Securitization, Shadow Banking, and Bank Regulation*

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This paper studies the capital regulation of banks that choose whether to become traditional, deposit taking banks or shadow banks that provide credit intermediation through securitization. If capital regulation only covers traditional banks, it will lead to the emergence of excessively risky shadow banks that can fully crowd out traditional banking. Optimal capital regulation includes shadow banks and can prevent excessive risk taking and crowding-out by ensuring that banks' equity per unit of investment remains the same for all securitization strategies. Capital requirements cause underinvestment that cannot be mitigated by securitization.

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1. Introduction

This paper explores the regulation of shadow banks and traditional banks that engage in securitization. Shadow banking describes a system of financial institutions that provide credit intermediation parallel to traditional banks. To raise outside financing, shadow banks rely on securitization, a process that transforms loan portfolios into marketable securities that can be sold to investors such as mutual funds and insurance companies.

Unlike traditional banks, shadow banks do not issue deposits and as a result are typically not subject to capital regulation. Securitization is also heavily used by traditional banks. This allows banks to reduce their balance sheet size and capital requirements because the securities they sell to investors do not appear on banks' balance sheets for regulatory purposes.

Securitization and shadow banks play central roles in the financial systems of the US and Europe. The total amount of outstanding asset backed securities (ABS), including mortgage backed securities, stood at about 10 trillion USD in the US and 1.9 trillion USD in Europe by the end of 2014 (SIFMA, 2015a,b,c). Lending by shadow banks in 2013 amounted to over 50% of total lending by banks and shadow banks in the US and over 25% in the Euro area (Valckx et al., 2014, p. 67). During the financial crisis of 2007-2009, the market for asset backed commercial papers (ABCP) contracted significantly which further led to distress in interbank markets (Acharya and Merrouche, 2012; Krishnamurthy et al., 2014). In September 2008, the US government deemed it necessary to guarantee the holdings in money market mutual funds (MMFs) to stop ensuing runs (Treasury, 2008; Kacperczyk and Schnabl, 2013). Consequently, shadow banks and securitization have become central topics of the international regulatory agenda (e.g., BCBS, 2014; FSB, 2014).

I study the optimal capital regulation of both traditional and shadow banks. The paper's main novelty is that banks can choose whether to become traditional banks

or shadow banks that provide parallel credit intermediation. The central goal of bank regulation in this paper is to reduce banks' risk taking.

I show that when banks' risk taking opportunities are sufficiently large, capital regulation cannot prevent excessive risk taking if it only constrains the behavior of traditional, deposit taking banks and does not regulate shadow banks. When capital requirements are such that traditional banks do not have an incentive to engage in excessive risk taking, then some banks will find it profitable to become unregulated shadow banks, which allows them to raise less costly equity. These shadow banks will engage in excessive risk taking due to their high leverage.

If capital regulation is set without taking the possibility of shadow banking into account, then all banks find it profitable to become shadow banks, fully crowding out the traditional banks. These shadow banks will separate themselves into a group of risky banks and a group of sound banks who signal their respective risk choice by using different securitization strategies. Some unregulated shadow banks may invest in negative net present value projects.

To prevent excessive risk taking optimal capital regulation has to ensure that both traditional and shadow banks must raise the same amount of equity per unit of investment for all securitization strategies pursued in equilibrium. Hence, under optimal capital regulation securitization cannot decrease the amount of costly equity that banks have to raise, which prevents banks from increasing their investment. Banks are indifferent between becoming shadow banks or traditional banks. The optimal capital requirements implicitly define limits on the amounts of securitization that traditional and shadow banks can engage in, respectively. Regulators can use direct constraints on securitization that limit the amount of leverage that can be obtained from securitization as substitutes for capital regulation.

In an extension, I consider shadow banks that face lower bankruptcy costs than

traditional banks. In this case optimal capital requirements that deter risk taking by shadow banks must be so high that shadow banking becomes unprofitable.

I derive these results in a model where banks have an incentive to pursue excessively risky strategies because of high leverage and limited liability. Banks can choose the riskiness of their investment portfolio, which remains their private information. The expected return on investment differs among banks and also remains their private information. Market participants and regulators, however, are aware of banks' risk taking opportunities and differences in expected returns. Banks can use three sources of funds: publicly insured deposits, equity capital, and securitization. Traditional banks always finance themselves with deposits and equity and may also issue securities. The presence of a risk insensitive deposit insurance subsidizes risk taking by traditional banks. Shadow banks differ from traditional banks by not issuing deposits and financing themselves with equity and securitization only.[1]

Equity capital is costly for banks, which makes it optimal for banks to minimize their equity financing. Banks cannot sell their entire investment to outside investors because of adverse selection. Banks can, however, raise large amounts of outside finance by issuing securities. To reduce adverse selection banks collateralize theses securities with the proceeds from loan portfolios that are held by distinct legal entities know as special purpose vehicles (SPVs). These SPVs also typically receive liquidity insurance by their sponsoring institutions that ensure that senior tranches constitute senior claims on the sponsor (Acharya et al., 2013). By retaining the risk associated with junior tranches and liquidity insurance, banks can credibly signal the profitability of their investment, overcoming the adverse selection problem. When banks sells securities through SPVs outside investors claims do not appear on banks' balance sheets which reduces balance

[1] As described in Pozsar et al. (2012), the credit intermediation by the shadow banking system is often spread out over several institutions that form a financing chain between ultimate lenders and borrowers. For simplicity, the model abstracts away this institutional feature and treats shadow banks as single institutions that provide credit intermediation.

sheet size relative to the amount of investment. Selling securities increases banks' risk taking incentives because it increases their leverage while keeping them exposed to their investment risk, which increases the option value of bankruptcy. These risk taking incentives are not present in models where banks sell their entire loan portfolio because they are not exposed to the loans' riskiness once sold.

Capital regulation can provide incentives against risk taking by reducing banks' leverage. Because banks' riskiness is not observable, regulators cannot rely on risk weighted capital requirements. Capital regulation can, however, depend on the extent of securitization in which banks engage. Basel III, for example, imposes higher capital requirements for banks' securitization activities (BCBS, 2014). To ensure that traditional banks do not engage in excessive risk taking, capital requirements must ensure that their equity does not fall below a certain threshold. This ensures that less profitable banks, which would otherwise engage in excessive risk taking, will not find it profitable to become traditional banks due to their cost of capital. The necessary capital requirements increase in bank risk taking opportunities that increase the option value of bankruptcy. Because securitization reduces banks' balance sheet size, on-balance-sheet capital requirements must increase with higher levels of securitization. This implies that capital requirements must prevent deposit-issuing traditional banks from engaging in very high levels of securitization, for which the off balance sheet leverage would always cause traditional banks to engage in excessive risk taking.

If shadow banks remain unregulated, they have the option to engage in high levels of securitization which allows them to reduce the amount of costly equity they have to raise. Becoming a shadow bank will be profitable when the capital requirements for traditional banks are high because risk taking opportunities are high. Banks with low expected returns will engage in excessive risk taking because of the high leverage they obtain as shadow banks. Crowding-out of the traditional banking sector occurs because banks are

able to signal their risk taking behavior. Shadow banks signal low risk taking by choosing a level of securitization that lies between those of traditional banks and shadow banks that take excessive risk. More profitable banks, which do not engage in excessive risk taking, can thus benefit from higher leverage without suffering from adverse selection. Overinvestment by shadow banks occurs because banks cannot perfectly signal their type, which leads to the cross subsidization of banks with negative NPV projects by other banks that engage in excessive risk taking.

Optimal capital requirements must ensure that the amount of capital that banks must raise remains constant for all levels of securitization of shadow banks and traditional banks. Otherwise some securitization strategies would result in lower capital costs and higher risk taking incentives. This results in underinvestment irrespective of banks' securitization strategies because equity is costly for banks. Banks are indifferent between becoming traditional and shadow banks because they face the same capital costs. Such capital regulation must require shadow banks to hold additional safe and liquid assets financed by equity on their balance sheet because otherwise their off balance sheet leverage achieved thorough high levels of securitization would result in excessive risk taking.

Shadow banking is only profitable when it allows for high levels of securitization that increase leverage. Hence, shadow banking can be prevented by constraining the types of securities that can be sold. Such regulation can substitute for the capital regulation of shadow banks.

If shadow banks face lower bankruptcy costs than traditional banks, then, in order to prevent risk taking, the capital requirements for shadow banks must be higher. Higher capital requirements makes shadow banking unprofitable because they increase capital costs and banks that do not engage in risk taking do not benefit from lower bankruptcy costs.

2. Related Literature

Pozsar et al. (2012) provide an excellent overview of the shadow banking system that also describes how shadow banks provide credit in parallel to the traditional banking system.[2] The securitization process is described in detail by Gorton and Metrick (2013). Several studies have documented the use of securitization for regulatory arbitrage to decrease regulatory capital requirements (Jones, 2000; Calomiris and Mason, 2004; Ambrose et al., 2005; Acharya et al., 2013; Gorton and Metrick, 2010). The idea that securitization can increase the riskiness of banks goes back at least to the eighties and papers such as Greenbaum and Thakor (1987), James (1988), and Santomero and Trester (1998). On the other hand it has been pointed out that securitization may also be used to achieve better risk sharing and lower funding cost by Benveniste and Berger (1987), Allen and Gale (1989), Gorton and Pennacchi (1995), and Chiesa (2008), for example. Among other papers Fender and Mitchel (2009) have explored how different securitization structures interact with banks' moral hazard problems.

