Systemic Risk-Taking:
Amplification Effects, Externalities, and Regulatory Responses

Anton Korinek*
University of Maryland

March 22, 2010

Abstract

This paper develops a simple macroeconomic model of systemic risk in the form of financial accelerator effects: adverse developments in financial markets and in the real economy mutually reinforce each other and lead to a feedback cycle of falling asset prices, deteriorating balance sheets and tightening financing conditions. We show that decentralized agents choose to expose themselves to financial accelerator effects to a socially inefficient extent and do not take on sufficient insurance against systemic risk even if given access to a complete ex-ante insurance market. We use the framework to shed light on a number of current policy issues. First, we develop a new analytical framework of macro-prudential capital adequacy requirements that take into account systemic risk by employing an externality pricing kernel. Second, we show that agents employ ex-ante risk markets to fully undo any expected government bailout. Finally, we find that constrained market participants face socially insufficient incentives to raise more capital during systemic crises.

JEL Codes: E44, D62, G28, H23
Keywords: financial amplification, systemic risk, systemic externalities, social pricing kernel, macroprudential regulation, bailout neutrality

*The author would like to thank Claudio Borio, Sudipto Bhattacharya, Fernando Broner, Markus Brunnermeier, Allen Drazen, Matteo Iacoviello, Olivier Jeanne, Pete Kyle, Enrique Mendoza, Marcus Miller, Tommaso Monacelli, John Shea, Joseph Stiglitz, Martin Summer, and Michael Woodford as well as participants at several conferences and seminars for helpful discussions and comments. Address for correspondence: 4118F Tydings Hall, University of Maryland, College Park, MD 20742, USA. Telephone number: +1 (301) 405-4536. Email contact: `akorinek@umd.edu`

1 Introduction

The current financial crisis has powerfully demonstrated how prone modern economies are to systemic risk, i.e. the risk that a shock of sufficient magnitude impairs the financial system to the point that it can no longer perform its function of allocating capital to the most efficient use. This paper develops a simple model of systemic risk stemming from financial accelerator effects, whereby declining asset prices and deteriorating balance sheets mutually reinforce each other and thereby magnify the effects of shocks to the financial system.

Accelerator effects typically involve the following four elements:[1] First, a negative shock tightens financial constraints on entrepreneurs and limits their economic activity. Second, the decline in aggregate economic activity reduces the price of productive assets in the economy. Third, the price decline decreases the net worth of entrepreneurs who own the assets. Fourth, the decline in net worth reduces the creditworthiness of entrepreneurs and tightens their financial constraints further. This feeds back into the first element, leading to a self-reinforcing cycle of tightening financing conditions, declining economic activity, falling asset prices and shrinking net worth (see figure 1).

Every crisis therefore brings up the question of whether exisiting regulations are sufficient or whether new regulations to limit risk-taking by financial market participants are desirable.For government regulations to enhance social welfare, they must correct a market imperfection. Otherwise, if markets functioned well and rational market participants knowingly took on extensive risk, then crises would be a socially desirable outcome (see e.g. Allen and Gale, 1998), and government regulations to limit risk-taking would reduce social welfare.

This leads to the central question that we pose in this paper: *Are the financing and investment decisions of decentralized agents in an economy that is prone to systemic risk socially optimal?* We find that the answer is a clear no. We show that rational atomistic agents do not internalize that their actions give rise to amplification effects when financing constraints in the economy are binding. They balance off the private benefits and costs of their financing and investment decisions, including the private costs of potential future constraints, while taking aggregate prices as given. However, when a significant number of agents are forced to reduce their economic activity in response to an aggregate shock, general equilibrium effects imply that asset prices have to decline.[2] In perfect markets, this would constitute a purely pecuniary externality, which has no efficiency implications. However, in an economy with binding financing constraints, this pecuniary externality has real effects: asset price declines tighten financing constraints and trigger amplification effects.

[1] See for example Bernanke and Gertler (1989); Kiyotaki and Moore (1997); Bernanke et al. (1999).

[2] For a detailed discussion of the reasons behind such price declines see e.g. Shleifer and Vishny (1992).

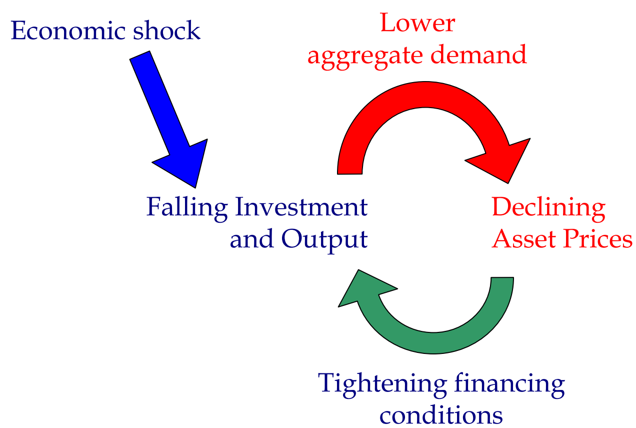

Figure 1: A simple schematic model of financial amplification

Since atomistic agents do not internalize this, they undervalue the social benefits of liquidity in crisis states. This leads them to take on a *socially excessive level of systemic risk* in their financing and investment decisions. We call the distortion that arises from individual agents' failure to internalize the amplification effects that they give rise to a *systemic externality*.[3,4] A social planner would internalize that a lower level of risk-taking or a higher level of insurance would mitigate financing constraints and amplification effects in low states of nature. This would lead to lower volatility in aggregate economic activity, in asset prices and in financing constraints, benefitting all agents in the economy.

Translating our theoretical results into practical policy advice, we develop a comprehensive theoretical framework of macro-prudential financial regulation. We derive a *social pricing kernel* and an *externality kernel* as a guide for how capital adequacy requirements can be adjusted for systemic risk. The social pricing kernel quantitatively captures a social planner's state-contingent valuation of liquidity, accounting for the social costs of financial amplification effects. The externality kernel is the difference between social and private valuation of liquidity in each state of nature, i.e. it reflects the state-contingent magnitude of

[3]In recent policy discussions, the term *systemic risk* has been used to describe risk that endangers the stability of the entire financial system. Note that this definition contrasts with the definition of systemic risk (or systematic risk, aggregate risk, market risk) in the asset pricing literature as risk that cannot be diversified. The view proposed in this paper captures both definitions, as the excessive exposure of individual agents to undiversifiable market risk can give rise to large amplification effects that destabilize the financial system when financial constraints in the economy are binding.

[4]The analogy to more traditional forms of externalities should be clear: for example, when a polluter ceases to pollute, he bears all the costs, but society at large reaps the benefits. In our example, a financial institution that limits its risk-taking bears all the costs in terms of foregone profits, but society at large benefits from the mitigation of amplification effects and greater financial stability.

systemic externalities created by the excessive risk-taking of decentralized agents. In states when financing constraints are loose, the externality kernel is zero as no amplification effects arise; in constrained states the externality kernel captures the social costs of amplification effects created by payoffs. Just as pricing kernels are used to calculate the decentralized market price of risky assets, the externality kernel can be used by regulators to price the systemic externalities created by assets and liabilities with state-contingent payoffs. The externality can be corrected by imposing a Pigovian tax of equal magnitude, or any policy measure that has tax-like effects, such as e.g. increased capital adequacy requirements.

