

# A Theory of Balance Sheet Recessions with Informational and Trading Frictions \*

Vladimir Asriyan <sup>†</sup>

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## Abstract

I propose a novel theory to rationalize limited sharing of macroeconomic risk that drives *balance sheet recessions* as a result of informational and trading frictions in financial markets. I show that borrowers and creditors will find it costly to share macroeconomic risk in environments where creditors value the liquidity of financial claims but where information about the future states of the economy is *dispersed* and the secondary markets for financial claims feature *search* frictions. As a result, borrowers will optimally choose to retain disproportionate exposures to macroeconomic risk on their balance sheets, and adverse shocks will be amplified through the balance sheet channel. I show that the magnitude of this amplification becomes closely linked to the level of information dispersion and the severity of search frictions in financial markets. In this setting, I study the implications of the theory for macro-prudential regulation and find that subsidizing contingent write-downs of borrowers' liabilities can be welfare improving.

**Keywords.** Balance sheet recessions; balance sheet channel; risk-sharing; liquidity, dispersed information; search frictions; macro-prudential regulation.

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\*For the latest version, please visit my website <http://econgrads.berkeley.edu/vasriyan/research>

<sup>†</sup>UC Berkeley Department of Economics, 530 Evans Hall #3880, Berkeley, California 94720-3880. Email: [vasriyan@econ.berkeley.edu](mailto:vasriyan@econ.berkeley.edu). Acknowledgments: I am indebted to my advisers Pierre-Olivier Gourinchas, Willie Fuchs, Yuriy Gorodnichenko, and Demian Pouzo for their support and invaluable guidance in the process of writing my dissertation. I also thank Liang Bai, Matthew Botsch, Julie Cullen, Sebastian Di Tella, Haluk Ergin, Ben Faber, Nicolae Gârleanu, Brett Green, Terrence Hendershott, Amir Kermani, Gustavo Manso, Pascal Michailat, John Mondragon, Takeshi Murooka, Maury Obstfeld, Aniko Öery, Marcus Opp, Michaela Pagel, Christine Parlour, Romain Rancière, Ana Rocca, Andrés Rodríguez-Clare, David Romer, Michel Serafinelli, Viacheslav Sheremirov, Asrat Tesfayesus, Robert Townsend, Victoria Vanasco, Johan Walden, and seminar participants at the UC Berkeley Department of Economics and the Haas School of Business for helpful comments and suggestions.

# 1 Introduction

The Great Recession has once again underscored the significant role that financial frictions play in the transmission and propagation of macroeconomic shocks. The macroeconomic literature on credit frictions has long recognized that the conditions of household and firm balance sheets are important drivers of macroeconomic activity. In normal times, a well-functioning financial system allows economic agents to use leverage to undertake productive investments and thus enhance economic growth and prosperity. In bad times, disproportionate exposures to macroeconomic risk by these leveraged agents can lead to perverse feedback effects between asset prices and balance sheets that can turn shocks of modest magnitude into full-blown *balance sheet recessions*.<sup>1</sup> The theory, however, remains incomplete. While the literature has shown how limited sharing of macroeconomic risk between borrowers and creditors can generate balance sheet recessions, we do not have a complete understanding of why risk-sharing become so limited to begin with.<sup>2</sup> Answering this question is particularly important in view of the recent policy discussions on how to regulate systemic risk.<sup>3</sup>

In this paper, I propose a theory that rationalizes limited sharing of macroeconomic risk that drives balance sheet recessions as a result of informational and trading frictions in financial markets. I show that when borrowers issue contracts contingent on the state of the economy, they need to trade off the risk-sharing benefits that contingent contracts provide with the ‘illiquidity’ costs that they must pay creditors for holding such contracts. These costs arise because creditors value claims that are liquid in secondary markets and because *information dispersion* and *search frictions* in these markets prevent contingent contracts from trading at their ‘fair’ value. As a result, borrowers optimally choose to retain disproportionate exposures to macroeconomic risk on their balance sheets, and adverse shocks become amplified through the balance sheet channel. I show that the magnitude of this amplification becomes closely linked to the level of information dispersion and the severity of search frictions in

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<sup>1</sup>Balance sheet recessions refer to recessions driven by feedback effects between borrowers’ balance sheets and general economic activity (e.g. asset prices, aggregate demand). The seminal papers in the literature on balance sheet recessions are Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). Some of the more recent contributions are He and Krishnamurthy (2011) and Brunnermeier and Sannikov (2012). Mian et al. (2013) and Adrian et al. (2012) provide empirical support for the importance of balance sheets in the recent recession.

<sup>2</sup>In standard models of the balance sheet channel, it is typically assumed that agents are unable to write contracts contingent on aggregate states of the economy (e.g. Kiyotaki and Moore (1997), Brunnermeier and Sannikov (2012)). The papers by Krishnamurthy (2003) and Di Tella (2013), however, show that amplification effects disappear when contingent contracts are allowed.

<sup>3</sup>See, for example, Calomiris and Herring (2011) and McDonald (2011) for a discussion of Contingent Convertible (CoCo) debt requirements, and Mian (2011) for the introduction of contingent write-downs of households’ liabilities.

financial markets. In particular, the model predicts that amplification effects should be expected to be large when information dispersion and search frictions are large, and vice versa. In this setting, I study the implications of the theory for macro-prudential regulation and, consistent with some recent policy proposals,<sup>4</sup> I find that policy measures geared towards subsidizing contingent write-downs of borrowers' liabilities can be welfare improving.

This paper uses a model of the financial accelerator *à la* Kiyotaki and Moore (1997). Entrepreneurs (borrowers) issue financial contracts to investors (creditors) to finance long-term projects whose cash-flows are exposed to aggregate risk. If these cash-flows fall short of the promised repayments, then entrepreneurs must meet their liabilities by liquidating projects prematurely. In aggregate, such liquidations lead to 'fire-sales' and become amplified through the endogenous interaction of entrepreneurial balance sheets and asset prices, thus generating balance sheet recessions. To understand the risk-sharing benefits of contractual contingencies, I allow economic agents to write financial contracts contingent on the aggregate state of the economy. More specifically, entrepreneurs can contract with investors ex-ante to write-down some of their liabilities in the adverse state of the world. In the absence of secondary market frictions, both entrepreneurs and investors will find such write-downs mutually beneficial; as they are introduced, the aggregate impact of macroeconomic shocks becomes endogenously muted.

To explain why such write-downs may be endogenously limited, I augment the basic model in three directions. First, I suppose that investors may experience idiosyncratic funding (liquidity) needs prior to the maturity of financial contracts and thus want to sell these contracts in secondary financial markets. These funding needs intend to capture a variety of reasons (e.g. intermittent consumption/investment opportunities) for which investors may want to trade financial contracts before they mature. Second, I assume that secondary markets for financial contracts are subject to a form of search friction: an investor who wants to sell his contract can solicit offers only from a finite number of buyers. This assumption is meant to capture various search frictions that may limit the number of potential counterparties that an investor can trade with on short notice.<sup>5</sup> These types of frictions are particularly relevant in over-the-counter type markets where many important assets (corporate bonds,

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<sup>4</sup>For example, Mian (2012) states that contingent write-downs could have considerably ameliorated the negative repercussions of the deleveraging-aggregate demand cycle of the Great Recession. Similarly, Calomiris and Herring (2012) argue that, with such write-downs in place, we would have avoided the financial meltdown of 2008.

<sup>5</sup>See Duffie (2010) for a discussion of the relevance of search frictions in financial markets. See Zhu (2011) and Duffie and Manso (2007) for related models of financial markets.

asset-backed securities, a wide range of derivatives, etc.) are traded, as well as in centralized markets that are relatively thin. Finally, I introduce information dispersion by supposing that, prior to trade in financial markets, investors observe noisy private signals about the future state of the economy. This assumption is supported by a growing literature in macroeconomics that documents substantial disagreements among economic agents about a variety of macroeconomic variables; this literature further shows that an important reason for these disagreements is the disparity of information held by economic agents.<sup>6</sup>

These ingredients then deliver the main results of the paper. I show that in equilibrium contracts contingent on the state of the economy are expected to trade at a discount in secondary markets. This discount arises because of informational rents that investors must forgo when selling their contracts in secondary markets, and it is directly linked to the level of informational dispersion and the severity of search frictions in these markets.<sup>7</sup> As investors rationally anticipate future liquidity needs, they pass these (trading) costs of contractual contingencies onto entrepreneurs, who then face a tradeoff between insurance against macroeconomic fluctuations and the scale of their operations. This gives rise to a ‘pecking order’ theory for liability design: entrepreneurs prefer to borrow with non-contingent contracts, and write-downs are only introduced when entrepreneurs expect shocks to be sufficiently severe. Finally, as entrepreneurs optimally design their liabilities, the costs of contractual contingency also limit the extent to which macroeconomic fluctuations are endogenously stabilized. The model thus closely links the magnitude of amplification effects that arise in response to economic shocks to the level of information dispersion and the severity of search frictions in financial markets.