The two most closely related papers in the literature are Cerasi and Rochet (2012) and Plantin (2014). These papers explore the possibilities for banks to refinance themselves through securitization activities. In both papers, securitization is valuable because it is the only available source of finance when additional investment opportunities arise. In Plantin (2014), banks can sell securities to shadow banks when other funding opportunities are not available. Selling securities to shadow banks allows traditional banks to circumvent leverage restrictions because securitization activities cannot be observed by the regulator. Due to this assumption, the paper cannot discuss capital requirements for securitization activities, which are central to the present paper. Cerasi and Rochet (2012) consider the optimal capital regulation for securitization activities in a framework where equity capital provides banks with monitoring incentives. They show that the amount of lending should

[2] Valckx et al. (2014, p. 69, fig.2.3) contains a helpful simple graphical representation.

be limited to a multiple of the banks' equity irrespective of the banks' securitization decision. This multiple, however, depends on the macroeconomic conditions of the economy. I obtain a similar result based on a different modeling approach. In their model, capital ensures that the banks' stake in higher returns generated by monitoring are large enough to cover the monitoring cost. In my model, capital ensures that the banks' share in losses is large enough such that gambling on the option value of bankruptcy is not profitable.

The main difference between my paper and Cerasi and Rochet (2012) and Plantin (2014) is that I explore both traditional banks' refinancing from outside investors through securitization and the possibility for banks to become shadow banks that provide credit intermediation parallel to the traditional banking sector. Pozsar et al. (2012) calls these two phenomena the *internal* and *external* shadow banking system, respectively. Hence my model encompasses a larger set of shadow banking activities than Cerasi and Rochet (2012) and Plantin (2014), which only consider the internal shadow banking system that refinances traditional banks via securitization. I show that the regulation of the *external* shadow banking system is necessary for effective capital regulation.

In macroeconomics, shadow banks that operate parallel to traditional banks appear in Verona et al. (2013) and Mazelis (2015). These papers focus on monetary policy transmission and do not study bank regulation.

Nicolò and Pelizzon (2008) consider a model where banks engage in securitization to reduce their capital requirements. They do not discuss optimal capital regulation, but instead assume that capital requirements are always such that banks' capital fully covers their maximum possible losses. Hence securitization only reduces banks' capital when it reduces their riskiness.

Restrictions on securitization activities have been discussed by Gorton and Metrick (2010) and Kashyap et al. (2010) without providing a formal model. Current recommen-

dations by the Financial Stability Board (FSB, 2014) include such restrictions under the title of product based regulation.

From a modeling perspective, the present paper is based on Freixas et al. (2007). They determine optimal capital requirements for banking conglomerates that can engage in excessive risk taking. I extend their model to discuss the regulation of securitization activities[3] and shadow banks.

3. Model

Banks have exclusive access to an investment opportunity with expected return $R \in [R^l, R^h]$. Banks differ in returns R, which determine their type. This captures a situation where banks specialize in information gathering in certain market segments such as specific industries. Banks can choose the riskiness of their investment by choosing investments with certain return correlations. Investments generate a strictly positive payoff

$$X(R,b) = \begin{cases} R+b, & \text{with probability } 1/2 \\ R-b, & \text{with probability } 1/2 \end{cases}$$

where $b \in [0, B]$ measures the bank's risk taking. Investment costs are normalized to one, and the risk free interest rate is normalized to zero. An investment opportunity has a positive net present value (NPV) if $\mathbb{E}[X] = R \geq 1$.[4]

Banks' types are continuously distributed over the interval $[R_l, R_h]$. To ensure that banks with positive and negative NPV projects will both be present in the model $R_h > 1 > R_l > B$. The cumulative distribution function of banks' types is denoted by

[3] They do consider loan sales, which they call securitization. Their model, however, is such that loan sales to outside investors will never be optimal in equilibrium, which is similar to my result in Section 4.3.

[4] The probabilities 1/2 are only chosen for the ease of exposition and are not necessary for the qualitative results.

$F(R)$. I assume that $\mathbb{E}[R]$ is sufficiently low so that adverse selection prevents banks from selling their entire investment to outside investors, which is discussed in Section 4.3.

Banks' portfolios of financial assets are more opaque and can more easily be changed than the investments of traditional firms (Flannery, 1994), which makes it difficult for outsiders to evaluate banks' investments. To capture this opaqueness I assume that banks' investment characteristics (R, b) are private information.[5]

3.1. Traditional and Shadow Banks

Banks have access to three sources of finance: equity, publicly insured deposits, and selling securities to outside investors. A bank's financing decision determines whether it is a traditional or a shadow bank. Traditional banks take deposits, issue equity and may use securitization to finance themselves. Shadow banks exclusively rely on equity and securitization.[6] Shadow banks include institutions that do not have a bank license and hence cannot issue deposits as well as banks that in principal could take deposits but are prevented from doing so by capital requirements, which are formally introduced in Section 3.2.

To engage in securitization banks create special purpose vehicles (SPVs) that issue asset backed securities (ABS) to outside investors. The SPV and the ABS contracts are structured such that outside investors (that buy senior tranches) obtain senior claims on the bank's entire investment portfolio. To achieve this, banks transfer assets as collateral to their SPVs and provide credit and liquidity guarantees. The transfer of assets to the SPV removes them from the bank's balance sheet and ensure that they are no caught up

[5] This is not meant to claim that regulation that conditions on banks' riskiness is not or should not be important. It acknowledges, however, the fact that regulators have to account for unobservable characteristics on top of of some observable risk characteristics. The model abstracts from the observable characteristics of banks' portfolios for simplicity.

[6] Shadow banks differ from other firms that rely on market finance by making financial investments. These investments, as already mentioned, are more opaque and allow for higher levels of private information risk taking.

in possible bankruptcy proceedings. The value of the collateral is weakly higher than the claims of outside investors at the time of issuance. Liquidity and credit guarantees are structured such that they provide seniority by priority and ensure that investors are fully paid even if the value of the collateral held by the SPV falls short of their claims. The prevalence and structure of credit and liquidity guarantees is documented in Acharya et al. (2013). Gorton and Souleles (2006) discuss the legal issues involved in ensuring that the transfer of assets to the SPV is upheld in the case of bankruptcy.

Outside investors that buy senior ABS tranches with a face value of A thus obtain claims that offer cash flows $\min\{A, X\}$. Banks make outside investors a take it or leave it offer to buy their SPVs' senior tranches at a price P. Outside investors are assumed to be risk neutral. Hence outside investors will buy securities that, given their beliefs, provide an expected return larger or equal to zero. The bank retains the right to the cash flow $\max\{X - A, 0\}$ and receives the SPV's proceeds from selling securities P. The structure of the SPVs ensures that the claims of outside investors buying securities do not appear on banks' balance sheets for regulatory purposes (Acharya et al., 2013). Thus, the size of banks' balance sheets after selling securities is $1 - P$.

Banks also raise equity E and possibly deposits D. I abstract away from other forms of on-balance-sheet outside finance such as bonds. The balance sheet identity implies that $D \equiv 1 - P - E$. Negative amounts of deposits $D < 0$ constitute holdings of additional safe and liquid assets. I assume that funds raised from depositors or outside investors cannot be used to pay out dividends before investment returns have realized.

The following Definition formalizes the distinction between traditional, deposit taking banks and shadow banks that raise their entire funds from equity and securitization.

Definition 1. A bank is a *shadow bank* when $P + E \geq 1$ and it is a *traditional bank* when $P + E < 1$.

Equity financing carries an opportunity cost for banks' current shareholders that

forego other investment opportunities because they are not able to sell their bank entire investment (which will be shown in Section 4.3). The opportunity cost of providing one unit of equity is $1 + \kappa$. Another reason commonly used in the literature to motivate higher costs of equity are tax disadvantages.[7]

Depositors are fully protected by a public deposit insurance, and hence, accept deposits with an interest rate of zero. Since individual bank risk taking is not observable, it cannot be reflected in a deposit insurance premium, which thus must be a flat fee. For the rest of the analysis I set it to zero, which provides a subsidy for the potential risk taking of traditional banks.

When a bank goes bankrupt shareholders incur private costs ζ that include losses of franchise value and reputation as well as forgone investment opportunities. As discussed above the claims of outside investors holding collateralized securities have a higher priority in bankruptcy than depositors. Equity holders have the lowest priority and are protected by limited liability.

3.2. Regulator

The regulator will set minimum capital requirements $C(A)$ that determine a lower bound for banks' on-balance-sheet equity ratio

$$\frac{E}{(1-P)} \geq C(A).$$

[7] Admati et al. (2011) have recently challenged the notion that bank capital is socially costly. Their main argument is based on Modigliani-Miller and they point out that several reasons for costly bank capital, such as taxes, are regulatory distortions. In my model, however, assets markets are characterized by asymmetric information and hence Modigliani-Miller will not hold. Moreover, the present paper's main concern is regulation and the regulator's objective will not directly include the private costs of equity. (see Definition 2 and Section 7). The private costs of equity will, however, concern the regulator via their impact on banks' behavior. Recent empirical evidence shows that, in violation of Modigliani-Miller, equity capital has some cost for banks (Miles et al., 2013; Baker and Wurgler, 2015).

