Banks, Shadow Banking, and Fragility[*]

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This paper studies a banking model of maturity transformation in which regulatory arbitrage induces the existence of shadow banking next to regulated commercial banks. We derive three main results: First, the relative size of the shadow banking sector determines the stability of the financial system. If the shadow banking sector is small relative to the capacity of secondary markets for shadow banks' assets, shadow banking is stable. In turn, if the sector grows too large, it becomes fragile: an additional equilibrium emerges that is characterized by a panic-based run in the shadow banking sector. Second, if regulated commercial banks themselves operate shadow banks, the parameter space in which a run on shadow banks may occur is reduced. However, once the threat of a crisis reappears, a crisis in the shadow banking sector spreads to the commercial banking sector. Third, in the presence of regulatory arbitrage, a safety net for banks may fail to prevent a banking crisis. Moreover, the safety net may be tested and may eventually become costly for the regulator.

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1. Introduction

This paper contributes to the theoretical understanding of how shadow banking activities can set the stage for a financial crisis. Maturity and liquidity mismatch in unregulated financial intermediation – often described as shadow banking – were a key ingredient to the 2007-09 financial crisis (Brunnermeier, 2009; FCIC, 2011). Prior to the crisis, the shadow banking sector was largely involved in financing long-term real investments such as housing. With an increase in delinquency rates of subprime mortgages, uncertainty about the performance of returns of those investments emerged. This led to various kinds of run-like events in the shadow banking sector, including the collapse of the market for asset-backed commercial papers (ABCP) (Kacperczyk and Schnabl, 2009; Acharya et al., 2013; Covitz et al., 2013), the counterparty runs on Bear Stearns and Lehman Brothers in tri-party repo (Copeland et al., 2011; Krishnamurthy et al., 2014), and the large-scale run on the money market fund industry in the aftermath of the Lehman failure (Kacperczyk and Schnabl, 2013; Schmidt et al., 2014). The turmoil in the shadow banking sector ultimately translated into broader financial-sector turmoil in which several commercial banks were on the brink of failure. Ultimately, governments and central banks had to intervene on a large scale.

We develop a model in which shadow banking emerges alongside commercial banking in order to circumvent financial regulation. We show that if the shadow banking sector grows too large, fragility arises in the sense that panic-based runs may occur. The size of the shadow banking sector is crucial because it determines the volume of assets being sold on the secondary market in case of a run. We assume that arbitrage capital in this market is limited. Therefore, if the shadow banking sector is too large relative to available arbitrage capital, fire-sale prices are depressed due to cash-in-the-market pricing, and self-fulfilling runs become possible. Moreover, if shadow banking activities are intertwined with activities of commercial banks, a crisis in the shadow banking sector may also trigger a crisis in the regulated banking sector. Eventually, the efficacy of existing safety nets for regulated banks may be undermined. By considering regulatory arbitrage, our model challenges the view that a credible deposit insurance may eliminate adverse run equilibria in model with maturity transformation at no cost.

The term "shadow banking" was coined during the 2007-09 financial crisis in order to describe financial intermediation activities that were unknown to a broader public prior to the crisis.[1] However, the term is imprecise and ambiguous, and its definition varies

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[1]The expression was first used by Paul McCulley at the Jackson Hole Symposium in Wyoming, who described shadow banking as "the whole alphabet soup of levered up non-bank investment conduits, vehicles, and structures" (McCulley, 2007).

substantially even within the academic debate. Among the most prominent definitions are the ones by Pozsar et al. (2013), by the Financial Stability Board (FSB, 2013), and by Claessens and Ratnovski (2014).[2] Building on these definitions, we use the term "shadow banking" to describe banking activities (risk, maturity, and liquidity transformation) that take place outside the regulatory perimeter of banking and do not have direct access to public backstops, but may require backstops to operate.

Prior to the crisis, shadow banking had evolved as a popular alternative to commercial banking in order to finance long-term real investments via short-term borrowing. E.g., asset-backed securities (ABS) were financed through asset-backed commercial papers (ABCP). While the shadow banking sector had a stable record prior to the crisis, its activities expanded rapidly in the years up to the crisis (see, e.g., FCIC, 2011; FSB, 2013; Claessens et al., 2012).[3]

The 2007-09 financial crisis began when an increase in delinquency rates of subprime mortgages induced uncertainty about the performance of ABS. In August 2007, BNP Paribas suspended convertibility of three of its funds that were exposed to risk of subprime mortgages bundled in ABS, and there was a sharp contraction of short-term funding of off-balance sheet conduits such as ABCP conduits and structured investment vehicles (SIVs) that financed their ABS holdings by issuing ABCP and medium-term notes (Kacperczyk and Schnabl, 2009). The empirical evidence suggests that this contraction resembled the essential features of a run-like event or a rollover freeze in the ABCP market (see Covitz et al., 2013). Due to the breakdown of the ABCP market and due to continuing bad news from the housing market, the institutions that produced ABS got into trouble. This culminated in the counterparty runs on Bear Stearns in March 2008 in tri-party repo, and finally in the collapse of Lehman Brothers in September 2008.[4] The failure of Lehman Brothers caused further turmoil, including "Reserve

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[2]Pozsar et al. (2013) define shadow banking as "credit, maturity, and liquidity transformation without direct and explicit access to public sources of liquidity or credit backstops". The FSB (2013) describes shadow banking as "credit intermediation involving entities and activities (fully or partially) outside the regular banking system". Finally, Claessens and Ratnovski (2014) propose the label "shadow banking" for "all financial activities, except traditional banking, which require a private or public backstop to operate". All approaches describe shadow banking as financial activities that are similar to those of traditional banks. While the FSB emphasizes regulatory aspects, the other two address the access to or the need for backstops. Our definition borrows from all three and tries to combine the different aspects.

[3]The only MMF that ever broke the buck before Lehman's default was the "Community Bankers Money Fund" (see Kacperczyk and Schnabl (2013)). Shadow banking activities had been evolving since the 1970s and experienced a growth boost in the 1990s when MMFs expanded their investments from government and corporate bonds towards ABS also.

[4]In the direct aftermath of the crisis, the academic debate had – due to the availability of data –

Primary Fund" breaking the buck, thus finally triggering a full-blown run on the money market fund industry (Kacperczyk and Schnabl, 2013; Schmidt et al., 2014). Our model contributes to the theoretical understanding for why sharp contraction in short-term funding may occur in the shadow banking sector. In particular, our model offers a rationale of how regulatory arbitrage may set the stage for panic-based runs such as the run on ABCP conduits and MMFs in the 2007-09 crises, and how such runs can also adversely affect the regulated banking sector – even in the absence of runs on commercial banks.

We discuss a simple banking model of maturity transformation in the tradition of Diamond and Dybvig (1983) and Qi (1994) in order to illustrate how shadow banking can sow the seeds of a financial crisis. In our model, commercial banks' liabilities are covered by a deposit insurance. Because this might induce moral hazard on the part of the banks, they are subject to regulation, which induces regulatory costs for the banks. The shadow banking sector competes with commercial banks in offering maturity transformation services to investors. In contrast to commercial banks, shadow banking activities are neither covered by the safety net nor burdened with regulatory costs.

Our first key result is that the relative size of the shadow banking sector determines its stability. If the short-term financing of shadow banks breaks down, they are forced to sell their securitized assets on a secondary market. The liquidity in this market is limited by the budget of arbitrageurs. If the size of the shadow banking sector is small relative to the capacity of this secondary market, shadow banks can sell their assets at face value in case of a run. Because they can raise a sufficient amount of liquidity in this way, a run does not constitute an equilibrium. However, if the shadow banking sector is too large, the arbitrageurs' budget does not suffice to buy all assets at face value. Instead, cash-in-the-market pricing à la Allen and Gale (1994) leads to depressed fire-sale prices in case of a run. Because shadow banks cannot raise a sufficient amount of liquidity, self-fulfilling runs constitute an equilibrium. Depressed fire-sale prices are reminiscent of theories on the limits to arbitrage (see, e.g., Shleifer and Vishny, 1992, 1997, 2011) and give rise to multiple equilibria in our model.

As a second key result we find that if commercial banks themselves operate shadow banks, a larger size of the shadow banking sector is sustainable. In this case, the shadow banking sector indirectly benefits from the safety net for commercial banks. Because of

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largely focused on the run on repo (Gorton and Metrick, 2012). Copeland et al. (2011) as well as Krishnamurthy et al. (2014) point out that the repo market experienced a margin spiral in the sense of Brunnermeier and Pedersen (2009), but did not necessarily experience a run. The counterparty runs on Bear Stearns in tri-party repo programs in March 2008 and the run on Lehman Brother in September 2008 are exceptions.

this safety net, bank depositors never panic and banks thus have additional liquid funds to support their shadow banks. This enlarges the parameter space for which shadow banking is stable. However, once the threat of a crisis reappears, a crisis in the shadow banking sector also harms the sector of regulated commercial banking.

Finally, the third important result is that a safety net for banks may not only be unable to prevent a banking crisis in the presence of regulatory arbitrage. In fact, it may become tested and costly for the regulator (or taxpayer). If banks and shadow banking are separated, runs only occur in the shadow banking sector, while the regulated commercial banking sector is unaffected. If they are intertwined, a crisis in the shadow banking sector translates into a system-wide crisis and ultimately the safety net becomes tested, and eventually costly, for its provider. This is at odds with the view that safety nets such as a deposit insurance are an effective measure to prevent panic-based banking crises. In traditional banking models of maturity transformation, such as Diamond and Dybvig (1983) and Qi (1994), credible deposit insurance can break the strategic complementarity of investors and eliminate adverse run equilibria at no costs, as it is never tested. The efficacy of such safety nets was widely agreed upon until recently; see, e.g., Gorton (2012) on "creating the quiet period". We show that this may not be the case when regulatory arbitrage is possible. Regulatory arbitrage may undermine the efficacy of safety nets.

For most parts of this paper we treat the shadow banking sector as consisting of one vertically integrated institution. However, we show that our model can be extended such that its structure is closer to the actual shadow banking sector in the US prior to the crisis, see also Figure 5. We mostly follow and simplify the descriptions by (Pozsar et al., 2013) and show that all results hold when we consider a shadow banking sector that consists of investment banks (broker dealers), ABCP conduits such as special investment vehicles (SIVs) and money market mutual funds (MMFs) instead of single shadow banks. This also allows us to derive separate conditions for runs from investors on MMFs and for runs from MMFs on ABCP conduits.

