A Model of Shadow Banking: Crises, Central Banks and Regulation*

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ABSTRACT

We build a two-period model *à la* Holmström and Tirole (1998) in which bankers have access to a shadow banking technology which allows to liquefy partially illiquid investment projects (e.g. mortgages) and to manufacture shadow collateral (e.g. MBS). We study the bankers' security design of shadow collateral. By seeking *simple shadow banking*, bankers design shadow collateral which is liquid in all states of nature; in this case, the technology also provides liquidity insurance against aggregate shocks (crisis). Conversely, with *complex shadow banking*, shadow collateral is designed to be extremely liquid in states without aggregate shocks, thereby boosting bankers' leverage, but illiquid in a crisis. We frame this leverage-insurance choice into the modern financial ecosystem bankers inhabit, characterized by *two structural developments*. First, the rise of institutional cash pools which manage large cash balances. Their demand for parking space is accommodated by sovereign bonds and shadow collateral. Second, the proliferation of balance sheets with asset-liability mismatches (ALMs), like those of insurance companies and pension funds; these entities have liabilities in fixed nominal amount and, in a low yield environment, seek to allocate funds to bankers which deliver leverage-enhanced returns. We show that when the demand for parking space from cash pools - as compared to the supply of sovereign bonds - and the demand for returns from entities with ALMs are high, complex shadow banking is the competitive equilibrium outcome and the economy is prone to massive deleveraging in the case of aggregate shocks. The paper has several implications in terms of central banks' policy (e.g. Reverse Repo Programs), regulation (capital and liquidity) and, more generally, policies aimed at tackling the two structural developments.

JEL classification: G01, G23, G28.

Keywords: Shadow banking; Financial crisis; Leverage; Liquidity.

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‡Credit Suisse and INET Shadow Banking Colloquium.

I. Introduction

Shadow banking - or market-based credit intermediation - is officially defined as "credit intermediation involving entities and activities outside of the regular banking system". According to the Financial Stability Board (FSB), shadow banking accounts for a large and increasing fraction of global intermediation worldwide. During the last decades the growth of shadow banking was facilitated by financial innovation, like securitization and repo finance (Gorton and Metrick, 2012); these techniques essentially permit the "liquification" of historically illiquid assets - such as loans to non financial firms and households - and the manufacturing of private-label marketable securities (e.g. asset-backed securities) which serve as *shadow collateral* to raise funding in wholesale money markets. These private-label securities proliferated in the balance sheets of an assorted universe of *levered bond portfolio managers* (henceforth, shortly bankers) which include dealers, large banks and also less supervised/regulated entities across the asset management complex, like bond mutual funds, hedge funds and separate accounts. Shadow banking intermediation permits a relatively cheap money market funding of large portfolios of historically illiquid assets, can boost the credit to borrowers with limited direct access to banks' loans and capital markets, expand the supply of marketable securities available in financial markets and be beneficial to the entire economy. However, the experience of the 2007-2008 financial crisis casts doubts on the stability of this intermediation mechanism. At the onset of the crisis, shadow collateral suddenly lost investors' confidence, its market liquidity dropped sharply, haircuts spiked and the funding liquidity of firms with large levered portfolios of shadow collateral was severely impaired. Since then, the FSB put forward a global shadow banking reform agenda. Several regulatory changes have been proposed and introduced, changes which affect entities (e.g. C-NAV money market funds), markets (e.g. tri-party repo market) and instruments (e.g. derivatives and securities financing transactions). The Basel Committee and IOSCO, within a wider revision of the securitization framework, are investigating the possibility to single out fundamental properties of simple, transparent and comparable (STC) securitization structures. This proposal, also supported by the ECB and the Bank of England in its general spirit, would pave the way to the creation of transparent and liquid securitization markets. The broader attempt is to grasp all potential benefits of market-based credit intermediation, while minimizing risks with large social costs.

This paper proposes a simple model which incorporates the above-mentioned "liquification view" of the shadow banking into the canonical framework of Bengt Holmström and Jean Tirole (henceforth, HT): as standard, the only departure from Arrow-Debreu is the existence of a wedge between the full value of a bank's assets (real investment projects) and the amount which can be pledged to market investors to raise funding. Limited pledgeability caps the leverage of the bank and also limits bank's refinancing in the case of liquidity shocks: a leverage-insurance trade-off emerges. We build on this setup and endow bankers with a shadow banking technology which expands the pledgeability of investment projects. This is liquification, namely the manufacturing of shadow collateral from previously illiquid investment projects. The technology also exacerbates the leverage-insurance trade-off. More in detail, we assume bankers can use the shadow banking technology in different ways: on one extreme, bankers manufacture shadow collateral which preserves its liquidity/pledgeability in all states of nature. In this way, named *simple shadow banking* for the sake of expositional convenience, bankers can pledge shadow collateral and obtain refinancing in the presence of an aggregate liquidity shock (henceforth, crisis) which, in the model, arrives with a positive exogenous probability. Under simple shadow banking, the technology serves also as a liquidity insurance mechanism. On the other extreme, *complex shadow banking*, shadow collateral is designed to be extremely liquid/pledgeable in normal times (i.e. no aggregate shock), but becomes illiquid in a crisis. In this way, bankers boosts the initial leverage to its limit but are forced to deleverage in a crisis, as their funding liquidity is impaired by the illiquidity of shadow collateral. As a result, under complex shadow banking, the technology is a pure leverage-enhancing mechanism. This modeling device gives a simple description of some relevant trade-offs associated to shadow banking, its benefits and potential risks. Complex shadow banking guarantees higher output in normal times but massive deleveraging in the case of aggregate shocks; this case is meant to capture the recent experience with the 2007-2008 crisis. Conversely, simple shadow banking delivers a relatively lower output, but no or little deleveraging in a crisis; this case is coherent with the idea that shadow banking can be a stable market-based credit intermediation mechanism.

We study the incentives of bankers in the security design of shadow collateral, i.e. their choice between simple versus complex shadow banking. We show that the choice is not orthogonal to the financial ecosystem bankers inhabit. In particular, it is crucially affected by two structural developments of the global economy.

- First, on the one side of the spectrum, the rise of *institutional cash pools*, market investors which are the main providers of funding raised by bankers to finance their levered bond portfolios. Cash pools manage very large balances and look for stores of value (*parking space*). Relevantly, within the current institutional setting, cash pools do not access central bank reserve accounts and their balances are far too large to be eligible for bank's deposit insurance.[1] Available options are limited to (i) *public parking space*, in the form of short-term sovereign bonds and repos issued by dealers and backed by longer-term sovereign bonds and (ii) *private parking space*, mainly repos issued by dealers and backed by shadow collateral.[2] In the model, the price of sovereign bonds and the cost of funding for banks are jointly determined in the market of parking space by the demand of cash pools and its supply, which comes from the government (exogenous) and the bankers (endogenous).
- Second, on the opposite side of the spectrum, the proliferation of balance sheets with *asset-liability mismatches* (ALMs), like those of pension funds and insurance companies: these entities have liabilities in fixed nominal amount and, in a low yield environment, their portfolios traditionally dominated by sovereign bonds do not generate adequate returns to meet future obligations. For this reason, they reach for yield

[1] Differently from small retail savers like households, it would be physically impossible for institutional cash pools to handle billions in cash in the form of currency.

[2] Private parking space is "purely private money" or "private-private money" in the terminology of Pozsar (2014). More in detail, it refers to the lower-right corner of the Money Matrix of Figure 1 of Pozsar's paper and represents money claims which are backed by private assets and are not supported by public liquidity and credit puts explicitly.

and seek to allocate funds to bankers, which generate and deliver leverage-enhanced returns.

The main result of the model is that when the demand for parking space from cash pools and the one for leveraged-enhanced returns from entities with ALMs are high, complex shadow banking is the competitive equilibrium outcome. The intuition is the following: the higher the demand for parking space (as compared to the supply of public parking space), the lower the cost of funding for bankers. A low cost of leverage makes high-leverage-low-insurance strategies, i.e. complex shadow banking, relatively more attractive. In addition, a large demand for parking space also depresses sovereign bonds' yields, thereby widening asset-liabilities mismatches of entities with liabilities in fixed nominal amount. The latter, as a response, reduce sovereign bond holdings and increase allocations to bankers, in the search for leverage-enhanced returns. In particular, when also the fundamental (i.e. unlevered) return on investment projects is relatively low, any combination of sovereign bonds and allocation to simple shadow banking is unable, in a crisis, to bridge the asset-liability mismatch. Under these conditions, complex shadow banking is optimal as, in no crises states, it guarantees (i) the largest private parking space to cash pools and (ii) the highest leverage-enhanced returns for entities with ALMs.

The model has policy implications which may be also relevant within the ongoing debate on the operational framework of central banks in a market-based credit intermediation system (Section IV.A). Central banks have an active role in the market for parking space, for several reasons. First, they may hold large amounts of sovereign bonds and other collateral assets in pursuing their monetary policy targets. Second, central banks decide the set of counterparties - banks and non-banks - which have access to their liquidity facilities. By changing the supply of public parking space to non-bank financial firms (e.g. cash pools), central banks can affect funding conditions in the market-based credit intermediation system. In particular, central banks can expand the supply of public parking space beyond the amount of sovereign bonds that are freely available in the market through reverse repo programs (RRPs).[3] In the model, RRPs drive up the cost of leverage for bankers and make complex shadow banking relatively less attractive. These policy measures are particularly effective in curbing systemic risk-taking when (i) a relevant fraction of the demand for parking space comes from large (non-bank) institutions, (ii) a high amount of sovereign bonds are siloed into the central bank's balance sheet, as in the aftermath of large scale asset purchases and (iii) there is ample demand for returns from entities with ALMs.