We find that from our macro-prudential perspective, the optimal tax on an asset that offsets the externality is given by the expected magnitude of payoffs in constrained states times the social cost of such payoffs in terms of inducing amplification effects, as measured by the externality kernel. This would induce market participants to internalize their systemic externalities. Such regulations should also apply to the so-called "shadow financial system," which contributes strongly to amplification effects in modern financial systems.

We believe that the systemic externalities laid out in this paper should be a cornerstone of financial regulation. The main motivation behind current banking regulations (see e.g. the discussion in Borio, 2003; Brunnermeier et al., 2009) is to limit the risk of failure of financial institutions, originally with a view towards protecting their depositors. The framework is largely based on a partial equilibrium view that analyzes each single institution in isolation and cannot adequately account for the systemic feedback effects and externalities that are the topic of our paper. However, note that strong amplification effects can arise even in the absence of individual bank failures, and that the social costs of a bank failure consist largely of the resulting shockwaves in the financial system (i.e. of amplification effects) rather than the direct losses that accrue to the failed bank's creditors.

It has been argued that risk-sensitive capital adequacy regulations with a purely microeconomic focus can contribute to pro-cyclicality (see e.g. Catarineu-Rabell et al., 2005): when financial institutions suffer losses or when the riskiness of their assets rises, they have to set aside more capital and are often forced to engage in fire sales, which can lead to financial amplification effects and magnify the increase in risk. Our analysis indicates that banks will not internalize the social costs of the resulting pro-cyclicality, and that it is privately optimal for them to take on excessive systemic risk in the presence of such regulations. It is often argued that market discipline would induce transparent banks to adopt rules that smooth their capital holdings throughout the business cycle (Gordy and Howells, 2006). However, our analysis implies that markets would punish financial institutions that behave socially responsibly and reward those that behave irresponsibly, since maximizing shareholder value involves socially excessive risk-taking.

The paper also discusses a number of additional results. A consequence of our finding that decentralized agents undervalue liquidity in crisis states is that they also undervalue the social benefits of raising new capital in constrained states of nature: any capital injection mitigates financial amplification effects and moderates the decline in asset prices; again, atomistic agents do not internalize the social value of stabilizing asset prices since they take prices as given.

We show that the largest systemic externalities arise when financial market participants that are prone to financing constraints are close to risk-neutral (e.g. hedge funds) but trade with risk averse creditors: they do not face an insurance motive as a result of their utility function and are willing to take on large amounts of risk, which exposes them to financial constraints in bad states of nature and leads to systemic amplification effects.

We analyze the effectiveness of bailouts to constrained market participants so as to avert amplification effects, and we find that any anticipated bailouts will be undone by market participants and will therefore have no effects. However, transfers that are unanticipated or that are made to agents that do not have sufficient access to financial markets to undo them can be be effective.

We also discuss the importance for market participants of having correct expectations about future prices. In crisis times when constraints are binding, the welfare costs of expectational errors are by an order of magnitude larger than in normal times, since financial amplification effects magnify the impact of any unexpected change to the liquidity position of market participants. There is therefore a role for financial regulators to conduct "systemic stress tests," which serve to ensure that market participants are better informed about the potential magnitude of declines in asset prices during crises.

While our benchmark model captures a situation where only one constrained sector is affected by an aggregate shock, we also analyze the potential for contagion among different sectors in an extension. We describe two channels of contagion, through asset prices and through contingent lines of liquidity. A sector can suffer from contagion through asset prices if is financially constrained in some states of the world and it uses as collateral assets that experience price fluctuations because of the pecuniary externalities of other sectors. This channel was of great importance for hedge funds and financial institutions in the subprime crisis (Adrian and Brunnermeier, 2009). Similarly, a sector can experience contagion through contingent lines of liquidity if it offers credit lines to other sectors that, if drawn upon in case of crises, are sufficiently large to make the lending sector itself financially constrained. Examples include the credit lines from their parent banks that many SIVs and conduits drew upon in the subprime crisis (Brunnermeier, 2008). In both cases, decentralized agents in sectors that are subject to binding financing constraints in some states generally underinsure against contagion from other sectors.

Our work fundamentally builds on the literature on financial amplification effects, which started with Fisher (1933)'s work on the debt deflation theory of the Great Depression. We described the basic mechanism above in figure 1. More recent seminal contributions to this literature are for example Bernanke and Gertler (1990), Kiyotaki and Moore (1997) and Bernanke et al. (1999). While these papers analyze the mechanism of financial amplification effects, we focus on the implications for ex ante decentralized financing decisions and analyze welfare implications.

In this vein, Krishnamurthy (2003) shows that if entrepreneurs have access to risk-neutral financial markets (so that insurance against adverse shocks is actuarially fair), they would always fully insure against systemic risks that lead to amplification effects, and a social planner could not improve on this allocation. This result is a special case that only holds when lenders are perfectly risk-neutral and ex-ante insurance markets are perfect. In the real world, entrepreneurs are clearly not fully insured against shocks. Instances of binding financing constraints and financial amplification effects are a recurring feature of modern market economies. Krishnamurthy (2003) captures this by assuming that limited aggregate supply of collateral prevents full insurance.

By a similar token, Lorenzoni (2008) analyzes the case where two-sided limited commitment constrains the amount of insurance that entrepreneurs can obtain from lenders and shows that this leads entrepreneurs to over-invest, since they do not internalize that higher investment increases the amount of fire-sales that they need to engage in in bad states of nature. Whereas he examines the socially optimal amount of investment, our main focus is on the optimal degree of risk-taking in the financing and investment decisions of decentralized agents. We show that even when entrepreneurs have access to unconstrained insurance markets, they take on excessive risk if we deviate from the benchmark of risk-neutrality. In this respect, the paper is related to Korinek (2009), who shows that decentralized agents in an emerging market economy borrow excessively in dollars from international lenders because they do not internalize that risky financing decisions contribute to the financial amplification effects that are triggered during emerging market crises. Gromb and Vayanos (2002) show that constrained arbitrageurs fail to take on the socially efficient level of risk in their arbitrage activities.

More generally, the externality result in our paper is an application of the proposition that the market equilibrium in economies with constraints that endogenously depend on market prices is not constrained efficient (Arnott et al., 1992): decentralized agents do not internalize that their pecuniary externalities affect the tightness of the constraint. In our case, asset prices determine the tightness of financing constraints, and decentralized agents do not internalize that changes in their net worth affect asset prices.

A number of recent papers document the importance of amplification effects empirically. For example, Adrian and Shin (2009) find that leverage among investment banks is strongly pro-cyclical, implying that they take on more risk in good times and sell off risky assets in bad times. Adrian and Brunnermeier (2009) show that VaR – a measure for the riskiness of a financial institution's assets – rises strongly when another financial is in distress. They also document that financial institutions that increase their exposure to systemic risk raise their expected return, consistent with our theoretical model.

We model bankers as agents in a simplified version of Kiyotaki and Moore (1997)
[5]

The rest of the paper is structured as follows. The following section 2 develops a simple model of financial amplification effects, which are triggered if bankersface binding financing constraints and need to engage in fire sales. We show that in states with binding constraints, a social planner always values liquidity more highly than decentralized bankers. In section 3.3 we analyze their financing decision and show that the undervaluation of liquidity induces them to take on too much systemic risk. Section 4 shows a number of applications of our baseline model to policy questions such the optimal design of macro-prudential regulation to offset the systemic externalities, the effectiveness of bailouts, and the incentives for raising capital. Section 5 concludes.