The main contribution of this paper is to show how regulatory arbitrage-induced shadow banking can contribute to the evolution of financial crises. We illustrate how shadow banking activities undermine the effectiveness of a safety net that is installed to prevent self-fulfilling bank runs. Moreover, we show how shadow banking may make the safety net costly for the regulator in case of a crisis. We argue that the understanding of how shadow banking activities contribute to the evolution of systemic risk is not only key to understanding the recent financial crisis. Our results indicate that circumvention of regulation can generally have severe adverse consequences on financial stability. We

argue that it is an essential part of any analysis of the efficacy of regulatory interventions to consider the extent of possible regulatory arbitrage. Thus, this paper is not only concerned with the 07-09 crisis but attempts to make more general point on the dangers associated with regulatory arbitrage. This may be of importance for those economies in which shadow banking is booming such as currently in China (see Awrey, 2015; Dang et al., 2014).

While the simple nature of our model keeps the analysis tractable, we exclude certain features that might be considered relevant. In our view, the most important ones are the following two: First, in our model, a financial crisis is a purely self-fulfilling phenomenon. We do not claim that the turmoils in summer 2007 were a pure liquidity problem. Clearly, ABCP conduits had severe solvency problems as a consequence of increased delinquency rates. However, this paper is an attempt to demonstrate how the structure of the financial system can set the stage for a severe fragility: because of maturity mismatch in a large shadow banking sector without an explicit safety net, small shocks can lead to large repercussions. Second, by focusing on regulatory arbitrage as the sole reason for the existence of shadow banking, we ignore potential positive welfare effects of shadow banking and securitization. There are several other rationales for why shadow banking exists: securitization can be an effective instrument to share macroeconomic interest rate risk (Hellwig, 1994) or to cater to the demand for safe debt (Gennaioli et al., 2013); it can make assets marketable by overcoming adverse selection problems (Gorton and Pennacchi, 1990, 1995; Dang et al., 2013); and it can increase the efficiency of bankruptcy processes (Gorton and Souleles, 2006). In contrast, we focus on the regulatory arbitrage hypothesis which has received considerable support by the empirical findings of Acharya et al. (2013). Therefore, it is important to keep in mind that whenever we speak of shadow banking and its consequences for financial stability, we mainly address shadow banking that originates from regulatory arbitrage. However, the fragility that we find in our model may arguably also exists in a different context.

There is a fast-growing literature on theoretical aspects of shadow banking. Our modeling approach is related to the paper by Martin et al. (2014). However, their focus lies the run on repo and on the differences between bilateral and tri-party repo in determining the stability of single financial institutions. In turn, we focus on ABCP and system-wide crises. The paper by Bolton et al. (2011) is the first contribution to provide an origination and distribution model of banking with multiple equilibria in which adverse selection is contagious over time. Gennaioli et al. (2013) provide a model in which the demand for safe debt drives securitization. In their framework, fragility in the shadow banking sector arises when tail-risk is neglected.

Other contributions that deal with shadow banking are Ordoñez (2013), Goodhart et al. (2012, 2013), and Plantin (2014). Ordoñez focuses on potential moral hazard on the part of banks. In his model, shadow banking is potentially welfare-enhancing as it allows to circumvent imperfect regulation. However, it is only stable if shadow banks value their reputation and thus behave diligently; it becomes fragile otherwise. The emphasis of Goodhart et al. lies on incorporating shadow banking into a general equilibrium model. Plantin studies the optimal prudential capital regulation when regulatory arbitrage is possible. In contrast to all three, we focus on the destabilizing effects of shadow banking in the sense that it gives rise to run equilibria.

This paper proceeds as follows: In Section 2, we illustrate the baseline model of maturity transformation. In Section 3, we extend the model by a shadow banking sector and analyze under which conditions fragility arises. In Section 4, we show how the results change when commercial banks themselves operate shadow banks. Finally, we analyze different types of runs in the shadow banking sector in Section 5, and conclude in Section 6.

2. A Model of Intergenerational Banking

Our baseline model is an overlapping-generation version of the model of maturity transformation by Diamond and Dybvig (1983) which was first introduced by Qi (1994).

There is an economy that goes through an infinite number of time periods $t \in \mathbb{Z}$. There exists a single good that can be used for consumption as well as investment. In each period t, a new generation of investors is born, consisting of a unit mass of agents. Each investor is born with an endowment of one unit of the good, and her lifetime is three periods: $(t, t+1, t+2)$. Upon birth, all investors are identical, but in period $t+1$, their type is privately revealed: With a probability of π, an investor is impatient and her utility is given by $u(c_{t+1})$. With a probability of $1-\pi$, the investor is patient and her utility is given by $u(c_{t+2})$. Assume that the function $u(\cdot)$ is strictly increasing, strictly concave, twice continuously differentiable, and satisfies the following Inada conditions: $u'(0) = \infty$, and $u'(\infty) = 0$.

In each period t, there are two different assets (investment technologies): a short asset (storage technology), and a long asset (production technology). The short asset transforms one unit of the good at time t into one unit of the good at $t+1$, thus effectively storing the good. The long asset is represented by a continuum of investment projects. An investment project is a metaphor for an agent who is endowed with a project (e.g., an entrepreneur with a production technology or a consumer who desires to finance a

house), but has no funds she can invest.

There is no aggregate, but only idiosyncratic return risk: each investment project requires one unit of investment in t and yields a stochastic return of R_i units in $t + 2$. The return R_i is the realization of an independently and identically distributed random variable $\tilde{R}$, characterized by a probability distribution F. F is continuous and strictly increasing on some interval $[\underline{R}, \overline{R}] \subset \mathrm{R}^+$, with $\mathrm{E}[R_i] = R > 1$. We assume that the realization of an investment project's long-term return, R_i, is privately revealed to whoever finances the project.

The idiosyncratic return risk of the long asset implies that financial intermediaries dominate a financial markets solution in terms of welfare because of adverse selection in the financial market.[5] In turn, unlike participants of a financial market, a financial intermediary will not be subject to these problems as he is able to diversify and create assets that are not subject to asymmetric information.

Finally, an investment project may be physically liquidated prematurely in $t + 1$, yielding a liquidation return of $\ell R_i / R$, where $\ell \in (0, 1/R)$. The liquidation return of a project thus depends on the project's stochastic long-term return. The average liquidation return of a project is equal to ℓ.

Intergenerational Banking

In the following, we describe the mechanics of intergenerational banking and derive steady state equilibria, closely following Qi (1994). We assume that there is a banking sector operating in the economy, consisting of identical infinitely lived banks that take deposits and make investments. It is assumed that the law of large numbers applies at the bank level, i.e., a bank neither faces uncertainty regarding the fraction of impatient investors nor regarding the aggregate return of the long asset.

In each period $t \in \mathrm{Z}$, banks receive new deposits D_t. They sign a demand-deposit contract with investors which specifies a short and a long interest rate. Per unit of deposit, an investor is allowed either to withdraw $r_{t,1}$ units after one period, or $r_{t,2}$ units after two periods. In period t, banks yield the returns from the last period's investment in storage, S_{t-1}, and the returns from investment in the production technology in the second but last period, I_{t-2}. They can use these funds to pay out withdrawing investors and to make new investment in the production and in the storage technology.

We are interested in steady states of this intergenerational banking. A steady state is

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[5]Because asset quality is not observable, there is only one market price. Impatient consumers with high-return assets have an incentive to liquidate them instead of selling them, and patient consumers with low-return assets have an incentive to sell. This drives the market price below average return and inhibits the implementation of the first-best.

given by a collection of payoffs, i.e., a short and a long interest rate, (r_1, r_2), a deposit decision D, and an investment decisions I and S. We are only interested in those steady states in which investors deposit all their funds in the banks, $D = 1$, and the total investment in the storage and production technology does not exceed new deposits, i.e., $S + I \leq D$.[6] This yields the investment constraint

$$S + I \leq 1. \tag{1}$$

Moreover, we restrict attention to those steady states in which only impatient consumers withdraw early. We will show later that these withdrawal decisions as well as the deposit decision are actually optimal choices in a steady state equilibrium. In such a steady state, banks have to pay πr_1 units to impatient investors and $(1 - \pi)r_2$ units to patient consumers in every period. Since payoffs and investments are limited by returns and new deposits, the following resource constraint must hold:

$$\pi r_1 + (1 - \pi)r_2 + S + I \leq RI + S + 1. \tag{2}$$

This constraint can be simplified to obtain a simple feasibility condition for steady-state payoffs:

Definition 1 (Steady-state Payoff). *A steady-state payoff (r_1, r_2) is budget feasible if*

$$\pi r_1 + (1 - \pi)r_2 \leq (R - 1)I + 1. \tag{3}$$

In a next step, we want to select the optimal steady state among the set of budget feasible steady states. Our objective is to choose the steady state that maximizes the welfare of a representative generation of investors, or equivalently, the expected utility of one representative investor. We can partition this analysis by deriving the optimal investment behavior of banks in a first step, and then addressing the optimal interest rates. We see that the budget constraint (3) is not influenced by S. Thus, the banks' optimal investment behavior follows directly:

Lemma 1 (Optimal Investment). *The optimal investment behavior of banks is given by $I = 1$ and $S = 0$, i.e., there is no investment in storage. The budget constraint reduces to*

$$\pi r_1 + (1 - \pi)r_2 \leq R. \tag{4}$$

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[6]Steady states with $S + I > D$ also exists, but in those equilibria, banks have some wealth which is kept constant over time, the net returns of which are payed out to investors each period. This scenario does not appear particularly plausible or interesting.

The intergenerational feature of banking implies that storage is not needed for the optimal provision of liquidity. Any investment in storage would be inefficient and would hence imply a deterioration.

We can now derive the optimal steady-state payoffs (r_1, r_2), i.e., the optimal division between long and short interest rate. It is straightforward to see that the first-best steady-state payoff is given by perfect consumption smoothing, $(r_1^{FB}, r_2^{FB}) = (R, R)$. However, the first-best cannot be implemented as it is not incentive compatible. The incentive-compatibility and participation constraints are given by

$$r_1 \leq r_2, \tag{5}$$

$$r_1^2 \leq r_2, \tag{6}$$

$$\text{and} \quad r_2 \geq R. \tag{7}$$

Constraint (5) ensures that patient investors wait until the last period of their lifetime instead of withdrawing early and storing their funds. Constraint (6) ensures that patient investors do not withdraw early and re-deposit their funds. By this type of re-investment, investors can earn the short interest rate twice. As long as net returns are positive, the latter condition is stronger, implying that the yield curve must not be decreasing. Finally, constraint (7) ensures that investors do not engage in private investment and side-trading. In fact, this condition is the upper bound to the side-trading constraint. The adverse selection problem induced by the idiosyncratic return risk relaxed this constraint, but the constraint will turn out not to be binding anyhow.