Finally, the model can be used to analyze the capital and liquidity regulation in a market-based intermediation system (Section IV.B). We consider a regulatory authority with a financial stability mandate declined as the minimization of aggregate deleveraging in a crisis. Under capital regulation, the authority sets a cap on banks' leverage and can induce bankers to seek simple shadow banking. Under liquidity regulation, similarly to the Basel III Liquid-

[3]In a reverse repo program the central bank lends out its sovereign bonds and other safe assets holdings in exchange for cash. A wide set of counterparties can be eligible to the facility, as in the case of the Fed Reverse Repo Program which is in place since January 2014.

ity Coverage Ratio, banks are required to hold a minimum amount of sovereign bonds.[4] The liquidity requirement safeguards financial stability (no deleveraging in a crisis) as sovereign bonds can be used by bankers to raise funding and cover the aggregate shock. However, it also jeopardizes incentives (if any) for bankers to seek simple shadow banking: when liquidity insurance is provided by (the regulatory minimum amount of) sovereign bonds, bankers simply maximize utility by boosting leverage to its limit (i.e. adopting complex shadow banking). Trivially, liquidity regulation also creates an additional demand for sovereign bonds, which drives up (down) their liquidity premium (yield) and, as a result, depresses the cost of leverage for banks.

Relationship with the literature. Our contribution is partially related to the literature on financial intermediaries as producers of money-like claims (Diamond and Dybvig, 1983; Gorton and Pennacchi, 1990). In particular, we share the general approach to the demand for/supply of inside (i.e. produced within the private sector) versus outside (i.e. public, sovereign bonds) liquidity comprehensively described in Holmström and Tirole (2011), and adapt it to the modern financial ecosystem. Similarly to HT, inside liquidity and sovereign bonds have different risk-return profiles. Sovereign bonds are liquid in all states of nature and represent a "safe" storage option for market investors. Conversely, under risk neutrality, in line with HT optimal state-contingent contracting between bankers and market investors (i.e. cash pools) implies that the latter are not repaid in the case of aggregate shocks, regardless the leverage-insurance choice of the bankers. This feature of the HT optimal contract makes private parking space an imperfect substitute for sovereign bonds in the event of a crisis. One novelty of our model with respect to HT is that bankers are endowed with a shadow banking technology which gives them additional room for their desired leverage/insurance mix. The choice affects the ability of bankers to find refinancing at the interim stage in the case of aggregate shocks and is intertwined with the conditions in the market for parking space. Under complex shadow banking, there is plenty of liquidity in normal times and massive deleveraging in a crisis, coherently with the observed turmoil after the subprime crisis. In Gorton and Metrick (2010), Gorton and Metrick (2012) and Krishnamurthy and Vissing-Jorgensen (2012), shadow banking is approached as a way to supply money-like claims and the whole intermediation process - with its weakness and vulnerabilities - is described. The focus of our paper is on the effects of aggregate shocks on the ability of the shadow banking to expand the inside liquidity, manufacturing shadow collateral: while the latter is money-like and joins the safe assets club in normal times, aggregate shocks can disrupt its liquidity properties. Pozsar (2014) provides a comprehensive picture of what money and money-like claims are to different economic agents, including cash pools. Sunderam (2014) analyses the extent to which shadow banking liabilities constitute substitutes for high-powered money and finds that shadow banking liabilities respond to money demand. This finding is coherent with our view of shadow collateral as an elastic private-sector alternative to public parking space. Moreira and Savov (2014) have a macro model in which intermediaries maximize liquidity creation by issuing securities that are money-like in normal times but become illiquid in a crash when collateral is scarce. This modeling device, similar to the one proposed by Di Iasio and Pierobon (2013), is coherent with our complex shadow banking case. In Gennaioli,

[4] In the model, sovereign bonds are the only asset which is liquid in all states of nature for certain (see below).

Shleifer, and Vishny (2013), shadow banks pool their idiosyncratic risks, thereby increasing their systematic exposure, and use the safe part of these recombined portfolios to back the issuance of safe debt. This is conducive to financial instability when agents underestimate the tail of systematic risk. Similarly, one interpretation of our shadow banking technology are risk-management techniques which permit the liquification of partially illiquid assets through diversification of idiosyncratic risks. We consider the polar case of aggregate shocks but, differently from Gennaioli et al. (2013), exposures to systemic risk (i.e. complex shadow banking) can be fully rational. The relevance of information-insensitive private collateral in the form of debt securities is the building block in Dang, Gorton, and Holmström (2010). Debt preserves the symmetric ignorance between counterparties and minimize the value of producing or learning public information about the payoff. Similarly to our model, a public signal (or a liquidity shock, as in our case) can cause debt to become information-sensitive. Gorton and Ordonez (2012) analyze the disruptive effects of a "collateral check" in a highly leveraged environment in which a large fraction of contracts are backed by private money-like instruments. In section III.A we provide some real-world interpretations of the complex versus simple shadow banking, and the way our modeling device speaks to other contributions in the literature.

Section II provides a more detailed descriptions of macro developments in the global economic and financial system which drove the rise of cash pools and asset-liability mismatches. It also highlights essential features of the shadow banking intermediation mechanism and the role of different key players. Section III.A presents the baseline economy with bankers and characterizes their choice in terms of leverage and liquidity insurance (simple versus complex shadow banking). Then we formally introduce market investors (cash pools) and also sovereign bonds, as a public parking space alternative. Section III.B presents the competitive equilibrium in which, given the exogenous supply of sovereign bonds, market investors allocate their endowment between sovereign bonds and bankers. The latter seek their leverage/insurance profile, which affects and depends on the conditions in the market for parking space. Section III.C augments the framework with entities with ALMs which may seek allocations to bankers in their search for leverage-enhanced returns. Section IV describes the role that central banks and regulatory authorities may have to enhance financial stability in a market-based intermediation system. Section V concludes and frames the results of the paper within a broader policy reform agenda.

II. Shadow banking and the financial ecosystem

The financial ecosystem has undergone some fundamental transformations in the last decades, mainly reflecting structural economic developments on the global scale. The growth of shadow banking, its past, current and future manifestations, are all intertwined with these transformations and developments.

The first transformation comes from the funding side: wholesale funding is just as important a source of funding as retail funding. The instrumentality and stability of these two sources of funding differ. Retail funding is dominated by deposits, which tend to be small and ultimately guaranteed by official sector insurance schemes. Wholesale funding is dominated by repos, which are uninsured. Furthermore, retail funding is provided by households and wholesale funding is provided by institutions – or more precisely non-bank institutional cash investors, or institutional cash pools (Pozsar, 2013; Claessens, Pozsar, Ratnovski, and Singh, 2012). Examples of institutional cash pools are the cash balances of multinational corporations, the central liquidity desks of large asset managers and the liquidity tranche of real money accounts like FX reserve managers. At end-2014 they managed cash balances exceeding US$ 6 trillion (Figure 1).

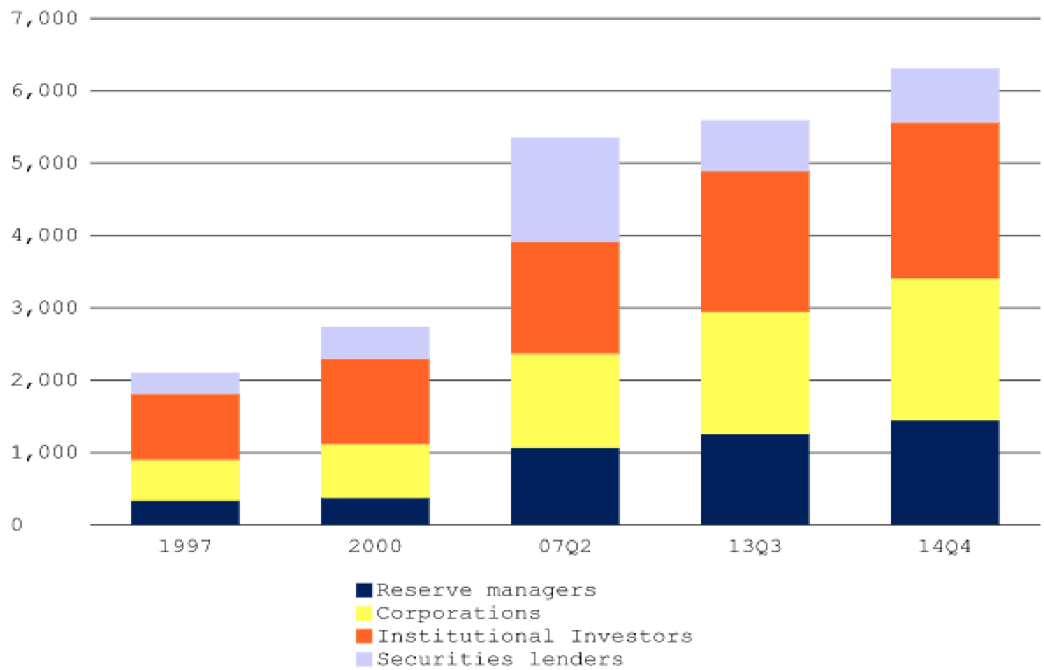

Figure 1. Cash balances of institutional cash pools, US$ billions.