Since banks' types R and their risk taking b are private information they cannot be used to determine capital requirements. Capital requirements can be very sophisticated, however, by taking into account a banks securitization choice A, which is an observable characteristic of the contracts that are used for securitization.[8]

I assume that the regulator aims to ensure a sound banking system, and therefore sets capital regulation such that all active banks choose to be sound. This is the primary objective of international policy institutions such as the Basel Committee:

> "The first Core Principle [of bank regulation] sets out the promotion of safety and soundness of banks and the banking system as the primary objective for banking supervision. Jurisdictions may assign other responsibilities to the banking supervisor provided they do not conflict with this primary objective." (BCBS, 2012, p.4f)

The most standard motivation for this objective is to protect banks' creditors or to minimize the costs of public deposit insurance. But in this model, the outside investors that finance shadow banks are risk neutral, sophisticated, and not publicly insured. Shadow banks' fragility nevertheless imposes externalities on other participants in the financial system. Fire sales of assets caused by a bank's bankruptcy can result in very large falls in asset prices that also affect the holdings and solvency of other banks that are protected by deposit insurance. A bank's bankruptcy also affects its relationship borrowers who cannot simply obtain comparable credit from other banks due to information asymmetries.[9] This externality equally affects shadow banks' borrowers.

The fact that regulators consider the failure of banks costly even in the absence of insured depositors was demonstrated when US regulators permitted Goldman Sachs and Morgan Stanley to convert into bank holding companies, which gave them access to

[8] Allowing capital requirements to depend in addition on the price P does not provide additional insights.

[9] A summary of the empirical evidence on the value of bank lending relationships can be found in Degryse et al. (2009, p. 19ff).

the public assistance set up to prevent the bankruptcy of commercial banks covered by deposit insurance. The Financial Stability Board explains that

> "[...] experience from the crisis demonstrates the capacity for some non-bank entities and transactions to operate on a large scale in ways that create bank-like risks to financial stability [...]." (FSB, 2014, p. ii)

Another recurring justification for the public support of banks during the recent financial crises was to ensure the credit supply to firms.

Capital requirements increase banks funding costs because equity is costly. This reduces banks profits and leads to underinvestment in positive NPV projects. Hence, among those capital regulations that can ensure a sound banking system, the regulator has an incentive to choose the capital regulation that minimizes underinvestment. Maximizing banks' profits minimizes this underinvestment.

Ranking capital regulations is not trivial because for many capital regulations there exist multiple equilibria. The following definition of optimal capital regulation accounts for the possibility of multiple equilibria by requiring that the optimal capital regulation always maximizes the set of positive NPV projects that get financed in any equilibrium where all banks are sound.

Definition 2. A capital regulation $C(A)$ is *optimal* if

1. In all equilibria, all active banks choose to be sound.

2. For all other capital regulations, all equilibria where all banks are sound are such that all banks obtain a weakly lower equilibrium payoff than in all equilibria under $C(A)$.

The very strong second requirement of this definition is appropriate because such a capital regulation exists, as will be shown in Proposition 4. The social costs of bank

failures are explicitly modeled in Section 7, which connects optimal capital regulation in the above sense with the maximization of the social surplus.

3.3. Outside Investors

When banks offer securities to outside investors, they face an adverse selection problem because their profitability R is private information. At the same time, the possibility to engage in risk taking constitutes a moral hazard problem. The securities (A, P) that banks offer constitute a two-dimensional signal, which outside investors use to form beliefs about the banks' profitability R and its choice of risk b. Outside investors will buy any security that given their beliefs yields a non negative payoff.

I assume that the amount of equity raised by a bank E does not serve as a signal. Outside investors, who observe E, ignore any deviation from the amount of equity that maximizes a bank's profits after selling securities subject to $C(A)$. This assumption reflects the difficulty of banks to commit to sustaining a certain equity position in the future. In a more complete model, banks would have the option to reduce equity by paying dividends after selling securities. In such a model, banks' equity obviously cannot serve as a credible signal.[10]

Outside investors are sophisticated and understand banks' incentives and the signaling value of securitization decisions. Consider a bank that deviates to a securitization strategy off the equilibrium path. Whether it could be more profitable to sell this security than the equilibrium payoff depends on the bank's type R. Outside investors anticipate for which types of banks it would be profitable to successfully sell a certain security off the equilibrium path. Hence, outside investors believe that whenever a bank deviates, it is of a type for which this deviation could be profitable.[11] I also require that outside

[10] If E were to serve as a signal this would considerably complicate the analysis. I do not think that it would yield additional insights because banks can signal their risk taking behavior (and to some extent their leverage) by choosing different securitization strategies.

[11] When such a type does not exist, the beliefs of outside investors are not restricted.

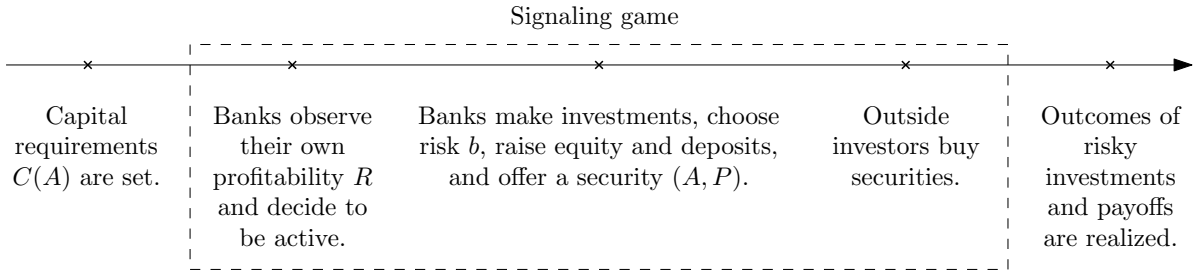

Figure 1: Time-line of Events

investors correctly anticipate a bank's choice of b, which will be uniquely determined given outside investors' beliefs about the bank's type, the securitization strategy (A, P), and capital regulation $C(A)$. Such beliefs are a straightforward application of the logic of the intuitive criterion (Cho and Kreps, 1987). While formally the intuitive criterion is only defined for 2 player signaling games, I will simply refer to the intuitive criterion when I apply the above restrictions to players' beliefs.

Modeling securitization as a signaling game fits the OTC markets that are used to sell securitization products. It differs from a setup where the price of a security is determined by a zero profit constraint for outside investors because the corresponding price function $P(A)$ may not be well defined off the equilibrium path. The reason is that for a given A the sets of banks that are willing to sell such securities will depend on the price P. This will be reflected in outside investors' beliefs and hence there may not exist a price at which outside investors are willing to buy and make zero profits.

3.4. Time-line

Figure 1 shows the time-line of events. Capital regulation is analyzed by studying how capital requirements $C(A)$ change the outcome of the subsequent signaling game between banks and outside investors. Banks first observe the expected return of their investment opportunity R. Banks then make their investments, choose their risk, raise equity and

deposits and offer securities. For simplicity, I model these decisions as simultaneous.[12] Outside investors buy securities depending on their beliefs. In the following analysis, equilibrium refers to a perfect Bayesian equilibrium that satisfies the intuitive criterion. The signaling game will typically have multiple equilibria.

4. Signaling Game

4.1. Banks' Riskiness

The bank's risk neutral shareholders make expected profits $\pi(R, E, A, P, b)$, to which I refer simply as bank's profits. A bank's strategy (E, A, P, b) determines whether it can default or not. A bank is called sound if it never defaults on its depositors and outside investors always receive the face value A. This is the case when the return in low state satisfies $R - b \geq A + (1 - P - E)$. The profits of a sound bank are

$$\pi_S(R, E, A, P, b) = R - A - (1 - P - E) - E(1 + \kappa).$$

A bank is called fragile if it goes bankrupt in the low return state. Bankruptcy occurs in the low return state when $R - b \leq A + (1 - P - E)$, in which case equity holders incur the private bankruptcy costs ζ. The profits of a fragile bank, protected by limited liability, are

$$\pi_F(R, E, A, P, b) = 1/2[R + b - A - (1 - P - E)] - 1/2\zeta - E(1 + \kappa).$$

Banks are active when their expected profit is larger than zero. Otherwise they are inactive and create zero payoff. The threshold above which a bank makes positive profits

[12] In a more realistic model, banks would first raise equity and deposits, make some investments, securitize them, and then use the proceeds to make further investments that will again be securitized, etc. The timing of the investment and financing decisions is not crucial for the results of the model.

is $\underline{R}(E, A, P)$.

Banks' profits π_S and π_F depend negatively on the amount of equity they raise. Since equity does not serve as a signal, banks will choose $E = (1 - P)C(A)$. The profit of a fragile bank depends positively on b. Hence, a bank that chooses to be fragile will always choose $b = B$. A sound bank is indifferent between all b for which it is sound. For convenience, I assume that sound banks choose $b = 0$.