2 Model

Our model economy consists of three time periods $t = 0, 1, 2$ and is inhabited by two categories of atomistic agents, bankers and households. Bankers represent the consolidated productive sector of the economy and could alternatively be interpreted as entrepreneurs – the important characteristic is that they make financing decisions and are subject to business risk. Households come in two generations; they are less productive than bankers, but they receive endowments and therefore have the ability to provide finance to bankers. There are two types of goods, a homogeneous consumption good and a productive asset.

Bankers Bankers are risk-neutral and value consumption in periods 1 and 2 according to

[5]However, despite being risk-neutral, we can show in the following section that bankers have an incentive to hedge against binding financing constraints, as emphasized by Froot et al. (1993). The assumption of risk-neutrality was made for analytical simplicity; our results continue to hold if bankers are assumed to be risk-averse.

the function

$$V = E[c_{1,b}^{\omega} + c_{2,b}^{\omega}] \tag{1}$$

where we use the subindex "b" for banker-specific variables and where we assume $c_{1,b}, c_{2,b} \geq 0$. In period 0, they have access to a lumpy investment technology that allows them to invest αt_1 consumption goods and obtain t_1 units of productive capital goods. We can think of this as planting a seed that costs α on t_1 units of land each. (We will discuss a generalization of this later.) They have no endowment, so they need to finance their period 0 investment by selling financial claims in a complete one-period market of Arrow securities contingent on the state of nature $\omega \in \Omega$ in period 1. We denote the amount to be repaid in state ω of period 1 as b_1^{ω} and the state price at which a claim trades in period 0 as m_1^{ω}. The resulting period 0 budget constraint is

$$\alpha t_1 = E\left[m_1^{\omega} b_1^{\omega}\right] \tag{2}$$

In period 1, each unit of capital goods produces a stochastic net payoff A_1^{ω}, which depends on the state of nature ω, is bounded by an interval $[A^{\min}, A^{\max}]$ and is assumed to satisfy the normalization $E\left[A_1^{\omega}\right] = \bar{A} = 1$. Next, they repay the state-contingent claim b_1^{ω}. They have access to a security market in which a promise to repay b_2^{ω} units in period 2 trades at a market price $m_2^{\omega} b_2^{\omega}$. They also have access to a market for productive assets that trades at price q_1^{ω}. As we will see below, asset sales in this market share many characteristics of fire-sales; therefore we denote the quantity of capital that bankers sell as f_1^{ω}. The resulting period 1 budget constraint is

$$c_{1,b}^{\omega} + b_1^{\omega} = A_1^{\omega} t_1 + q_1^{\omega} f_1^{\omega} + m_2^{\omega} b_2^{\omega} \tag{3}$$

We follow Kiyotaki and Moore (1997) in assuming that there is a commitment problem and that bankers can only pledge the future value of their asset holdings as collateral, not their future production. Since the economy ends after period 2 the asset is worthless at that end of that period, i.e. $q_2^{\omega} = 0$. As a result, bankers have no collateral and cannot borrow in period 1,[6]

$$b_2^{\omega} \leq 0 \tag{4}$$

Given their linear preferences, bankers are willing to substitute consumption between periods 1 and 2 at a rate of one to one. The non-negativity constraint on period 1 consumption $c_{1,b}^{\omega} \geq 0$ prevents them from using this substitutability to circumvent the borrowing constraint.

[6]Following the same argument, we could also impose a borrowing constraint that limits period 0 borrowing by the value of productive assets in period 1. However, such a constraint would not affect the main results of our paper. We therefore assume that initial investment costs αt_1 are such that this constraint never binds.

In period 2, bankers employ their remaining asset holdings to produce and consume $c^{\omega}_{2,b} = \bar{A}(t_1 - f^{\omega}_1) - b^{\omega}_2$, where we keep the productivity parameter $\bar{A}$ constant for simplicity. We do not explicitly impose the non-negativity constraint on period 2 consumption, but we note that any solution to the maximization problem below is only admissible for $c_{2,b} \geq 0$.[7] The resulting optimization problem for bankers is

$$V = \max_{\{b^{\omega}_1, b^{\omega}_2, c^{\omega}_{1,b}, f^{\omega}_1\}} E\left[c^{\omega}_{1,b} + \bar{A}(t_1 - f^{\omega}_1) - b^{\omega}_2\right] \quad \text{s.t. (2), (3), (4) and } c^{\omega}_{1,b} \geq 0 \qquad (5)$$

First-Generation Households We assume that there are two generations of households that live for two periods each. The first generation lives across periods 0 and 1. They are risk averse and derive utility from consumption according to the function

$$U^{\omega} = E[u(c_{0,h}) + u(c^{\omega}_{1,h})]$$

where $u(\cdot)$ is a standard neo-classical utility function. We use the sub-index "h" for first-generation households. They receive an endowment e every period that satisfies $e > \alpha t_1$. In period 0 they buy a bundle $\{b^{\omega}_1\}$ of Arrow securities at cost $E[m^{\omega}_1 b^{\omega}_1]$ that offers a contingent repayment of b^{ω}_1 in period 1. Their optimization problem is

$$\max_{\{b^{\omega}_1\}} u\left(e - E[m^{\omega}_1 b^{\omega}_1]\right) + E\left[u(e + b^{\omega}_1)\right] \qquad (6)$$

The Euler equation that captures their demand for Arrow securities contingent on state ω

$$FOC(b^{\omega}_1): \; m^{\omega}_1 = \frac{u'(c_{1,h})}{u'(c_{0,h})}$$

which is downward-sloping, i.e. $\partial m^{\omega}_1 / \partial b^{\omega}_1 < 0$. Furthermore, $\partial m^{\omega}_1 b^{\omega}_1 / \partial b^{\omega}_1 > 0$ for standard parameter values (detailed conditions are given in appendix A).

Second-Generation Households Second generation households live from period 1 to period 2. They value consumption according to the utility function

$$W = E\left[w(c^{\omega}_{1,l}) + w(c^{\omega}_{2,l})\right]$$

We use the sub-index "l" for second-generation households. They receive an endowment e every period and buy b^{ω}_2 discount bonds in period 1 at price m^{ω}_2 that repay b^{ω}_2 in period 2. In addition, they buy f^{ω} productive assets at the given market price q^{ω} and employ them for period 2 production using a decreasing returns-to-scale production function $F(\cdot)$ that satisfies $F'(0) = \bar{A}$ and $F'' < 0$, i.e. the marginal productivity is equal to the productivity of

[7] In general, this condition is satisfied as long as the initial investment requirement αt_1 is sufficiently low.

bankers at zero, and is a declining function of the amount of assets purchased, i.e. households are less productive than bankers for any positive amount of assets employed. The resulting optimization problem is

$$\max_{\{f^\omega, b_2^\omega\}} w(e - q^\omega f^\omega - m_2^\omega b_2^\omega) + w(e + b_2^\omega + F(f^\omega)) \tag{7}$$

The first-order conditions yield the demand for productive assets and bonds

$$m_2^\omega = \frac{w'(c_{2,l}^\omega)}{u'(c_{1,l}^\omega)} \tag{8}$$

$$q^\omega = \frac{u'(c_{2,l}^\omega)}{u'(c_{1,l}^\omega)} \cdot F'(f^\omega) \tag{9}$$

Note that ceteris paribus, both demand functions are downward-sloping, i.e. $\partial m_2^\omega / \partial b_2^\omega < 0$ and $\partial q^\omega / \partial f^\omega < 0$. Furthermore, the amount of spent on asset purchases is increasing in f, i.e. $\partial qf / \partial f > 0$, as long as the regularity conditions detailed in appendix A.2 are met. This allows us to define a pair of functions $f(s)$ and $q(s)$ that express the amount of asset purchases and the corresponding asset price as a function of the amount s spent on asset purchases so that $s = q(s)f(s)$.