Size matters: cash pools are stuck between a rock and a hard place when it comes to investing their balances – funds earmarked for short-term investments. This is because bank deposits are insured only up to a limited amount (at present $250,000 in the U.S.), which is far below the billions cash pools seek to invest.[5] After a point, cash pools exhibit inelastic demand for uninsured bank deposits. Other alternatives include facing the sovereign which supplies public parking space in two ways. First, in the Treasury bill market: T-bills are guaranteed, represent no credit and duration risk and are an ideal option for cash pools' balances; however T-bills come with an insufficient and inelastic supply. The second public parking space option are repos backed by Treasury bonds collateral, issued by the government-desk of dealers; although representing contracts with a private counterparty, they provide cash pools with a good proximity to the sovereign. Both the latter alternatives are constrained

[5]Were these billions parked at banks as uninsured deposits, cash pools would assume large credit risk exposures towards depository institutions. While this is reasonable to do up to a limit, no manager of a cash pool, or the chief risk officer it reports to, would sign off on large volumes of unsecured credit risk exposure to a bank.

by sovereign bonds' availability and often come at very unfavorable yield conditions. As a middle ground, shadow banking offers a private-sector elastic alternative to cash pools. A large demand for parking space from cash pools fosters the issuance of additional credit to the economy; these credit claims are liquified and support the manufacturing of private-label securities used by dealers as (shadow) collateral to back repos issued by their credit-desks (right-hand side of Figure 2). From the cash pools' vantage point, repos backed by shadow collateral represent instruments not quite as safe as T-bills or repos backed by Treasuries, but a whole lot safer than banks' deposits, which are concentrated doses of unsecured credit risk exposures to individual banks. However, as the 2007-2008 crisis has largely demonstrated, shadow collateral may well protect cash pools from idiosyncratic shocks (e.g. the failure of a single counterparty) but could represent a very poor substitute for the safety granted by the sovereign in the case of aggregate shocks.[6]

While a detailed discussion of the precise types, attributes and causes of cash pools is beyond the scope of this paper, it is important to note that their emergence is a secular, not a cyclical *development* and is deeply rooted in macroeconomic themes that span globalization, income distribution and tax arbitrage (Pozsar, 2015). Relevantly, when savings accumulate in the hands of large investors – such as FX reserve managers and treasurers of multinational corporations – that have a sizable appetite for liquid assets, the provision of private parking space by the shadow banking system - as imperfect substitute for T-bills and insured bank deposits - may pose threats to financial stability. In this sense, concepts such as (i) imbalances in the distribution of income between nations (surplus versus deficit countries) and factors of production (labor versus capital), (ii) wholesale funding, (iii) demand for and supply of parking space are closely interlinked, and their mutual interaction has financial stability implications.

Figure 2. The stylized modern financial ecosystem.

The second transformation undergone by the modern financial ecosystem is on the lending side. Dealers use less than 20 per cent of their repo funding to finance their own securities inventories.[7] The rest is used to fund their matched book money dealing activity (Mehrling,

[6] A case in point is Lehman Brothers which got into trouble due to a large exposure to subprime mortgages in its inventory; the Reserve Primary Fund which got into trouble due to a large unsecured commercial paper exposure to Lehman; and AIG which got into trouble for guaranteeing the AAA nature of shadow collateral (subprime mortgages) and lending agency RMBS and reinvesting the cash proceeds in subprime RMBS to earn a spread - effectively doubling down on subprime.

[7] For a detailed discussion see Pozsar (2015).

Pozsar, Sweeney, and Neilson, 2013), which essentially refers to dealers intermediating between cash borrowers in the asset management complex and cash lenders, like institutional cash pools. It is a facilitation role dealers play, a high-volume-low-margin arbitrage business, where dealers mostly borrow and lend overnight often using the same collateral, i.e. re-hypothecating the securities pledged by borrowers to raise the funding they ultimately provide to borrowers.[8] This is the rise of securities financing transactions, the principal use of short-term wholesale funding. The users of wholesale funding and securities financing extended by dealers via matched books are levered bond portfolio managers. The composition of portfolio managers which use dealers' matched books went through major changes in recent decades, with hedge funds, mutual funds (such as total return funds) and index funds progressively taking the lead. Moreover, moving one step further, these funds no longer exclusively manage the private funds of wealthy individuals, but rather those (of households through the portfolios) of insurance companies and pension funds. The latter, disappointed by historically low yields on sovereign bonds and other safe assets, have been increasing their allocation to alternative investments delivered by hedge funds, institutional-class total and absolute return bond funds. The main explanation for this portfolio re-allocation can be traced back to the second structural macro *development*, namely the build-up of asset-liability mismatches (ALMs). Insurance companies and pension funds have a large fraction of liabilities (future obligations) expressed in fixed nominal amount; ALMs originate when realized market returns fall short of returns which were expected when obligations have been signed and promises made. For instance, insurance companies sell products offering guaranteed returns, such as fixed annuities. As regards pension funds, the gap between pension managers discount rates and (unlevered) yields that can be earned in bond markets has been widening relentlessly since about 2000, and is currently as wide as it has ever been. Hurt by the burst of the dot.com bubble, pension funds aimed to reduce their exposure to volatile stocks and searched for products that offered leveraged-enhanced returns. In general, entities with ALMs[9] were stuck between the high yields offered by stocks, at the cost of high volatility, and the low yields offered by bonds, with the benefit of low volatility. Leveraged fixed income strategies aim to bridge these two worlds and essentially employ investment techniques like funding, short-selling and derivatives which all absorb cash and ideally deliver excess (leverage-enhanced) returns, thereby accommodating the reach for yield of end-investors like entities with ALMs (left-hand side of Figure 2).

Reach for yield is omnipresent when financial firms are hardwired to beat their benchmarks and intensifies when actual yields drift farther and farther away from the return targets of end-investors with fixed liabilities. This drift may have secular and cyclical reasons behind it. One key driver behind structural reach for yield has been accumulating pension promises and ever lower yields on safe, long-term assets – both due in large part to the same demographic reason, namely aging. As described above, ALMs may represent risks to financial stability as they generate a fundamental demand for levered investments, especially in the

[8] In the process dealers collect a spread based on the their credit risk and the credit risk of the counterparties they fund. In essence, dealers (good counterparties, well know name) borrow from cash pools at a rate and pass on this funding to their customers (leveraged bond portfolios) at a rate plus some basis points.

[9] ALMs affect also FX reserve managers in emerging countries, as the bills they issue to sterilize FX interventions yield far in excess of the developed market bonds on their asset side (mostly U.S. Treasury).

presence of disappointing returns on real investments (low economic growth) in countries with deep capital markets and sophisticated financial systems.

The two structural developments, namely the rise of cash pools and that of ALMs, set the stage for the rise of shadow banking and decisively affect its shape and, more generally, the balance between leverage-enhanced growth and financial stability associated to this intermediation mechanism.

III. The model

A. *The baseline setup*

We develop an economy in line with Holmström and Tirole (2011). There are three dates $t = 0, 1, 2$. All financial commitments have to be backed up by claims on pledgeable assets.[10] There is a continuum of unit mass of identical *banking entrepreneurs* (shortly, bankers). Bankers are protected by limited liability, have equity A at $t = 0$ and maximize utility $u_b = c_0 + c_1 + c_2$, where c_k is consumption at $t = k$. Bankers run banks that can borrow from market investors and initiate at $t = 0$ investment projects that, when brought to completion, offer a per-unit total return ρ_1 at $t = 2$. The return of the investment project is only partially pledgeable: the banker and market investors can write state-contingent and enforceable contracts on all pledgeable income while no contracts can be made on the private part of income. In this section we treat market investors as deep-pocket risk-neutral investors which are willing to lend to bankers in exchange for pledgeable income and require a gross return R. We first characterize the banker's choice for any given R; in Section III.B market investors are introduced and R is endogenized.

During the implementation of investment projects, at the interim date $t = 1$, the banker may receive a liquidity shock: with a given exogenous probability $1 - \alpha$, ρ must be reinvested for each unit of investment to be brought to completion, otherwise the investment is liquidated. For simplicity the liquidation value is taken to be 0. Let i be the initial scale of the investment. Partial continuation $j < i$ is admitted, and $(i - j)/i$ is the extent of deleveraging (Figure 3). We focus on aggregate leverage and systemic crises and consider the extreme case in which shocks are perfectly correlated across bankers. Then, at $t = 1$ the economy operates in one of the following two states: (i) crisis or bad state, in which all bankers receive the shock and must reinvest ρj to continue the projects at scale j and (ii) no crisis or good state, in which no continuation problem emerges and all bankers continue at full scale i.

Shadow banking technology. One main difference with HT is that in our model, the banker has access to a technology that we name *shadow banking*. Shadow banking is always attractive to the banker as it increases the pledgeability of investment projects. We also

[10] Throughout the paper the terms liquidity, pledgeability and marketability are used interchangeably.

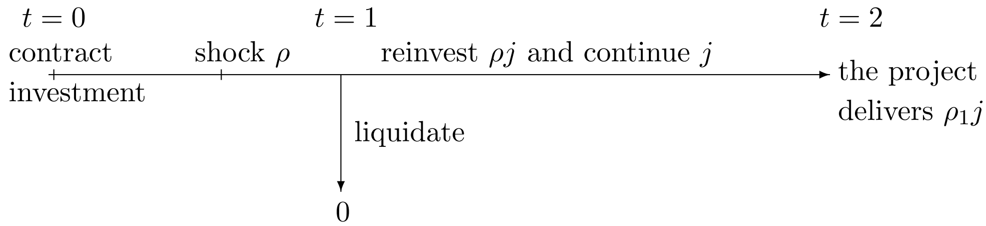

Figure 3. The (aggregate) liquidity shock.

assume that the banker decides how to allocate this extra-pledgeability generated by the shadow banking technology between the two states, crisis and no-crisis. In detail, let $\rho_0 < \rho_1$ be the per-unit pledgeability of investment projects as in the original HT contribution, and l_c and l_{nc} the (per-unit of investment) extra-pledgeability the banker allocates to the crisis (c) and the no-crisis (nc) state, respectively. One convenient interpretation of the technology is that at $t = 0$ the banker manufactures $l_{nc}i$ shadow collateral out of the originally illiquid part $(\rho_1 - \rho_0)i$ of her projects. At $t = 1$ the liquidity of the shadow collateral remains $l_{nc}i$ in the good state so that total pledgeable assets are $(\rho_0 + l_{nc})i$. Conversely, the liquidity of shadow collateral becomes $l_c \leq l_{nc}$ in a crisis, so that total pledgeability becomes $(\rho_0 + l_c)i$. For the sake of simplicity, we focus on two polar opposite ways to use the shadow banking technology:

Simple shadow banking. With the first one, that for the sake of expositional convenience we name simple shadow banking, the banker sets $l_{nc} = l_c = l$ (blue dot in Figure 4), where l is given and exogenous and represents a technological parameter. With simple shadow banking the liquidity of shadow collateral is always l and is not affected by the aggregate shock. Total pledgeability of investment projects is $\rho_0 + l$ regardless the state of the world.