Whether a bank wants to become sound or fragile depends on the option value of bankruptcy, which decreases with banks' expected return $\frac{\partial \pi_S}{\partial R} > \frac{\partial \pi_F}{\partial R} > 0$ and the amount of equity financing $\frac{\partial \pi_F}{\partial E} < \frac{\partial \pi_S}{\partial E} < 0$. Securitization makes risk taking more profitable. The face value A increases the option value of bankruptcy $\frac{\partial \pi_S}{\partial A} < \frac{\partial \pi_F}{\partial A} < 0$. Higher proceeds from securitization P allow banks to reduce their equity for a fixed capital requirement. When a bank prefers to be fragile it has the possibility to do so because

$$\pi_F(R, E, A, P, B) > \pi_S(R, E, A, P, 0) \Rightarrow R - B < A + (1 - P - E).$$

For a fixed equity and securitization strategy, we can thus define a threshold above which banks will choose to be sound $\tilde{R}(E, A, P)$. A necessary but not sufficient condition for fragile banks to exist in equilibrium is that the potential private benefits of risk taking exceed the private bankruptcy costs $(B - \zeta) > 0$. Positive bankruptcy costs $\zeta > 0$ ensure that banks do not always (weakly) prefer to maximize their risk taking in order to benefit from limited liability. Throughout the paper, I assume $(B - \zeta) > 0$ and $\zeta > 0$; to simplify notation drop b from the arguments of the profit functions π_S and π_F.

4.2. Signaling Value of Securitization

A bank's securitization strategies only depends on whether the bank chooses to be sound or fragile. Conditional on banks' being sound or fragile, their respective preferences over

securitization strategies are the same. This can be seen from banks' indifference curves

$$\pi_S(R, E, A, P) \geq \pi_S(R, E', A', P') \Leftrightarrow (A - A') - (P - P') \leq (E' - E)\kappa \tag{1}$$

and

$$\pi_F(R, E, A, P) \geq \pi_F(R, E', A', P') \Leftrightarrow (A - A') - (P - P') \leq (E' - E)(1 + 2\kappa). \tag{2}$$

These indifference curves do not directly depend on banks' types R. A bank's type only determines whether the banks chooses to be sound sound or fragile. The securitization preferences of fragile banks are aligned because all fragile banks go bankrupt with the same probability.

In equilibrium, banks always choose an optimal securitization strategy. Hence (1) implies that a sound bank is indifferent between all securitization strategies that are used by sound banks of different types R in equilibrium. For fragile banks (2) has analogous implications. Since sound banking becomes relatively more profitable than fragile banking as a bank's profitability R increases, there exists a threshold above which all banks prefer to be sound $\dot{R}$.

Lemma 1. *Let $\mathbb{S}$ be the set of banks' strategies that are chosen in equilibrium. $\mathbb{S}$ consists of 2 components $\mathbb{S}_S$ and $\mathbb{S}_F$ such that*

1. *for all strategies $(E, A, P), (E', A', P') \in \mathbb{S}_S$ the profits of sound banks satisfy*

$$\pi_S(R, E, A, P, 0) = \pi_S(R, E', A', P', 0) \text{ for all } R. \tag{3}$$

2. *for all strategies $(E, A, P), (E', A', P') \in \mathbb{S}_F$ the profits of fragile banks satisfy*

$$\pi_F(R, E, A, P) = \pi_F(R, E', A', P') \text{ for all } R. \tag{4}$$

When $\mathbb{S}_F$ is non empty then there exists a single threshold $\dot{R}(\mathbb{S})$ such that all banks with $R > \dot{R}$ are sound banks that choose a strategy in $\mathbb{S}_S$ and all active banks with $R < \dot{R}$ are fragile banks that choose a strategy in $\mathbb{S}_F$.

This Lemma shows that banks cannot precisely signal their type. By choosing a securitization strategy, a bank can at most signal whether its type is above or below the threshold $\dot{R}$ and whether they are sufficiently profitable to become active.

Because banks' preferences for different securitization strategies only coarsely depend on their types equilibrium refinements such as the intuitive criterion or D1 (Cho and Kreps, 1987), which exploit differences in the bank types' incentives to deviate, have only limited power. Hence, these refinements cannot provide a unique equilibrium.

The intuitive criterion restricts outside investors beliefs such that banks are always able to sell certain types of securities. Consider a securitization strategy off the equilibrium path (A', P') that would be a profitable deviation for banks that prefer to be fragile. Let $\underline{R}^F((1-P')C(A'), A', P')$ denote the lowest type of bank that can make positive profits when it chooses to securitize (A', P') and be fragile. Banks are never active when they expect to earn less than zero profits. Hence outside investors must believe that the deviating bank's profitability is larger or equal than $\underline{R}^F((1-P')C(A'), A', P')$. This implies that outside investors expect to make non-negative profits whenever

$$\tfrac{1}{2}(A' + \underline{R}^F((1-P')C(A'), A', P') - B) - P' \geq 0. \tag{5}$$

Consider now a different deviation (A', P') that would only be profitable for banks that prefer to be sound. Outside investors will anticipate that the bank that offers the security must be of a type that prefers to be sound. Because all sound banks always fully pay back A, outside investors will always be willing to buy such securities when $A' \geq P'$.

Lemma 2. *Assume the beliefs of outside investors satisfy the intuitive criterion. Let*

(A', P') *be a securitization strategy off the equilibrium path. Outside investors are always willing to buy securities* (A', P') *if this could be a profitable deviation for banks of which (i)* some *prefer to be fragile and (5) holds or (ii)* all *prefer to be sound and* $A' \geq P'$.

Note that sufficiently pessimistic beliefs about the types of banks that would sell securities off the equilibrium path can support equilibria where outside investors make strictly positive profits. For example, outside investors make positive profits whenever a bank with $R > \underline{R}^F$ sells a security that satisfies (5) on the equilibrium path.

4.3. Limits of Outside Financing

Banks never have a strict incentive to choose securitization strategies where $P > 1$. The reason is that banks cannot pay out dividends before investment returns have realized and thus, must always pay back any funds they receive and do not use for investment. Formally, suppose a securitization strategy (A, P) with $P > 1$ is sold in equilibrium. Consider now the securitization strategy $(A', P') = \Big(A - (P-1), 1\Big)$. From inspection of the profit functions it follows that this securitization strategy is payoff equivalent for all players. Thus, without loss of generality, I only consider $P \leq 1$.

Alternatively a banks' initial shareholders could try to sell their bank's entire investment to outside investors. If a bank truly sells its entire investment, the initial shareholders will not be affected by any bankruptcy costs that the new owners of the investment might experience at a later point in time. Equity holders will only be willing to sell their bank's investment if they can recoup their initial investment outlay and make profits $P - 1 > 0$. This condition, however, is independent of the bank's expected return R. Hence if shareholders can sell their banks' investments at a price $P > 0$ this will be profitable for all banks that would not make positive profits otherwise. The resulting adverse section prevents shareholders from selling their banks' entire investments because the average rate of return of banks' investment opportunities is sufficiently negative.

Initial shareholders must thus always retain stakes in their bank's investment.

Lemma 3. *If $\mathbb{E}[R] < 1 - B$, a bank's initial shareholders never sell their bank's entire investment in equilibrium.*

Note that from a regulatory perspective, selling the entire investment (after choosing its riskiness) would eliminate excessive risk taking. The reason is that initial shareholders' profits would not depend on the bank's risk when it is sold and hence, there are no risk taking incentives. The adverse selection problem faced by banks thus results in securitization structures that increase banks' risk taking incentives.

5. Unregulated Shadow Banks

Before analyzing the optimal capital regulation I consider capital requirements that only concern traditional banks, which resembles typical, real world bank regulations. Capital regulation only concerns traditional banks when $C(A) \leq 1$ for all A since banks with $\frac{E}{1-P} > 1$ are shadow banks by definition. Conditional on a bank being a shadow bank, such a regulation does not impose any constraints except preventing them from issuing deposits.

Capital regulation that does not constrain the behavior of shadow banks cannot prevent excessive risk taking when banks' risk shifting incentives are large. Banks' risk shifting incentives depend on the option value of bankruptcy that increases in banks' risks taking opportunities B and decreases in their bankruptcy costs ζ.

Unregulated shadow banking allows banks bank with relatively low expected returns R to make positive profits. These banks can make positive profits because the can securitize large parts of their balance sheet which increases their leverage and reduces their equity costs. Consider a bank with $R = 1 + \frac{1}{2}\zeta$. This bank breaks even when it sells securities $(A', P') = (1 + B - \frac{1}{2}\zeta, 1)$ for all $C(A') \leq 1$. It is easy to check that this securitization

strategy satisfies (5) and thus Lemma 2 implies that outside investors are always willing to buy securities (A', P').[13] When a bank with $R > 1 + \frac{1}{2}\zeta$ sells securities (A', P') it suffers from adverse section but still makes positive profits.

All banks with $R \geq 1 + \frac{1}{2}\zeta$ must thus be active in equilibrium, either as shadow banks or traditional banks. The trade-off between becoming a shadow bank or a traditional bank depends on the relative amounts of equity that banks have to raise and the possible costs of averse selection when selling securities to outside investors. Clearly, higher capital requirements for traditional banks make becoming a shadow bank relatively more profitable. Adverse selection increases in R and hence, banks with low R find shadow banking relatively more profitable.