The theory suggests that financial market microstructure (depth) may be an important determinant of macroeconomic fluctuations. In particular, the model predicts that amplification effects should be expected to be large only for shocks for which contracts are traded in markets with significant trading frictions (e.g. real estate). Consistent with this, Shiller (1993) argues that establishing and promoting liquid markets for a variety of macroeconomic risks would significantly improve households’ welfare by allowing them to better manage their risks. Englund et al. (2002) provide an empirical evaluation

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<sup>6</sup>Mankiw et al. (2004) find substantial heterogeneity in inflation forecasts among professional forecasters, economists, and consumers, and Doern et al. (2009) show similar findings for GDP and prices in a cross-country study of surveys of professional forecasters. Coibion and Gorodnichenko (2012) provide extensive evidence that informational disagreements are pervasive across a variety of population groups and macroeconomic variables.

<sup>7</sup>This insight is drawn from the literature on common value auctions (e.g. Milgrom and Weber (1982)), which shows that, in a variety of trading mechanisms, sellers forgo informational rents when faced with buyers who have informational disagreements about the object being offered for sale.

of these welfare gains in the context of real estate related risks. That liquid secondary markets may further smooth out the business cycle has, for example, been noted by Case et al. (1993). In line with these claims, my model also predicts that when secondary markets for financial contracts are more liquid (i.e. trading frictions are small), then insuring risks is less costly and fluctuations due to amplification effects are smaller.

The theory also has implications for the design of macro-prudential regulation. I show that a policy of capping (or taxing) entrepreneurial borrowing against adverse states of the world can indeed be welfare improving. This result is due to pecuniary externalities that arise in times of systemic distress: atomistic entrepreneurs undervalue the social benefits of insurance which come from the general equilibrium effects that it has on asset prices. This finding thus suggests that policy makers should actively encourage (subsidize) contingencies in borrowers' liabilities as their stabilizing benefits are likely to remain uninternalized by economic agents. Furthermore, because amplification effects in my framework become closely linked to informational and trading frictions in financial markets, the model also suggests that policy efforts to improve transparency and competition in financial markets may have an extra benefit of stabilizing macroeconomic fluctuations.<sup>8</sup>

**Related Literature.** This paper is related to a large literature on the balance sheet channel. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) are the seminal contributions to the literature. Some of the more recent works include Bernanke, Gertler, and Gilchrist (1999), He and Krishnamurthy (2012), Brunnermeier and Sannikov (2012). Much of this literature eliminates risk-sharing considerations by assuming that economic agents are unable to issue contracts contingent on the state of the economy. In contrast, I allow economic agents to write contracts contingent on aggregate states in order to understand why risk-sharing may be limited endogenously. My work is thus closer in spirit to the recent papers by Krishnamurthy (2003), Korinek (2009), Rampini and Viswanathan (2009), and Di Tella (2013) who also study the balance sheet channel when contingent contracts are feasible.

Krishnamurthy (2003) showed that, within the Kiyotaki and Moore (1997) framework, allowing economic agents to write contingent contracts mutes balance sheet amplification and thus has a sta-

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<sup>8</sup>For example, the Dodd-Frank Act of 2010 has provisions relating to the transparency and stability of derivatives markets: it requires public disclosure of volumes and price data of standardized derivatives. Furthermore, a wide range of derivatives will be required to be traded on open platforms and cleared centrally. The model suggests that these type of policies may be stabilizing if, of course, they do not introduce other forms of transaction costs.

bilizing effect on macroeconomic fluctuations. He proposes to explain periods of amplification and limited risk-sharing by problems of commitment on the side of the lenders.<sup>9</sup> Lenders' commitment, however, is only necessary for equilibrium risk-sharing if debt write-downs are insufficient for borrowers to avoid costly liquidations. In my framework, debt write-downs are in fact sufficient for risk-sharing but they are endogenously limited (or absent altogether) as they expose lenders to secondary market 'illiquidity.'

Korinek (2009) also supposes that write-downs are sufficient, but he limits equilibrium risk-sharing by supposing that lenders are more risk-averse than borrowers. Di Tella (2013) instead argues that the type of aggregate shock hitting the economy matters; in particular, he shows that volatility shocks can create balance sheet recessions. My work is complementary to these papers. I suppose that agents have symmetric risk attitudes but that creditors have a preference for claims that are 'liquid' in secondary markets, and the amplification effects in my framework depend on the type of shock through the level of information dispersion and search frictions in secondary markets where contingent contracts can be traded.

Rampini and Viswanathan (2009) show that, in the presence of collateral constraints, borrowers may optimally choose to forgo risk-sharing opportunities if their funding needs are sufficiently high ex-ante. In particular, they argue that this may potentially explain why poor households and small firms engage insufficiently in hedging macroeconomic risks. While their mechanism arises in my framework as well, I am also able to explain limited sharing of macroeconomic risks when borrowers' financing needs do not override their risk-sharing concerns.

The costs to risk-sharing in my framework result from discounting of contingent contracts in secondary markets. The secondary market setting in my model, in fact, resembles a collection of first-price common value auctions for financial contracts, but where the seller may also be adversely selected. Thus, the paper is also related to the classic literature on common value auctions (e.g. Wilson (1977) and Milgrom and Weber (1982)). An important insight from this literature is that in a wide variety of trading mechanisms sellers must forgo informational rents when faced with buyers who disagree about the value of the object being offered for sale.<sup>10</sup> Hence, the logic that drives costly contractual

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<sup>9</sup>This insight is also related to the literature on asset pricing with market incompleteness arising from lack of commitment (e.g. Alvarez and Jermann (2000), Chien and Lustig (2009)).

<sup>10</sup>See, for example, Axelson (2007) for an application to the problem of a firm that designs a security to raise funds from more informed investors.

contingencies extends well beyond the basic environment presented in this paper.

That liquidity concerns may play an important role in precipitating financial crises through their impact on contractual design has also been emphasized in a recent paper by Dang et al. (2010). They argue that debt contracts are ‘best’ at providing liquidity to economic agents but that they also expose the financial system to fragility: ‘bad’ news may induce economic agents to acquire private information about contracts being traded, and thus destroy trade. In contrast to their paper, crises (balance sheet recessions) in my paper are driven by limited risk-sharing that arise from such liquidity concerns; furthermore, because information is *dispersed* rather than private per se, *search* frictions are essential to generate costs to contractual contingency.<sup>11</sup>

The welfare implications of my paper are related to the recently growing literature on macro-prudential regulation (e.g. Lorenzoni (2008), Korinek (2009), Stein (2010)). As in this literature, my policy results are driven by the pecuniary externalities that arise in periods of systemic distress. One of the interesting differences with the existing analyses is that my framework features the possibility that economic agents endogenously borrow with the non-contingent claims but the planner wants to introduce contingencies into financial contracts. Thus, the model can also rationalize the recent policy proposals to introduce macro-contingencies into firms’ and households’ liabilities.

Finally, my paper contributes to the literature that investigates the macroeconomic implications of heterogeneity of information. Lucas (1972) is the seminal paper in this literature, and Angeletos and La’O (2009, 2011) and Lorenzoni (2010) are some of the recent contributions. These papers also study how information dispersion may help propagate macroeconomic shocks. My work contributes to this literature by showing that informational dispersion influences fluctuations by limiting the extent to which macroeconomic risks can be shared.

**Organization.** The paper is organized as follows. In Section 2, I describe the economic environment. In Section 3, I setup the economic agents’ problems and I define the equilibrium of the economy. In Section 4, I characterize the equilibrium of the economy and I analyze the policy implications of the theory in Section 5. In Section 6, I consider several extensions, and I conclude in Section 7. All proofs are relegated to the Appendix.

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<sup>11</sup>The assumption of dispersed information is arguably more plausible for aggregate states. While in reality agents may differ in their ability to process information, it is unlikely that any agent has exclusive access to information about aggregate states. This is an important difference with the traditional literature on security design in the presence of informational asymmetries (e.g. Myers and Majluf (1984), DeMarzo and Duffie (1999)).