3 Decentralized Equilibrium

An equilibrium in the economy consists of a set of allocations $\left(c_{0,h}, c_{1,h}^\omega, c_{1,b}^\omega, c_{2,b}^\omega, c_{1,l}^\omega, c_{2,l}^\omega, b_1^\omega, b_2^\omega, f^\omega\right)$ and prices $(m_1^\omega, m_2^\omega, q^\omega)$ which satisfy the maximization problems (5), (6), (7) of all three agents as well as the market-clearing conditions for bonds and fire-sales.

3.1 Backward Induction: Period 1 Equilibrium

We solve the problem of bankers by backwards induction: we first analyze their optimal period 1 and 2 allocations, after the state of the world ω is realized at the beginning of period 1; then we proceed to solve for the optimal financing decision in period 0.

After the productivity shock ω has been realized, denote by $V(a)$ the utility that a banker obtains if he holds liquid asset holdings $a = A_1^\omega t_1 - b_1^\omega$ in the beginning of period 1. We denote the Lagrangian of the associated optimization problem as follows. (Since there are no further shocks after period 1, we drop the superscript ω for ease of notation.)

$$V(a) = \max_{\{c_{1,b}, f, b_{2,h}\}} c_{1,b} + \bar{A}(t_1 - f^\omega) - b_2 - \mu\left[c_{1,b} - a - qf - m_2 b_{2,h}\right] - \nu b_{2,h} + \lambda c_{1,b} \tag{10}$$

The first order conditions are

$$\text{FOC}(c_{1,b}) : \mu = 1 + \lambda$$
$$\text{FOC}(f) : \bar{A} = \mu q$$
$$\text{FOC}(b_{2,h}) : 1 + \nu = \mu m_2$$

Bankers cannot borrow between periods 1 and 2 because of the borrowing constraint 4. Furthermore, in equilibrium, it will never be profitable for bankers to save between periods 1 and 2, since the price at which second generation households would provide savings to them would satisfy $m \geq 1$ for $b_{2,l} \leq 0$, and at that price bankers would weakly prefer consuming the resources immediately.

Assumption 1 *We assume that bankers consume immediately whenever they are indifferent between consumption and savings.*

Taking these observations together, we set $b_2^\omega = 0$ and drop the variable and its associated constraint from the optimization problem of bankers.

Depending on the amount of liquid assets a, we distinguish between two equilibria:
Unconstrained equilibrium for $a \geq 0$: For positive liquid asset holdings in the beginning of period 1, the optimum allocation of bankers is unconstrained: they consume their liquid wealth in period 1 $c_{1,h} = a$ and do not engage in fire sales $f_h = 0$. In period 2, they consume their entire production $c_{2,h} = \bar{A}t_1$. The shadow prices satisfy $\mu = 1$ and $\lambda = 0$. The allocation $f = 0$ together with a price $q = \bar{A}$ also constitutes an optimum for second generation households.

Constrained equilibrium for $a < 0$: For negative liquid asset holdings, i.e. when the net output in period 1 is insufficient to cover the debt b_1, bankers would like to roll over debt into period 2 but are prevented from doing so by binding constraints. Instead they choose a period 1 level of consumption $c_{1,h} = 0$ and engage in asset sales of $f(-a)$ at price $q(-a)$ so as to cover their debts

$$q(-a)f(-a) + a = 0$$

In period 2, they consume the output from their remaining asset holdings $c_{2,h} = \bar{A}(t_1 - f)$. Second-generation households are willing to buy a level $f(-a) > 0$ of assets if the price declines sufficiently below $\bar{A}$ so as meet their optimality condition $q = \frac{w'(c_{2,l})}{w'(c_{1,l})}F'(f)$. Since bankers sell assets at prices that are below their marginal product, we call these sales "fire sales." The shadow price of liquidity of bankers is $\mu = \bar{A}/q > 1$, reflecting that an additional unit of liquidity could buy up $1/q$ assets and earn a return $\bar{A}$.

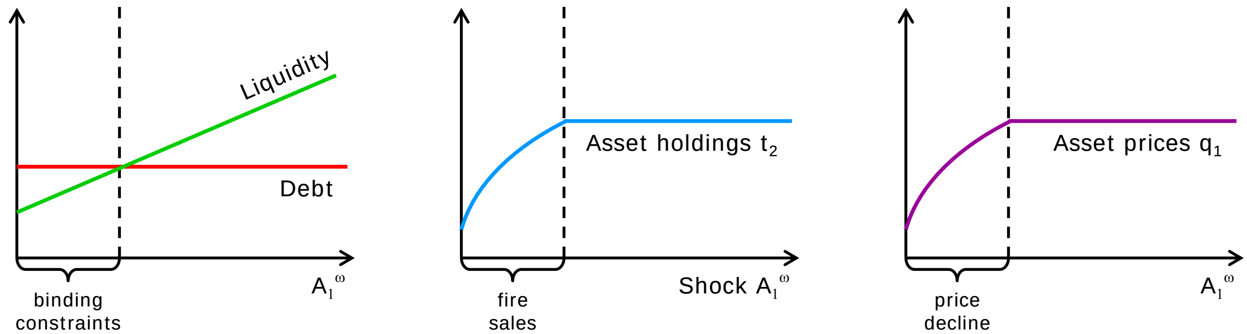

Figure 2: Fire sales and price declines as a function of A_1^ω

Comparative Statics

Figure 2 depicts a comparative static analysis of the economy's equilibrium in period 1 for a given level of repayment b_1. The lower productivity A_1^ω, the lower the liquidity of bankers (left panel). If bankers' earnings $A_1^\omega t_1$ are less than the debt level b_1, bankers experience binding constraints. As a result, they have to engage in fire sales of their productive asset holdings (center panel), which reduces the equilibrium price q (right panel).

The effects of any shock under this constrained regime are magnified by financial amplification: suppose e.g. that bankers are constrained and experience a small negative shock da to their liquidity position. Then the partial equilibrium effect is that the they are forced to sell an amount $\frac{da}{q^\omega}$ of their productive assets. In general equilibrium this sale depresses the price q^ω by an amount of $\frac{da}{q^\omega} \cdot \frac{\partial q^\omega}{\partial f^\omega}$. By implication bankers receive less for all of their asset sales f^ω and need to increase fire sales even further, and so on. As a result, both period 2 holdings of productive assets and asset prices are concave in bankers' liquidity.