When capital requirements for traditional banks are high then banks with low R will become shadow banks. These banks will engage in excessive risk taking due to their high leverage, low R, and high B. Importantly this risk taking occurs although shadow banks do not benefit from a deposit insurance subsidy and have to compensate outside investors for the risk of a low return state. When capital requirements for traditional banks are sufficiently low, then there are equilibria in which all active banks become traditional banks. But to attain such equilibria capital requirements must be so low that banks with small R will engage in excessive risk taking due to their high leverage and high B.

Proposition 1. *If $C(A) \leq 1$ for all A and*

$$B > \zeta \frac{1 + 3\kappa}{2\kappa} \tag{6}$$

then there does not exist an equilibrium that satisfies the intuitive criterion where all active banks are sound.

Proposition 1 implies that when banks have substantial private risk taking opportunities,

[13] The securitization strategy (A', P') maximizes the profits of fragile banks with $E = 1$ subject to (5). Hence $1 + \frac{1}{2}\zeta$ is the lowest type of bank that will be active in all equilibria.

then any optimal capital regulation that prevents fragile banking must include shadow banks. The on-balance-sheet capital requirements for shadow banks must exceed 100% ($C(A) > 1$) to prevent fragility. To implement such capital requirements the regulator can require shadow banks to hold additional safe and liquid assets (e.g., cash) financed by equity on their balance sheets.[14]

5.1. Naive Capital Regulation

When capital regulation not only excludes shadow banks from regulation, but *naively* ignores their existence for the purpose of bank regulation, shadow banks can fully crowd out traditional banking. Crowding-out of the traditional banking sector is of course problematic because banks provide essential services such as money-like claims and payment systems. It is not clear to what extent less regulated shadow banks can take over these functions.

Definition 3. A capital regulation is *naive* if (i) $C(A) \leq 1$ for all A and (ii) it would be optimal if banks never chose to become shadow banks.

In general, there exist infinitely many naive capital regulations. I focus on the naive capital regulation that maximizes the set of securitization levels A that can appear in equilibrium. Any other naive capital regulation would arbitrarily reduce the set of securitization strategies that traditional banks may use in equilibrium.

Lemma 4. *The capital regulation*

$$C^N(A) = \begin{cases} \frac{B-\zeta}{(1+\kappa)(1-A)} & A < 1 - \frac{B-\zeta}{1+\kappa} \\ 1 & \textit{otherwise} \end{cases}$$

is naive.

[14] Liquidity requirements such as those proposed by the Basel Committee BCBS (2013) require banks to hold a certain amount of safe and liquid assets on their balance sheet.

For any other naive capital regulation $C'(A)$ and any A' for which $C'(A') \neq C^N(A')$, no traditional bank will use any securitization strategy (A', P) in any equilibrium under $C'(A)$.

Capital regulation ensures that all active traditional banks are sound when all banks that would prefer to be fragile prefer to remain inactive. This is possible because higher capital requirements C make being fragile relatively less profitable, and thus the threshold above which a bank wants to become sound $\tilde{R}$ decreases. At the same time, it also makes banking overall less profitable, which increases the threshold $\underline{R}$ above which a bank wants to be active. The lowest capital requirement such that $\underline{R} \geq \tilde{R}$ for all (A, P) and $A < 1 - \frac{B-\zeta}{1+\kappa}$ is given by $C^N(A)$.[15] At the same time, the capital regulation prevents banks with securitization strategies where $A \geq 1 - \frac{B-\zeta}{1+\kappa}$ from becoming traditional banks by requiring $C^N(A) = 1$, which implies that $E = 1 - P$. Thus naive capital regulation implicitly defines a limit on the amount of securitization that is admissible for traditional banks. From the perspective of a naive regulator, who ignores the possibility of banks becoming shadow banks, this constitutes a limit on the securitization activities for the whole banking sector, ensuring a sound banking system.

The profits of sound banks are the same for different securitization strategies with $A = P \leq 1 - \frac{B-\zeta}{1+\kappa}$. The reason is that banks' equity costs $(1-P)C^N(P)(1+\kappa) = E(1+\kappa)$ remain constant. Thus sound banks are indifferent between those securitization strategies in equilibrium. When another naive capital regulation $C'(A)$ differs from $C^N(A)$, two cases can arise. First $C'(A) > C^N(A)$ for some A. This makes securitization strategies with (A, P) less profitable and hence they will not be used in equilibrium. Second, $C'(A') < C^N(A')$ for some A'. When this makes securitization strategies (A', P) more profitable, some traditional banks will prefer to become fragile which violates the definition of naive capital regulation.

[15] Freixas et al. (2007) already showed this for banks that do not engage in securitization.

5.2. Crowding-out of Traditional Banking

Under a naive capital regulation, two types of equilibria can emerge: either all banks become sound traditional banks or all banks become shadow banks.

Proposition 2. *Assume that the capital regulation is $C^N(A)$. There does not exist a banking system where both traditional and shadow banks are active.*

In equilibrium fragile shadow banks are only active when they make strictly higher profits than sound traditional banks. Otherwise they would not either not be active or become sound banks traditional banks. Banks' profits under under C^N are continuous by construction. This implies that there exist securitization strategies off the equilibrium path that are only profitable for sound banks that become shadow banks. For sufficiently small ϵ, $(A, P) = (1 - \frac{B-\zeta}{1+\kappa} + \epsilon, 1 - \frac{B-\zeta}{1+\kappa} + \epsilon)$ is such a strategy. Since these banks can signal that they are sound Lemma 2 implies that they will not suffer from adverse selection and outside investors are willing to by their securities.

From Proposition 1 it follows that fragile shadow banks will be active under naive capital regulation when (6) holds. Following the above arguments this implies that sound banks will become shadow banks as well and traditional banking ceases to exist.

Corollary 1. *Assume that the capital regulation is $C^N(A)$. If (6) holds, then all active banks are shadow banks.*

If shadow banks remain unregulated, the regulator could lower the capital requirements of traditional banks to prevent crowding-out of traditional banks. But there exist multiple equilibria with different profits for fragile shadow banks. It follows that for a single capital regulation there might exist different equilibria where either full crowding-out occurs or some traditional banks become fragile. This multiplicity of equilibria make it impossible to implement a regulation that guarantees the existence of sound traditional banks in the presence of unregulated shadow banks.[16]

[16]The extension in Section 9 shows that when the bankruptcy costs differ between traditional and

5.3. Overinvestment by Shadow Banks

Another problem of naive capital regulation is that in some equilibria, banks with negative net present value projects ($R < 1$) find it profitable to become active. Because banks cannot single their precise type in equilibrium outside investors cannot distinguish different types of fragile banks. As a result, they may cross-subsidize less efficient fragile banks with the profits they make from more efficient fragile banks.[17] This cross subsidization can make banks with negative NPV project profitable. Their investments are inefficient even without taking into account the private and social bankruptcy costs.

Proposition 3. *Assume that the capital regulation is C^N and $R \sim U[R_l, R_h]$. There exists an equilibrium where banks with $R - 1 < 0$ are active when*

$$B > \frac{2 + 3\kappa}{1 + 2\kappa}\zeta. \tag{7}$$

6. Optimal Capital Regulation

The optimal capital regulation is such that whenever a bank prefers to be active it prefers to be sound. This is the same mechanism that ensures that traditional banks are always sound under C^N. Contrary to naive capital regulation, however optimal capital regulation extends to shadow banks to ensure that for all securitization strategies (A, P) an active bank will prefer to be sound.

Proposition 4. *The capital regulation*

$$C^*(A) = \frac{B - \zeta}{(1 + \kappa)(1 - A)}$$

is optimal.

shadow banks, then naive capital regulation may lead to an equilibrium where fragile shadow banks and sound traditional banks coexist.

[17] This is a well understood mechanism in corporate finance (e.g., Tirole, 2006, sec. 6.2).

For any other optimal capital regulation $C'(A)$ and any A' for which $C'(A') \neq C^*(A')$, no bank will use any securitization strategy (A', P) in any equilibrium under $C'(A)$.

Banks' profits under any optimal capital regulation equal $\pi_S(R, C^*(0), 0, 0)$. Under $C^*(A)$ banks are indifferent between all securitization strategies where $A = P < 1$.

All active banks will prefer to be sound for all levels of securitization if for all A

$$\underline{R}((1-P)C^*(A), A, P) \geq \tilde{R}((1-P)C^*(A), A, P). \tag{8}$$

The optimal capital regulation is constructed such that (8) holds with equality for all securitization strategies (A, A), and hence, holds for all securitization strategies with $A \geq P$. As a result there does not exist a combination (E, A, P) where all banks prefer to be sound and sound banks make higher profits. This implies that C^* is optimal and that if another optimal capital regulation differs for some securitization level A, it must be such that this securitization level is never used in equilibrium.

When banks engage in securitization the amount of equity they have to raise under C^* never decreases

$$E = (1-P)C^*(A) = \frac{1-P}{1-A}C^*(0) \geq C^*(0).$$

Banks profits under C^* do not depend on the level of securitization they engage in because they are always sound and hence can always sell securities with $P = A$, as shown in Lemma 2. Banks are thus indifferent between becoming shadow banks or traditional banks because their profits are the same whether the choose a level of securitization where $C^*(A) > 1$ or not.