## 2 The Model

The model has three periods,  $t = 0, 1, 2$ . There are two sets of agents, entrepreneurs and investors, each of unit mass. Entrepreneurs have no endowments, are risk-neutral, and consume only in period 2, so their preferences are given by  $\mathbb{E}\{\tilde{c}_2\}$ . Investors receive endowment  $e$  in all periods, are risk-neutral, and are exposed to idiosyncratic liquidity needs  $\beta \in \{0, 1\}$ . In particular, if an investor is hit with a liquidity shock in  $t = 1$ , he becomes an “early” type ( $\beta = 1$ ) and does not value consumption in period 2: his preferences are  $\mathbb{E}\{c_0 + c_1\}$ . Otherwise, an investor becomes a “late” type ( $\beta = 0$ ) and values consumption in all periods: his preferences are  $\mathbb{E}\{c_0 + c_1 + c_2\}$ . Investors are ex-ante identical and the probability of experiencing an idiosyncratic liquidity need in  $t = 1$  is given by  $\lambda$ . Thus,  $\lambda$  also denotes the fraction of investors who become early types in  $t = 1$ .<sup>12</sup>

*Entrepreneurial Technology.* Entrepreneurs have access to long-term investment projects. An entrepreneur can install  $k$  units of capital in period 0 at a convex cost  $\chi(k)$ , and each unit of capital delivers a cash-flow  $a$  at the *beginning* of period 2 and a cash-flow  $A$  at the *end* of period 2. The final cash-flow  $A$  should be interpreted as the continuation payoff of the project. Entrepreneurial cash-flows are stochastic and vary with the aggregate state of the economy, which is realized in period 2 and is denoted by  $s \in \{l, h\}$  with  $\Pr(s = l) = \pi(l)$ . In particular, the cash-flow  $a$  takes values in  $\{a(l), a(h)\}$  with  $a(l) < a(h)$ , while the cash-flow  $A$  remains deterministic.<sup>13</sup>

*Liquidation and Fire-Sales.* In period 2, when in need of funds, an entrepreneur has the option to liquidate her capital in a competitive capital goods market. If an entrepreneur has begun her project at scale  $k$  and the price of capital is  $q$ , she can liquidate a fraction  $z \in [0, 1]$  of her capital and receive  $qzk$  units of the consumption good. The remaining  $(1 - z)k$  units of capital deliver  $A(1 - z)k$  units of the consumption good at the end of the period. Thus, entrepreneurs may face a trade-off: they can liquidate capital pre-maturely to raise funds in the capital goods market vs. they can keep capital intact to receive a per unit return  $A$  in the future.

The units of capital that entrepreneurs liquidate are absorbed by a “traditional” sector, that is

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<sup>12</sup>This modeling device is meant to capture investors’ preference for holding liquid claims. For example, an investor may have new investment/consumption opportunity, or an institution may experience a ‘run’ and need to sell assets to pay its depositors. The main results of the paper do not depend on this particular approach.

<sup>13</sup>The fluctuations in the intermediate cash-flow capture any fluctuations in the firms’ ability to repay its creditors while in operation. For example, firms may experience demand fluctuations; or financial institutions may experience losses on existing positions (e.g. mortgages).



composed of a mass of competitive firms. Each of these firms can convert capital goods to consumption goods according to an increasing and concave production technology  $g(\cdot)$  that satisfies  $g'(0) = A$ . Thus, the productivity of firms in this sector decreases below that of entrepreneurs as the units of capital employed by these firms increases. This technological assumption is a simple way to introduce amplification effects in the form of ‘fire-sales’.<sup>14</sup>

*Information.* Information about the state of the economy arrives between periods 0 and 1. Investor  $i \in [0, 1]$  observes private signal  $x_i \in [\underline{x}, \bar{x}]$ . The signals  $\{x_i\}$  are distributed independently across investors conditional on the state, with a continuously differentiable conditional cdf denoted by  $F_s(\cdot)$  for  $s \in \{l, h\}$ . The conditional distributions are related by the monotone likelihood ratio property; that is,  $\frac{f_h(x)}{f_l(x)}$  is increasing in  $x$  on  $[\underline{x}, \bar{x}]$ , where  $f_s(\cdot)$  denotes the pdf of signal  $x_i$  conditional on state  $s \in \{l, h\}$ . In addition, I suppose that signals are boundedly informative.<sup>15</sup>

*Financial Contracts.* In period 0, to finance projects, entrepreneurs raise funds from investors by issuing financial contracts to them. An entrepreneur approaches an investor and makes him a take-it-or-leave-it contractual offer that specifies a desired loan amount  $L$  and state-contingent repayments  $b(s)$  and  $B(s)$  made at the beginning and at the end of period 2, respectively.<sup>16</sup> The investor can accept or reject the offer. If he rejects, the entrepreneur does not invest. Investors’ idiosyncratic liquidity needs are assumed to be non-verifiable and thus non-contractable; furthermore, to motivate trade in secondary markets, I assume that there is no centralized mechanism by which investor liquidity needs can be pooled.

As in Lorenzoni (2008), entrepreneurial promises of repayment must be backed by her capital plus a fraction  $\theta \in (0, 1)$  of the project’s cash-flows. This friction can be microfounded by assuming that the entrepreneur can always default and walk away with a fraction  $1 - \theta$  of her cash-flows; this threat of default and renegotiation then puts a limit on the entrepreneur’s borrowing capacity. Finally, I assume that investors do not have claims to back up promises and they are thus unable to borrow. Thus, if the scale and the fraction of the project liquidated are  $k$  and  $z(s)$  respectively, the financial

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<sup>14</sup>See, for example, Kiyotaki and Moore (1997) for a similar modeling approach. The idea of ‘fire-sales’ in response to common industry shocks goes back to Shleifer and Vishny (1992).

<sup>15</sup>There exist positive constants  $\underline{\phi}, \bar{\phi}$  such that  $\underline{\phi} < \frac{f_h(x)}{f_l(x)} < \frac{f_h(\bar{x})}{f_l(\bar{x})} \leq \bar{\phi}$ .

<sup>16</sup>As there are no gains from diversification, the assumption of one-to-one matching between entrepreneurs and investors is without loss.

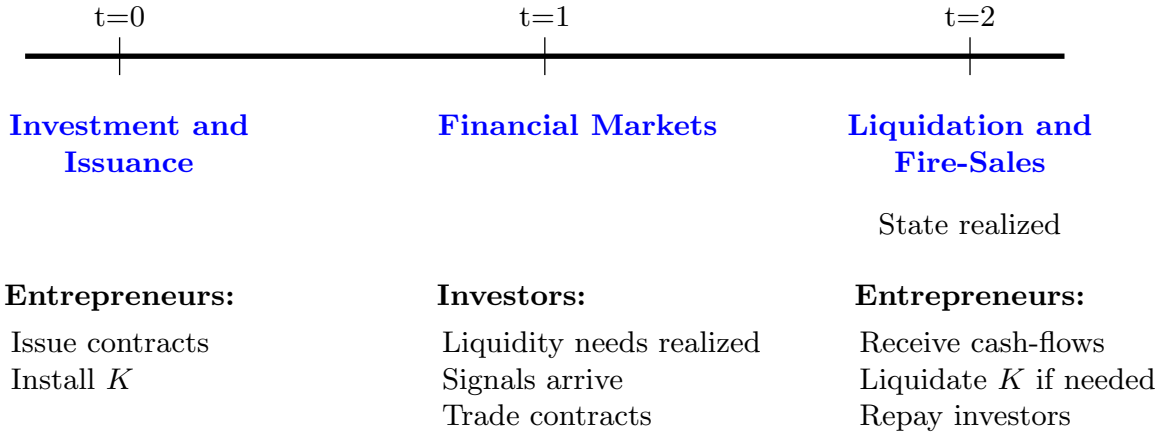


Figure 1: **Timeline**

contracts must satisfy the following no-default conditions for  $s \in \{l, h\}$ :

$$0 \leq b(s) + B(s) \leq (\theta a(s) + q(s))k$$

$$0 \leq B(s) \leq \theta A(1 - z(s))k$$

*Secondary Markets.* In period 1, *after* liquidity needs and signals are realized, investors participate in secondary markets where they can sell and/or buy financial contracts. If an investor chooses to sell his contract, he solicits *private* price offers from a finite number  $n \geq 2$  of buyers and commits to sell to the highest bidder.<sup>17</sup> If an investor chooses to become buyer, then he submits a price offer to a contacting seller and receives the contract if his offer is highest. Contacts are established according to a random process that matches each seller with  $n$  buyers. A detailed description of investors' sorting strategies and of the matching process is deferred to Section 3.2. Once all trades are executed, secondary markets close, investors consume and holders of financial contracts wait to receive contractual repayments at date 2.

**Timeline.** The heuristic timeline of the economy is illustrated in Figure 1. To summarize, in period 0, entrepreneurs issue contracts in order to raise funds and invest. In period 1, after liquidity needs and signals are realized, investors are matched to trade in secondary markets. In period 2, the aggregate

<sup>17</sup>The assumption of commitment to sell is imposed for simplicity. In the baseline case, where investor liquidity needs are observable, this assumption is not binding. However, when liquidity needs are unobservable, this assumption allows me to eliminate the possibility that investors solicit offers, learn other investors' information, but choose not to trade.

state is realized, entrepreneurs receive cash-flows, liquidate capital if needed, and repay liabilities.

### 3 Equilibrium

In this section, I setup the problems solved by entrepreneurs and investors, and then I define the general equilibrium of the economy.