3.2 Period 0 Financing Decisions

Given the definition of V in equation (10), we re-formulate the period 0 optimization problem of bankers as

$$\max_{\{b^\omega_{1,b}\}} V\left(A_1^\omega t_1 - b_1^\omega\right) \quad \text{s.t.} \quad E[m_1^\omega b_{1,b}^\omega] = \alpha t_1 \tag{11}$$

Assigning a shadow price of ν to the period 0 budget constraint, the first-order condition of the Lagrangian to this problem is

$$-V'(a^\omega) = \nu m_1^\omega \tag{12}$$

where we observe that $V'(a^\omega) = -\mu^\omega$ reflects the shadow price of liquidity of bankers.

If bankers are unconstrained in a given state of nature ω, then $\mu^\omega = 1$. We substitute the optimality condition of first generation households into the first-order condition (12) to obtain the repayment $b_1^\omega = b_1^{unc}(\nu)$ as an increasing function of ν:

$$b_1^{unc}(\nu) = u'^{-1}\left[\frac{u'(e-\alpha t_1)}{\nu}\right] - e \tag{13}$$

On the other hand, if bankers are constrained in state ω, then $\mu^\omega = \frac{\bar{A}}{q(-a)}$. We substitute this condition as well as the optimality condition of first generation households in the first-order condition to obtain

$$\frac{\bar{A}}{q(b_1^\omega - A_1^\omega t_1)} = \nu \frac{u'(e+b_1^\omega)}{u'(e-\alpha t_1)} \tag{14}$$

The left-hand side of this equation is strictly increasing in b_1^ω, as higher repayments in constrained states require larger fire sales, which push down the price q^ω further and raise the shadow value of banker liquidity in period 1. The right hand side is strictly decreasing in b_1^ω, implying that for given parameter values, equation (14) has a unique solution. Varying the parameters A_1^ω and ν in the equation defines a function $b_1^\omega = b_1^{con}(\nu, A_1^\omega)$ that satisfies $\partial b_1^{con}/\partial \nu > 0$ and $\partial b_1^{con}/\partial A_1^\omega > 0$. In words, the higher the shadow value ν of raising finance in period 0 and the higher the productivity shock in period 1, the greater the repayment that bankers contract in period 1. Note that in any constrained state, $b_1^{con}(\nu, A_1^\omega) < b_1^{unc}(\nu)$ since the binding constraints in period 1 make repayments more costly to bankers.

Combining the two functions, we define a function $b_1(\nu, A_1^\omega)$ such that

$$b_1(\nu, A_1^\omega) = \begin{cases} b_1^{unc}(\nu) & \text{if } A_1^\omega t_1 \geq b_1^{unc}(\nu) \\ b_1^{con}(\nu, A_1^\omega) & \text{otherwise} \end{cases} \tag{15}$$

This function is continuous and increasing in both arguments and strictly increasing in ν. For low values of ν close to zero, the unconstrained function determines the value of b_1^ω since b_1^{unc} is very low and satisfies the inequality. As ν increases, the threshold $A_1^\omega t_1 = b_1^{unc}(\nu)$ will be surpassed and b_1^ω is determined by the constrained function.

Let us rewrite the period 0 budget constraint of bankers as

$$E[m_1^\omega b_1(\nu, A_1^\omega)] = \alpha t_1 \tag{16}$$

The expectation on the left-hand side is strictly increasing in ν under the conditions outlined in appendix A. Therefore there is a unique solution ν^* that satisfies equation (16). Given the equilibrium ν, we express the borrowing choices of bankers according to (15). All other variables follow.

Proposition 1 (Decentralized Equilibrium Under Loose Constraints) *If the period 0 investment requirement αt_1 is sufficiently low so that $b_1^{unc}(\nu^*) \leq A_1^{\min} t_1$, then bankers* *contract a constant repayment across all states of nature $b_1^\omega = b_1^{unc}(\nu^*)\ \forall\omega$. This corresponds to a risk-free bond.*

If bankers are unconstrained across all states of nature, they carry all risk and provide households with a fixed repayment.

Proposition 2 (Decentralized Equilibrium Under Occasionally Binding Constraints) *Otherwise the equilibrium is described by a threshold $\hat{A}_1$ such that:*

- *For $A_1^\omega \geq \hat{A}_1$, bankers repay a constant amount $b_1^\omega = b_1^{unc}(\nu^*)\ \forall\omega$. Their consumption is positive for $A_1^\omega > \hat{A}_1$. They absorb all risk beyond this threshold and engage in no fire sales.*
- *For $A_1^\omega < \hat{A}_1$, bankers reduce their period 1 repayment compared to unconstrained states $b_1^\omega < b_1^{unc}(\nu^*)$ and engage in some fire sales. Their period 1 consumption is zero $c_{1,h} = 0$.*

Reducing the repayment b_1 and engaging in fire sales f are both costly ways of conserving liquidity: When they engage in fire-sales, asset prices decline so that their proceedings are less than the marginal product that they could have earned on the assets. When they repay more contingent bonds in some states than in others, the total interest bill of bankers rises since the price m_1^ω at which first generation households are willing to buy bonds is a declining function of the quantity of bonds sold in a given state. Bankers pick their portfolios such that the relative costs of the two are equal from their private perspective.

3.3 Planner's Allocation

Let us compare the allocations of the decentralized equilibrium with those that would be chosen by a planner. Before proceeding we make the following simplifying assumption:

Assumption 2 *The utility function of second generation households is linear $w(c) = c$.*

Assumption 2 simplifies the planner's problem in achieving a Pareto improvement: since there is no uncertainty once second generation households are born, there is no role for risk aversion. The assumption thus only restricts the intertemporal elasticity of substitution of households. Note that our results would still hold under more general utility functions.

Backward Induction: Optimal Period 1 Solution

We first focus on a planner in period 1 who takes the net liquid assets a of bankers as given and who maximizes total surplus over periods 1 and 2. Since both bankers and second generation households have linear utility, it is straightforward that a planner who increases total surplus can achieve a Pareto improvement by choosing appropriate transfers between the two sets of agents.

The planner is subject to the same borrowing constraints as decentralized agents and has no choice but to pick the same allocation when constraints in period 1 are binding, since there are no free decision variables. However, the crucial difference is that in evaluating the constrained equilibrium, she internalizes that the valuation of productive assets declines the more she sells. In analogy to equation (10), we denote total period 1 surplus in a given state as

$$S(a) = 2e + a + \bar{A}(t_1 - f) + F(f) = a + F(f(-a)) - \bar{A}f_1(-a) + \text{const} \tag{17}$$

where $f(s)$ denotes the quantity of assets that need to be fire-sold to raise s in liquidity, as defined above. This expression satisfies $s = qf(s) = F'(f(s))f(s)$ and $\partial f/\partial s = 1/\left(F'(f(s)) + f(s)F''(f(s))\right)$. We find the derivative of the planner's surplus is

$$\mu^{SP} = S'(a) = 1 + [\bar{A} - F'(f)]\frac{\partial f}{\partial s} = 1 + \frac{\bar{A} - F'}{F' + fF''} = \frac{\bar{A} + fF''}{F' + fF''}$$

In comparing the marginal valuation of liquidity of decentralized bankers and the planner, we find

Proposition 3 (Valuation of Liquidity) *For $a \geq 0$, financing constraints are loose and the valuations of liquidty of decentralized bankers and a planner coincide $\mu^{SP} = \mu = 1$. For $a < 0$, financing constraints on bankers are binding, and a social planner values liquidity more highly than decentralized agents $\mu^{SP} > \mu > 1$.*

A planner internalizes that a decline in asset prices hurts all bankers since it reduces the amount of liquidity that they can raise from the sale of each unit of assets. By contrast, decentralized bankers take asset prices as given since they realize that their individual behavior has only an infinitesimal effect on asset prices. However, in general equilibrium, the aggregate behavior of bankers determines the level of asset prices. This is the basis of the externality results in our paper.