Obviously, constraint (6) is violated in the first-best, inducing patient investors to withdraw early and to deposit their funds in the banks a second time. In the second-best, constraints (4) and (6) are binding, resulting in a flat yield curve, $r_2 = r_1^2$. Following Equation (4), the interest rate is such that

$$\pi r_1 + (1 - \pi) r_1^2 = R. \tag{8}$$

Proposition 1 (Qi 1994)**.** *In the second-best steady state, the intergenerational banking sector collects the complete endowment, $D = 1$, and exclusively invests in the long-asset, $I = 1$. In exchange, banks offer demand-deposit contracts with a one-period interest rate given by*

$$r_1^* = \frac{\sqrt{\pi^2 + 4(1 - \pi)R} - \pi}{2(1 - \pi)}, \tag{9}$$

and a two-period interest rate given by

$$r_2^* = r_1^{*2}. \tag{10}$$

It holds that $r_2^* > R > r_1^* > 1$. Unlike in the Diamond and Dybvig (1983) model, the first-best and the second-best do not coincide. The intergenerational structure introduces the new IC constraint that the long interest rate must be sufficiently larger than the short one in order to keep patient investors from withdrawal and reinvestment.[7]

Steady-State Equilibrium

Until now, we have not formally specified the game in a game-theoretic sense. Consider the infinite game where in each period $t \in \mathbb{Z}$, investors born in period t decide whether to deposit, and investors born in $t - 1$ decide whether to withdraw or to wait for one more period. We do not engage in a full game-theoretic analysis. In particular, we do not characterize all equilibria of this game, but only focus on the equilibrium characterized by the above steady state, and analyze potential deviations. Banks are assumed to behave mechanically according to this steady state.

Lemma 2. *The second-best steady state constitutes an equilibrium of the infinite game.*

If all investors deposit their funds in the banks, and if only impatient consumers withdraw early, it is in fact individually optimal for each investor to do the same. The second-best problem already incorporates the incentive compatibility constraints as well as the participation constraint. Patient investors have no incentive to withdraw early, given that all other patient investors behave in the same way and given that new investors deposit in the bank. Nor do investors have an incentive to invest privately in the production or storage technology, as the bank offers a weakly higher long-run return that R.

Fragility

We will now study the stability of intergenerational banking in the absence of a deposit insurance. Models of maturity transformation such as Diamond and Dybvig (1983) and Qi (1994) may exhibit multiple equilibria in their subgames. Strategic complementarity between the investors may give rise to equilibria in which all investors withdraw early, i.e., bank run equilibria.

In the following, we analyze the subgame starting in period t under the assumption that behavior until date $t - 1$ is as in the second-best steady-state equilibrium. We derive the condition under which banks might experience a run by investors, i.e., the condition for the existence of a run equilibrium in the period-t subgame. In the case

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[7]However, the intergenerational structure also relaxes the feasibility constraint. Although the yield curve is allowed to be decreasing in the model of Diamond and Dybvig (1983), the second-best of intergenerational banking dominates the first-best of Diamond and Dybvig (1983) for a large set of utility functions because banks do not have to rely on inefficient storage.

of intergenerational banking, we consider a "run" in period t to be an event in which all investors born in $t-1$ withdraw their funds, and none of the newly-born investors deposit their endowment. In case of such a run, the bank has to liquidate funds in order to serve withdrawing investors. In addition to the expected withdrawal of impatient consumers, the bank now also has to serve one additional generation of patient investors withdrawing early.

Lemma 3. *Assume that the economy is in the second-best steady state. In case of a run, the banks' liquidity shortfall is $(1-\pi)r_1^*$.*

Proof. In case of such a run in period t, banks have to repay what they have invested on behalf of the mass of $(1-\pi)$ patient investors in $t-2$ who have claims worth r_1^{*2}. Moreover, they have to pay all funds that they invested on behalf of those investors from $t-1$ who have claims worth r_1^*. Banks thus need a total amount of $(1-\pi)r_1^{*2} + r_1^*$ in case of a run.

However, banks only have an amount R of liquid funds available in t from the investment they made in $t-2$. Recall from Proposition 1 that $\pi r_1^* + (1-\pi)r_1^{*2} = R$. The banks' liquidity shortfall in case of a run by investors is thus given by

$$(1-\pi)r_1^{*2} + r_1^* - R = (1-\pi)r_1^*. \tag{11}$$

$\square$

Let us assume that the liquidation rate is sufficiently small relative to the potential liabilities of banks in case of a run:

Assumption 1. $\ell < (1-\pi)r_1^*$.

Assumption 1 implies that, if in some period t all depositors withdraw their funds and newborn investors do not deposit their endowment, the liquidation return that the bank can realize does not suffice to serve all withdrawing consumers. Therefore, the bank is illiquid and insolvent.

Proposition 2. *Assume that the economy is in the second-best steady state. In the subgame starting in period t, a run of investors on banks constitutes an equilibrium.*

This proposition states that the steady state is fragile in the sense that there is scope for a run. Assumption 1 implies that it is optimal for a patient investor to withdraw early if all other patient investors do so and if new investors do not deposit. Note that Proposition 2 only states that a run is an equilibrium of a subgame, but does not

say anything about equilibria of the whole game. However, our emphasis lies on the stability/fragility of the steady-state equilibrium.

An important insight from Diamond and Dybvig (1983) and Qi (1994) is that a credible deposit insurance may actually eliminate the adverse equilibrium at no cost. If the insurance is credible, it eliminates the strategic complementarity and is thus never tested. In fact, this is also true in the setup described above. Assume that there is a regulator that can cover the liquidity shortfall in any contingency, including a full-blown bank run. In the context of our model, this amounts to assuming that the regulator has funds of $(1-\pi)r_1^* - \ell$ at its disposal in any period. Whenever patient investors are guaranteed an amount r_1^* by the regulator, they do not have an incentive to withdraw early.[8] In contrast, this does not hold in the presence of regulatory arbitrage, as we will show in the following sections.

3. Banks and Shadow Banking

We now extend the model described above by three elements: First, we make the assumption that commercial banks are covered by a safety net, but are also subject to regulation and therefore have to bear regulatory costs. Second, there are unregulated shadow banks that compete with banks by also offering maturity transformation services. Investors can choose whether to deposit their funds in a bank or in the shadow bank. Depositing in the shadow bank is associated with some opportunity cost that varies across investors. Third, there is a secondary market in which shadow banks can sell their assets to arbitrageurs. The amount of liquidity in this market is assumed to be exogenous.

In the following, we describe the extended setup in detail and derive the steady-state equilibrium, before analyzing whether the economy is stable or whether it features multiple equilibria and panic-based runs may occur.

Commercial Banking and Regulatory Costs

From now on, we assume that commercial banks are covered by a safety net that is provided by some unspecified regulator, ruling out runs in the commercial banking sector.[9] Because of this safety net, banks are not disciplined by their depositors, such that – in a

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[8]We ignore the possibility for suspension of convertibility. Diamond and Dybvig (1983) already indicate that suspension of convertibility is critical if there is uncertainty about the fraction of early and late consumers. Moreover, as Qi (1994) shows, suspension of convertibility is also ineffective if withdrawing depositors are paid out by new depositors.

[9]The regulator is assumed to have sufficient funds to provide a safety net. Moreover, he can commit to actually applying the safety net in case it is necessary, i.e., in case of a run.

richer model – moral hazard could arise. We therefore assume that banks are regulated (e.g., they are subject to a minimum capital requirement). This is assumed to be costly for the bank. In what follows, we will not model the moral hazard explicitly and assume that regulatory costs are exogenous. However, in Appendix A we provide an extension of our model in which we illustrate how moral hazard may arise from the existence of the safety net, and why costly regulation is necessary to prevent moral hazard. The presence of a credible deposit insurance implies that depositors have no incentive to monitor their bank. Because banks have limited liability, this gives bankers an incentive to engage in excessive risk-taking or to invest in assets with private benefits. This in turn calls for regulatory interventions, e.g., in the form of minimal capital requirements which are costly for bank managers.

We assume that banks have to pay a regulatory cost γ per unit invested in the long asset, resulting in a gross return of $R - \gamma$. We further assume that regulatory costs are not too high, i.e., even after subtracting the regulatory costs, the long asset is still more attractive than storage.

Assumption 2. $R > 1 + \gamma$.

Because of the lower gross return, banks can now only offer a per-period interest rate r_b such that

$$\pi r_b + (1 - \pi)r_b^2 = R - \gamma. \tag{12}$$

Under this regulation, the interest rate on bank deposits is explicitly given by

$$r_b = \frac{\sqrt{\pi^2 + 4(1 - \pi)(R - \gamma)} - \pi}{2(1 - \pi)}. \tag{13}$$

The banking sector thus functions like the banking sector in the previous section. The only difference is that banks cannot transfer the gross return R to investors, but only the return net of regulatory cost, $R - \gamma$.

Shadow Banking

We now introduce a shadow banking sector that also offers credit, liquidity, and maturity transformation to investors. We start out with very simple structure of the financial system, see Figure 1. Shadow banks, like regular banks, invest in long assets and transform these investments into short-term claims. In this section, we do not distinguish between different actors in the shadow banking sector, but assume that there is one representative, vertically integrated institution that we call shadow bank. This shadow bank is essentially identical to a commercial bank, with the exception that its deposits
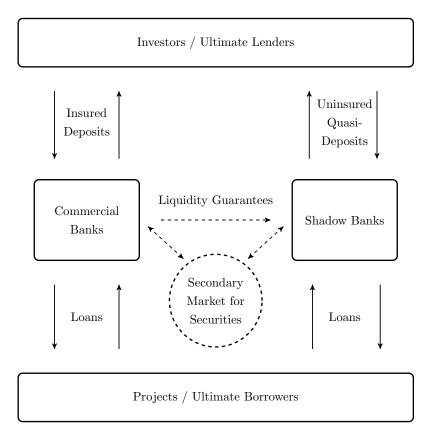
Figure 1: *Structure of the Financial System. Shadow banks, like regular banks, invest in long assets and transform these investments into short-term claims. There is a secondary market in which shadow banks can sell their assets to arbitrageurs.*

are not insured, and that it is not subject to the same regulation. While by legal standards shadow banks do not offer demand deposits in reality, they do issue claims that are essentially equivalent to demand deposits, such as equity shares with a stable net assets value (stable NAV). For tractability, we will assume that shadow banks are literally taking demand deposits.

We assume that shadow banks are subject to some shadow-banking cost. We assume that shadow banks face some cost of managing their loan portfolio, of securitizing loans, and of reporting to their investors. Since shadow banking is not completely unregulated, they might also incur some cost of regulation which is substantially smaller than that or regular banks. Finally, shadow banking cost may also include the cost of finding regulatory loopholes that allow to conduct shadow banking in the first place.