#### 3.1 Entrepreneurs' Problem

In period 0, an entrepreneur chooses how much to invest and raises funds by proposing contractual terms  $\{L, b(s), B(s)\}$  to an investor. An investor accepts the contract if  $L$ , the loan amount, does not exceed the expected present value of the repayments to the investor, which in this section I take as given and denote by  $\mathcal{L}(\{b(s), B(s)\})$ . I refer to the function  $\mathcal{L}(\cdot)$  that maps a financial contract to a maximal loan amount as the *contract price schedule*.

Entrepreneur takes the prices  $\{q(s)\}$  of capital goods and the schedule  $\mathcal{L}(\cdot)$  as given and chooses her investment and the contractual terms in order to maximize her expected period 2 consumption subject to the investor participation constraint, the no-default conditions, and her budget constraints in period 0 and 2. Entrepreneur's problem is thus given by

$$\max_{\{k, L, b(s), B(s), z(s), \tilde{c}_2(s)\}} \mathbb{E}\{\tilde{c}_2(s)\}$$

subject to

$$\tilde{c}_2(s) = a(s)k + q(s)z(s)k - b(s) + A(1 - z(s))k - B(s) \tag{1}$$

$$\chi(k) = L \leq \mathcal{L}(\{b(s), B(s)\}) \tag{2}$$

$$b(s) \leq a(s)k + q(s)z(s)k \tag{3}$$

$$0 \leq b(s) + B(s) \leq (\theta a(s) + q(s))k \tag{4}$$

$$0 \leq B(s) \leq \theta A(1 - z(s))k \tag{5}$$

$$0 \leq z(s) \leq 1 \tag{6}$$

for  $s = l, h$ .

Constraint (1) is the entrepreneurial budget constraint in period 2, where entrepreneurs consume the returns of the project net of repayments. Constraint (2) is the period 0 budget constraint combined with the investor participation constraint. Because there are no informational asymmetries in period 0, it is without loss to assume that entrepreneurs issue contracts that investors accept. Constraint (3) states that the entrepreneur must be able to cover her repayment  $b(s)$  from the intermediate cash-flow  $a(s)k$  and capital goods liquidations  $q(s)z(s)k$ . Constraints (4) and (5) are the no-default conditions and, finally, constraint (6) states that the fraction  $z(s)$  of capital goods liquidated must lie between zero and one.

The prices of capital goods in period 2 are determined by the traditional firms' optimal demand for capital and the clearing condition in the capital goods market. The profits (if any) from these firms' operations are rebated lump sum to late investors. Before proceeding further, I make the following parametric assumptions that simplify the subsequent analysis,

**Assumption 1** *I assume that (1)  $(g'(x) - \theta A)x$  is increasing in  $x$ , (2)  $\chi'(x) - \frac{\chi(x)}{x}$  is increasing in  $x$ , and (3)  $a(l) < A \leq a(h)$ .*

Assumption 1.1 ensures equilibrium uniqueness in the capital goods market, Assumption 1.2 ensures that entrepreneurs face decreasing returns to scale, and Assumption 1.3 implies that entrepreneurs will not need to liquidate capital in state  $h$ .<sup>18</sup> An immediate result that follows from Assumption 1.1 is that, in equilibrium, the prices of capital goods satisfy

$$q(s) = g'(z(s)k) \in (\theta A, A] \tag{7}$$

for  $s = l, h$ .<sup>19</sup> Entrepreneurs thus face a downward sloping inverse demand schedule for capital that is bounded above by the return to capital at its best use,  $A$ , and below by the portion of this return that can be credibly promised to investors,  $\theta A$ .

### 3.2 Investors' Problem

In period 0, an investor's problem is to accept or reject the entrepreneur's contractual offer. In period

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<sup>18</sup>The first two assumptions are standard. See, for example, Lorenzoni (2008) and Jeanne and Korinek (2012). The third assumption is only made for simplicity; the analysis is qualitatively the same if it is relaxed.

<sup>19</sup>See Lemma 0 in Appendix.

1, investors participate in secondary markets where they can trade contracts. In period 2, investors consume the payments received on their contractual holdings and the profits from the traditional firms' operations. Since investors' decision whether to accept the contract in period 0 will depend on investors' buying and selling decisions in secondary markets, I solve the investors' problem by backwards induction.

### 3.2.1 Investors' Problem at $t=1$ : Trading Contracts in Secondary Markets

Let  $\mathcal{C} = \{b(s), B(s)\}$  denote the financial contract offered by the entrepreneurs in  $t = 0$ . After liquidity needs and signals are realized, investors enter secondary markets and decide whether to post their contracts for sale and whether to become potential buyers of contracts from other investors. Let  $(x, \beta) \in [\underline{x}, \bar{x}] \times \{0, 1\}$  denote the type of an investor who has received signal  $x$  and has a liquidity need  $\beta$ .

*Sorting into Buying and Selling.* I make the following indifference-breaking assumptions. First, I suppose that an investor becomes a potential buyer only if he is willing to pay a positive price for some contract. Second, I suppose that an investor posts his contract for sale only if he strictly prefers to do so.<sup>20</sup> Since only investors of type  $\beta = 0$  value consumption in period 2, we immediately have that an investor is a potential buyer if and only if he has  $\beta = 0$ . On the other hand, an investor's posting decision may depend both on his liquidity need and his signal. Let  $\gamma_i \in \{0, 1\}$  denote investor  $i$ 's decision whether to sell his contract or not, with  $\gamma_i = 1$  iff he decides sell. I consider symmetric posting strategies in which conditional on the contract  $\mathcal{C}$ , the strategy  $\gamma_i$  is a measurable function of the investor's type. In particular, for an investor  $i$  who has type  $(x, \beta)$  and holds contract  $\mathcal{C}$ ,  $\gamma_i = \gamma(x, \beta, \mathcal{C})$ .

*Matching Buyers and Sellers.* Each seller is matched randomly with  $n$  buyers, while each buyer is matched with at most one seller.<sup>21</sup> In the Appendix, I construct an explicit matching function that has these features, and I provide the conditions on the primitives that ensure that the buyer-to-seller ratio is consistent with such matching.

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<sup>20</sup>The first assumption eliminates trivial offers from equilibrium, while the second assumption minimizes the ratio of sellers-to-buyers in the economy; it can be rationalized by assuming that there is a small cost to posting contracts.

<sup>21</sup>The assumption that a buyer is contacted by at most one seller is made for simplicity; the results are similar if a buyer is matched with multiple sellers but when trades are executed simultaneously.

The secondary market is thus a collection of sub-markets, each with a single seller and  $n$  buyers. Given contract  $\mathcal{C}$ , each sub-market is fully characterized by the type  $(x^S, \beta^S)$  of the seller, and the signals  $\{x_1^B, \dots, x_n^B\}$  of the buyers (recall that all buyers have  $\beta = 0$ ). In the main analysis, I assume that buyers observe the liquidity need of the seller. As I show below, this assumption eliminates the problem of adverse selection on the side of the seller. Because the discounting of contingent contract occurs due to informational rents of the buyers, the main results of the paper are best illustrated in this baseline case. I relax this assumption in Section 6 and show that the results of the paper remain robust.

**Assumption 2 (Baseline)** *Buyers observe the liquidity need  $\beta^S$  of the seller.*

*Buyer's Payoff.* When a buyer is contacted by a seller, he submits a price offer for the seller's contract. I consider symmetric offer strategies, in which conditional on contract  $\mathcal{C}$ , the price offer that a buyer submits is a measurable function of his own signal and the liquidity need of the seller. In particular, a buyer who has received signal  $x$  and is matched with a seller with a liquidity need  $\beta^S$  submits offer  $p(x, \beta^S, \mathcal{C})$ . In what follows, I omit the superscript  $S$  on the seller's liquidity need and his signal whenever this dependence is clear. When a buyer is matched with a seller, he (possibly) makes an inference about the seller's signal. The reason why a buyer cares about the seller's signal is that it helps him make an inference about the state of the economy and thus about the payoffs of the entrepreneurial contracts. If other buyers follow offer strategy  $p(\cdot, \beta, \mathcal{C})$ , the payoff to buyer  $j$  who has received signal  $x_j^B = x$  and submits offer  $\hat{p}$  is given by

$$U^B(\hat{p}|x, \beta, \mathcal{C}, p) = \mathbb{E}\{(b(s) + B(s) - \hat{p}) \phi(\hat{p}, \max_{-j} \{p(x_i, \beta, \mathcal{C})\}) | x, \beta, \mathcal{C}\}$$

where

$$\phi(\hat{p}, \max_{-j} \{p(x_i, \beta, \mathcal{C})\}) = \begin{cases} 1 & \text{if } \hat{p} > \max_{-j} \{p(x_i, \beta, \mathcal{C})\} \\ 0 & \text{if } \hat{p} < \max_{-j} \{p(x_i, \beta, \mathcal{C})\} \\ l^{-1} & \text{if } \hat{p} = \max_{-j} \{p(x_i, \beta, \mathcal{C})\} \end{cases}$$