Proof. Analytically, we note that

$$\frac{\bar{A} + fF''}{F' + fF''} > \frac{\bar{A}}{F'} \quad \text{whenever} \quad f > 0$$

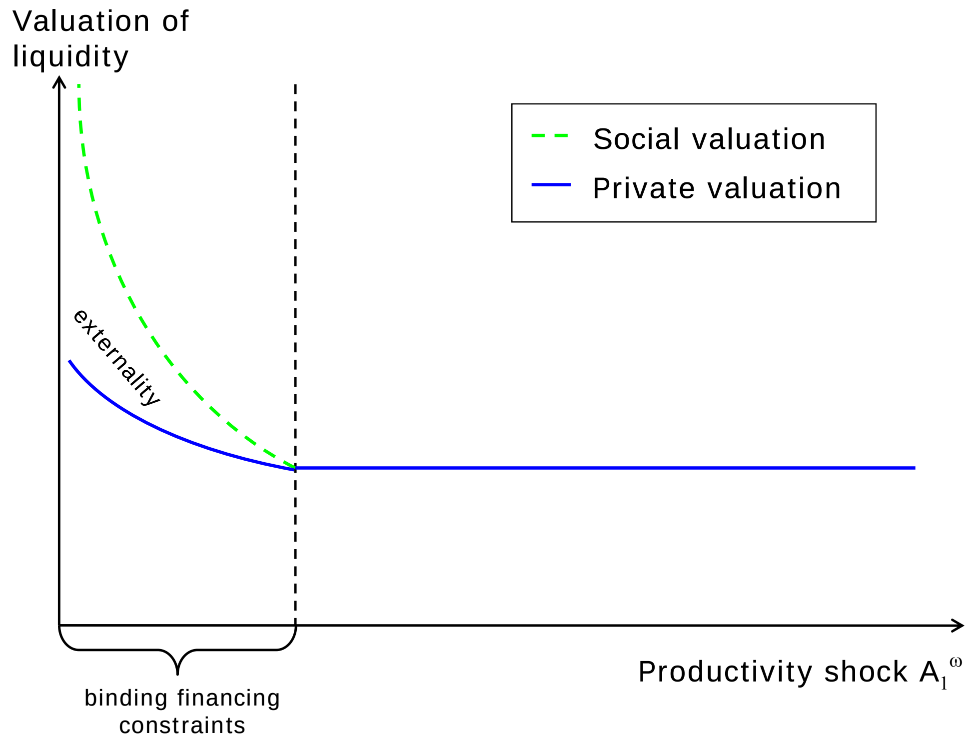

Figure 3: Private and Social Valuation of Liquidity

This result holds since $F'' < 0$ and $\bar{A} > F'$ whenever $f > 0$. ■

Figure 3 depicts the decentralized and the planner's valuation of liquidity across different states of nature for a fixed debt level b_1. In normal times when constraints are loose, the two coincide and equal one. When financing constraints are binding, $\mu^{\omega}_{SP} > \mu^{\omega}$ since the planner internalizes that higher liquidity would mitigate the downward spiral in asset prices and production.

Optimal Period 0 Financing Decisions

Given the different valuations of liquidity in period 1, it follows naturally that the planner will pick different allocations in the period 0 market of Arrow securities than decentralized agents. Suppose a planner maximizes the expected period 1 joint surplus of bankers and second generation households, subject to raising the initial investment requirement from first generation households:

$$\max_{\{b^{\omega}_{1,b}\}} S\left(A^{\omega}_1 t_1 - b^{\omega}_1\right) \quad \text{s.t.} \quad E[m^{\omega}_1 b^{\omega}_{1,b}] = \alpha t_1 \tag{18}$$

Assigning a shadow price of ν^{SP} to the constraint, the first order condition is along the same lines as (12),

$$\mu^{\omega,SP} = -S'(a^\omega) = \nu^{SP} m_1^\omega \tag{19}$$

We follow the steps outlined in section 3.2 to obtain the following findings:

- The function $b_1^{unc,SP}$ for constrained states is defined analogously to $b_1^u nc$ in equation (13). For given ν, the planner and decentralized bankers repay identical amounts in unconstrained states.

- The function $b_1^{con,SP}$ takes account of the higher valuation of liquidity perceived by the planner. The repayment chosen by the planner in a constrained state ω is given by the following implicit function, where we denote $a = A_1^\omega t_1 - b_1^\omega$:

$$\mu^{\omega,SP} = \frac{\bar{A} + f(-a)F''(f(-a))}{F'(f(-a)) + f(-a)F''(f(-a))} = \nu \frac{u'(e + b_1^\omega)}{u'(e - \alpha t_1)} \tag{20}$$

  The left-hand side of this equation is strictly increasing in the repayment b_1^ω, whereas the right-hand side is strictly decreasing, implying a unique solution.

  Following proposition 3, the repayment b_1^ω chosen by the planner for a given ν is less than that chosen by decentralized bankers.

- Since the planner repays an identical amount in unconstrained states but a lower amount in constrained states, the shadow price ν^{*SP} has to rise above the shadow price ν^* in the decentralized equilibrium to raise the required amount αt_1 in period 0.

Proposition 4 (Planner's Solution Under Loose Constraints) *If the period 0 investment requirement αt_1 is sufficiently low so that $b_1^{unc}(\nu^*) \leq A_1^{\min} t_1$, then constraints are loose across all states of nature and the decentralized equilibrium is socially optimal.*

Proposition 5 (Planner's Solution Under Occasionally Binding Constraints) *Otherwise the planner's solution is described by a shadow price $\nu^{*SP} > \nu^*$ and a threshold $\hat{A}_1^{SP} > \hat{A}_1$. Compared to the decentralized alloction, the planner reallocates period 1 repayments b_1^ω from strongly constrained states to unconstrained and marginally constrained states.*

Under occasionally binding constraints, the planner's allocates more liquidity to bankers in bad states of nature and reduces the severity of fire-sales and output declines nature since she internalizes the financial amplification effects. At the same time, the planner marginally increases the probability of experiencing binding constraints since she raises repayments in marginally unconstrained states.

Naturally, the planner raises joint welfare of bankers and second generation households in the occasionally binding case. Note that the welfare of first generation households is also unambiguously increased, as households' utility is a strictly increasing function of ν.

3.4 Comparative Statics

In the described economy, the productivity shock ω constitutes systemic risk when financial constraints are binding. In states of the world when productivity A_1^ω is low, bankers' liquidity position will be strained. Since first generation households are risk-averse, they require compensation for taking on some of this risk, and the decentralized equilibrium is characterized by the privately optimal trade-off between the cost of consumption volatility for households and the efficiency cost for bankers of having to sell assets at fire-sale prices when constrained. However, since decentralized bankers internalize only part of the social benefit of insuring against such fire-sales, they will take on too much systemic liquidity risk. As a result, financial amplification effects are magnified and the economy exhibits excessive volatility.