Shadow banks invest in a continuum of long assets with idiosyncratic returns R_i.

As the law of large numbers is assumed to apply, the return of their portfolio is R. Similar to regulatory costs, shadow banking is assumed to come with a per-unit cost of ρ. Therefore, the per-unit return of assets in the shadow banking sector is $R - \rho$. Similar to the regulatory cost γ, we also assume that the shadow-banking cost is not too high, i.e., even after subtracting the shadow-banking cost, the long asset is still more attractive than storage:

Assumption 3. $R > 1 + \rho$.

Given this shadow-banking cost, shadow banks offer a per-period interest rate r_{sb} to investors such that

$$\pi r_{sb} + (1 - \pi)r_{sb}^2 = R - \rho, \tag{14}$$

implying a return of

$$r_{sb} = \frac{\sqrt{\pi^2 + 4(1 - \pi)(R - \rho)} - \pi}{2(1 - \pi)}. \tag{15}$$

Secondary Markets and Arbitrageurs

There exists a secondary market for the shadow banks' assets. The potential buyers on this market are arbitrageurs who have an outside option with a risk-free return of $\hat{r}$, i.e., they are willing to buy the shadow banks' assets at a price that offers them a safe return of at least $\hat{r}$. Arbitrageurs can be thought of as experts (pension funds, hedge funds) that do not necessarily hold such assets in normal times, but purchase them if they are available at some discounts and thus promise gains from arbitrage. Moreover, we assume that arbitrageurs do not want to deposit their funds in shadow banks because their outside option is more attractive:

Assumption 4. $\hat{r} > r_{sb}$.

This reservation interest rate implies that arbitrageurs' reservation price for an asset with a return of $R - \rho$ is given by $p_a = (R - \rho)/\hat{r}$.

Assume that there is no market power on any side of the secondary market. Moreover, there is a fixed amount of cash in this market. We assume that arbitrageurs have a total budget of A, implying that cash-in-the-market pricing can occur. The equilibrium supply and price of shadow banks' assets on the secondary market will be derived below.

The idea behind this assumption is that not every individual or institution has the expertise to purchase these financial products. Moreover, the equity and collateral of these arbitrageurs is limited, so they cannot borrow and invest infinite amounts.[10]

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[10] See Shleifer and Vishny (1997) for a theory on the limits to arbitrage.

Upon birth, investors can choose whether to deposit their endowment in a regulated bank or in a shadow bank. Depositing at shadow bank comes at some opportunity cost. We assume that investors are initially located at a regulated bank. Switching to a shadow bank comes at a cost of s_i, where s_i is independently and identically distributed according to the distribution function G. We assume that G is a continuous function that is strictly increasing on its support R^+, and that $G(0) = 0$. The switching cost is assumed to enter into the investors' utility additively separable from the consumption utility.

This switching cost should not be taken literally. One can think of these costs as monitoring or screening costs for investors that become necessary when choosing a shadow bank (e.g., an MMF) as these are not protected by a deposit insurance (see Appendix A for more details). For simplicity, we have assumed that all depositors have the same size. However, we could alternatively come up with a model where investors have different endowments (see Appendix B). It is very plausible that the ratio of switching costs to the endowment is lower for larger investors (e.g., for corporations that need to store liquid funds of several millions for a few days). Another interpretation is the forgone service benefits that depositors lose when leaving commercial banks, such as payment services and ATMs.

Investors' Behavior

Given the interest rates of commercial banks, r_b, of shadow banks, r_{sb}, and given the switching cost distribution G, we can pin down the size of the shadow banking sector.

Lemma 4. *Assume that banks offer an interest rate r_b and shadow banks offer an interest rate of r_{sb}, as specified above. Then there exists a unique threshold s^* such that an investor switches to a shadow bank if and only if $s_i \leq s^*$. The mass of investors depositing in the shadow banking sector is given by $G(s^*)$. It holds that $s^* = f(\gamma, \rho)$, where $f_\gamma > 0$ and $f_\rho < 0$.*

Proof. Take r_b and r_{sb} as described above. We know r_b decreases in γ, and r_{sb} decreases ρ. Staying at a commercial bank provides an investor with an expected consumption utility of $EU_b = \pi u(r_b) + (1-\pi)u(r_b^2)$. Switching to a shadow bank is associated with an expected consumption utility of $EU_{sb} = \pi u(r_{sb}) + (1-\pi)u(r_{sb}^2)$. Observe that EU_b decreases in γ and EU_{sb} decreases in ρ.

An investor with switching cost s_i switches to the shadow banking sector if $EU_b < EU_{sb} - s_i$. This implies that all investors with $s_i \leq EU_{sb} - EU_b$ switch to shadow banks. We define $s^* \equiv f(\gamma, \rho) = EU_{sb}(\rho) - EU_b(\gamma)$. A mass $G(s^*)$ of each generation's investors switches to shadow banks, and a mass $1 - G(s^*)$ stays at commercial banks. Because

u is twice continuously differentiable, it holds that $\partial EU_b/\partial \gamma < 0$ and $\partial EU_{sb}/\partial \rho > 0$. Thus, f is a continuously differentiable function with $f_\gamma > 0$ and $f_\rho < 0$. $\qquad\square$

An investor with $s_i = s^*$ is indifferent between depositing at a bank or a shadow bank. All investors with lower switching costs choose a shadow; their mass is given by $G(s^*)$. The size of the shadow banking sector increases in the regulatory cost γ and decreases in the shadow-banking cost ρ. For the case of logarithmic utility, the switching point is given by $s^* = (2 - \pi)\gamma - \rho$.

We are now equipped to characterize the economy's steady state equilibrium:

Proposition 3. *In the second-best steady-state equilibrium, the intergenerational banking sector collects an amount of deposits $D_b = 1 - G(s^*)$ in each period, and invests all funds in the long-asset, $I_b = 1 - G(s^*)$. They offer demand-deposit contracts with a per-period interest rate of*

$$r_b = \frac{\sqrt{\pi^2 + 4(1-\pi)(R-\gamma)} - \pi}{2(1-\pi)}. \tag{16}$$

Shadow banks collect an amount of deposits $D_{sb} = G(s^*)$ and exclusively invest in ABS, $I_{sb} = 1 - G(s^*)$. They offer a demand-deposit contracts with a per-period interest rate of

$$r_{sb} = \frac{\sqrt{\pi^2 + 4(1-\pi)(R-\rho)} - \pi}{2(1-\pi)}. \tag{17}$$

It holds that $s^* = f(\gamma, \rho)$, where $f_\gamma > 0$ and $f_\rho < 0$. There are no assets traded in the secondary market.

Proposition 3 described the steady state in which regulated commercial banks and shadow banks coexist. The interest rates are given by r_b and r_{sb} and depend on γ and ρ, which determines the size of the shadow banking sector as described by Lemma 4. It is important to notice that, in this steady-state equilibrium, no assets are being sold to arbitrageurs on the secondary market, as there are no gains from trade.

3.1. Fragility of Shadow Banking

As in the previous section, we now study the stability of shadow banks. We analyze the subgame starting in period t under the assumption that behavior until date $t - 1$ is as in the steady-state equilibrium specified in Proposition 3. We derive the condition under which shadow banks might experience a run by investors, i.e., the condition for the existence of a run equilibrium in the period-t subgame.

Because deposits in the shadow banking sector are not insured, a run on shadow banks is not excluded per se. However, as will become clear below, runs only occur if

the shadow banking sector is too large. Generally, there are two types of runs that could potentially take place in the adverse equilibrium of the $t = 1$ subgame.

In our model, a run is the event where all old investors withdraw their funds from shadow banks, and new investors do not deposit any new funds. Whether a run on shadow banks constitutes an equilibrium depends on whether shadow banks can raise enough liquidity in the secondary market to serve all their obligations.

Lemma 5. *Assume that the economy is in the second-best steady state. In case of a run on shadow banks, their liquidity shortfall is given by $G(s^*)(1 - \pi)r_{sb}$.*

Proof. See proof of Lemma 3. $(1 - \pi)r_{sb}$ is the relative liquidity shortfall, the amount of missing liquidity per unit of investment in the shadow banking sector. □

In order to cover this shortfall, shadow banks can either sell their investment of period $t-1$ to the arbitrageurs, or they can liquidate these assets.[11] We assume that liquidation of assets will never be enough to cover the shortfall:

Assumption 5. $\ell < (1 - \pi)r_{sb}$.

This assumption implies that the liquidation value is sufficiently smaller than the long-run net return $R - \rho$. Similar to Assumption 1, also in the case of shadow banks, which pay a per-period interest of r_{sb}, liquidation cannot be used to serve investors.

In the last section, the assumption of a low liquidation value implied that (in the absence of a deposit insurance) a run on banks can always occur. The presence of arbitrageurs who are willing to buy shadow banks' assets in a secondary market implies that the threat of a run is not necessarily omnipresent. We will show that the arbitrageurs' valuation of these assets and, more importantly, the size of their budget determines whether run equilibria exist.

Lemma 6. *Assume that the economy is in the second-best steady state. A run on shadow banks constitutes an equilibrium of the period-t subgame if*

$$\frac{R - \rho}{\hat{r}} < (1 - \pi)r_{sb}. \tag{18}$$

If the arbitrageurs' outside option is very profitable, they are only willing to pay a low price. If this price is lower than the relative liquidity shortfall, a run is always

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[11]Liquidation is not essential to our model. It also goes through in case liquidation is not possible; we can just set $\ell = 0$.

self-fulfilling. Shadow banks have to sell their assets, and the resulting revenue does not suffice to serve all investors because the arbitrageurs' valuation and thus the market price are too low.

From now on, we will assume that the arbitrageurs' outside option is not too profitable, i.e., their reservation price is sufficiently large:

Assumption 6. $(R - \rho)/\hat{r} \geq (1 - \pi)r_{sb}$.

Observe that, in case of a run shadow banks' supply is partially inelastic as they have to cover their complete liquidity shortfall. There are two cases to be considered: In the first case, the arbitrageurs' funds are sufficient to purchase all funds the shadow banks sell at face value, while in the second case, the arbitrageurs' budget is not sufficient and the price is determined by cash-in-the-market pricing. Runs on shadow banks constitutes an equilibrium only in this second case.

Proposition 4. *Assume that the economy is in the second-best steady state. A run on shadow banks constitutes an equilibrium of the period-t subgame if and only if*

$$G(s^*) > \frac{A}{(1 - \pi)r_{sb}} \equiv \xi. \tag{19}$$

Proof of Proposition 4. Assume that investors collectively withdraw funds from shadow banks and deposit no new funds in period t. It will be optimal for a single investor also to withdraw if the shadow banks become illiquid and insolvent in t.