is the allocation rule with  $l \in \{1, \dots, n\}$  denoting the number of buyers who have submitted the maximal offer: a buyer gets the contract if his bid is highest and the contract is allocated randomly among

highest bidders in case of a tie. By symmetry, the offer strategy  $p(\cdot, \beta, \mathcal{C})$  is optimal for buyers if

$$p(x, \beta, \mathcal{C}) \in \operatorname{argmax}_{\hat{p}} U^B(\hat{p}|x, \beta, \mathcal{C}, p)$$

for all  $x \in [\underline{x}, \bar{x}]$ .<sup>22</sup>

*Seller's Payoff.* A seller commits to sell his contract to the buyer with the highest offer. Let  $p^{\max}(\beta, \mathcal{C}) \equiv \max_{j=1, \dots, n} \{p(x_j, \beta, \mathcal{C})\}$  be the maximal offer that the seller receives conditional on buyers having received signals  $\{x_j\}_{j=1}^n$ , and note that  $p^{\max}(\beta, \mathcal{C})$  is random as it depends on the entire vector of realizations of the buyers' signals (I omit this dependence for brevity). The expected payoff to a seller who has received signal  $x$  and has a liquidity need  $\beta$  is thus given by

$$U^S(x, \beta, \mathcal{C}) = \mathbb{E}\{p^{\max}(\beta, \mathcal{C})|x\} - \beta \mathbb{E}\{b(s) + B(s)|x\}$$

Investor of type  $(x, \beta)$  will therefore post his contract if only if he is strictly better off selling it than keeping it, i.e.  $\gamma(x, \beta, \mathcal{C}) = 1$  if and only if  $U^S(x, \beta, \mathcal{C}) > 0$ .

Let  $\hat{F}(\cdot|x, \beta, \mathcal{C}) : [\underline{x}, \bar{x}] \rightarrow [0, 1]$  denote the belief (cdf) that a buyer with signal  $x$  holds over the seller's signal conditional on seller having a liquidity need  $\beta$  and holding contract  $\mathcal{C}$ . An equilibrium in secondary markets is then defined as follows,

**Definition 1** *Given financial contract  $\mathcal{C}$ , an equilibrium in secondary markets is given by a posting strategy  $\gamma$ , price offer strategy  $p$ , and belief function  $\hat{F}$ , such that*

1. *Seller Optimality:  $\gamma(x, \beta, \mathcal{C})$  is optimal for an investor of type  $(x, \beta)$ , given that buyers follow strategy  $p$ ,*
2. *Buyer Optimality:  $p(x, \beta, \mathcal{C})$  is optimal for a buyer with signal  $x$  who is matched with a seller with a liquidity need  $\beta$ , given that other buyers follow strategy  $p$  and given belief  $\hat{F}$ , and*
3. *Belief Consistency:  $\hat{F}$  is derived from strategy  $\gamma$  using Bayes' rule where possible.*

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<sup>22</sup>Note that I implicitly assume that investors' endowment  $e$  is large enough for their budget constraint not to bind when making offers.

### 3.2.2 Investors' Problem at t=0: Pricing Financial Contracts

An investor decides whether to accept the contract  $\mathcal{C}$  offered by the entrepreneur in period 0. He accepts the contract if the loan amount specified by the entrepreneur does not exceed the expected present value of the contract. If the investor accepts the contract, he can keep it to maturity and consume its cash-flows  $\{b(s), B(s)\}$  in period 2, or he can sell the contract in secondary markets and consume the proceeds from this sale in period 1. Given the equilibrium strategies  $\gamma$  and  $p$ , the expected present value of the contract to the investor is

$$\mathcal{L}(\mathcal{C}) = \mathbb{E}\{\gamma(x, \beta, \mathcal{C})\mathbb{E}\{p^{max}(\beta, \mathcal{C})|x\} + (1 - \gamma(x, \beta, \mathcal{C}))\beta\mathbb{E}\{b(s) + B(s)|x\}\} \quad (8)$$

i.e. if the investor is of type  $(x, \beta)$ , then he sells his contract if  $\gamma(x, \beta, \mathcal{C}) = 1$ , in which case he is expected to receive  $\mathbb{E}\{p^{max}(\beta, \mathcal{C})|x\}$ ; otherwise he keeps the contract and expects to receive  $\beta\mathbb{E}\{b(s) + B(s)|x\}$ . Since investors are ex-ante symmetric and matching is random, equation (8) is computed by taking expectations over  $x$  and  $\beta$ . This equation fully specifies the *contract price schedule*  $\mathcal{L}(\cdot)$ , because it is defined for any contract  $\mathcal{C}$  issued by the entrepreneur at the initial date.

### 3.3 General Equilibrium

In the previous sections, I described the entrepreneurial problem for given *contract price schedule*  $\mathcal{L}(\cdot)$  and prices of capital  $\{q(s)\}$ , and the determination of the equilibrium prices of capital. I have also setup the investors' problem for a given financial contract issued by entrepreneurs, and I thus obtained the *contract price schedule* that entrepreneurs face in period 0. A general equilibrium of this economy is then defined as follows,

**Definition 2** *An equilibrium consists of an allocation  $\{k, L, b(s), B(s), z(s), \tilde{c}_2(s)\}$ , capital goods prices  $\{q(s)\}$ , a contract price schedule  $\mathcal{L}(\cdot)$ , and a triple  $\{\gamma, p, \hat{F}\}$ , such that*

1. *Entrepreneurs' Optimality: the allocation  $\{k, L, b(s), B(s), z(s), \tilde{c}_2(s)\}$  is optimal for entrepreneurs, given the capital goods prices  $\{q(s)\}$  and the contract price schedule  $\mathcal{L}(\cdot)$ ,*
2. *Investors' Optimality: the triple  $\{\gamma, p, \hat{F}\}$  is an equilibrium in secondary markets, given financial contract  $\mathcal{C} = \{b(s), B(s)\}$ ,*



3. *Market Clearing: the prices  $\{q(s)\}$  of capital goods are given by (7), and the schedule  $\mathcal{L}(\cdot)$  is given by (8).*

Note that in defining the equilibrium of the economy, I omitted the allocations of the investors. I have done this only for brevity, as investors' allocations affect the equilibrium quantities of interest only through the prices of capital goods and of the financial contracts in secondary markets. These prices in turn are fully summarized by (i) the contract price schedule implied by optimal posting and offer strategies, and (ii) the traditional sector's optimal demand for capital. I now proceed to characterize the equilibrium of the economy.

## 4 Equilibrium Characterization

In this section, I characterize the equilibrium of the economy and derive the main result of the paper which states that the magnitude of balance sheet amplification is directly linked to the level of information dispersion and the severity of search frictions in financial markets. I solve for the equilibrium in three steps. First, in Section 4.1, I show how contractual choices made by entrepreneurs in period 0 determine the magnitude of amplification in period 2, and I show that there are benefits to contingent write-downs of entrepreneurial liabilities in adverse states of the world. Second, in Section 4.2, I solve for the equilibrium in secondary markets and determine the costs of contractual contingency that entrepreneurs face when issuing contracts at the initial date. Finally, in Section 4.3, I solve for the financial contract issued by entrepreneurs that optimally trades off the costs and insurance benefits, and I characterize the equilibrium fluctuations in the economy.

### 4.1 Contracts and Fire-Sales

In period 2, after cash-flows are realized, entrepreneurs decide how much capital to liquidate in order to meet their liabilities. Recall that  $\{b(s), B(s)\}$  denote the contractual repayments that entrepreneurs have promised to make to investors in period 2, and let  $d(s) \equiv \frac{b(s)+B(s)}{k}$  denote the 'per unit' equivalent of the total period 2 repayments. Since liquidations are costly, it is without loss to assume that entrepreneurs would have chosen to repay as much as possible at the end of period 2, i.e.  $B(s) =$

$\theta A(1 - z(s))k$  for  $s \in \{l, h\}$ . We can thus re-express entrepreneurial consumption in period 2 as

$$\tilde{c}_2(s) = (a(s) + q(s)z(s) + (1 - z(s))A - d(s))k$$

Entrepreneurs choose  $z(s) \in [0, 1]$  to maximize  $\tilde{c}_2(s)$  subject to the beginning of period resource constraint given in equation (3), which can be re-written as

$$0 \leq (a(s) + q(s)z(s) - d(s) + \theta A(1 - z(s)))k$$

where I used the fact that  $B(s) = \theta A(1 - z(s))k$  for  $s \in \{l, h\}$ . Since entrepreneurs will only choose to liquidate capital if the resource constraint is violated at  $z(s) = 0$ , we can immediately make the following conclusion: in equilibrium, entrepreneurs liquidate capital in state  $s$  if and only if the cash-flows at hand plus the pledgeable portion of future cash-flows are insufficient to cover debt obligations, i.e. if  $d(s) > a(s) + \theta A$ . Given this, the following proposition characterizes how entrepreneurs' contractual choices made in period 0 translate into liquidations and equilibrium fluctuations in the prices of capital in period 2,

**Proposition 1 (Contracts and Fire-Sales)** *In equilibrium, entrepreneurs do not liquidate capital in state  $h$ , and they liquidate capital in state  $l$  if only if  $d(l) > a(l) + \theta A$ . The prices of capital goods satisfy*

$$\theta A < q(l) \leq q(h) = A$$

where  $q(l) = g'(z(l)k)$  and  $z(l) = \max\{0, \frac{d(l) - a(l) - \theta A}{q(l) - \theta A}\} \in [0, 1]$ .

