first possibility is that, in steady state, there is no information acquisition about collateral of uncertain quality \bar{p} . Then

$$k = j = \bar{p} \quad \text{with prob. 1.}$$

This *information-insensitive steady state* is the same as the two-period model with known quality (as $\bar{p}\kappa_G = 1$), as characterized by equations (10) and (11).

The second possibility is that, in steady state, there is information acquisition about collateral of uncertain quality \bar{p} . Then

$$k = j = \begin{cases} 1 & \text{with prob. } \bar{p} \\ 0 & \text{with prob. } 1 - \bar{p}. \end{cases}$$

This *information-sensitive steady state* displays idiosyncratic risk, which reduces the value of both bonds and private assets.

Whether the steady state is information-sensitive or information-insensitive depends on whether condition (15) fails or not, for an asset of perceived quality \bar{p} . From Proposition 1, the information-insensitive steady state is more likely when there are more bonds in the economy, both because lenders are wealthier in the second period (there is less utility value of information) and because borrowers rely less on private collateral (there is less at stake from acquiring information). Similarly, such a steady state is more likely the better is collateral on average (high \bar{p}), the more likely the project succeeds (low d) and the higher is the examination cost of private assets (high ψ).

4.4 Conventional Policy and the Bond Exchange Facility

From an ex-ante perspective, a planner's optimal implementation would require implementation of $P = 1$. In this case, we have assumed away the distortionary effect of taxes, which is endogenous. When $P < 1$, there is a reduction of endowment for all generations in the first period, which increases $\mathbb{E}_k(U'(C_{k,1}))$ and lowers bonds available in the economy to be used as collateral. The distortionary tax then enters endogenously by the use of bonds as collateral, breaking the Ricardian Equivalence.

Also from an ex-ante perspective, the planner wants to supply enough bonds to limit the use of private assets as collateral and to relax information acquisition pressures. These two goals, however, may not be implementable jointly: the government should supply enough bonds for markets to clear at $P = 1$, while at the same time not inducing production and use of private assets to trigger information acquisition.

More specifically, when the government only has access to *conventional policy* of providing bonds in exchange for numeraire, achieving both goals imply that B_S^* is such that

$$U'(C_1) = \beta\mathbb{E}_i(U'(C_2)) + \beta q_p \mathbb{E}_s[U'(C_{ps,2})R_s] \quad (18)$$

and

$$d\bar{p}[U(C_{np,2}^I) - U(C_{np,2}^U)] \leq \psi \quad (19)$$

when consumption is evaluated at $P = 1$.

As we discussed, the second condition is guaranteed when B_S is large enough. A large supply of bonds, however, may drive P below 1. If the government reduces the supply of bonds to avoid triggering information acquisition (inequality (19) becomes an equality) and still there is an excess supply (this is equation (18) only holds when $P < 1$), the conditions become inconsistent and the government is not able to both implement optimal consumption smoothing and discourage information acquisition.

The main reason for this result is that bonds are supplied in exchange for numeraire in the first period (open market operations), so providing more bonds as collateral relaxes pressures for information production at the cost of reducing numeraire to consume in the first period (as $C_1 = Y_1 - PB - z^\gamma - (1 - \delta)Z$). A possibility to achieve both goals is to use a *Bond Exchange Facility*, offering agents the opportunity to borrow a government bond in exchange for private assets. In this case the government

can both provide bonds to sustain no information acquisition in the second period, without reducing consumption in the first period.

Proposition 2 *When the quality of private collateral is good enough, conventional policy is enough to implement the constrained optimum. When the quality of private collateral declines, the government may need to resort to using BEF (unconventional policy) to fulfill both financial stability and consumption smoothing goals.*

4.5 Shocks to the supply or demand of bonds

Assume the economy is in a steady state such that $P = 1$ and there is no information acquisition in credit markets. In this section we analyze how the economy fares when, at period t , B_{SS} temporarily declines to \widehat{B} (for instance because the central bank reduces interest rates in response to a recession or because there are foreign shocks that increase the foreign demand for bonds, making them scarcer domestically).