Recall from Lemma 5 that the liquidity shortfall of shadow banks in case of a run is given by $LS = G(s^*)(1 - \pi)r_{sb}$. Liquidating all assets would yield $G(s^*)\ell$. According to Assumption 5, this will always be less than the liquidity shortfall. Shadow banks will never be able to cover the liquidity shortfall by liquidating their assets.

The relevant question is whether shadow banks can raise sufficient funds by selling their assets to arbitrageurs. There are two conditions which are jointly necessary and sufficient: First, the funds of arbitrageurs have to exceed the liquidity shortfall, and second, the arbitrageurs' valuation of shadow banks' assets has to exceed the liquidity shortfall. The second condition is met by assumption.

Regarding the first condition, there are two cases to be considered: In the first case, the arbitrageurs' funds exceed the liquidity shortfall. Because the shortfall by assumption is lower than the valuation of arbitrageurs, their funds are sufficient to purchase all funds the shadow banks sell at the reservation price. In the second case, the arbitrageurs' budget is not sufficient, and the price is determined by cash-in-the-market pricing.

The first case is given by $A \geq (1 - \pi)r_{sb}G(s^*)$. All assets held by shadow banks can be sold at the arbitrageurs' reservation price $p_a = (R - \rho)/\hat{r}$. Because the arbitrageurs' valuation of shadow banks' assets as well as the amount of cash in the market exceeds the shadow banks' potential liquidity needs, all investors could be served in case of a run. It thus is a strictly dominant strategy for each old patient investor not to withdraw, and for new investors to deposit new funds, and a run does not constitute an equilibrium.

The second case is given by $A < (1 - \pi)r_{sb}G(s^*)$. In this case, shadow banks cannot sell all their assets at the arbitrageurs' reservation price. If all existing investors withdraw and no new investors deposit, shadow banks cannot raise the required funds to fulfill their obligations by selling their assets because the amount of assets on the secondary market exceeds the budget of arbitrageurs. The asset price drops below the reservation price and shadow banks are forced to sell their entire portfolio. Still, shadow banks can only raise a total amount A of liquidity, which is insufficient to serve withdrawing investors. It follows that, in this case, it is optimal for old and new investors to withdraw and not to deposit, respectively. A run thus constitutes an equilibrium if and only if the stated condition is satisfied. $\qquad\square$

The key mechanism giving rise to multiple equilibria is cash-in-the-market pricing (see, e.g., Allen and Gale, 1994) in the secondary market for long assets. It results from limited arbitrage capital (see, e.g., Shleifer and Vishny (1992)). The fact that there are not enough arbitrageurs (and that these arbitrageurs cannot raise enough funds) to purchase all assets of the shadow banks can induce the price of assets to fall short of p_a. This implies that shadow banks may in fact be unable to serve their obligations once they sell all their long-term securities prematurely. This, in turn, makes it optimal for investors to run on shadow banks once all other investors run.

In order to illustrate the role of limited availability of arbitrage capital we examine the hypothetical fire-sale price. Cash-in-the-market pricing describes a situation where the buyers' budget constraint is binding and the supply is fixed. The price adjusts such that demand balances the fixed supply. If the arbitrageurs' budget is a binding resource constraint, the price p is such that

$$pG(s^*) = A. \tag{20}$$

The fire-sale price is a function of the amount of assets that are on the market in case of a run on the shadow banking sector, which is given by the size of the shadow banking sector $G(s^*)$. The price is given by
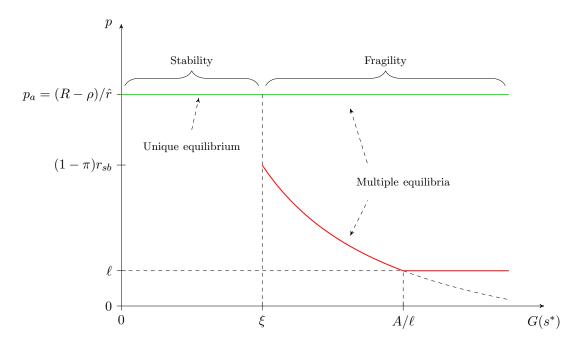
Figure 2: *Fire-sale Prices. This graph depicts the potential fire-sale prices of shadow banks' securities. Whenever $G(s^*) \leq \xi = A/(1-\pi)r_{sb}$, arbitrageurs' funds suffice to purchase all assets of shadow banks at face value. In the unique equilibrium of the period-t subgame, there are no panic-based withdrawals from shadow banks. In turn, if $G(s^*) > \xi$, the funds of arbitrageurs are insufficient, and the period-t subgame has multiple equilibria. If all investors withdraw from shadow banks, the price in the secondary market drops to the red line.*

$$p(s^*) = \begin{cases} (R-\rho)/\hat{r} & \text{if } G(s^*) \leq \xi, \\ A/G(s^*) & \text{if } G(s^*) \in (\xi, A/\ell], \\ \ell & \text{if } G(s^*) > A/\ell. \end{cases} \qquad (21)$$

The equilibrium fire-sale prices as a function of the size of the shadow banking sector is illustrated in Figure 2.

Whether the period t subgame has multiple equilibria ultimately depends on the parameters ρ and γ, as they determine the size of the shadow banking sector. This is depicted in Figure 3. Whenever the regulatory costs γ exceed the shadow-banking costs ρ (i.e., above the 45 degree line), the shadow banking sector has positive size in equilibrium, i.e. $G(s^*) > 0$. However, as long as the shadow banking sector is small relative to the arbitrageurs' budget, it is stable. Only when regulatory costs γ are
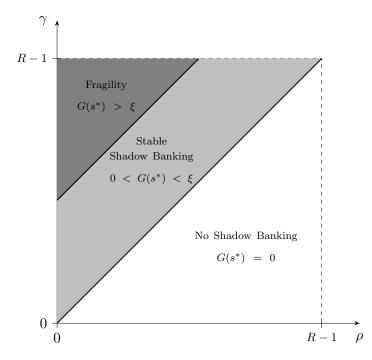
Figure 3: *Existence of Equilibria. This figure visualizes the equilibrium characteristics of the financial system for different values of γ and ρ. For $\gamma < \rho$, shadow banking is not made use of in equilibrium, as it is dominated by commercial banking. If $\gamma > \rho$, the shadow banking sector has positive size. As long as the difference $\gamma - \rho$ is small, shadow banking is stable. If the difference increases, the size of the shadow banking sector also increases and finally introduces fragility into the financial system.*

sufficiently larger than shadow-banking cost ρ does the size $G(s^*)$ of the shadow banking sector exceed the critical threshold ξ, and shadow banking becomes fragile.

3.2. Liquidity Guarantees

So far, there has been no connection between the regulated commercial banking sector and the shadow banking sector; both sectors compete for the investors' funds. We now assume that commercial banks themselves actively engage in shadow banking: They engage in shadow banking through off-balance sheet subsidiaries, i.e., they operate shadow banks as documented in Acharya et al. (2013). Our model provides a positive analysis, the fact that banks engage in shadow banking themselves does not result from optimal behavior in our setup. We assume that commercial banks explicitly or implicitly provide their shadow banks with liquidity guarantees. They may have strong incentives to support their conduits in case of distress, e.g., in order to protect their reputation, see

Segura (2014). Moreover, we assume that commercial banks can sell their assets on the same secondary market as shadow banks.[12]

As above, we assume that the commercial banks' demand-deposit liabilities are covered by a credible safety net. This safety net being credible implies that commercial banks do not experience runs by investors. Patient investors who are located at a commercial bank will thus never withdraw their funds early.

Liquidity guarantees imply that in case of a run on shadow banks, commercial banks supply them with liquid funds. This increases the critical size up to which the shadow banking sector is stable. However, this comes with an unfavorable side effect: Once this critical size is exceeded and shadow banks experience a run, the crisis spreads to the commercial banking sector and makes the safety net costly.

Proposition 5. *Assume that the economy is in the second-best steady state described in Proposition 3 and all shadow banks are granted liquidity guarantees by commercial banks. A run of investors on shadow banks constitutes an equilibrium of the subgame starting in period t if and only if*

$$G(s^*) > \frac{\max[A, \ell] + 1}{(1 - \pi)r_{sb} + 1} \equiv \vartheta, \tag{22}$$

where $s^* = f(\gamma, \rho)$. It holds that $\vartheta > \xi$.

Proof. In case of a run, the shadow banks' need for liquidity is given as above by

$$G(s^*)(1 - \pi)r_{sb}.$$

Banks can sell their loans on the same secondary market in case of a crisis. Still, the total endowment of arbitrageurs in this market is given by A. Therefore, either banks and shadow banks sell their assets in the secondary market, or both types of institutions liquidate their assets. They jointly still only raise an amount A from selling long-term securities on the secondary market or ℓ units from liquidating all long assets. The maximum amount they can raise is thus $\max[A, \ell]$. On top, commercial banks also have an additional amount $1 - G(s^*)$ of liquid funds available since new investors still deposit their endowment at commercial banks because of the safety net for commercial banks.

The liquidity guarantees by commercial banks can satisfy the shadow banks' liquidity needs in case of a run if

$$\max[A, \ell] + (1 - G(s^*)) \geq G(s^*)(1 - \pi)r_{sb}, \tag{23}$$

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[12]It is not straightforward that banks can sell their loans on the ABS market. In case of a crisis, however, banks might try to securitize their loan portfolio in order to sell it.

which is equivalent to

$$G(s^*) \leq \frac{\max[A, \ell] + 1}{(1 - \pi)r_{sb} + 1} = \vartheta. \tag{24}$$

If $G(s^*) \leq \vartheta$, the liquidity guarantees suffice to satisfy the liquidity needs in case of a run, so a run does not constitute an equilibrium. If $G(s^*) > \vartheta$, the liquidity guarantees do suffice to satisfy the liquidity needs in case of a run, and a run does constitute an equilibrium. □

If commercial banks themselves operate shadow banks and provide them with liquidity guarantees, the parameter space in which shadow banking is stable is enlarged compared to a situation without liquidity guarantees, i.e., the critical threshold for the size of the shadow banking sector ϑ is now larger than ξ, the threshold in the absence of liquidity guarantees. This shift is also depicted in Figure 4. The reason for this result is that banks have additional liquid funds, even in case of a crisis: Because of the deposit insurance, they always receive funds from new depositors, and their patient depositors never have an incentive to withdraw early.
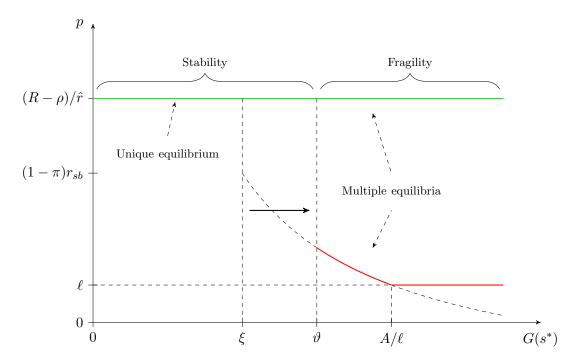

Figure 4: *Fire-sale Prices under Liquidity Guarantees. This graph depicts the potential fire-sale price of securities in case regulated commercial banks provide liquidity guarantees to shadow banks. The critical size above which multiple equilibria exist moves from ξ to ϑ.*

In traditional banking models, policy tools like a deposit insurance eliminate self-fulfilling adverse equilibria at no cost. This is not necessarily true in our model: once the shadow banking sector exceeds the size ϑ, a run in the shadow banking sector constitutes an equilibrium despite the safety net for commercial banks, and despite the liquidity guarantees of banks. Shadow banks – by circumventing the existing regulation – place themselves outside the safety net and are thus prone to runs. If the regulated commercial banks offer liquidity guarantees, a crisis in the shadow banking sector also spreads to the regulated banking sector. Ultimately, self-fulfilling adverse equilibria are not necessarily eliminated by the safety net and may become costly.