Complex shadow banking. On the polar opposite case, *complex shadow banking*, the banker sets $l_c = 0$ and $l_{nc} = \gamma l$, with $\gamma > 1$ given and exogenous (red dot in Figure 4). With complex shadow banking, the banker manufactures more shadow collateral at $t = 0$, as compared to the case of simple shadow banking, but shadow collateral becomes completely illiquid in a crisis. As we will see, higher pledgeability in the good state guarantees higher leverage at $t = 0$ but implies large exposure to the liquidity shock. In other terms, with complex shadow banking the banker is trading-off less insurance against liquidity risk for higher leverage. Total pledgeability is $(\rho_0 + \gamma l)i$ with probability α (no crisis) but drops to $\rho_0 i$ in a crisis.

Interpretations. Our modeling device is flexible and has several real world interpretations. The first interpretation for $l_c < l$ is a flawed securitization process. Tirole (2010) points out that securitization transforms otherwise illiquid assets into tradable ones when it is accompanied by scrutiny by buyers that certifies the quality of the portfolio to the market. In general, in the securitization and tranching process several informational problems arise once the intermediation chain is divided in sequential steps and progressive risk-shifting takes place (Ashcraft and Schuermann, 2008; Keys, Mukherjee, Seru, and Vig, 2010). The opacity of the ultimate assets that backed shadow collateral was an effective factor that hampered

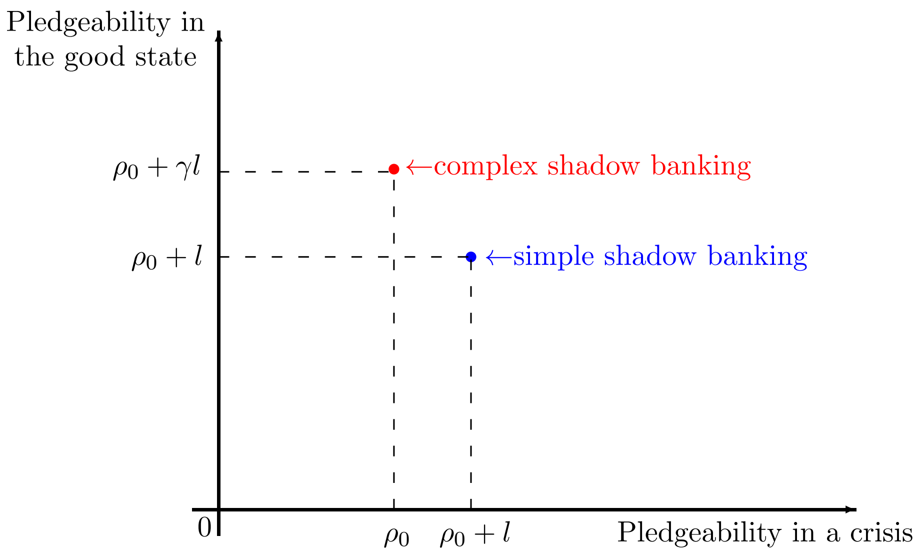

Figure 4. Pledgeability and the shadow banking technology. Red dot ($l_{nc} = \gamma l$ and $l_c = 0$, complex shadow banking): the banker allocates all the extra-pledgeability to the no-crisis state. Blue dot ($l_{nc} = l_c = l$, simple shadow banking): the banker allocates an equal amount l of extra-pledgeability to the two states.

financial firms' ability to find money-market funding at the onset of the crisis. Through the lens of the subprime event, $(l_{nc} - l_c)i$ can be taken as troubled assets whose liquidity plunged during the crisis. A second interpretation hinges upon institutional and contractual features like collateral re-use and re-hypothecation. To reduce liquidity costs, counterparties practice and permit collateral re-pledging (Monnet, 2011; Singh and Aitken, 2010) and the same securities are used to back more than one collateralized relationship at the same time, thereby creating a collateral chain. In the aggregate, collateral chains permit to sustain a large amounts of collateralized trades with a relatively small collateral base: collateral has a "velocity" and the higher the number of times it churns, the higher the leverage within the market-based credit intermediation system. Our assumption captures the fragility of this system in a systemic crisis: higher collateral velocity boosts pledgeability, liquidity and leverage in normal times ($l_{nc} > l$), at the risk of a liquidity shortfall ($l_c < l$) in a crisis. Finally, the effect of the liquidity shock on the shadow collateral can be interpreted in the spirit of Dang et al. (2010). The banker uses shadow banking to attract funds and enjoys a higher investment scale. In a crisis the banker must return to market investors to raise funds to accommodate the refinancing need and preserve the continuation scale. However, shadow collateral that in normal times is "information-insensitive" ($l_{nc}i$ in our model) can suddenly become "information-sensitive". Uncertainty regarding collateral value may trigger a "collateral check" (Gorton and Ordonez, 2012) with investors being concerned to tell pledgeable (good) collateral $l_c i$ from non-pledgeable (bad, toxic) private-label securities $(l_{nc} - l_c)\, i$ apart.

To make things interesting and as simple as possible, we make the following assumptions:

ASSUMPTION 1: *(finite leverage)* $\rho_0 + \gamma l < \min[R + (1-\alpha)\rho, R/\alpha]$.

ASSUMPTION 2: *(sufficiency)* $l = \rho - \rho_0$.

ASSUMPTION 3: *(positive NPV)* $\rho_1 > R + \rho$.

ASSUMPTION 4: *(reinvestment cost)* $\rho_0 < \rho < R$.

ASSUMPTION 5: *(expected pledgeability)* $\alpha\gamma \leq 1$.

Assumption 1 guarantees that the maximum pledgeability $\rho_0 + \gamma l$ is lower than the expected cost of investment. The latter is $R + (1-\alpha)\rho$ when the banker continues in both states and R/α otherwise. Assumption 2 states that shadow banking is in principle an effective insurance mechanism: by seeking simple shadow banking, the banker has enough liquid resources $\rho_0 + l$ to withstand the liquidity shock ρ. This assumption simplifies the presentation of the model and can be relaxed without affecting qualitative results.[11] Assumption 3 implies that the investment is worth undertaking from a net-present-value point of view, even with a crisis. The right inequality of Assumption 4 states that the per-unit reinvestment cost ρ is lower than the per-unit cost R that the banker has to bear to initiate the investment project. The left inequality guarantees that the shock is not self-financed. Finally, Assumption 5 states that the expected pledgeability with complex shadow banking is not higher than the one with simple shadow banking.[12]

The banker's problem. A contract specifies the level of investment i, the continuation scale $j \leq i$ and final payments to investors and the banker. As in Tirole (2006) it is optimal to allocate all the liquid/pledgeable returns to market investors, leaving the banker holding only the illiquid part. The banker maximizes her utility subject to a borrowing constraint (BC) and a liquidity constraint (LC) :

PROGRAM 1:

$$\max_{i,j,l_{nc},l_c} \quad u_b \equiv \alpha\rho_1 i + (1-\alpha)(\rho_1 - \rho)j - Ri \tag{Utility}$$

subject to

$$R(i - A) \leq \alpha(\rho_0 + l_{nc})i + (1-\alpha)(\rho_0 + l_c - \rho)j \tag{BC}$$

$$j = i \;\; \textit{if} \;\; l_c = l \quad \textit{and} \quad j = 0 \;\; \textit{if} \;\; l_c = 0 \tag{LC}$$

With probability α investment projects are intact and deliver $\rho_1 i$ at $t = 2$; with probability $1-\alpha$ the shock hits, ρj is reinvested and the projects deliver $\rho_1 j$ at completion. In

[11] Any deviation $l > \rho - \rho_0$ would not affect the liquidity constraint. Conversely, if $l < \rho - \rho_0$, simple shadow banking would not suffice to produce enough pledgeability to meet the reinvestment need. In that case, a banker that wants to continue at full scale has to resort to other forms of liquidity insurance. In the model, the banker would resort to sovereign bonds (see below) to meet the remaining liquidity need $\rho - \rho_0 - l$. This case is not interesting *per se* and a similar scenario is studied in Appendix A.