Thus, entrepreneurs liquidate capital only in the low state and only if the present value of their liabilities exceeds their cash-flow at hand plus the amount that they can 'roll-over' to the future.<sup>23</sup> In aggregate, as the entrepreneurial sector liquidates, the price of capital in state  $l$  also becomes depressed, since  $q(l) = g'(z(l)k) < A$ .

If contracts are such that  $d(l) > a(l) + \theta A$ , a negative shock to entrepreneurs' cash-flows will be amplified through the endogenous interaction between the price of capital and its liquidation. In

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<sup>23</sup>The result that entrepreneurs do not liquidate capital in state  $h$  follows from Assumption 1.3 and the financial constraint  $d(h) \leq \theta a(l) + q(h)$ .

particular, note that a decline in the price of capital  $q(l)$  forces entrepreneurs to liquidate even more capital to meet this shortfall, since  $z(l) = \frac{d(l)-a(l)-\theta A}{q(l)-\theta A}$  is decreasing in  $q(l)$ ; this further depresses the price of capital  $q(l)$ , and so on. Feedback effects of this type can potentially explain how small shocks get amplified into larger scale recessions.

The magnitude of such amplification and whether it occurs at all, however, will depend critically on the design of entrepreneurial liabilities at the initial date. When entrepreneurs promise to repay 'too much' in the low state and therefore aggregate liquidations are positive, asset prices become depressed,  $q(l) < A$ ; in this case, entrepreneurs' marginal utility of funds in the low state is therefore  $\frac{(1-\theta)A}{q(l)-\theta A} > 1$ ; this is because entrepreneurs can use each extra 'dollar' to reduce costly liquidations. Entrepreneurs' marginal utility of funds in state  $h$ , on the other hand, is equal to 1 as they use each extra 'dollar' for consumption. Therefore, a contract that has lower repayments in state  $l$  and higher repayments in state  $h$  is potentially beneficial because it allows entrepreneurs to insure against premature liquidations. As I show in the following section, this insurance benefit of contingent contracts will need to be traded off against the 'illiquidity' costs that entrepreneurs will need to pay investors for holding such contracts.

## 4.2 Equilibrium in Secondary Markets

I now solve for the equilibrium in secondary markets where investors trade financial contracts. The main result of this section is that contingent contracts are priced at a discount due to the presence of dispersed information and search frictions in financial markets. In period 1, an investor who has received signal  $x$  and has a liquidity need  $\beta$  decides whether to post his contract for sale. If the investor posts his contract, he is matched with  $n$  buyers that submit offers according to strategy  $p(\cdot, \beta, \mathcal{C})$ , where recall that  $\mathcal{C} = \{d(s)k\}$  denotes the financial contract issued by the entrepreneurs in period 0. The first immediate result of this section is that non-contingent contracts are always traded at their 'fair' value,

**Lemma 1** *If financial contract  $\mathcal{C} = \{d(s)k\}$  satisfies  $d(l) = d(h)$ , then the offer strategy*

$$p(x, \beta, \mathcal{C}) = \mathbb{E}\{d(s)k\} \quad \text{for } x \in [\underline{x}, \bar{x}] \quad \text{and } \beta \in \{0, 1\}$$

*is optimal for buyers for any belief  $\hat{F}$ .*

This result relies on the fact that when the payoff of the underlying contract does not depend on the state of the economy, informational asymmetries are irrelevant for pricing this contract. Competition then forces buyers to bid the prices of such contracts up to their 'fair' value. As I show below, this logic does not extend to contingent contracts. In this case, information dispersion causes buyers to disagree about expected payoffs of such contracts and, thus, to worry about the winner's curse - the fact that a buyer who gets to buy the contract must be more optimistic about the contract's payoffs than other buyers.

To analyze buyers' offer strategies for contracts contingent on the state, I further restrict my attention to offer strategies  $p$  that are monotonic and differentiable in buyers' signals. This restriction is standard in the literature (e.g. Milgrom and Weber (1982)), and it yields the reasonable result that buyers who are most optimistic about contractual payoffs are also the ones who receive the contracts in equilibrium. As I show in the Appendix, because buyers observe the seller's liquidity need  $\beta$ , an investor's optimal posting strategy is always to sell the contract if and only if he has experienced a liquidity need, i.e.  $\beta = 1$ . The reason is that, because there is common knowledge of gains from trade, non-liquidity hit investors are unable to earn rents by mimicking investors who have them.<sup>24</sup> Hence, to fully characterize the equilibrium pricing of financial contracts, it suffices to compute the offer strategy conditional on buyers' being matched with sellers who have experienced liquidity needs, i.e.  $p(\cdot, 1, \mathcal{C})$ .

Suppose that a seller of contract  $\mathcal{C}$  has been matched with buyers with signals  $x_1^B, \dots, x_n^B$ , and that the contract is positively correlated with the state, i.e.  $d(h) > d(l)$ . Let  $y_1^+$  denote the maximal signal among the signals  $\{x_2^B, \dots, x_n^B\}$  received by the opponents of buyer 1. Note that  $y_1^+$  is a random variable from buyer 1's perspective, and that this buyer's valuation of the contract conditional on his signal being  $x_1^B = x$  and conditional on receiving the contract is given  $\mathbb{E}\{d(s)k | x_1^B = x, y_1^+ < x\}$ : buyer 1 conditions on his own signal and the fact that his signal is highest. For a contract that is negatively correlated with the state, buyer 1's valuation of the contract conditional on his signal and conditional on receiving the contract is given by  $\mathbb{E}\{d(s)k | x_1^B = x, y_1^- > x\}$ , where  $y_1^-$  denotes the minimal signal among the signals  $\{x_2^B, \dots, x_n^B\}$  received by the opponents of buyer 1.

**Lemma 2** *If financial contract  $\mathcal{C} = \{d(s)k\}$  satisfies  $d(l) \neq d(h)$ , then the equilibrium offer strategy*

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<sup>24</sup>As I show in Section 6, this may no longer be the case when liquidity needs are unobservable.

of the buyers satisfies

$$p(x, 1, \mathcal{C}) < \begin{cases} \mathbb{E}\{d(s)k|x_1^B = x, y_1^+ < x\} & \text{if } d(h) > d(l) \\ \mathbb{E}\{d(s)k|x_1^B = x, y_1^- > x\} & \text{if } d(h) < d(l) \end{cases}$$

for  $x \in [\underline{x}, \bar{x}]$ .

The computation of buyers' optimal offer strategies is analogous to Milgrom and Weber (1982), with the exception that off-equilibrium path, buyers' beliefs are also updated to adjust for the adverse selection on the side of the seller.<sup>25</sup> Since the expressions for the optimal offer strategies are rather cumbersome, they are relegated to the Appendix. In what follows, I discuss the implication of these strategies for the equilibrium pricing of financial contracts.

Because each buyer shades his offer below his valuation of the contract, the unconditional expected resale price of a contingent contract satisfies

$$\mathbb{E}\{p^{max}(1, \mathcal{C})\} = \mathbb{E}\{\max_{j=1}^n \{p(x_j^B, 1, \mathcal{C})\}\} < \mathbb{E}\{d(s)k\}$$

and is thus below the unconditional expected value of that contract.<sup>26</sup> As will be seen below, such discounting of financial contracts in secondary markets is the precise reason why it is costly for entrepreneurs to introduce contingencies into financial contracts when raising funds at the initial date. In addition, the model predicts that there is a cross-sectional dispersion of prices for contingent contracts with similar characteristics. The maximal offer received by a seller of a financial contract is given by  $p^{max}(1, \mathcal{C}) = \max_i^n \{p(x_i, 1, \mathcal{C})\}$ , where the signals  $x_1, \dots, x_n$  are drawn independently from the distribution  $F_s(\cdot)$ . The maximal offer received by the seller, therefore, depends on the entire profile of signals received by the buyers within his match.<sup>27</sup>

The following proposition uses the equilibrium offer strategies to yield the main result of this section: it states that the period 0 price of a generic financial contract is given by its expected value net of a discount that is proportional to the degree of contingency of that contract on the state of the economy,

<sup>25</sup>If a buyer is contacted by a  $\beta = 0$  seller, he assigns a belief  $\Pr(x^S = \underline{x}) = 1$  for a contract with payoffs  $d(h) \geq d(l)$ , and he assigns a belief  $\Pr(x^S = \bar{x}) = 1$  otherwise.