Corollary 1. *Assume that $G(s^*) > \vartheta$, and assume banks provide liquidity guarantees to shadow banks. In case of a run in the shadow banking sector, the safety net for regulated commercial banks is tested and the regulator must inject an amount*

$$G(s^*)(1-\pi)r_{sb} - \max[A, \ell] > 0. \tag{25}$$

Proof. This corollary follows directly from the proof of Proposition 5. $G(s^*)(1-\pi)r_{sb}$ denotes the liquidity need of shadow banks in case of a run, and $\max[A, \ell]$ denotes the amount that shadow banks can raise by selling or liquidating their assets. While commercial banks may cover part of the shadow banks' liquidity short-fall by fulfilling their liquidity guarantees, this amount also has to be compensated by the regulator because otherwise banks cannot serve their depositors in the future. $\square$

If the regulated commercial banking and the shadow banking sector are intertwined, a crisis may not be limited to the shadow banking sector, but also spread to the commercial banks, thus testing the safety net. Ultimately, the regulator has to step in and cover the commercial banks' liabilities. Therefore, the model challenges the view that policy measures like a deposit insurance necessarily are an efficient mechanism for preventing self-fulfilling crises. Historically, safety nets such as a deposit insurance schemes were perceived as an effective measure to prevent panic-based banking crises. The view is supported by traditional banking models of maturity transformation such as Diamond and Dybvig (1983) and Qi (1994). In the classic models of self-fulfilling bank runs, a credible deposit insurance can break the strategic complementarity in the withdrawal decision of bank customers at no cost. We show that this may not be the case when regulatory arbitrage is possible and regulated and unregulated banking activities are intertwined.

4. MMFs, ABCP Conduits, and SPV

In the last section we presented a model in which the shadow banking sector consisted of one vertically integrated, representative shadow bank. We will now consider a shadow banking sector that offers credit, liquidity, and maturity transformation to investors through vertically separated institutions. This structure of the shadow banking sector (compare Figure 5) is exogenous in our model. It is empirically motivated; we selectively follow and simplify the descriptions by Pozsar et al. (2013). Altogether, the actors of the shadow banking system invest in long assets and transform these investments into short-term claims. However, we distinguish between different actors in the shadow banking sector.

In our setup, shadow banking consists of special purpose vehicles (SPVs), ABCP conduits, and money market mutual funds (MMFs). Investment banks securitize assets such as loans (i.e., the long assets in our model) via SPVs, thereby transforming them into asset-backed securities (ABS). Through diversified investments, they eliminate the idiosyncratic risk of loans and conduct risk transformation. Note that SPVs typically do not lend to firms or consumers directly, but rather purchase loans from loan originators such as mortgage agencies or commercial banks.

SPVs buy long assets with idiosyncratic returns, transform them into ABS, and sell them to ABCP conduits. The empirically motivated narrative is that investment banks use SPVs to purchase loans from loan originators such as mortgage brokers or commercial banks. These SPVs bundle the claims into securitized loans (ABS), successfully diversifying the idiosyncratic return risk. Securitization makes the long assets tradable by eliminating the adverse selection problem that is associated with idiosyncratic return risk. For simplicity, we assume that the shadow-banking cost ρ occurs at this stage. Thus, the ABS that are sold by SPVs have a return of $R - \rho$.

ABCP conduits purchase these securitized assets with long maturities (ABS) and finance their business by issuing short-term claims that they sell to MMFs. To put it more technically, ABCP conduits (such as structured investment vehicles (SIVs)) purchase ABS and finance themselves through asset-backed commercial papers (ABCPs), which they sell to MMFs.[13] ABCP conduits hence conduct maturity transformation. Maturity transformation is the central element and the key service of banking in our model, and it is the main source of fragility.

For investors, MMFs are the door to the shadow banking sector as they transform short-term debt (such as ABCP) into claims that are essentially equivalent to demand

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[13]ABCP conduits also use other securities to finance their activities, such as medium term notes. For simplicity, we focus on ABCPs.
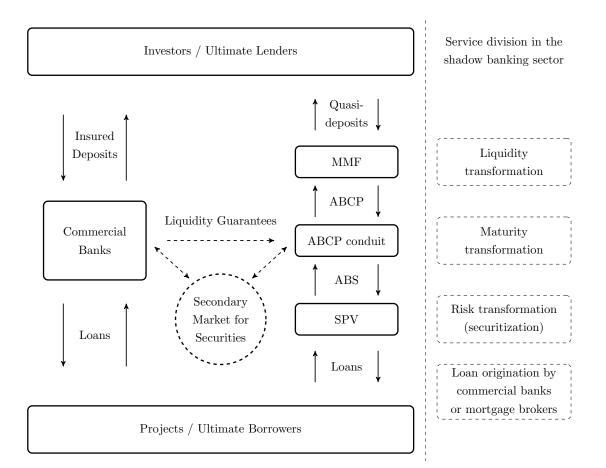
Figure 5: *Detailed Structure of Shadow Banking. The structure of the shadow banking sector is mostly exogenous in our model; we selectively follow and simplify the descriptions by Pozsar et al. (2013). Shadow banking consists of special purpose vehicle (SPVs), ABCP conduits such as structured investment vehicles (SIVs), and money market mutual funds (MMFs). SPVs transform assets into asset-backed securities (ABS) in order to make them tradable, i.e., they conduct risk and liquidity transformation (securitization). ABS have a long maturity; they are bought by ABCP conduits. ABCP conduits, in turn, use short-term debt to finance these long-term assets; they sell asset-backed commercial papers (ABCP) to MMFs, i.e., they conduct maturity transformation. MMFs are the door to the shadow banking sector: They offer deposit-like claims to investors, such as shares with a stable net assets value (NAV), thus conducting another form of liquidity transformation. Finally, there is a secondary market in which ABS can be sold to arbitrageurs.*

deposits, such as equity shares with a stable net assets value (stable NAV). MMFs thus conduct liquidity transformation. Again, we will assume that MMFs are literally taking demand deposits.

At the heart of the shadow banking sector is the maturity transformation by ABCP conduits. ABCP conduits purchase securitized assets (ABS) from investment banks' SPVs. As described above, these assets have a return of $R - \rho$ and a maturity of two periods. ABCP conduits can finance themselves by borrowing from MMFs via ABCPs. Moreover, they can also sell ABS to arbitrageurs in the secondary market as specified above. ABCP conduits may be legally independent entities, but they are largely founded and run by regulated banks in order to engage in unregulated off-balance sheet maturity transformation (Acharya et al., 2013). Because such maturity transformation is very fragile, banks stabilize their conduits by providing them with liquidity guarantees. In this section, we assume that ABCP conduits are fully insured through such liquidity guarantees.

Investors can access the services of the shadow banking sector via MMFs, which are assumed to intermediate between investors and ABCP conduits.[14] MMFs offer demand-deposit contracts to investors while purchasing short-term claims on ABCP conduits.[15] MMFs offer a per-period interest rate r_{mmf} to investors and purchase ABCP (short-term debt) with a per-period return r_{abcp}. Competition among MMFs and among ABCP conduits implies that $r_{mmf} = r_{abcp} = r_{sb}$. Investors face the same situation as described in the last section, and the size of the shadow banking sector is again given by $G(s^*)$.

In the following, we will analyze the fragility of the different institutions within the shadow banking sector. First, we will assume that MMFs have perfect support by a sponsor and analyze under which condition a run of MMFs on ABCP conduits constitutes an equilibrium. Second, we will relax the assumption of sponsor support and analyze under which conditions investors might run on MMFs.

4.1. Runs on ABCP Conduits

As in the previous section, we now study the stability of the shadow banking sector. We analyze the subgame starting in period t under the assumption that behavior until date $t - 1$ is as in the steady-state equilibrium specified in Proposition 3. We again analyze the case in which banks grant liquidity guarantees to the shadow banking sector, in

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[14]This is equivalent to assuming that investors face large transaction costs or do not have the expertise to buy ABCP directly.

[15]A MMF typically sells shares to investors, and the fund's sponsor guarantees a stable NAV, i.e., it guarantees to buy back shares at a price of one at any time. As mentioned above, the stable NAV implies that an MMF share is a claim that is equivalent to a demand-deposit contract.

this case to ABCP conduits. Moreover, we assume for the moment that MMFs receive absolutely credible sponsor support, implying that investors will never run on MMFs. We derive the condition under which ABCP conduits might experience a run by MMFs, i.e., the condition for the existence of a run equilibrium in the period-t subgame.

Proposition 6. *Assume that the economy is in the second-best steady state described in Proposition 3 and all ABCP conduits are granted liquidity guarantees by commercial banks. A run of MMFs on ABCP conduits constitutes an equilibrium of the subgame starting in period t if and only if*

$$G(s^*) > \frac{\max[A, \ell] + 1}{(1 - \pi)r_{sb} + 1} \equiv \vartheta, \tag{26}$$

where $s^* = f(\gamma, \rho)$. It holds that $\vartheta > \xi$.

Proof. See the proof of Proposition 5. MMFs have the same type of claims that investors had in the last section, and the ABCP conduits have the same liabilities and assets, i.e., the same maturity structure, that shadow banks had before. □

Proposition 6 is the equivalent to Proposition 4. If commercial banks engage in off-balance sheet activities, i.e., if banks themselves operate ABCP conduits and provide them with liquidity guarantees, the critical threshold for the size of the shadow banking sector is ϑ. Again, deposit insurance does not eliminate self-fulfilling adverse equilibria at no cost. If the shadow banking sector exceeds the size ϑ, a run in the shadow banking sector constitutes an equilibrium despite the safety net for commercial banks, and despite the liquidity guarantees of banks. By running off-balance sheet conduits and providing them with liquidity guarantees, banks circumvent the existing regulation and abuse their safety net.