[12] Trivially, the expectation at $t = 0$ of the pledgeability at $t = 1$ is $\rho_0 + l$ with simple shadow banking and $\rho_0 + \alpha\gamma l$ with complex shadow banking. When γ is indefinitely high, the banker's choice would be trivially complex shadow banking. In addition, Appendix A shows that in the competitive equilibrium when $\alpha\gamma > 1$ simple shadow banking is always dominated by the following policy: the banker adopts complex shadow banking and purchase sovereign bonds to insure against the liquidity shock. In this scenario, the shadow banking technology would be, by construction, a pure leverage-enhancing mechanism.

the utility function, $\alpha\rho_1 i$ is the expected return in the good state, $(1-\alpha)(\rho_1-\rho)j$ is the expected return of the part of projects brought to completion in the bad state and Ri is the total cost of funding (expected repayment to market investors). The borrowing constraint (BC) stipulates that the sum of pledgeable repayments in the two states (right hand side) covers the borrowed amount $i-A$ to finance the projects times the gross interest rate R (left hand side).[13] In a crisis, the repayment to investors is always zero: indeed either $l_c = l$ so that $\rho_0 + l_c = \rho$ or $l_c = 0$ so that $j = 0$. The whole banker's problem boils down to the choice of the utility-maximizing policy between simple and complex shadow banking. These are the payoffs associated to the two policies:

- Simple shadow banking: $l_c = l_{nc} = l$. This implies $j^S = i^S$ (the banker continues in both states) and the utility is

$$u^S = z^S i^S \equiv [\rho_1 - (1-\alpha)\rho - R]\frac{A}{1-\alpha(\rho_0 + l)/R} \tag{1}$$

  where $z^S \equiv \rho_1 - (1-\alpha)\rho - R$ is the per-unit utility and i^S is the investment scale derived from BC with the equality where $l_{nc} = l_c = l$ (and $j = i$). Under this policy, the shadow banking technology - which also boosts the leverage as $l_{nc} = l > 0$ - is also used as an insurance mechanism: when the shock hits, the banker has still enough pledgeable assets to bring to completion the whole investment scale as shadow collateral can be used to raise fresh funding and cover the liquidity need.
- Complex shadow banking: $l_c = 0$ and $l_{nc} = \gamma l$. This implies $j^C = 0$ (the banker continues only in the good state) and the utility is:

$$u^C = z^C i^C \equiv (\alpha\rho_1 - R)\frac{A}{1-\alpha(\rho_0 + \gamma l)/R}. \tag{2}$$

  where $z^C \equiv \alpha\rho_1 - R$ is the per-unit utility and i^C is the investment scale derived from BC with the equality where $l_{nc} = \gamma l$ (and $j = 0$). Under this policy, the shadow banking technology is used as a pure leverage-enhancing mechanism: the banker allocates all the extra-pledgeability to the no crisis state, thereby boosting leverage at its limit and accepting maximal exposure to liquidity risk.

Discussion. The banker and market investors can write state-contingent contracts on the pledgeable part of the investment. As in HT, in the optimal contract the reinvestment shock (if any) is met by the banker using pledgeable assets $(\rho_0 + l_c)j$ to raise fresh funding and diluting initial investors. This event is anticipated by market investors and is fully priced in the borrowing constraint. Note that the NPV of projects at $t = 1$ is still positive in a crisis (Assumption 3) so that the shock can be intended as a liquidity shock (with no solvency concern). However, investors' initial outlay $i - A$ is not repaid in a crisis and the shock represents the materialization of aggregate credit risk to market investors. This feature of the optimal contract which we inherit from HT depends mainly on two factors. First, bankers are essential to bring projects to completion and must have enough "skin in

[13] Also note that the Lagrangian of the problem is linear and even if we let the banker to choose $l_c \in [0, l]$ we would still obtain a corner solution.

the game".[14] Second, the liquidation value of projects which are abandoned at the interim stage is assumed to be zero, for simplicity. A positive liquidation value would have been optimally allocated to investors to maximize initial leverage. In general, the features of the optimal contract are consistent with the idea that shadow collateral constitute only an imperfect substitute of sovereign bonds or other forms of public parking space (see below) and carry some aggregate risk.

PROPOSITION 1: *The banker prefers complex shadow banking when the cost of funding R is low.*

Proof. The utility-maximizing policy is affected by the cost of funding R. Comparing utilities u^S and u^C we obtain $u^S \leq u^C \; \forall R \leq \bar{R}_{SC}$, where

$$\bar{R}_{SC} \equiv \frac{\alpha\{(\rho_0 + \gamma l)[\rho_1 - (1-\alpha)\rho] - \alpha(\rho_0 + l)\rho_1\}}{(1-\alpha)\rho_1 + \alpha(\rho_0 + \gamma l) - \rho} \tag{3}$$

□

The intuition is that the banker obtains utility from a combination of leverage (investment scale) and insurance (continuation scale). When the price of leverage R is low, the insurance provided by simple shadow banking is particularly costly in terms of utility, as the banker would obtain a large amount of (cheap) leverage for each unit of extra-pledgeability allocated to the good state. Conversely, when R is high, each unit of pledgeability allocated to the good state delivers only a small amount of (expensive) leverage, thereby making insurance relatively more attractive.

RESULT 1: *Proposition 1 also defines the supply of private parking space: when $R \leq \bar{R}_{SC}$, bankers supply is $(\rho_0 + \gamma l)i^C$; the quantity drops to $(\rho_0 + l)i^S$ when $R > \bar{R}_{SC}$.*

The probability of the shock also affects the banker's choice: intuitively, when α approaches 1, the banker prefers complex shadow banking as the cost of insurance - in terms of lower leverage - is high. Similarly, the same policy becomes more attractive when γ is high, as saving on insurance (i.e. reducing l_c) yields a large gain in terms of leverage. withs u^S and u^N. The difference $\bar{R}_{NC} - \bar{R}_{SC}$ is positive for $\gamma = 1$ and decreasing in γ.

B. The competitive equilibrium

In this section we explicitly consider market investors as risk-neutral agents that want to postpone consumption and look for storage. They have large endowments Y_0 and Y_1 at $t = 0$ and $t = 1$, respectively, and maximize utility $u_m = \beta c_{0,m} + c_{1,m} + c_{2,m}$, where c_k represents consumption at $t = k$ and $\beta < 1$.

Sovereign bonds. We enrich our baseline setup and introduce sovereign bonds: sovereign bonds are issued at $t = 0$ by the government, come in a fixed exogenous supply X, cost q

[14] The whole "limited pledgeability" issue can be derived from moral hazard or adverse selection considerations, see Tirole (2006)).

(endogenous, see below) at $t = 0$ and yield 1 with certainty at $t = 1$. The government distributes to consumers/taxpayers the revenues from the bond sale at $t = 0$ and tax them at $t = 1$ to redeem the bonds; consumers/taxpayers have to be intended as passive risk-neutral agents, with constant utility of consumption, no pledgeable income and with large endowment at each date. In order to rule out the possibility for sovereign bonds to redistribute wealth from taxpayers to bondholders, we consider $q \geq 1$; when $q = 1$ sovereign bonds are neutral in terms of distribution.[15]

Market investors have two options to store the endowment Y_0. First, they can buy risk-free sovereign bonds and consume the proceeds at $t = 1$ when the government redeems the bonds. For sovereign bonds to be attractive to market investors, $q \leq 1/\beta$, otherwise the latter would prefer to consume at $t = 0$. The second storage option consists - as also described in the previous section - in lending to bankers in exchange for the pledgeable part of investment projects. For each unit lent to banks at $t = 0$, investors receive R units (here endogenous, see below) in expectation at $t = 2$. Trivially, $R \geq \beta$, otherwise investors would not be willing to lend. Also note that investors are indifferent between $t = 1$ and $t = 2$ consumption, so the interest rate between these two dates is normalized to 1.

ASSUMPTION 6: *(relative scarcity of public parking space)* $X < Y_0$.

Assumption 6, which implies that at the lowest possible price $q = 1$ the supply of sovereign bonds is not sufficient to meet the potential demand from market investors, essentially guarantees that in the economy there is a demand for private parking space. The economy's aggregate resource constraint is

$$i = Y_0 - qX + A - c_{0,m}. \tag{4}$$

Investors' endowment Y_0 is allocated at $t = 0$ to purchase sovereign bonds qX, provide funding to banks $i - A$ and possibly devoted to consumption ($c_{0,m}$).

In equilibrium, the cost of funding R and the price of bonds q are jointly determined in the market for parking space. Investors pay qX at $t = 0$ for sovereign bonds that return X at $t = 1$, and lend $i - A$ to banks at $t = 0$ which repay $\alpha(\rho_0 + l_{nc})i$ in expectation. In equilibrium the two parking options offer the same expected return when

$$\frac{1}{R} \equiv \frac{i - A}{\alpha(\rho_0 + l_{nc})i} = \frac{qX}{X} \tag{5}$$

Therefore the equilibrium is characterized by $q = 1/R$ and, with simple substitution into condition 4, the demand for private parking space $i - A$ can be expressed as a positive function of the cost of funding R:

$$\begin{aligned} i - A &= Y_0 - \frac{X}{R} \quad \text{when} \quad R \in (\beta, 1] \\ i - A &= Y_0 - \frac{X}{\beta} - c_0 \quad \text{when} \quad R = \beta \end{aligned} \tag{6}$$

[15]Note that no distortion from taxation is considered.

When $R \in (\beta, 1]$, the whole endowment Y_0 is parked into sovereign bonds and banks; when $R = \beta$, the equilibrium can be characterized by market investors' consumption at $t = 0$. The lower is β, the wider the set of feasible equilibrium values of R.