The magnitude of the externality is greater the higher the degree of risk aversion of households, since risk aversion makes them more reluctant to provide socially beneficial insurance. In the case that households are perfectly risk-neutral, they would be willing to fully insure bankers; as a result constraints would never be binding. Note also that households can perfectly diversify idiosyncratic risk; therefore they can insure bankers against this form of risk at no cost, and idiosyncratic risk would never lead to crises as long as risk markets are complete.

Proposition 6 *The externality is stronger the more risk averse first generation households.*

Proof. See appendix A.3 ■

In our model above we assumed that bankers are risk neutral. While this was mainly a simplifying assumption, it can be shown that the externality declines if bankers become risk averse, since the risk aversion makes it privately optimal for them to take on more insurance, with the side effect of mitigating socially costly fire-sales. However, note that even if bankers were more risk averse than households, privately optimal risk-sharing would still entail that both parties hold some risk (as long as households are not perfectly risk-netural) and that binding constraints may arise and result in the described externality. We summarize our findings in the following. This may explain for example why hedge funds routinely expose themselves to large amounts of systemic risk that result in the liquididation of large positions and strong fire sale effects when adverse shocks are realized.

A decentralized financial system always allocates risks into the hands of those who are privately most willing to bear it, even if this leaves the financial system excessively exposed to systemic risk.

4 Applications

Having analytically characterized the systemic externality that is the subject of this paper, we now turn our attention to a number of applications, including the effects of anticipated government bailouts, the suboptimal incentives for raising new capital in the midst of crises, the possibility of contagion and bankers' excessive exposure to it and the role of rational expectations during crises.

4.1 Bailout Neutrality

The externality in this paper arises because decentralized bankers make their privately optimal insurance decisions without regard for systemic feedback effects. When a financial crises in such an economy is triggered, government authorities are usually tempted to intervene by providing bailouts to constrained agents so as to mitigate the downward spiral into which the economy is plunged. However, we can show that if such liquidity assistance is anticipated, then decentralized agents will fully undo it.

Assume that the government is committed to a transfer T^{ω} that is in expectation revenue-neutral, i.e. which is positive $T^{\omega} > 0$ in case of binding constraints and negative $T^{\omega} < 0$ in normal times so as to raise revenue for the transfers in crisis times. Assume that the government buys the respective bonds from first generation households at time 0 and distributes the transfers to them at time 1 after the productivity shock is realized. The assumption of revenue neutrality implies that the total outlays of cash in period 0 are

$$E\left[m_1^{\omega} T^{\omega}\right] = 0$$

However, note that if we add these transfers to the problem described in the previous section, the first order conditions of all agents are unaffected: decentralized bankers chose their equilibrium allocations on the basis of an optimal tradeoff of risk versus return. If they receive one more dollar in period 1 of a given state ω, they will sell one more bond contingent on that state so as to restore their privately optimal equilibrium. This leads to the following proposition:

Proposition 7 (Bailout Neutrality) *Any form of anticipated liquidity transfer to bankers is undone and will be ineffective.*

This result is reminiscent of the common claim that government bailouts induce moral hazard. However, our result is even stronger than that: moral hazard is a phenomenon that occurs under asymmetric information when a principal (the government) cannot observe the inefficient actions of an agent (the banker). In our example, it is common knowledge that any bailout will be undone, and that anticipated government transfer are therefore ineffective. Our finding is therefore much more closely related to Ricardian equivalence (Barro, 1974).

On the other hand, liquidity assistance can be effective if it is either unanticipated or if it is directed at agents who do not have access to financial markets and cannot undo the effects of the transfer, such as e.g. unemployed workers who might be forced to fire-sell assets.

Furthermore, note that if a bailout was expected in a particular state of the world and does not take place, the negative effects on the economy will be severe: The expectation of a bailout leads bankers to take on even larger risks than what is privately optimal in the absence of government intervention; their liquidity position after the shock is therefore strongly impaired in the absence of a bailout, and amplification effects magnify the impact of this unexpected shock to their liquidity position even further.

4.2 Macroprudential Regulation

In light of our bailout neutrality result that anticipated ex-post transfers to alleviate binding constraints will be ineffective, financial regulators are interested in how to employ second-best policy measures to address the systemic externality that we have identified in this paper so as to induce bankers to internalize the potential social costs that they impose on others by taking on excessive systemic risk. A natural way of doing so is to impose regulations that increase the cost of holding systemic risks to banks. For simplicity we will formulate our policy measures below in the form of traditional taxes. In practice, regulations of the banking system usually take the form of capital adequacy ratios (which have tax-like effects since bank capital is costly).

Let us define the difference between the private and social valuation of liquidity in period 1 as the externality kernel τ^ω:

$$\tau^\omega = \mu^{\omega,SP} - \mu^{\omega,DE} \tag{21}$$

This τ^ω measures the un-internalized social cost of making a payment of one dollar in state ω. It is straightforward to see that a standard Pigovian tax in the amount of τ^ω on any payoff made in state ω could restore constrained social efficiency. The tax revenue raised can be used to compensate second generation households for the reduction in fire sales.

To relate our discussion from Arrow-Debreu assets to real world financial assets, assume that bankers in our model have sold a financial asset with a state-contingent profile of payoffs

X^ω in period 1. The optimal period 0 tax that makes bankers internalize the social cost of selling this claim would be

$$\tau^* = E[\tau^\omega X^\omega]$$

To gain some intuition for this, let us compare the optimal tax on a risk-free one-dollar bond and on an asset with a face value of one dollar and payoffs that are indexed to the systemic risk factor A_1^ω. For the risk-free bond, $X^\omega \equiv 1$ across all states of nature[8], including constrained states. The optimal tax on such a bond is therefore $E[\tau^\omega]$.

On the other hand, the return on the indexed security moves in parallel with the state of productivity A_1^ω. To guarantee that the expected payoff is unity we normalize the payoffs of one unit of the security to $\frac{A_1^\omega}{E[A_1^\omega]}$. Selling such indexed securities diversifies systemic risk away from bankers. Using the formula above we can therefore see that the optimal tax (or capital adequacy requirement) on selling such a claim is

$$E\left[\frac{\tau^\omega A_1^\omega}{E[A_1^\omega]}\right] = E[\tau^\omega] + Cov\left(\tau^\omega, \frac{A_1^\omega}{E[A_1^\omega]}\right) < E[\tau^\omega]$$

since the covariance between the two terms is negative (the social valuation of liquidity is high when the state of productivity is low). In a regulatory framework that addresses the systemic externalities arising during financial crises, what matters for the determination of taxes/capital adequacy requirements is not the risk inherent in a given asset, but the correlated systemic risk that the bank takes on that has the potential of leading to system-wide fire sales and financial amplification effects.

Reach of Regulation To whom shall such a tax or capital adequacy requirement apply? Any financial market participant who might potentially be forced to engage in fire-sales, including hedge funds and other actors in the so-called "shadow financial system," is prone to imposing an externality on other market participants, because he does not internalize the price effects of his fire sale and the consequences on the financing constraints of other market participants. Therefore any institution that might be forced to engage in fire-sales during systemic crises should be covered by the discussed regulations.[9]

Socially Risk-Neutral Probabilities It is a standard result in finance that pricing kernels can alternatively be represented as a risk-neutral probability measure that weighs states against which agents are risk-averse more highly. We can apply a similar transformation

[8]For simplicity we abstract from the possibility of default here.