The equivalent to Corollary 1 also holds in this setup:

Corollary 2. *Assume that $G(s^*) > \vartheta$, and assume banks provide liquidity guarantees to ABCP conduits. In case of a run in the shadow banking sector, the safety net for regulated commercial banks is tested and the regulator must inject an amount*

$$G(s^*)(1 - \pi)r_{sb} - \max[A, \ell] > 0. \tag{27}$$

Because the liquidity guarantees that commercial banks provide to ABCP conduits induces contagion of the regulated banking sector, a crisis becomes costly for the regulator.

4.2. Runs on MMFs

In the previous sections, we ruled out runs on MMFs by assuming that they have credible support by a sponsor. Credible sponsor support means that even if all investors withdraw their funds from an MMF, the sponsor is able to provide sufficient liquidity to the MMF such that it can serve all investors. Recall that we use the narrative that MMFs are literally offering demand-deposit contracts. In practice, an MMF issues equity shares, and its sponsor guarantees stable NAV for theses shares, i.e., it promises to buy these shares at face value in case of liquidity problems.

We now relax the assumption that the guarantee is always credible. We explicitly model the credibility of the guarantee by assuming that the sponsors have m units of liquidity per unit of investment in the MMF that they can provide in case of a crisis. Moreover, we keep the assumption of existing liquidity guarantees. We show that providing $mG(s^*)$ units only credibly prevents a run on MMFs if this amount is sufficient to fill the liquidity shortfall in case of a run of investors on MMFs, which in turn triggers a run of MMFs on ABCP conduits.

Proposition 7. *Assume that the economy is in the second-best steady state equilibrium described in Proposition 3. Assume further that all ABCP conduits are granted liquidity guarantees by commercial banks, and that per unit of investment, MMFs receive m units of liquidity support from their sponsor. A run of investors on MMFs may occur whenever*

$$G(s^*) > \frac{\max[A, \ell] + 1}{(1 - \pi)r_{sb} + 1 - m} = \nu > \vartheta. \tag{28}$$

If the $\nu > G(s^*) > \vartheta$, investors never run on MMFs. However, MMFs might run on ABCP conduits, which then draw on the sponsor support.

Proof. Observe that once an MMF needs liquid funds because investors withdraw unexpectedly, it will stop rolling over ABCP. Now, whenever the shadow banking sector exceeds the critical threshold ϑ, a run of MMFs on ABCP conduits is self-fulfilling, as ABCP conduits will make losses only in this case. This is therefore a necessary condition for a run by investors on MMFs. If it is not satisfied, MMFs are always able to fulfill their obligations by stopping the rollover of ABCP, making it a weakly dominant strategy for patient investors not to withdraw early. However, it is not a sufficient condition.

Observe that the resulting liquidity shortfall for the MMFs is given by

$$[(1 - \pi)r_{sb} + 1] G(s^*) - \max[A, \ell] - 1. \tag{29}$$

Therefore, a run of investors on MMFs constitutes an equilibrium only if

$$mG(s^*) < [(1 - \pi)r_{sb} + 1] G(s^*) - \max[A, \ell] - 1. \tag{30}$$

□

The result builds on the fact that sponsor support is like a liquidity backstop. If there is a run by MMFs on ABCP conduits, MMFs will make losses. This additionally triggers a run of investors on MMFs if the sponsor is not able to cover these losses. Again, losses depend on the fire-sale price. The fire-sale price, in turn, depends on the amount of assets sold in case of a run by MMFs on ABCP conduits, which is determined by the size of the shadow banking sector. If the shadow banking sector is so large that runs by MMFs on ABCP conduits occur, but not so large that losses cannot be covered by the sponsors, investors do not run. This is the case for $\nu > G(s^*) > \vartheta$. In turn, if the shadow banking sector size exceeds ν, a run by MMFs on ABCP conduits will always be accompanied by a run of investors on MMFs because sponsor support is insufficient to cover losses in case of a run.

5. Conclusion

The main contribution of this paper is to show how regulatory arbitrage-induced shadow banking can sow the seeds of a financial crisis. We illustrate how shadow banking activities undermine the effectiveness of a safety net that is installed to prevent a financial crisis. Moreover, we show how regulatory arbitrage may even induce the safety net to be costly for the regulator (or taxpayer) in case of a crisis.

Our model features multiple equilibria. The key mechanism giving rise to multiple equilibria is cash-in-the-market pricing in the secondary market for shadow banks' long-term securities which results from limited availability of arbitrage capital. Cash-in-the-market pricing leads to depressed fire-sale prices if there are too many assets on the market. The amount of assets is thus crucial in determining whether shadow banking is fragile or not. In turn, the amount of assets sold in case of a run on shadow banks is determined by the size of the shadow banking sector. Therefore, multiple equilibria only exist if the shadow banking sector is large.

As indicated earlier, our model lacks certain features that might be considered relevant that should be considered in future research. First, a financial crisis is a purely self-fulfilling phenomena in our model, while fundamental values do play a role in reality. However, this paper is an attempt to demonstrate how the structure of the financial system can set the stage for severe fragility: Because of maturity mismatch in a large shadow banking sector without access to a safety net, small shocks can lead to large repercussions. Second, by focusing on regulatory arbitrage as the sole reason for the existence of a shadow banking, we ignore potential positive welfare effects of shadow

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banking and securitization, such as catering to the demand for liquid assets or improving risk allocation. However, the fragility that arises in the context of regulatory arbitrage arguably also exists for other types of banking activities outside the regulatory perimeter.

Despite the simple nature of our model, we can still draw some conclusions. Our key finding is that the size of the shadow banking sector plays a crucial role for the stability of the financial system. However, the actual quantities of shadow banking activities are not completely clear to academics and regulators. Therefore, a first important implication of our model is that the size of the shadow banking sector (or, more precisely, the magnitude of maturity mismatch in the shadow banking sector) and the interconnectedness of banking and shadow banking should be variables that regulating authorities keep track of. The *Global Shadow Banking Monitoring Report 2013*[16] displays a very valuable step in the right direction. Still, the report calls for devoting even more resources to tackling concrete data issues. Our model can be taken as an argument in support of this view.

We make a strong case for why regulatory arbitrage poses a severe risk to financial stability. However, it would be wrong to conclude that regulation should thus be reduced.[17] One needs to keep in mind that – under the presumption that regulation is in place for a good reason – it is not regulation itself that poses a problem, but the circumvention of regulation. If the regulator insures depositors in order to eliminate self-fulfilling runs of depositors, she may need to impose some regulation on banks in order to prevent moral hazard. Regulatory arbitrage may eventually reintroduce the possibility of runs. However, this does not alter the fact that it is a good idea to aim at preventing runs in the first place.

Under the premise that regulatory arbitrage cannot be prevented at all, our model indicates that financial stability may not always be reached by providing a safety net and regulating banks. One may consider a richer set of policy interventions that go beyond safety nets and regulation. E.g., the government or the central bank may have the ability to intervene on the secondary market in case of a crisis. However, such interventions are likely to give rise to different problems as they may change incentives ex-ante, e.g., they may give rise to excessive collective maturity mismatch as in Farhi and Tirole (2012). A richer model than ours would be needed to analyze such effects consistently.

In turn, under the premise that regulatory arbitrage can be prevented or can be made more difficult, we argue that it should be prevented or at least reduced. Given that regulatory arbitrage can be very costly in terms of creating systemic risk, it should be made

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[16]FSB (2013).

[17]There are also argument against strict regulation, building on reputation concerns or charter value effects, see, e.g., Ordoñez (2013).

very costly to those who are conducting it. While this may sound self-evident at first, a glimpse at the history of bank regulation and its loopholes should be a reminder that regulatory arbitrage and the associated risks have not always been a major concern.[18]

The regulatory response to the 2007-09 financial crisis has tried to deal with many of the aspects in which shadow banking has contributed to the crisis by circumventing regulation. However, it is less clear what arbitrage of current regulation may look like, particularly because shadow baking activities are of great and still growing importance, especially in emerging countries such as China (Awrey, 2015; Dang et al., 2014). We argue that in a dynamic world with constant financial innovation, regulatory arbitrage is not adequately dealt with by focusing on regulatory loopholes of the past only. In contrast, prudential supervision calls for strong awareness and constant monitoring of newly developing forms of regulatory arbitrage.

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[18]See, e.g., Jones (2000) for an early analysis of how the Basel requirements were circumvented.

References

Acharya, Viral V., Philipp Schnabl, and Gustavo Suarez (2013). "Securitization without Risk Transfer". *Journal of Financial Economics* 107, 515–536.

Allen, Franklin, and Douglas Gale (1994). "Limited Market Participation and Volatility of Asset Prices". *American Economic Review* 84, 933–955.

Awrey, Dan (2015). "Law and Finance in the Chinese Shadow Banking System". *Cornell International Law Journal, forthcoming.*

Bolton, Patrick, Tano Santos, and Jose A. Scheinkman (2011). "Outside and Inside Liquidity". *Quarterly Journal of Economics* 126, 259–321.

Brunnermeier, Markus K. (2009). "Deciphering the Liquidity and Credit Crunch 2007-2008". *Journal of Economic Perspectives* 23, 77–100.

Brunnermeier, Markus K., and Lasse H. Pedersen (2009). "Market Liquidity and Funding Liquidity". *Review of Financial Studies* 22, 2201–2238.

Claessens, Stijn, and Lev Ratnovski (2014). "What is Shadow Banking?" *IMF Working Paper 14/25.*

Claessens, Stijn, Zoltan Poszar, Lev Ratnovski, and Manmohan Singh (2012). "Shadow Banking: Economics and Policy". *IMF Staff Discussion Note.*

Copeland, Adam, Antoine Martin, and Michael Walker (2011). "Repo Runs: Evidence from the Tri-Party Repo Market". *Federal Reserve Bank of New York Staff Reports.*

Covitz, Daniel, Nellie Liang, and Gustavo A. Suarez (2013). "The Evolution of a Financial Crisis: Panic in the Asset-Backed Commercial Paper Market". *The Journal of Finance* LXVII, 815–847.

Dang, Tri Vi, Gary B. Gorton, and Bengt Holmström (2013). "Ignorance, Debt and Financial Crises". *Working Paper.*

Dang, Tri Vi, Honglin Wang, and Aidan Yao (2014). "Chinese Shadow Banking: Bank-Centric Misperceptions". *Hong Kong Institute for Monetary Research Working Paper No. 22/2014.*

Diamond, Douglas W., and Philip H. Dybvig (1983). "Bank Runs, Deposit Insurance, and Liquidity". *Journal of Political Economy* 91, 401–419.