From the previous section, the supply of private parking space is a negative function of the cost of funding and, in particular, is $i^S - A$ when $R \geq \bar{R}_{SC}$, with i^S described by equation (1) and $i^C - A$ when $R < \bar{R}_{SC}$, with i^C described by equation (2). Then, given the demand and supply of private parking space, it is easy to pin down the banker's optimal choice, the equilibrium cost of funding R^* and investment scale i^*. Figure 5 provides a graphical illustration of the equilibrium in the market for parking space.[16]

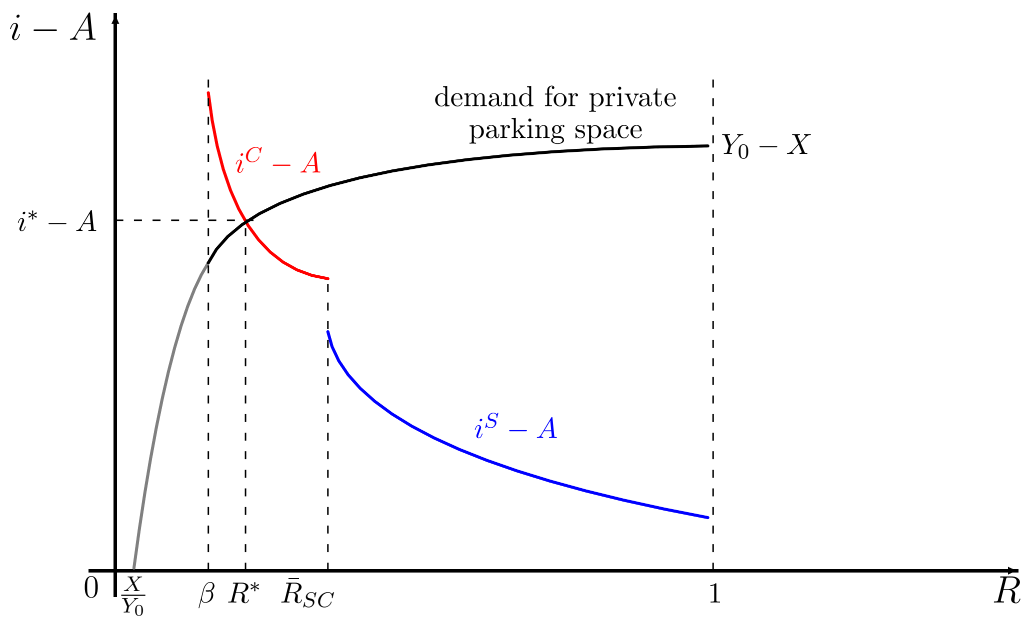

Figure 5. Demand for and supply of private parking space. Red curve: supply under complex shadow banking. Blue curve: supply under simple shadow banking. Black curve: demand. In the specific case depicted in the figure, the banker would choose complex shadow banking.

Discussion. The banker's choice between simple and complex shadow banking is crucially intertwined with the conditions in the market for parking space. On the one hand, bankers determine the supply of private parking space; on the other, their choice is affected by the excess demand for parking space which is related to Y_0, X and β. Any increase of Y_0 moves the demand curve upward and shifts it to the left, thereby expanding the region of parameters in which bankers prefer complex shadow banking. Changes of X have the opposite effect: when the supply of public parking space is abundant, for a large set of parameters

[16]If the demand curve intersects the supply curve in the dotted segment which corresponds to $R^* = \bar{R}_{SC}$, one can imagine bankers play a mixed strategy with a fraction of bankers opting for complex shadow banking, while the remaining fraction that seeks simple shadow banking.

bankers seek simple shadow banking, the leverage is relatively low, shadow collateral preserves its liquidity in a crisis and output volatility (computed between the the two states of the world) is zero. Finally, the parameter β, which is the market investors' utility from consumption at $t = 0$, determines the domain of R: in the trivial case $\beta = 1$, the equilibrium is simply $q^* = R^* = 1$ and the banker's choice is driven only by technological parameters (i.e. α, ρ_1, ρ and γ). When β declines below $\bar{R}_{SC}$, complex shadow banking becomes a feasible equilibrium outcome. In our cash pools' view of market investors, β can be interpreted as the a proxy for the need of dollar-denominated parking space: the lower is β, the higher the need. Indeed, differently from small retail investors like households, the large volume of cash pools' balances rules out storage alternatives, such as simply keeping the cash under the mattress. Moreover, the global shadow banking system is basically dollar-based and the non-US demand for dollar-denominated parking space has been steadily growing. These two considerations support the view that large cash investors may accept a very low reward for their short-term dollar lending.

C. Entities with asset-liability mismatches

The framework with market investors and bankers is augmented with entities, like insurance companies and pension funds (henceforth, ICPFs) with liabilities in fixed nominal amount and a potential asset-liability mismatch. In the model ICPFs have an equity endowment at the initial date and need to obtain a fixed return to meet their future liabilities. To this aim, ICPFs can buy sovereign bonds and allocate the remaining fraction (if any) of their equity endowment to bankers. As before, bankers have access to investment projects and may generate leverage-enhanced returns. In this section we assume that bankers simply maximize the utility of ICPFs, which are also the unique source of bankers' equity.[17] ICPFs have an equity endowment A_0^p at $t = 0$ and a commitment to repay a fixed amount $\bar{c}^p$ at $t = 1$ or $t = 2$ to their clients. To simplify, let $\bar{c}^p = A_0^p$. Let c^p be the sum of the ICPFs' assets at $t = 1$ and $t = 2$ and assume that ICPFs maximize the following utility function:

$$u_p = \begin{cases} c^p - \bar{c}^p & \text{if} \quad c^p \geq \bar{c}^p \\ \\ -M & \text{if} \quad c^p < \bar{c}^p \end{cases} \tag{7}$$

where M is very large. The rationale behind the utility function is straightforward: when ICPFs meet the target $\bar{c}^p$, the utility is simply $c^p - \bar{c}^p$; otherwise, ICPF's utility drops sharply. Also assume that bankers have $A = 0$, receive an equity allocation $a^p A^P \leq A^p$ from ICPFs and maximize the utility of ICPFs in exchange for a per-unit return $\rho_1 - \rho_1^p$ on the projects brought to completion (if any). As before, bankers can borrow from market investors, implement real investment projects and access the shadow banking technology. Let $m^S \equiv 1 - \alpha(\rho_0 + l)/R$ and $m^C \equiv 1 - \alpha(\rho_0 + \gamma l)/R$ be the equity multipliers with simple and complex shadow banking, respectively. Using $q = 1/R$, when ICPFs allocate a fraction a^p to simple shadow banking and the remaining $1 - a^p$ to purchase sovereign bonds, ICPFs obtain:

[17] In a sense, bankers are redundant in this section. We prefer this representation and not to change terminology during the presentation of the different parts of the model.

$$c^{p,S} = \begin{cases} \left[R(1-a^p) + \frac{\rho_1^p - R}{m^S} a^p\right] A^p & \text{with prob} \quad \alpha \\ \\ \left[R(1-a^p) + \frac{\rho_1^p - \rho - R}{m^S} a^p\right] A^p & \text{with prob} \quad 1-\alpha \end{cases} \tag{8}$$

Conversely, when a fraction a^p is allocated to complex shadow banking (and the remaining to sovereign bonds), ICPFs obtain:

$$c^{p,C} = \begin{cases} \left[R(1-a^p) + \frac{\rho_1^p - R}{m^C} a^p\right] A^p & \text{with prob} \quad \alpha \\ \\ R(1-a^p)A^p & \text{with prob} \quad 1-\alpha \end{cases} \tag{9}$$

Consider first, as a benchmark, the case in which $\beta = 1$ or, equivalently, no scarcity of public parking space ($X \geq Y_0 + A_0$). In equilibrium $q = R = 1$. The policy of full allocation to sovereign bonds $a^p = 0$ yields $c^p = \bar{c}^p$ so that $u_p = 0$. In this case ICPFs allocate the endowment to simple shadow banking if and only if the associated leverage-enhanced return in a crisis $(\rho_1^p - \rho - 1)/m^S$ is higher than 1. Indeed, when the latter condition is not met, the optimal policy is $a^p = 0$. Furthermore, when $q = R = 1$ complex shadow banking is not an equilibrium outcome as it implies $u_p = -M$ with a positive probability $1 - \alpha$, while there exists at least one alternative policy which guarantees non-negative utility in both states of the world.

The most interesting case is the one in which $R < 1$ (and $q > 1$, scarcity of public parking space, and $\beta < 1$). The policy $a^p = 0$ is not attractive to ICPFs as it would yield $c^p < \bar{c}^p$ and $u_p = -M$. ICPFs seek to allocate the endowment to bankers to obtain leverage-enhanced returns that compensate for the low yield on sovereign bonds. More in detail, we have two relevant sub-cases:

- Full allocation to simple shadow banking when $(\rho_1^p - \rho - R)/m^S \geq 1$. The condition states that in a crisis the leverage-enhanced return from simple shadow banking is not lower than 1. Under this condition, ICPFs allocate the whole endowment to simple shadow banking and their utility is non-negative in both states of the world. This result is again related to the fact that complex shadow banking always fails to deliver the desired return in the bad state. Note also that $(\rho_1^p - \rho - R)/m^S$ is decreasing in R and increasing in ρ_1^p.
- Full allocation to complex shadow banking when $(\rho_1^p - \rho - R)/m^S < 1 < (\rho_1^p - R)/m^C$. The condition states that in a crisis the return from simple shadow banking is lower than 1, while the return from complex shadow banking is higher than 1. These conditions drive ICPFs towards complex shadow banking. The intuition is that, when the conditions above are met, no combination of simple shadow banking and sovereign bonds is unable to generate the desired return in a crisis. Then the optimal policy is simply the one that maximizes the income in the good state. The right inequality in the previous condition states that complex shadow banking guarantees $c^{p,C} \geq \bar{c}^p$ in the good state. In other terms, when the income generated in a crisis is always below the

commitment threshold $\bar{c}^p$, complex shadow banking is optimal as it yields the highest leverage-enhanced returns ($m^C < m^S$ by construction) in the good state. Note that the previous condition is met when the un-levered return ρ_1^p is low enough.

Summing up, conditions in the market for parking space do play a role for the allocation choice of ICPFs. When $q = R = 1$, the traditional sovereign bonds portfolio allows ICPFs to meet their fixed commitment $\bar{c}^p$. Conversely, scarcity of public parking space, besides creating the need for market investors to look for private alternatives, also creates the need for leverage-enhanced returns from ICPFs. In addition, when the un-levered return ρ_1^p is low, complex shadow banking emerges as the equilibrium market-based credit intermediation mechanism, delivering in no crisis states (i) the largest private parking space for market investors and (ii) the highest leverage-enhanced returns to ICPFs.