In practice, capital requirements such as $C^*(A)$ may appear to be excessive. The reason is that banks have to satisfy high capital requirements for assets that are risk-free in equilibrium, which will be reflected in historical returns. The low risk of the underlying

assets, however, is determined endogenously and does depend on the incentives provided by the capital requirements. Optimal capital requirements must be excessive when banks' risk taking is not observable and hence capital requirements cannot reflect banks' risk choice.

To implement the optimal capital regulation $C^*(A)$, regulators must have estimates of the maximum amount of risk taking B, banks' bankruptcy costs, and the cost of equity. Importantly, regulators do not need to know an individual bank's type R or risk choice b, nor the distribution of banks' types $F(R)$. The optimal capital regulation C^* defines the maximum amount of securitization for traditional banks in the same way as the naive capital regulation C^N. Shadow banks are required to hold additional safe and liquid assets financed by equity on their balance sheets because the capital regulation $C^*(A)$ exceeds 100% for $A > 1 - \frac{B-\zeta}{1+\kappa}$. Note that $C^*(A) \to \infty$ as $A \to 1$. and hence, the optimal capital regulation $C^*(A)$ implicitly defines a limit on the amount of securitization that is admissible for banks. The reason is that when banks raise all their financing from outside investors then the size of their balance sheet goes to zero on-balance-sheet capital requirements loose their bite. Instead of preventing banks from engaging in certain securitization activities those activities could in general be limited, which is discussed in Section 8. Another alternative would be to consolidate banks' securitization activities for regulatory purposes. When securitization activities are not off-balance-sheet, capital regulation directly constrains the banks overall leverage and thus their risk taking incentives.

7. Welfare

Capital requirements for banks increase banks' funding costs due to the cost of equity κ. This results in underinvestment because sound banks' funding costs are larger than the risk-free interest rate and hence banks with marginal positive NPV projects will not

become active. Since under optimal capital regulation banks' profits do not depend on their chosen level of securitization, Proposition 4 implies the following Corollary.

Corollary 2. *Securitization activities cannot reduce the amount of underinvestment under optimal capital regulation.*

To connect the definition of optimal capital regulation with standard welfare analysis, assume that a bank's bankruptcy creates social costs ϕ which include the private costs ζ. Given the social costs of bankruptcy, a sound bank creates surplus $R-1$ and a fragile bank creates a surplus $R-1-\frac{1}{2}\phi$. Bank thus create a total surplus of

$$\int_{\underline{R}}^{R^h} R-1\, dF(R) - \int_{\underline{R}}^{\dot{R}} \frac{1}{2}\phi\, dF(R).$$

A capital regulation that prevents excessive risk taking maximizes the total surplus if the marginal surplus, which the least profitable active bank generates, is weakly lower than the social cost of bankruptcy. In this case lower capital requirements cause marginal banks that will be fragile to become active. The associated social costs of bankruptcy would exceed the additional surplus .

Proposition 5. *The optimal capital regulation maximizes the total surplus if the expected social cost caused by bank fragility $\frac{1}{2}\phi$ is higher than $\underline{R}(C^*(0),0,0)-1$.*

Otherwise it might increase welfare to allow for the presence of fragile banks in order to generate additional investment. This will be the case if banks' risk taking opportunities B are very large compared to the social costs of bankruptcy. The reason is that for a high B, capital requirements must be high to prevent excessive risk taking, which lead to a high minimal expected return $\underline{R}$ for banks to become active.

The social costs of bankruptcy could be higher for traditional banks because public deposit insurance has to bail out depositors if the bank fails. In this case, Proposition 5 remains valid when ϕ measures the social cost caused by the bankruptcy of a shadow

bank. When shadow banks' social costs of bankruptcy do not satisfy the condition of Proposition 5, it could be optimal to allow the presence of fragile shadow banks while ensuring the soundness of traditional banks. This is problematic, however, because the presence of shadow banks can crowd out traditional banks and lead to overinvestment, as discussed in Sections 5.2 and 5.3.

8. Regulating Securitization

The optimal capital regulation implicitly constrains the amount of securitization traditional and shadow banks banks can engage in, respectively. Instead of regulating securitization at the level of the banks, it is possible to restrict the types of securities that can be traded in the market. Such restrictions limit the amount of funding and the leverage that banks can obtain through securitization, which allows to prevent either shadow banking, full crowding-out of traditional banking, or overinvestment by shadow banks.

When capital regulation is naive, securitization restrictions can prevent shadow banking by banning the use of all securitization activities that are only available to shadow banks i.e., imposing $A \leq 1 - \frac{B-\zeta}{1+\kappa}$. Banning all securitization strategies that would make it profitable for sound banks to become shadow banks i.e., all securitization strategies where $\pi_S(1-P, A, P) \geq \pi_S(C^N(0), 0, 0)$, prevents crowding-out of traditional banking. Restricting the admissible securitization activities to those where $\underline{R}((1-P)C(A), A, P) > 1$ prevents overinvestment by shadow banks.

The literature typically conceives restrictions of tradable securities as minimum haircuts (Gorton and Metrick, 2010; Kashyap et al., 2010), which restrict the amount of financing for a given collateral value. Current recommendations by the Financial Stability Board include both restrictions of securitization activities at the bank and the market level (FSB, 2014).

It might be easier for regulators to implement restrictions on the types of securities that market participants can use than to subject all the diverse institutions that constitute the shadow banking sector to capital regulation. But unlike in the present model, shadow banks and the securities they issue might serve some purpose that cannot be fully substituted by other financial instruments. Capital regulation can ensure that these activities will not lead to excessive risk taking while leaving their use to market participants. This flexibility is lost by the direct regulation of securitization activities.

9. Differential Bankruptcy Costs.

Shadow banks are typically subject to fewer regulations than traditional banks that issue insured deposits. Hence, it is often easier to create new shadow banks which increases competition that decreases franchise values. Since the private bankruptcy costs ζ include losses of franchise value this implies lower bankruptcy cost for shadow banks.

Assume that shadow banks face bankruptcy costs ξ that are lower than those of traditional banks ζ. The expected profit of a fragile bank is

$$\pi'_F(R, E, A, P, b) = 1/2[R + b - A - (1 - P - E)] \\ - 1/2[\zeta \mathbf{1}_{E+P<1} + \xi(1 - \mathbf{1}_{E+P<1})] - E(1 + \kappa)$$

where $\mathbf{1}_{E+P<1}$ is an indicator function that takes the value of 1 if $E + P < 1$ (traditional bank) and 0 if $E + P \geq 1$ (shadow bank).

Lower bankruptcy costs require higher capital requirements to prevent excessive risk taking. Hence, the optimal capital requirements for shadow banks with lower bankruptcy costs must be higher than for traditional banks. Sound shadow banks do not benefit from lower bankruptcy cost, though and make strictly lower profits than sound traditional banks that face lower optimal capital requirements. Hence in equilibrium all active banks

will be sound traditional banks. This shows that optimal capital regulation facing lower bankruptcy costs of shadow banks must prevent the emergence of shadow banks.

Proposition 6. *When $\xi < \zeta$, then any optimal capital regulation is such that in equilibrium no active bank will be a shadow bank.*

Conversely, lower bankruptcy costs make fragile shadow banks more profitable when shadow banking remains unregulated. Hence, capital requirements that do not constrain the behavior of shadow banks lead to the emergence of fragile banks for a larger set of parameters.

Proposition 7. *If $C(A) \leq 1$ and the bankruptcy costs of shadow banks $\xi > 0$ are sufficiently small, then there does not exist an equilibrium that satisfies the intuitive criterion where all active banks are sound.*

Differential bankruptcy costs, however, make it possible for traditional and fragile banks to coexist in a segregating equilibrium under naive capital regulation. The presence of fragile shadow banks under naive capital regulation does no longer necessitate full crowding out of the traditional banking sector.

Proposition 8. *Assume that the capital regulation is $C^N(A)$ and let $(A^F, P^F) = (1 + B - \frac{1}{2}\xi, 1)$. There exists a segregating equilibrium where sound and traditional banks coexist if*

$$\pi'_F(R, 1 - P^F, A^F, P^F) > \pi'_F(R, C^N(0), 0, 0) \tag{9}$$

and

$$\pi'_F(R, 1 - P^F, A^F, P^F) < \pi'_F(R, C^N(0), 1 - C^N(0), 1 - C^N(0)) \tag{10}$$

With differential bankruptcy costs fragile shadow banks benefit from lower costs of bankruptcy, unlike sound shadow banks that never go bankrupt. This difference makes it possible that the following two conditions are met at the same time:

1. Fragile shadow banks find it profitable to be active i.e., (9) holds.

2. Any shadow banking activity that would be profitable for sound banks would also be a profitable deviation for shadow banks i.e, (10) holds.[18]

As a result sound banks cannot signal their risk taking behavior when they become shadow banks. Hence it is not profitable for sound banks to deviate from being a traditional bank because they would have to pay an adverse selection premium if the want to become shadow banks and sell the corresponding securities to outside investors.

10. Conclusions

Capital regulation can only prevent excessive risk taking when securitization activities and shadow banks are properly taken into account. Risk taking can be prevented when the amount of equity capital that banks have to raise per unit of investment does not decrease with higher levels of securitization. Such capital requirements must require shadow banks to hold additional capital that exceeds their on-balance-sheet investment. Regulating securitization can substitute for capital regulation of shadow banks. Securitization restrictions limit the amount of leverage that shadow banks can take, which has the same effect as capital regulation.