<sup>26</sup>As discounting will be greater when dispersion of information is greater, this is consistent with investors facing larger trading costs in more 'opaque' markets. See Bessembinder and Maxwell (2008).

<sup>27</sup>See Ashcraft and Duffie (2007), Bessembinder and Maxwell (2008), and Ang et al. (2013) for evidence on dispersion in over-the-counter markets.

**Proposition 2 (Costs of Contingency)** *The price of a generic contract  $\mathcal{C} = \{d(s)k\}$  satisfies*

$$\mathcal{L}(\mathcal{C}) = \mathbb{E}\{d(s)k\} - \lambda\zeta_{\mathcal{C}} \cdot |d(h) - d(l)|k \quad (9)$$

where  $\zeta_{\mathcal{C}} = \zeta^+ \cdot 1\{d(h) \geq d(l)\} + \zeta^- \cdot 1\{d(h) < d(l)\}$  and  $\zeta^+, \zeta^- > 0$ .

The intuition for this result can be understood as follows. Recall the definition of the *contract price schedule*  $\mathcal{L}(\cdot)$  in equation (7) and note that given contract  $\mathcal{C} = \{d(s)k\}$  issued by entrepreneurs at the initial date, we have that

$$\begin{aligned} \mathcal{L}(\mathcal{C}) &= \mathbb{E}\{\gamma(x, \beta, \mathcal{C})\mathbb{E}\{p^{\max}(\beta, \mathcal{C})|x\} + (1 - \gamma(x, \beta, \mathcal{C}))\beta\mathbb{E}\{d(s)k|x\}\} \\ &= \lambda\mathbb{E}\{p^{\max}(1, \mathcal{C})\} + (1 - \lambda)\mathbb{E}\{d(s)k\} \\ &= \mathbb{E}\{d(s)k\} - \lambda(\mathbb{E}\{d(s)k\} - \mathbb{E}\{p^{\max}(1, \mathcal{C})\}) \end{aligned}$$

The above expression follows from the fact that an investor sells his contract only when he has  $\beta = 1$  (a probability  $\lambda$  event), and the assumption that investor liquidity needs are idiosyncratic and therefore independent of the state of the economy. The precise form of the schedule  $\mathcal{L}(\cdot)$  in Proposition 2 then follows from the fact that the offer strategy  $p$  is linear in the contractual payoffs  $\{d(s)k\}$  and because buyers are able to earn rents only when contracts are contingent on the state of the economy.

The schedule  $\mathcal{L}(\cdot)$  has the following simple interpretation for the entrepreneurs' cost of funds in period 0. If entrepreneurs want to issue contracts that are non-negatively correlated with the state, i.e.  $d(l) \leq d(h)$ , then it is as if entrepreneurs face investors who are more pessimistic about the future state of the economy: the implicit probability that they assign to state  $l$  is given by  $\tilde{\pi}(l) = \pi(l) + \lambda\zeta^+$ . As I show in the next section, the magnitude of such implicit pessimism is closely linked to the severity of equilibrium amplification in the adverse state of the world.

### 4.3 Optimal Contracts and Equilibrium Fluctuations

In this section, I characterize the general equilibrium of the economy. In Proposition 3, I derive a pecking order for entrepreneurial liability design. I show that entrepreneurs prefer to raise funds

with non-contingent claims unless they expect fluctuations to be sufficiently severe. In Proposition 4, I derive the main result of the paper that relates the magnitude of balance sheet amplification in the economy to the information dispersion and search frictions in financial markets.

In period 0, entrepreneurs choose what financial contract to issue, taking as given the *contract price schedule*  $\mathcal{L}(\cdot)$  and the prices  $\{q(s)\}$  of capital goods. This choice then fully characterizes the solution to the entrepreneurial problem as well as the equilibrium of the economy: given the contract, investment is pinned down by the period 0 budget constraint, and Proposition 1 fully characterizes entrepreneurial liquidation decisions  $\{z(s)\}$  and thus consumptions  $\{\tilde{c}_2(s)\}$ . Before proceeding further, however, I make a further simplifying assumption that reduces the number of cases to be considered. Let  $\underline{k}$  be defined by  $\chi(\underline{k}) = (a(l) + \theta A)\underline{k}$  and thus be the largest scale that entrepreneurs can achieve by borrowing with non-contingent claims and avoiding liquidations at the same time (see Proposition 1). Let  $k^{fb} \equiv \chi'^{-1}(\mathbb{E}\{a(s) + A\})$  be the scale of investment that would be optimal in a frictionless economy.<sup>28</sup> Then I assume that

**Assumption 3**  $\underline{k} < k^{fb}$

This assumption ensures that in equilibrium entrepreneurs face a meaningful tradeoff between the scale of their investment and the premature liquidations of their projects in the low state. The following proposition provides a pecking order for entrepreneurial liability design. It characterizes the optimal financial contract issued by entrepreneurs as a function of expected fluctuations in the prices of capital goods,

**Proposition 3 (Optimal Contract)** *Given the contract price schedule  $\mathcal{L}(\cdot)$  as in Proposition 2 and prices  $\{q(s)\}$  of capital goods that satisfy  $q(l) \leq q(h) = A$ , there exists a threshold  $\underline{q} \in (\theta A, A)$  such that the optimal financial contract issued by entrepreneurs falls into one of the following categories,*

- *Type I (Non-Contingency):* If  $q(l) > \underline{q}$ , then either (i)  $a(l) + \theta A \leq d(l) = d(h) \leq \theta a(l) + q(l)$ , or (ii)  $d(l) = \theta a(l) + q(l) < d(h) \leq \theta a(h) + A$ ,
- *Type II (Contingency):* If  $q(l) < \underline{q}$ , then either (i)  $a(l) + \theta A = d(l) < d(h) \leq \theta a(h) + A$  or (ii)  $a(l) + \theta A < d(l) < d(h) = \theta a(h) + A$ ,

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<sup>28</sup>In a frictionless economy, projects would be valued at their expected value and the optimal investment scale would satisfy  $\chi'(k^{fb}) = \mathbb{E}\{a(s) + A\}$ .

- *Type III (Indifference):* If  $q(l) = \underline{q}$ , then  $a(l) + \theta A \leq d(l) \leq \theta a(l) + q(l)$  and  $d(l) \leq d(h) \leq \theta a(h) + A$ .

where the threshold price is given by

$$\underline{q} = \left( \theta + (1 - \theta) \frac{\pi(l)}{1 - \pi(l)} \frac{1 - \pi(l) - \lambda \zeta^+}{\pi(l) + \lambda \zeta^+} \right) \cdot A$$

and is strictly decreasing in  $\lambda \zeta^+$ .

Proposition 3 states that if the price of capital  $q(l)$  in low state is above the threshold  $\underline{q}$ , then entrepreneurs prefer to borrow with non-contingent claims: they set their repayments to  $d(l) = d(h)$  unless the borrowing capacity in state  $l$  is exhausted, i.e. if  $d(l) = \theta a(l) + q(l)$ . On the other hand, if the price  $q(l)$  is below the threshold  $\underline{q}$ , then introducing contingency becomes desirable. In fact, entrepreneurs fully insure themselves against fluctuations as long as their borrowing capacity in the high state is not exhausted, i.e. if  $d(h) < \theta a(h) + A$ . Finally, when the price  $q(l)$  is equal to the threshold  $\underline{q}$ , entrepreneurs are indifferent between the two types of contracts.

The above result thus shows that because contractual contingencies are costly, entrepreneurs are willing to sacrifice the risk-sharing benefits that contingent contracts provide and liquidate their projects prematurely even if price of capital in low state falls below  $A$ . As will be seen next, this behavior is precisely what gives rise to equilibrium fluctuations in asset prices and allows for balance sheet amplification to occur. The final and main result of this section combines the result in Proposition 3 with the results of the previous sections to give a full characterization of the general equilibrium of the economy.

**Proposition 4 (Equilibrium Fluctuations)** *In equilibrium,*

1. *The optimal financial contract satisfies  $d(l) \in (a(l) + \theta A, \theta a(l) + q(l)]$  and  $d(h) \in [d(l), \theta a(h) + A]$ , and depending on parameters, it may or may not be contingent.*
2. *Entrepreneurs invest at scale  $k \in (0, k^{fb})$  and liquidate a fraction  $z(l) = \frac{d(l) - a(l) - \theta A}{q(l) - \theta A} > 0$  of capital in state  $l$ .*
3. *The prices of capital goods satisfy  $q(l) < q(h) = A$ . Furthermore, whenever the financing*



constraint in state  $h$  is loose, we have that

$$0 \leq q(h) - q(l) \leq (1 - \theta) \left( 1 - \frac{\pi(l)}{1 - \pi(l)} \frac{1 - \pi(l) - \lambda\zeta^+}{\pi(l) + \lambda\zeta^+} \right) \cdot A$$

and thus the fluctuations in asset prices are bounded by the cost of contractual contingency.