IV. Policy

Credit rationing models raise conceptual problems for welfare analysis. First of all, even when agents are all risk neutral, Pareto optimal allocations cannot simply be determined by total surplus maximization. In the model, any deviation from $q^* = R^* = 1$ (i.e. relative scarcity of public parking space) implies that sovereign bonds are traded with a liquidity premium $q^* - 1$. The scarcity translates into a net transfer through equilibrium prices from market investors to taxpayers (through the redistribution of the liquidity premium commanded by sovereign bonds) and bankers (through a lower cost of funding and higher leverage).

In addition, section III.B presents the competitive equilibrium in which bankers have an optimal choice for any R. Still, they disregard the feedback effect of their choice on equilibrium prices and utility. For instance, a banker that seeks complex shadow banking boosts the supply of private parking space, thereby increasing the equilibrium R and negatively affecting other bankers' utility. For this reason one natural extension of our framework would be to explicitly consider the externality in the bankers' choice and control whether a monopolistic banker, which fully internalizes the effect of her choice on equilibrium prices, arrives at a different solution. However, it is worth noting that, according to the redistribution effects of the variations of the equilibrium R mentioned above, the maximization of banker's utility does not necessarily imply welfare maximization.

For all these reasons, this policy part simply expands Section III.B by introducing a central bank (CB) with a financial stability mandate. For simplicity, we consider a CB which is both the monetary policy and regulatory authority. Trivially, the CB has no direct control on the the bankers' private choice regarding shadow banking (simple versus complex) and can only implement monetary policy measures and impose regulatory constraints to achieve its mandate. We decline the financial stability mandate as achieving zero deleveraging in a crisis. We focus on two cases. In section IV.A we have a CB with large sovereign bond holdings that implements a reverse repo program (RRP), lending out its sovereign bonds and absorbing a fraction of market investors' demand for parking space. The RRP expands the supply of public parking space, thereby affecting the banker's choice. In section IV.B we consider a CB which imposes regulatory (capital and liquidity) constraints.

A. Reverse Repo Program

Consider a CB which holds X_{CB} of sovereign bonds at $t = 0$. The CB implements a a reverse repo program under which $X_{RRP} \leq X_{CB}$ sovereign bonds are lent out to market investors in exchange for (a fraction of) their endowment at an endogenous (reverse) repo rate. The size X_{RRP} of the RRP would sum up to freely available sovereign bonds X and expand the supply of public parking space. At $t = 0$ market investors are indifferent between outright purchases of sovereign bonds at price q which return 1 at $t = 1$ or paying to the CB a negative rate $1 - q$ to park their endowment. Using $q = 1/R$, under RRP the demand for private parking space of equation (6) becomes:

$$i - A = Y_0 - \frac{X + X_{RRP}}{R} \tag{10}$$

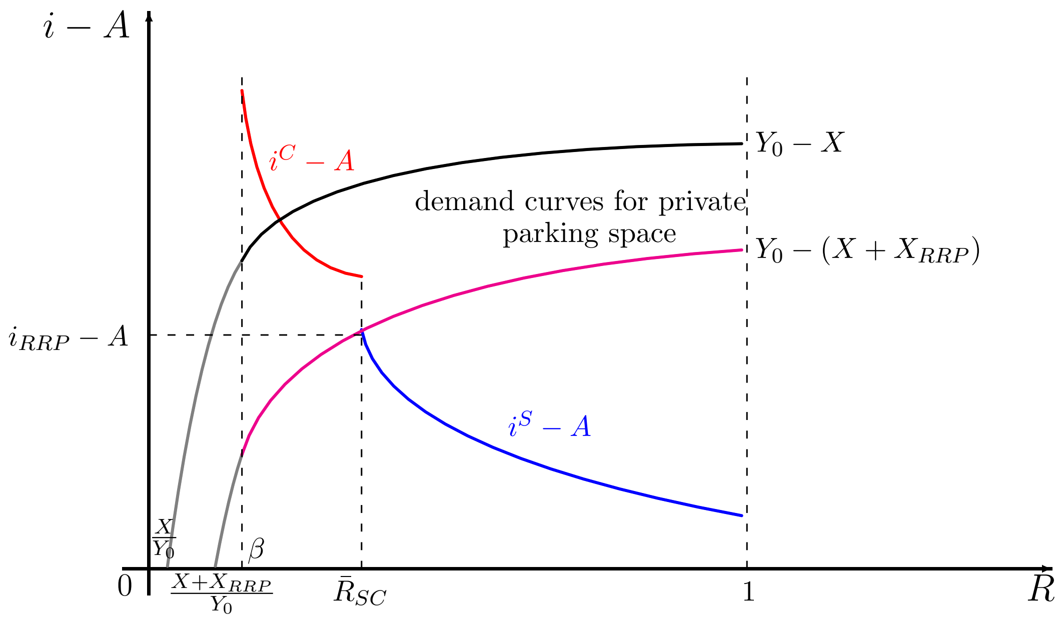

Figure 6. The effects of RRP. Black curve: demand for private parking space without RRP. Magenta curve: demand for private parking space with RRP, which absorbs a fraction of market investors' endowment.

Figure 6 shows the effects of the RRP when the scarcity of public parking space induces bankers to seek complex shadow banking. Without the RRP the equilibrium is given by the intersection between the black curve $i - A = Y_0 - X/R$ (demand for private parking space) and the red curve (supply of private parking under complex shadow banking) and bankers choose complex shadow banking. The program of size X_{RRP} partially absorbs market investors' endowment and shifts the demand curve for private parking space rightward/downward (magenta curve). In Figure 6 the shift is such that bankers switch from complex to simple shadow banking and the equilibrium cost of funding R^{RRP} is exactly equal to $\bar{R}_{SC}$, so that bankers' investment scale is maximized under the constraint of zero deleveraging in a crisis. The choice of the size of the RRP, once the goal of the CB's financial stability mandate is achieved, entails distributional issues, as mentioned above.

RRPs may effectively give cash pools direct access to the reserve accounts and relax the shortage of sovereign bonds. This crowds out levered portfolio managers (bankers) from tapping into wholesale funding markets. In practice, whereas funds raised via repos are used by dealers to finance their bond inventories and passed on to other levered bond portfolio managers, the funds absorbed by the central bank via the RRP remain siloed in the central bank's balance sheet, thereby limiting the leverage available to bond portfolio managers.[18] In the model RRPs reduce the probability of severe deleveraging in a crisis by increasing the equilibrium cost of funding for banks which, alternatively, would be driven down by the scarcity of public parking space. Therefore RRPs are particularly effective in periods that follow large scale asset purchases by the CB (e.g. Quantitative Easing) which, as a side effect, reduce the safe collateral in the market.

B. *Regulation*

When bankers seek not to insure against the aggregate shock, massive deleveraging ensues. In our framework, a regulatory authority with a financial stability mandate can pursue its objective by imposing both capital and liquidity regulation. While with the RRP the CB constraints the banks' scale indirectly, through an increase of the supply of public parking space that reduces the leverage available to bankers, capital and liquidity regulations operate directly as constraints to the banks' balance sheet.

Capital regulation. The authority imposes a cap on bankers' investment scale to induce bankers to seek simple shadow banking. In detail:

$$i \leq i_k^S(\bar{R}_{SC}) \equiv \frac{A}{1 - \alpha(\rho_0 + l)/\bar{R}_{SC}}$$

Figure 7 depicts the equilibrium without regulation (point E) and the one with regulation (point E'). The effect of the regulatory cap depends on the demand for private parking space. When the equilibrium without the regulation is complex shadow banking (as depicted in the Figure with point E), the regulation is binding and effectively avoids deleveraging in a crisis. Indeed, the cap induces bankers to prefer simple shadow banking: when the higher leverage that can be obtained under complex shadow banking is forbidden by the regulation, the banker finds it optimal to extract utility from the insurance delivered by simple shadow banking. Conversely, the regulatory constraint is slack when the banker chooses simple shadow banking in the competitive equilibrium without regulation and has no effect at all.

[18] Our model is very stylized. In reality, one side effect would be for bond portfolio managers to take on leverage migrating towards the derivative markets, by assuming cash plus derivative overlay investments.

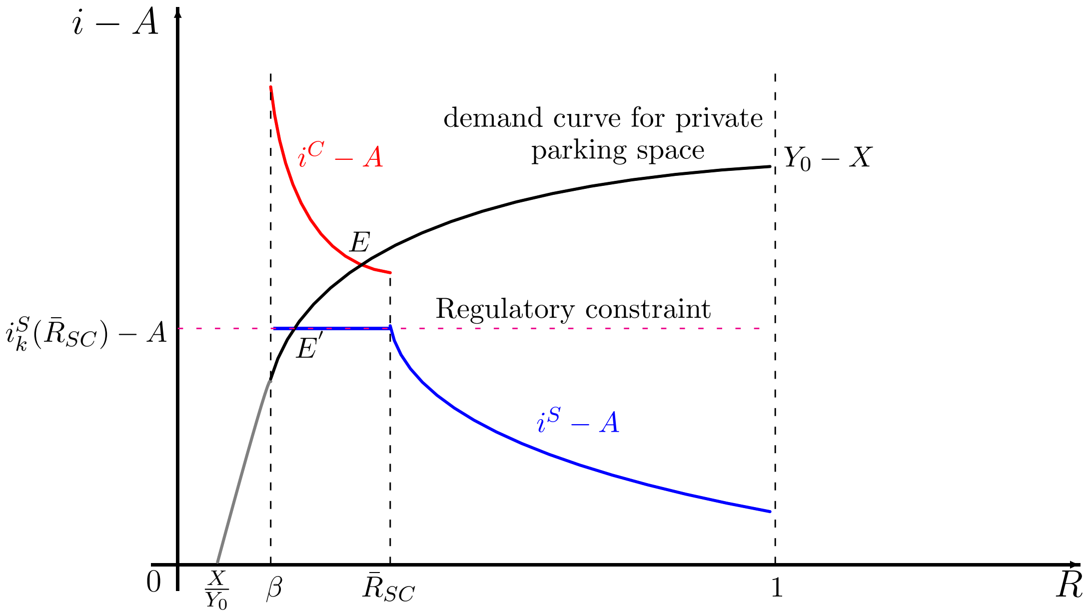

Figure 7. The effects of capital regulation. Black curve: demand for private parking space. Magenta dotted line: regulatory constraint on the investment scale. Point E: equilibrium without the regulation, the banker seeks complex shadow banking. Point E': equilibrium with the regulation, the banker seeks simple shadow banking.