If capital regulation only regulates the behavior of traditional, deposit taking banks, then shadow banks will emerge and take excessive risk. In addition, unregulated shadow banking might fully crowd out traditional banking, when capital regulation is only concerned with ensuring that traditional deposit taking banks are sound. This potentially jeopardizes additional functions of the traditional banking system such as the provision of a payment system.

[18] Technically (9) and (10) imply that $\pi_F(R, C^N(0), 1 - C^N(0), 1 - C^N(0)) > \pi_F(R, C^N(0), 0, 0)$. Due to the construction of C^N this holds if and only if $\xi < \zeta$.

Under optimal capital regulation, securitization cannot decrease banks' capital costs and hence, the underinvestment that is caused by capital regulation cannot be mitigated. When shadow banks have lower bankruptcy costs than traditional banks, then to prevent excessive risk taking their capital requirements per unit of investment must be higher than for traditional banks. This makes sound shadow banking unprofitable. Hence, shadow banks are likely not to be present in an optimally regulated banking system.

Overall the results in this paper indicate that in order to create a stable financial system, it might be necessary to enact substantial changes to current regulation. While such changes carry large uncertainties with them, the costs of not addressing the shortcomings of current regulation can be huge, as experienced in the recent financial crises.

A. Proofs

A.1. Proof of Lemma 1.

Proof. Because equations 1 and 2 do not depend on R, equations 3 and 4 must hold for all strategies that are used in equilibrium by sound and fragile banks, respectively.

Because $\frac{\partial \pi_F}{\partial R} < \frac{\partial \pi_S}{\partial R}$, there exists a single type of bank $\dot{R}$ that would be indifferent between all equilibrium strategies $\mathbb{S}$. All banks with $R > \dot{R}$ prefer to be sound banks and choose a strategy in $\mathbb{S}_S$. All active banks with $R < \dot{R}$ prefer to be sound banks and choose a strategy in $\mathbb{S}_F$. □

A.2. Proof of Lemma 2.

Proof. Let D be the non empty set of banks that find a deviation (A', P') profitable. The intuitive criterion requires that when outside investors observe such a deviation, they believe that the banks' type is in D with probability 1.

In equilibrium all banks always make profits of at least zero. Hence, when some banks in

D prefer to be fragile then $\frac{\partial \pi_F}{\partial R} < \frac{\partial \pi_S}{\partial R}$ implies that the least profitable bank that could find (A', P') profitable is given by $\underline{R}^F((1-P')C(A'), A', P')$. Thus outside investors believe that they make profits that are greater or equal to $1/2(A' + \underline{R}^F((1-P')C(A'), A', P') - B) - P'$. They will always buy securities (A', P') if this implies non-negative profits.

When all banks in D prefer to be sound then outside investors anticipate that they will earn profits greater or equal to $A' - P'$ which yields non-negative profits for outside investors when $P' \leq A'$. □

A.3. Proof of Lemma 3

Proof. Suppose some banks sell their entire investment in equilibrium for a price P^e. Since the entire investment is sold, the shareholders of these banks will not be affected by bankruptcy costs. Let $G(R)$ denote the cumulative distribution of expected returns of banks' investments that are sold in equilibrium. Obviously, the price for selling the entire investment must be unique and $P^e > 1$. Because it is impossible to pay dividends before investment returns materialize and $A \geq P$ for all securitization strategies, banks' initial shareholders with $R + B < 1$ will make positive profits if and only if they sell their banks' investments. Because $\mathbb{E}[R] = \int_{R^l}^{R^h} R dF(R) \leq 1 - B$ it follows that the expected profit from buying a bank's investment

$$\int_{R^l}^{R^h} R - P \, dG(R) \leq \int_{R^l}^{R^h} R - P \, dF(R) < 0$$

is negative. This cannot be an equilibrium because outside investors make negative expected profits, which proves the Lemma. □

A.4. Proof of Proposition 1

The proof uses the following Lemma 5, which describes a potential deviation that is possible if the beliefs of outside investors satisfy the intuitive criterion.

Lemma 5. *Assume that $C(A) \leq 1$. Every equilibrium where some banks' profits are lower or equal to $\pi_F(R, 0, 1 + B - \frac{1}{2}\zeta, 1)$ fails the intuitive criterion.*

Proof. Suppose that in equilibrium some banks' profits are lower or equal to $\pi_F(R, 0, 1 + B - \frac{1}{2}\zeta, 1)$. Then the securitization strategy $(1 + B - \frac{1}{2}\zeta, 1)$ would be a profitable deviation for these banks. Algebra yields that this securitization strategy satisfies 2 for all $C(A)$. Hence, banks will be able to sell these securities, which cannot be the case in equilibrium □

The Proof of Proposition 1 provides sufficient conditions under which no equilibrium where all active banks are sound can satisfy the condition provided by Lemma 5.

Proof of Proposition 1. From Lemma 5 it follows that a bank can always make profits $\pi_F(R, 0, 1 + B - \frac{1}{2}\zeta, 1) = \frac{1}{2}(R - 1 - \frac{1}{2}\zeta)$. Hence all banks with $R > 1 + \frac{1}{2}\zeta$ must be active in an equilibrium that satisfies the intuitive criterion.

If all banks with $R > 1 + \frac{1}{2}\zeta$ are active as sound banks then

$$\pi_S(1 + \frac{1}{2}\zeta, (1 - P')C'(A'), A', P') \geq 0$$

for some securitization strategy (A', P'). This implies that

$$C'(A') \leq \frac{2P' + \zeta - 2A'}{2\kappa(1 - P')}.$$

Some of these banks will not be sound, however, if

$$\pi_S(1 + \frac{1}{2}\zeta, (1 - P')C'(A'), A', P') < \pi_F(1 + \frac{1}{2}\zeta, (1 - P')C'(A'), A', P').$$

This condition implies that

$$P' < \frac{2A' + 2A'\kappa + 2B\kappa - \zeta - 3\kappa\zeta}{2 + 2\kappa}.$$

Because in any equilibrium $P \leq A$ must hold, the above condition is always satisfied when

$$\frac{2A' + 2A'\kappa + 2B\kappa - \zeta - 3\kappa\zeta}{2 + 2\kappa} > A'$$

which holds if and only if (6) holds. □

A.5. Proof of Lemma 4

Proof. Suppose that banks never choose a securitization strategy with $C(A) \geq 1$. Thus under $C^N(A)$ banks will only choose securitization strategies with $A < 1 - \frac{B-\zeta}{1+\kappa}$.

The capital regulation C^N is such that

$$\pi_S(R, (1 - A)C^N(A), A, A) = \pi_S(R, C^N(A), 0, 0)$$

for all $A \leq 1 - \frac{B-\zeta}{1+\kappa}$. Hence banks must make profits that are $\pi_S(R, C^N(A), A, A)$ in equilibrium because they can always choose not to engage in securitization. Because

$$\tilde{R}((1 - A)C^N(A), A, A) = \underline{R}((1 - A)C^N(A), A, A)$$

for all $A < 1 - \frac{B-\zeta}{1+\kappa}$, C^N ensures that all active traditional banks will be sound.

Consider a different naive capital regulation $C'(A)$. Suppose that $C'(A') \neq C^N(A')$ for some A'. Since in equilibrium outside investors demand $P' \leq A'$, $\pi_S(R, (1 - P')C'(A'), A', P') > \pi_S(R, C^N(0), 0, 0)$ implies that $C'(A') < C^N(A')$. But because

$\frac{\partial \pi_F}{\partial E} < \frac{\partial \pi_S}{\partial E} < 0$ and $\frac{\partial \pi_S}{\partial P} > \frac{\partial \pi_F}{\partial P} > 0$ this also implies that

$$\underline{R}^F((1-P')C'(A'),A',P') < \tilde{R}((1-P')C'(A'),A',P')$$

i.e., some active banks will be fragile. Hence if a securitization strategy (A',P') is used in equilibrium and $C'(A') \neq C^N(A')$, $C'(A)$ cannot be a naive capital regulation. Conversely for any naive capital regulation $C'(A)$ and any securitization strategy (A',P') that is chosen by traditional banks in equilibrium $C(A') = C^N(A')$. □

A.6. Proof of Proposition 2

Proof. Consider a banking system with capital regulation C^N, where both traditional and shadow banks coexist. C^N is chosen such that traditional banks either prefer to be sound or to remain inactive. Hence traditional banks will be sound and choose some securitization strategy $A^S = P^S < 1 - \frac{B-\zeta}{1+\kappa}$. From Proposition 1 it follows that under C^N some fragile shadow banks will be active. Their profits must be strictly higher than those of fragile traditional banks would be. Otherwise it would not be profitable for them to remain active. Thus a fragile bank's securitization strategy (A^F,P^F) must satisfy

$$\pi_F(R,(1-P^S)C^N(A),A^S,P^S) < \pi_F(R,1-P^F,A^F,P^F). \tag{11}$$

Sound banks would find any securitization strategy $A = P > 1 - \frac{B-\zeta}{1+\kappa}$ a profitable deviation because it would reduce their capital requirements and associated costs per unit of investment. From Lemma 2.2 it follows that sound banks could profitably deviate when their deviation would not be profitable for fragile banks. Hence fragile banks' profits must satisfy

$$\pi_F(R,1-P^F,A^F,P^F) \leq \pi_F(R,\frac{B-\zeta}{1+\kappa},1-\frac{B-\zeta}{1+\kappa},1-\frac{B-\zeta}{1+\kappa}) \tag{12}$$

to ensure that sound banks cannot profitably deviate.