[9] In our model above, bankers needed liquidity if their net liquid earnings did not meet their debt due in period 1. More generally, financial amplification effects often arise when leveraged market participants suffer losses and engage in fire sales so as to unwind their leverage and e.g. meet margin calls. Institutions with high debt/leverage are therefore particularly prone to creating systemic externalities.

to the social planner's social pricing kernel. If regulators can instruct banks to employ the regulator's risk-neutral probabilities in their risk management systems, the systemic externality that is the topic of this paper would be alleviated.

Analytically the socially risk-neutral probabilities can be obtained from the standard formula

$$f_{rn}(\omega) = \frac{f(\omega)\mu^{SP,\omega}}{E[\mu^{SP,\omega}]}$$

and the true social value of an asset or cost of a liability with payoffs X^ω can be expressed as $E_{rn}[X^\omega]$, where $E_{rn}[\cdot]$ represents the expectations operator under the socially risk-neutral probability measure ν. Note that this socially risk-neutral probability measure weighs states of the world in which constraints are binding and changes in liquidity entail amplification effects more highly than what would be indicated by a traditional risk-neutral probability measure. The latter in turn assigns more weight to such states than the objective probability of the state.

4.3 Raising New Capital

The undervaluation of liquidity that we analyzed also implies that bankers will undervalue the benefits of raising new capital during crises: any increase in liquidity would mitigate bankers' need to engage in fire sales or would enable them to buy assets from the fire-sales of other bankers. This would moderate the decline in aggregate asset prices and reduce the pressure on the balance sheets of other bankers. As a result the social value of raising new capital $\mu^{\omega,SP}$ is higher than the private value $\mu^{\omega,DE}$ – individual bankers have socially insufficient incentives to issue new equity.

Analytically, we assume there exists an audit technology that allows investors to take ownership of a fraction α of bankers' stream of period 2 returns at a convex cost $c(\alpha)$. Given the concavity of $V(\cdot)$, bankers in our model would raise capital until the private marginal benefit $\mu^{\omega,DE}$ equals the marginal cost $c'(\alpha)\bar{A}(t_1 - f_1)$ in a given state ω. A planner would use the higher social marginal benefit $\mu^{\omega,SP}$ in the comparison. This implies that the planner is willing to give up a larger share of the banker's ownership to new equity holders.

Proposition 8 *A social planner would sell a higher equity stake $\alpha^{*SP} > \alpha^*$ than decentralized bankers so as to raise more new capital in systemic crisis states.*

Note that the fundamental difference between fire sales and our example of raising new equity is that fire sales lead to aggregate price declines, which entail pecuniary externalities on other agents, whereas we assumed here that equity issuance entails private convex costs that do not have external effects.

5 Conclusions

Financial markets are inherently pro-cyclical, i.e. that endogenous financing constraints loosen in good times and tighten in bad times, and this phenomenon can entail financial amplification effects: in case of negative aggregate shocks, many bankers experience binding borrowing constraints, which require them to cut back on their economic activity. This depresses asset prices, deteriorates their balance sheets, leads to tighter financing conditions etc.

This paper demonstrate that such financial amplification effects introduce an externality into the economy that leads individual bankers to undervalue liquidity in crisis states. Small agents take asset prices – and the tightness of financing conditions – as given and do not internalize the general equilibrium effects of their actions on prices and constraints. They do not realize e.g. that fire sales during crises depress asset prices, which trigger amplification effects that hurt other bankers in the economy.

The undervaluation of liquidity in crisis times in turn leads to a number of distortions: bankers take on too much risk in both their financing and investment decisions; more generally they over-borrow and over-invest; they also under-value the benefits of raising new capital during crises. Our paper develops a simple model that allows us to analytically examine these inefficiencies and investigate several related questions, such as the effectiveness of anticipated government bailouts.

Finally, our paper provides clear analytical guidelines for a new regulatory framework of macro-prudential capital adequacy requirements that account for systemic risk and systemic externalities, with the goal of reducing financial instability and avoiding future systemic financial crises.

References

Adrian, T. and Brunnermeier, M. (2009). Covar. *mimeo*.

Adrian, T. and Shin, H. S. (2009). Liquidity and leverage.

Allen, F. and Gale, D. (1998). Optimal financial crises. *Journal of Finance*, 53(4):1245–1284.

Arnott, R. J., Greenwald, B. C., and Stiglitz, J. E. (1992). Information and economic efficiency. *Information Economics and Policy*, 6(1):77–88.

Barro, R. J. (1974). Are government bonds net wealth? *Journal of Political Economy*, 82(6):1095–1117.

Bernanke, B. and Gertler, M. (1989). Agency costs, net worth, and business fluctuations. *American Economic Review*, 79:14–31.

Bernanke, B., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics*, volume 1C, pages 1341–1393. Elsevier.

Bernanke, B. S. and Gertler, M. (1990). Financial fragility and economic performance. *Quarterly Journal of Economics*, 105(1):87–114.

Borio, C. (2003). Towards a macroprudential framework for financial supervision and regulation? *CESifo Economics Studies*, 49(2/2003):181–215.

Brunnermeier, M. (2008). Deciphering the 2007-08 liquidity and credit crunch. *Journal of Economic Perspectives*, forthcoming.

Brunnermeier, M., Crocket, A., Goodhart, C., Persaud, A., and Shin, H. S. (2009). The fundamental principles of financial regulation. *Geneva Reports on the World Economy*, 11.

Catarineu-Rabell, E., Jackson, P., and Tsomocos, D. P. (2005). Procyclicality and the new basel accord – banks choice of loan rating system. *Economic Theory*, 26(3):537–557.

Froot, K. A., Scharfstein, D. S., and Stein, J. C. (1993). Risk management: Coordinating corporate investment and financing policies. *Journal of Finance*, 48(5):1629–1658.

Gordy, M. B. and Howells, B. (2006). Procyclicality in basel ii: Can we treat the disease without killing the patient. *Journal of Financial Intermediation*, 15(3):395–417.

Gromb, D. and Vayanos, D. (2002). Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics*, 66:361–407.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2):211–248.

Korinek, A. (2009). Excessive dollar borrowing in emerging markets: Balance sheet effects and macroeconomic externalities. *Columbia University, mimeo.*

Krishnamurthy, A. (2003). Collateral constraints and the amplification mechanism. *Journal of Economic Theory*, 111(2):277–292.

Lorenzoni, G. (2008). Inefficient credit booms. *Review of Economic Studies*, 75(3):809 – 833.

Shleifer, A. and Vishny, R. W. (1992). Liquidation values and debt capacity: A market equilibrium approach. *Journal of Finance*, 47(4):1343–1366.

A Mathematical Appendix

A.1 First Generation Households

$$\frac{\partial m_1^\omega b_1^\omega}{\partial b_1^\omega} =$$

A.2 Second Generation Households

$$\frac{\partial q_1^\omega f_1^\omega}{\partial f_1^\omega} =$$

A.3 Risk Aversion and the Extent of Externalities

We assume the period utility of households exhibits constant relative risk aversion:

$$u(c) = \frac{c^{1-\theta}}{1-\theta}$$