Liquidity regulation. In our framework, a regulatory liquidity requirement imposed for financial stability purposes has to be necessarily designed as a minimum amount of sovereign bonds banks have to purchase at $t = 0$.[19] These bonds can be used to meet the shock in a crisis as, differently from shadow collateral, they are liquid in all states of nature. Let xi be the amount of sovereign bonds held by the banker at $t = 0$. The liquidity requirement can be designed to guarantee full continuation scale in a crisis: $x \geq \bar{x}_l \equiv \rho - \rho_0$. Liquidity regulation avoids deleveraging in a crisis but also reduces banks' leverage: a fraction of bankers' borrowing capacity goes "wasted" to purchase sovereign bonds. Also note that with the liquidity requirement simple shadow banking is never optimal to the banker: the occasional reinvestment need would be covered attracting funding with sovereign bonds (or selling them) and liquidity insurance is not an issue. For these reasons, bankers opt for the policy that guarantees leverage maximization, namely complex shadow banking. In detail, the borrowing constraint is:

$$R(i - A + q\bar{x}_l i) \leq \alpha(\rho_0 + \gamma l + \bar{x}_l)i$$

Using $q = 1/R$ and solving with the equality, the investment scale is

[19]The underlying view is that the authority cannot observe whether bankers are performing complex or simple shadow banking at $t = 0$, but the choice and its effects are only visible in a crisis.

$$i_l = \frac{1}{1 + (1-\alpha)\bar{x}_l/R_l - \alpha(\rho_0 + \gamma l)/R_l} \tag{11}$$

where R_l is the equilibrium cost of funding in the market for parking space in which the demand is described by the following equation:

$$i - A = Y_0 - \frac{X - \bar{x}_l i}{R_l}$$

An amount $\bar{x}_l i$ of sovereign bonds X are absorbed by banks to fulfill their regulatory requirement; for this reason the demand curve becomes a steeper function of R. According to our previous results, when X is relatively small and bankers prefer complex shadow banking in the competitive equilibrium without regulation, liquidity regulation reduces output but is also effective in curbing systemic risk taking. However, when conditions in the market for parking space are such that simple shadow banking is the competitive equilibrium outcome without regulation, the liquidity requirement may have purely negative effects: it does not improve the continuation scale and depresses the investment scale, by forcing banks to invest in sovereign bonds, which are a low yield technology. In this respect, the model suggests a macroprudential (time-varying) approach to liquidity regulation.

V. Conclusions

This paper builds a simple model to frame the rise of shadow banking into a global financial ecosystem dominated by institutional cash pools on the one side, and balance sheets with asset-liability mismatches, like those of insurance companies and pension funds, on the other. We show that the institutional setting and financial ecosystem surrounding the shadow banking system are key to understand its past and possible future manifestations.

The starting point is that wholesale funding is parking space which cash pools demand as a private sector elastic alternative to stores of values supplied by the public sector that often come with insufficient/inelastic supply. This demand is accommodated by banks which liquefy historically illiquid assets and manufacture shadow collateral accepted by cash pools in exchange for funding. Wholesale funding is not only something that dealers/banks use to fund their own securities inventories/portfolios, but it is largely passed on through banks' matched repo books to less regulated/supervised portfolio managers, such as leveraged hedge and bond funds. Leveraged funds use securities financing transactions and other cash-absorbing investment strategies to generate excess (leverage-enhanced) returns over a benchmark. The returns of these so-called alternative investment strategies satisfy the reach for yield of entities, like pension funds and insurance companies, which have accumulated asset-liability mismatches (ALMs). These entities have liabilities in fixed nominal amount and the returns of their traditional asset portfolios, dominated by sovereign bonds and other safe assets, have been suffering in a low yield environment. As a response, they increase allocations (i.e. funds to be managed) to leveraged funds: the greater the reach for yield from entities with ALMs, the greater the need for leverage from leveraged funds, the higher the demand for dealers' balance sheet capacity, the greater the demand of dealers to raise funding for their matched books, the larger the volume of repos (and derivatives) absorbing the cash provided by institutional cash pools. In a nutshell, this is the modern financial ecosystem.

We focus on the incentives of bankers, to be intended as the complex of levered bond portfolio managers, which manufacture private-label securities (shadow collateral) and ultimately decide the economy's balance between leverage-enhanced economic growth and financial stability. We assume that the liquidity properties of the shadow collateral in different states of the world are a bankers' choice. This choice characterizes the type of shadow banking system that emerges in equilibrium. In the terminology of our model, bankers' decision is between (i) high leverage/output at the cost of large exposure to aggregate shocks (complex shadow banking) versus (ii) lower leverage/output and insurance against aggregate shocks (simple shadow banking). We show that the choice is largely affected by the financial ecosystem: when the demand for parking space from cash pools and the reach for yield from entities with liabilities in fixed nominal amount (asset-liability mismatches) are high, complex shadow banking is the competitive equilibrium outcome and the economy is prone to massive deleveraging in the case of aggregate shocks.

Currently, regulatory reforms are bringing about broad changes at the core of the financial ecosystem. First, recognizing that the ground zero of the crisis was letting shadow collateral get into the plumbing of the system, post-crisis reforms have focused on cleaning up the plumbing and using near-exclusively government securities as collateral. Second, recognizing the risks of aggressive maturity transformation, Basel III has been limiting in various ways the ability of banks to issue short-term instruments (repos) and run large matched books. The net effect has been a massive and ongoing reduction in dealer banks' repo volumes and, with it, a reduction in the habitat of cash pools. With the time, other corners of the ecosystem responded: in the US, the sovereign increased its supply of Treasury bills and short-term Treasury coupons, the Federal Reserve started a Reverse Repo Program (RRP), opened to a wide set of nonbank counterparties, to lend out a fraction of its large post-QE holdings of safe assets. These responses have increased the supply of public parking space available to cash pools, the shortage of which, by compressing the cost of leverage in the shadow banking system, elicited the creation of shadow collateral with poor liquidity properties in adverse market scenarios (complex shadow banking) and was one of the roots of the crisis. Herein lies one key policy implication of the model: a central bank focused on financial stability can fulfill that mandate actively managing its balance sheet by absorbing via reverse repo programs some of the demand for parking space from institutional cash pools. In the model, this type of policy intervention drives up the banks' cost of the leverage sourced from institutional cash pools, and reduces incentives in pursing strategies which deliver high-leverage-enhanced returns in good times at the cost of massive deleveraging in the case of aggregate shocks.

Looking forward, absorbing the demand for parking space of cash pools on the "one-sided" balance sheet of a central bank through RRPs, as opposed to a "two-sided" balance sheet such as that of a broker-dealer's matched repo book, means that leveraged hedge and bond funds - less/not affected by the post-crisis regulatory tightening - have access to less leverage, in the aggregate: with a large RRP in place, the wholesale funding that is usually absorbed by dealers and lent on to these levered bond portfolio managers, would be drained by the central bank and fund its assets portfolio. But, on the other side of the spectrum, asset-liability mismatches that levered bond portfolio managers are trying to bridge, still and will firmly remain and notably so in a prolonged low yield environment. Therefore, while dealing with problems in wholesale funding markets via RRPs solves one half of the problem, risk-taking can materialize in different corners of the system, in new ways and forms. For instance, the reach for yield from entities with ALMs may migrate even more towards activities which deliver synthetic leverage via derivatives. For all these reasons, a more comprehensive approach to financial stability and balanced growth may require policymakers to tackle the very structural and fundamental macro developments to which shadow banking has been the private sector - inefficient, so far - response. This paper argues that financial stability risks can be inherent in income/wealth inequality, global imbalances and other macro factors at the roots of the rise of institutional cash pools. In this respect, the benefits of redistributive policies – including global currency and corporate tax reforms – usually looked at from a demand management perspective, may have also relevant financial stability benefits, through their impact on the size of wholesale funding markets. Similarly, in a world where promises made in the past - like those of pensions - can be renegotiated whenever real returns fall short of expected returns, structural asset-liability mismatches would be much lower and the reach for yield from entities prone to ALMs would be less aggressive.

Appendix A. Insurance with sovereign bonds

Similarly to market investors, a banker that adopts complex shadow banking can purchase sovereign bonds at $t = 0$ and use them to cover the liquidity shock, if needed. In particular, the banker may purchase xi sovereign bonds, with $x = \rho - \rho_0$. The utility is $u = [\rho_1 - (1 - \alpha)\rho - R]i$, with

$$i = \frac{1}{1 + (1-\alpha)(\rho - \rho_0)/R - \alpha(\rho_0 + \gamma l)/R}$$

It is easy to see that this policy dominates simple shadow banking when the expected pledgeability $\rho_0 + \alpha\gamma l$ of complex shadow banking is higher than the expected pledgeability of simple shadow banking $\rho_0 + l$. Trivially, the higher γ, the more attractive is sovereign bonds insurance and when $\gamma > 1/\alpha$, shadow banking would be a pure leverage-enhancing mechanism as sovereign bonds insurance would always compare favorably against simple shadow banking. Finally, note that this policy is equivalent to the case studied in section IV.B under liquidity regulation.

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