The conditions (11) and (12) together imply

$$\pi_F(R,(1-P^S)C^N(A),A^S,P^S) < \pi_F(R,\frac{B-\zeta}{1+k},1-\frac{B-\zeta}{1+k},1-\frac{B-\zeta}{1+k}).$$

Since C^N ensures that capital costs are the same for all $A=P\leq 1-\frac{B-\zeta}{1+\kappa}$ this condition implies a contradiction. □

A.7. Proof of Proposition 3

Proof. Construct an equilibrium where all banks are shadow banks. Consider fragile banks that choose $(A^F,P^F)=(1+\frac{B+2B\kappa}{2+3\kappa},1)$ and sound banks that choose $A^S=P^S=\frac{2(1+k)-A^F}{1+2k}$.[19] These securitization strategies are such that for $R\sim U[R^l,R^h]$ outside investors make zero profits:

$$\int_{\underline{R}((1-P^F)C(A^F),A^F,P^F)}^{\dot{R}} {}^1\!/_2(R-B+A^F)-P^F dF(R)=0.$$

It is easy to check that $\underline{R}((1-P^F)C^N(A^F),A^F,P^F)<1$ when (7) holds.

Banks' strategies constitute an equilibrium when outside investors beliefs are such that only those deviations that satisfy the conditions of Lemma 2 are possible. Fragile banks then do not have an incentive to deviate because $\pi_F(R,1-P^F,A^F,P^F)$ is larger than $\pi_F(R,0,1+B-\frac{1}{2}\zeta,1)$ which maximizes the profit of sound banks subject to condition (5) in Lemma 2.

The strategy of sound banks satisfies $\pi_F(R,1,A^S,P^S)=\pi_F(R,1,A^F,P^F)$ and $A^S=P^S$. Note that for $E=(1-P)C^N$ the indifference curves of sound banks in the A-P-plane are steeper than those of fragile banks but flatter than the 45° line. This implies that any deviation with $P^S\leq A^S$ that would be profitable for sound banks would also be profitable

[19] This equilibrium is chosen such that it maximizes the profits of banks subject to the incentive compatibility constraints that are discussed in the remainder of this proof.

for fragile banks. Outside investors will thus not be willing to buy any securities that would be profitable deviations for sound banks.

In the above equilibrium, sound banks are of course only shadow banks when $C^N(A^S) = 1 \Leftrightarrow A^S \geq 1 - \frac{B-\zeta}{1+\kappa}$. Algebra yields that this is satisfied when (7) is satisfied. □

A.8. Proof of Proposition 4

Proof. The capital regulation $C^*(A)$ is such that for all $A < 1$ the profits of banks satisfy

$$\pi_S(R, (1-A)C^*(A), A, A) = \pi_S(R, C^*(A), 0, 0)$$

for all A. When $A \to 1$, $C^*(A) \to \infty$ and hence securitization strategies with $A \geq 1$ cannot be chosen by banks. Hence in equilibrium banks' profits must equal $\pi_S(R, (1-A)C^*(A), A, A)$. The capital regulation further implies that for all $A < 1$

$$\tilde{R}((1-A)C^*(A), A, A) = \underline{R}((1-A)C^*(A), A, A).$$

It follows that all active banks must prefer to remain sound.

By the same arguments used in the proof of Lemma 4, there cannot exist another optimal capital regulation $C'(A)$ where a securitization strategy (A', P') is chosen in equilibrium and $C'(A') \neq C^*(A')$. □

A.9. Proof of Proposition 5

Proof. Let (E, A, P) be a securitization strategy that is chosen by sound banks in equilibrium. From $\frac{\partial \pi_F}{\partial E} < \frac{\partial \pi_S}{\partial E} < 0$ and $\frac{\partial \pi_S}{\partial P} > \frac{\partial \pi_F}{\partial P} > 0$ it follows that $\pi_S(E, A, P) > \pi_S((1-A)C^*(A), A, A)$ and $P \leq A$ imply that $\tilde{R}(E, A, P) > \tilde{R}((1-A)C^*(A), A, A)$. Fragile banks will only choose a different securitization strategy from sound banks when this is at least as profitable for them. Hence in any equilibrium $\mathbb{S}$ where fragile banks are

active $\dot{R}(\mathbb{S}) > \tilde{R}((1-A)C^*(A), A, A)$.

The additional NPV that is created by allowing fragile banks is given by $\int_{\underline{R}(\mathbb{S})}^{\tilde{R}(C^*(0),0,0)} R-1\, dF(R)$ while the social costs of bankruptcy are given by $\int_{\underline{R}(\mathbb{S})}^{\dot{R}(\mathbb{S})} \frac{1}{2}x\, dF(R)$. Since $\tilde{R}((1-A)C^*(A), A, A) = \underline{R}((1-A)C^*(A), A, A)$ the social costs of bankruptcy exceed the additional NPV when $\frac{1}{2}\phi > (\underline{R}(C^*(0), 0, 0) - 1)$.

Hence the optimal capital regulation maximizes the total surplus. □

A.10. Proof of Proposition 6

In what follows let $\tilde{A} = 1 - \frac{B-\zeta}{1+\kappa} - \frac{\zeta-\xi}{1+2\kappa}$.

Proof. Lower bankruptcy costs $\xi < \zeta$ make shadow banking more profitable. Banks choose $E = 1 - P > (1-P)C^*(A)$ for $C^*(A)$ close to 1 because the increase in capital cost from setting $E = 1 - P$ is outweighed by the decrease in bankruptcy costs for fragile banks. It can easily be shown that

$$\tilde{R}((1-A)C^*(A), A, A) > \underline{R}((1-A)C^*(A), A, A)$$

for $A > \tilde{A}$ where fragile banks are shadow banks. Since any optimal capital regulation must prevent risk taking, optimal capital requirements must be higher than $C^*(A)$ for $A > \tilde{A}$.

For $A \leq \tilde{A}$ and $C^*(A) < 0$ the difference in bankruptcy costs is not sufficient to make fragile shadow banking with $E = 1 - P > (1-P)C^*(A)$ profitable. Hence it follows from the proof of Lemma 4 that under any optimal capital regulation sound banks' profits must equal $\pi_S(R, C^*(0), 0, 0)$. This implies that any optimal capital regulation must equal $C^*(A)$ for some $A \leq \tilde{A}$.

For $C(A) > C^*(A)$ sound banks' profits are strictly lower than $\pi_S(R, C^*(0), 0, 0)$. Hence under optimal capital regulation sound banks will never choose securitization

strategies with $A > \tilde{A}$. Since $C^*(A) < 0$ for $A \leq \tilde{A}$, banks under optimal capital regulation will never be shadow banks. □

A.11. Proof of Proposition 7

Proof. Analogous to the proof of Lemma 5 it can be shown that every equilibrium where some banks' profits are lower or equal to $\pi'_F(R, 0, 1+B-\frac{1}{2}\xi, 1)$ fails the intuitive criterion. Analogous to the proof of Proposition 1 it can be shown that there does not exist an equilibrium that satisfies the intuitive criterion where all active banks are sound if

$$B > \zeta + \xi \frac{1+\kappa}{2\kappa}$$

and $C(A) \leq 1$ for all A. Since $B > \zeta$ by assumption the proposition holds for sufficiently small ξ. □

A.12. Proof of Proposition 8

Proof. Consider the equilibrium where all sound banks choose $(A^S, P^S) = (0, 0)$ and all fragile banks choose (A^F, P^F). The beliefs of outside investors off the equilibrium path are such that Lemma 2 applies.

It is only profitable for shadow banks to sell securities (A^F, P^F) when (9) holds. There is no profitable deviation for shadow banks because $(1 + B - \frac{1}{2}\xi, 1)$ maximizes fragile banks' profits subject to (5).

Outside investors make zero profits from the least profitable active bank that sells securities (A^F, P^F). Hence the expected profit of outside investors is positive because $\dot{R} > \underline{R}^F$.

Sound banks would only be willing to deviate if they can make profits that are higher

than

$$\pi_S(R, C^N(0), 1 - C^N(0), 1 - C^N(0)) = \pi_S(R, C^N(0), 0, 0).$$

From equation (9) and the slopes of banks' indifference curves in the A-P-plane for $E = (1 - P)C^N(A)$ it follows that any profitable deviation of sound banks would be a profitable deviation for fragile banks as well. Since (A^F, P^F) maximizes sound banks' profits subject to (5), $\pi_S(R, 1, A^F, P^F)$ is the highest profit that sound banks can make off the equilibrium path. Simple algebra then shows that (5) implies that $\pi_S(R, C^N(0), 0, 0) > \pi_S(R, 1 - P^F, A^F, P^F)$ and hence there is no profitable deviation for sound banks. □

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