Farhi, Emmanuel, and Jean Tirole (2012). "Collective Moral Hazard, Maturity Mismatch and Systemic Bailouts". *American Economic Review* 102, 60–93.

FCIC – Financial Crisis Inquiry Commission (2011). *The Financial Crisis Inquiry Report.* Washington D.C.: Printing Office of the US Government.

FSB – Financial Stability Board (2013). *Global Shadow Banking Monitoring Report 2013.* Basel: Bank for International Settlement.

Gennaioli, Nicola, Andrei Shleifer, and Robert W. Vishny (2013). "A Model of Shadow Banking". *The Journal of Finance* LXVIII, 1331–1363.

Goodhart, Charles A. E., Anil K Kashyap, Dimitrios P. Tsomocos, and Alexandros P. Vardoulakis (2012). "Financial Regulation in General Equilibrium". *NBER Working Paper No. 17909*.

Goodhart, Charles A. E., Anil K. Kashyap, Dimitrios P. Tsomocos, and Alexandros P. Vardoulakis (2013). "An Integrated Framework for Analyzing Multiple Financial Regulations". *International Journal of Central Banking* 9, 109–143.

Gorton, Gary B. (2012). *Misunderstanding Financial Crises*. Oxford University Press.

Gorton, Gary B., and Andrew Metrick (2012). "Securitized Banking and the Run on Repo". *Journal of Financial Economics* 104, 425–451.

Gorton, Gary B., and George Pennacchi (1990). "Financial Intermediaries and Liquidity Creation". *The Journal of Finance* XLV, 49–71.

——— (1995). "Banks and Loan Sales: Marketing Nonmarketable Assets". *Journal of Monetary Economics* 35, 389–411.

Gorton, Gary B., and Nicholas S. Souleles (2006). "Special Purpose Vehicles and Securitization". In: *The risks of financial institutions*. Ed. by Rene M. Stulz, and Mark Carey. University of Chicago Press.

Hellwig, Martin (1994). "Liquidity Provision, Banking, and the Allocation of Interest Rate Risk". *European Economic Review* 38, 1363–1389.

Holmström, Bengt, and Jean Tirole (1997). "Financial Intermediation, Loanable Funds, and the Real Sector". *Quarterly Journal of Economics* 112, 663–691.

Jones, David (2000). "Emerging Problems with the Basel Capital Accord: Regulatory Capital Arbitrage and Related Issues". *Journal of Banking & Finance* 24, 35–58.

Kacperczyk, Marcin, and Philipp Schnabl (2009). "When Safe Proved Risky: Commercial Paper during the Financial Crisis of 2007-2009". *Journal of Economic Perspectives* 24, 29–50.

——— (2013). "How Safe are Money Market Funds?" *The Quarterly Journal of Economics* 218, 1073–1122.

Krishnamurthy, Arvind, Stefan Nagel, and Dmitry Orlov (2014). "Sizing Up Repo". *The Journal of Finance, forthcoming*.

Martin, Antoine, David Skeie, and Ernst-Ludwig von Thadden (2014). "Repo Runs". *Review of Financial Studies* 27, 957–989.

McCulley, Paul A. (2007). *Teton Reflections*. URL: http://www.pimco.com/EN/Insights/Pages/GCBFAugust-September2007.aspx (visited on 09/18/2014).

Ordoñez, Guillermo (2013). "Sustainable Shadow Banking". *NBER Working Paper No. 19022*.

Plantin, Guillaume (2014). "Shadow Banking and Bank Capital Regulation". *Review of Financial Studies, forthcoming.*

Pozsar, Zoltan, Tobias Adrian, Adam Ashcraft, and Hayley Boesky (2013). "Shadow Banking". *Federal Reserve Bank of New York Economic Policy Review*, 1–16.

Qi, Jianping (1994). "Bank Liquidity and Stability in an Overlapping Generations Model". *Review of Financial Studies* 7, 389–417.

Schmidt, Lawrence, Allan Timmermann, and Russ R. Wermers (2014). "Runs on Money Market Mutual Funds". *Working Paper.*

Segura, Anatoli (2014). "Why did Sponsor Banks Rescue their SIVs? A Signaling Model of Rescues". *Working Paper.*

Shleifer, Andrei, and Robert W. Vishny (1992). "Liquidation Values and Debt Capacity: A Market Equilibrium Approach". *The Journal of Finance* 47, 1343–1366.

——— (1997). "The Limits of Arbitrage". *The Journal of Finance* LII, 35–55.

——— (2011). "Fire Sales in Finance and Macroeconomics". *Journal of Economic Perspectives* 25, 29–48.

Appendix A   Moral Hazard and Regulatory Costs

In the model described above, regulatory costs enter as an exogenous parameter γ. In this section, we extend the model by a few aspects to provide a foundation for this assumption. We show that once a bank is covered by a safety net that is in place to prevent self-fulfilling runs (e.g., a deposit insurance), the bank will not be disciplined by investors and will have incentives to invest in a riskier project with private benefits. The regulator thus needs to impose a minimum capital requirement in order to ensure that the bank behaves diligently. As raising capital is assumed to be costly for the bank (e.g., due to dilution costs), the overall return a bank will make will be reduced by the regulation. We recommend reading this part only after having finished reading Section 4.

Let us assume that commercial banks as well as shadow banks are run by owner-managers. Assume that bank managers receive some constant private benefit w (per unit of deposits) as long as their (shadow) bank is operating. If the bank goes bankrupt, the manager loses his bank and his income. The manager discounts the future at rate $\delta < 1$, his discounted income over his (infinite) lifetime is given by $w/(1 - \delta)$. Now assume that next to the short asset and the long asset described in the beginning of Section 2, bank managers also have access to an additional production technology that we call "private asset". This private asset is similar to the long asset, but it has the property that, with some probability α, the asset defaults completely. In addition, this asset produces some private benefit b (per unit) for the bank manager. We assume that the long asset associated with a private benefit is never socially optimal, i.e.,

$$R > (1 - \alpha)R + b. \tag{31}$$

This structure is reminiscent of how moral hazard is introduced by e.g. Holmström and Tirole (1997).

If the manager invests in the private asset instead of the long asset, the bank still offers the same demand deposit contract as in the standard case. The bank can serve its depositors with probability $1 - \alpha$, but with probability α it defaults. We assume that investors can observe what the manager is doing. However, this monitoring is associated with private costs for the investors. We assume that these monitoring costs vary across investors and each investor i has some monitoring costs s_i which are drawn from $G(s)$. These monitoring costs are equivalent to the switching costs introduced in the main part of the paper.

There are three different environments that a (shadow) bank can operate in: In the first environment, the manager holds no equity and his depositors are not protected by a

deposit insurance. In the second environment, the manager does not hold (inside) equity either, but his depositors are protected by a deposit insurance. In the third environment, the manager does hold an equity position e.

Let us consider the case without equity and without deposit insurance first. The absence of deposit insurance induces investors to monitor the manager and to withdraw (or not deposit) their funds if the manager misbehaves. Therefore, the manager will behave diligently.[19]

In contrast, in the presence of a deposit insurance scheme, investors do not care about what the manager is doing. If the manager has no "skin in the game" (i.e., if he has no inside equity), he chooses the private asset iff

$$b > [1 - (1 - \alpha)\delta]\frac{w}{(1 + \delta)}. \tag{32}$$

If this inequality is satisfied, the deposit insurance becomes tested, i.e. has to cover claims, with probability α. The regulator therefore has an incentive to ensure diligence of the manager by regulating him. While there are multiple ways to regulate a bank manager, we assume that the regulation requires the bank to hold a minimal amount of equity e per unit of deposits.

This changes the manager's incentives. Because he now has "skin in the game", he will behave diligently whenever

$$e > b - [1 - (1 - \alpha)\delta]\frac{w}{(1 + \delta)}. \tag{33}$$

By choosing an equity requirement $\bar{e} \equiv b - [1 - (1 - \alpha)\delta]w/(1 + \delta)$ per unit of deposit, the regulator can ensure diligence.

Formally, incorporating this moral hazard and the resulting regulation into the framework of banking and shadow banking in Section 4 works in the following way: There exists a sector of commercial banking which is covered by a safety net and regulated to prevent moral hazard. Bank managers have to raise equity, and this is costly, e.g., due to dilution costs. We define the cost of raising e units of equity to be the regulatory cost γ.

There also exists an unregulated shadow banking sector which is not subject to this capital requirement. However, there is a shadow-banking cost of ρ. In addition, investors who choose to deposit their funds with the shadow banks have to spend the monitoring cost s_i. As shown in Section 4, only investors with costs $s_i < s^*$ will choose to invest in the shadow banking sector.

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[19]For tractability, we abstract from the strategic interaction between investors which arises because monitoring has positive externalities.

Appendix B Heterogeneous Investors

In the main part of the paper, we assumed that all investors have the same size (endowment of one unit). The heterogeneity among investors consists in the switching costs s_i that are distributed according to some distribution function G in the population. We argued that there are several reasons why investors have heterogeneous switching costs, and that the only necessary feature of the model is that switching costs relative to the investors' budget is heterogeneous.

In this appendix we want to show that we obtain qualitatively similar results if we assume that all investors have identical switching costs, but different endowments. For simplicity, let us assume that the investors' endowment is either high, $x_i = x_h$, or low, $x_i = x_l$. The fraction of "large investors", i.e., with a high endowment, is given by p. The switching cost is assumed to be identical across investors, $s_i = s$. For convenience, we assume that switching costs are monetary, i.e., the utility from receiving c units from a shadow bank is given by $u(c - s)$.

For an investor with endowment x_i, the expected utility of depositing at a commercial bank is given by

$$EU_b(x_i) = \pi u(x_i r_b) + (1 - \pi)u(x_i r_b^2), \tag{34}$$

while the utility from depositing at a shadow bank is given by

$$EU_{sb}(x_i) = \pi u(x_i r_{sb} - s) + (1 - \pi)u(x_i r_{sb}^2 - s). \tag{35}$$

Again, an investor chooses the shadow bank if $EU_{sb}(x_i) > EU_b(x_i)$. If the endowments and the switching costs are such that $EU_{sb}(x_h) > EU_b(x_h)$ and $EU_{sb}(x_l) < EU_b(x_l)$, all large investors choose the shadow banking sector, while all small investors stay with the commercial banks. The size of the shadow banking sector is thus given by the fraction of "large investors", p. And the size of the commercial banking sector is thus given by the fraction of "small investors", $1 - p$.