On impact, this transitory negative shock to the supply of bonds implies that $P_t > 1$ on impact, and that the consumption of the young compared to steady state increases (this is $C_{1t} > C_1$).⁷ As the production of private assets took place in period t by the time the shock to the supply of bonds happens, there is a reduction in the wealth available to the old in $t + 1$ (less available bonds to consume in $t + 1$). This implies that, not only are there fewer assets to sustain credit in the next period (a *credit crunch* because there are fewer bonds available), but there is also an increase in the incentives to acquire information about private collateral, potentially inducing a *crisis*. Recall that information is not acquired as long as

$$d\bar{p}[U(C_{np,2}^I) - U(C_{np,2}^U)] \leq \psi$$

where

$$\begin{aligned} C_{np,2}^U &= Y_2 + \widehat{B} + Z_{SS} \\ C_{np,2}^I &= Y_2 + \widehat{B} + Z_{SS} + \frac{(1 - \bar{p})}{\bar{p}} Z_{SS} \end{aligned}$$

⁷For simplicity we maintain the assumption that the extra resources the government obtains from $P > 1$ are thrown to the ocean and then do not affect future generations' consumption.

This inequality is less likely to hold in steady state, as $t + 1$ lenders are relatively poorer and the potential gains of investigating private collateral are larger in terms of marginal utility.

To see this, assume log utility:

$$\frac{\partial[U^I - U^U]}{\partial B} = \frac{1}{Y_2 + B + Z/p} - \frac{1}{Y_2 + B + Z} < 0$$

This is a pure wealth effect. Lenders are more afraid of providing loans.

In period $t + 1$, if the scarcity of bonds continues, young agents react by producing more private assets than in steady state. This is because the scarcity of bonds distorts consumption smoothing, increasing youth consumption and reducing old wealth and consumption. This induces the young at $t + 1$ to move consumption from young to old by producing private assets. Then $Z_{t+1} > Z_{SS}$, and then $l_{t+2} > l_{t+1}$.

The higher supply of private assets has the double effect of increasing credit and the wealth of lenders in period $t + 2$, compared to period $t + 1$. With log preferences

$$\frac{\partial[U^I - U^U]}{\partial Z} = \frac{1}{p(Y_2 + B + Z/p)} - \frac{1}{Y_2 + B + Z} > 0$$

Even though at $t + 2$ lenders are wealthier than in $t + 1$, and then less interested in acquiring information about private collateral, there is also more use of private assets as collateral. The second effect dominates. Hence, when bonds at t and $t + 1$ are scarce, fragility is larger on impact (at $t + 1$), but even larger subsequently (at $t + 2$). If the new, lower, level of government bonds is permanent, the economy moves to a new steady state with fewer bonds, more private assets and more fragility. Whether the new steady state is information-sensitive or insensitive depends on parameters and the extent of bond supply scarcity.

If, at a later period T , bonds suddenly return to the original steady state level (the source of the shock disappears, for instance), the economy takes time to return to the original level of fragility. The reason is that the economy has accumulated a relatively large volume of private assets, which takes time to depreciate. This implies that a transitory shock to the supply of bond can have long lasting consequences in terms of fragility through the accumulation of private collateral.

In this instance, the use of BEF, by taking private assets “out of circulation” and re-

placing them with bonds as collateral, also has the important role of speeding up the transition of the economy to a less fragile environment once the transitory shock has concluded. The optimal design of a BEF is discussed in Gorton and Ordonez (2020).

5 Conclusion

Economic agents demand safe assets to smooth consumption across periods and to use as collateral, which smooths lenders' consumption across states in a given period. The main difference between public and private safe assets is that the latter come in heterogeneous quality. Here we show that information about individual assets' quality may reduce their safety and make them less useful for smoothing consumption across states. When information acquisition is a choice, there are conditions (notably the volume of public safe assets) under which such information is not produced and private assets are indeed safe assets. Those conditions, however, may change if a large volume of private assets' qualities gets examined, *a crisis*.

We have explored the optimal supply of public safe assets needed to accommodate the demand when considering their effects on the creation of private assets and on information production about these assets. The government should strive to maintain intertemporal consumption smoothing and provide enough collateral to avoid too much private asset creation and, possibly, information production about those private assets.

Monetary policy and macroprudential policy, however, cannot be conducted in isolation. Open market operations exchange cash (numeraire) for government bonds. Monetary policy may require taking government bonds out of the economy (to reduce interest rates, for instance). But if this policy generates a scarcity of government bonds as collateral, the private sector reacts by creating more private safe assets. Private safe asset creation, however, increases the fragility of the financial system (the likelihood of a financial crisis). The goals of facilitating consumption smoothing while minimizing the likelihood of a financial crisis are two goals that may be mutually exclusive when the average quality of private assets is low. In this circumstance the government should also rely on the use of a Bond Exchange Facility that contemporaneously exchanges private assets for government bonds (in a repo-type operation).

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