Thus, because contingencies are costly to introduce, in equilibrium entrepreneurs will choose to make 'excessive' repayments in low state,  $d(l) > a(l) + \theta A$ , and they will thus liquidate capital in that state. As a result, the equilibrium prices of capital will fluctuate,  $q(l) < q(h) = A$ , and the perverse feedback between prices and liquidations will give rise to a balance sheet amplification: a decline in the price of capital,  $q(l)$ , will lead to an increase in entrepreneurial liquidations,  $z(l) = \frac{d(l) - a(l) - \theta A}{q(l) - \theta A}$ , which will lead to a further declines in the prices of capital,  $q(l) = g'(z(l)k)$ , and so on.

The costs of contractual contingency are essential for this result because in their absence ( $\lambda\zeta^+ = 0$ ) entrepreneurs would begin insuring even the slightest fluctuations in the prices of capital in order to avoid liquidations: note that  $\underline{q} < A$  if and only if  $\lambda\zeta^+ > 0$ . This behavior would then endogenously stabilize the equilibrium prices of capital and potentially eliminate balance sheet amplification altogether. The last part of the proposition, in essence, provides a necessary condition for balance sheet amplification to occur: it states that the fluctuations in the prices of capital and thus the magnitude of amplification will tend to be bounded by the cost of contractual contingency. The only scenario where fluctuations may be larger is when entrepreneurs are so 'desperate' for funds that they still want to raise more funds even after having exhausted their borrowing capacity in state  $h$ . In what follows, I will focus on the case where in equilibrium the financial constraint is non-binding in the high state.<sup>29</sup> The conditions on the primitives that ensure non-binding constraint in state  $h$  are provided in the Appendix. This allows me to illustrate my results most starkly because full-insurance will be obtained in the absence of secondary market frictions.

#### 4.4 Comparative Statics

I now provide comparative statics results that relate the magnitude of equilibrium amplification to the primitives of the economy. Because the magnitude of amplification in the model is tightly linked

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<sup>29</sup>While asset prices may still fluctuate when the borrowing constraint is exhausted in the high state, amplification will not occur because collateral constraints will play a stabilizing role. See also Krishnamurthy (2003).

to the fluctuations in the prices of capital, I will measure amplification by the percent fall of the price of capital in the low state below the price in the high state,  $V(q) \equiv \frac{q(h)-q(l)}{q(h)}$ . By Proposition 4,  $V(q)$  is bounded above by a term that is monotonically increasing in the costs of contractual contingency, which are given by  $\lambda\zeta^+$  for the equilibrium contracts. These costs are in turn closely linked to the three ingredients introduced in this paper: (i) liquidity needs, (ii) information dispersion, and (iii) search frictions in financial markets. Investor liquidity needs and search frictions in financial markets are captured by an investor's probability  $\lambda$  of being 'early' type and by the number  $n$  of buyers that a seller may contact respectively. To measure information dispersion, recall from Section 2 that there exist positive constants  $\underline{\phi}, \bar{\phi}$  such that  $\underline{\phi} \leq \frac{f_h(x)}{f_l(x)} \leq \bar{\phi}$  for all  $x \in [\underline{x}, \bar{x}]$ , and define  $\psi \equiv \bar{\phi} - \underline{\phi}$  as a measure of signal informativeness. Thus, as  $\psi$  decreases to 0, signals become uninformative of the state and information becomes less dispersed.

The following proposition shows that liquidity needs, information dispersion, and search frictions are essential for amplification effects to be present. In particular, it shows that amplification disappears as either liquidity needs, search frictions or information dispersion vanish.

**Proposition 5**  *$V(q)$  decreases to 0 when either  $\lambda$  or  $\psi$  decrease to 0, or when  $n$  increases to  $\infty$ .*

The fact that smaller liquidity needs reduce amplification effects is clear. Risk-sharing among entrepreneurs and investors is limited solely because contingent claims trade at a discount in financial markets. In the absence of liquidity needs, there is no trade in these markets, and thus the resale value of financial contracts is irrelevant for pricing them.<sup>30</sup> On the other hand, as  $\psi$  declines to 0, even when financial contracts are traded, the discount that sellers receive on them goes to 0 because the beliefs of all buyers become closer to their priors as their signals become less informative.

The effect of the search friction  $n$  is more subtle. While it is difficult to obtain a monotonicity result that relates  $n$  to the discount  $\zeta^+$ , the asymptotic result in Proposition 5 is derived in Kremer (2002): he shows that expected prices converge to expected values in first-price common value auctions, which is equivalent to  $\zeta^+$  going to 0 in my framework. The intuition is that the larger the number of buyers per seller, valuations within a match become less dispersed, and it becomes more likely that a buyer loses the contract when he sheds his offer below his conditional valuation. Note that I have implicitly

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<sup>30</sup>This result is akin to the insight from Milgrom and Stokey (1982) that non-strategic motives are essential to sustain trade. See Serrano-Padial (2007) for a qualification and refinement of this result to generalized trading mechanisms in a risk-neutral environment.

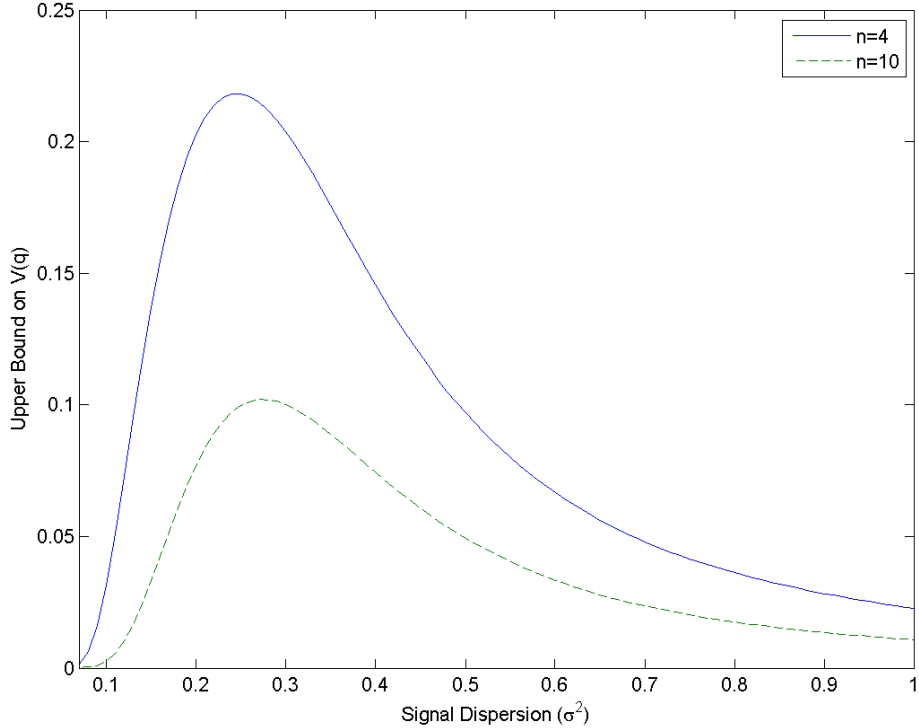


Figure 2: **Equilibrium Fluctuations (a)**

**Calibration:** Signal distribution  $N(\mu(s), \sigma^2)$  on  $[-0.5, 0.5]$  for  $s = l, h$ , with  $\mu(l) = -0.2$  and  $\mu(h) = 0.2$ ; prior:  $\pi(l) = 0.05$ ; liquidity needs:  $\lambda = 0.3$ ; pledgeability:  $\theta = 0.1$ .

decoupled the severity  $n$  of search frictions from an investor's probability  $\lambda$  of experiencing liquidity needs. While in the main analysis, I have assumed exclusive matching of buyers to sellers (i.e. that  $n\lambda \leq 1 - \lambda$ ), the result in Proposition 2 is the same in a variant of the model where buyers match with multiple sellers but when all trades are executed simultaneously.

Figure 2 illustrates the upper bound on  $V(q)$  derived in Proposition 4 for a particular parameterization of signal distributions: signals are drawn from a truncated normal,  $N(\mu(s), \sigma^2)$ , on interval  $[-0.5, 0.5]$  with state-dependent mean  $\mu(s)$  and variance  $\sigma^2$ . The upper bound on  $V(q)$  is depicted on the vertical axis, and the variance of signals  $\sigma^2$  is depicted on the horizontal axis. I plot this relationship for two different values of the search friction,  $n$ . As illustrated in the figure, amplification effects can be large when search frictions are severe and when signals are not too uninformative. The plot, however, also shows that amplification effects are small not only when signals are uninformative (high  $\sigma$ ) but also when signals are very informative (low  $\sigma$ ). In fact, when information is common

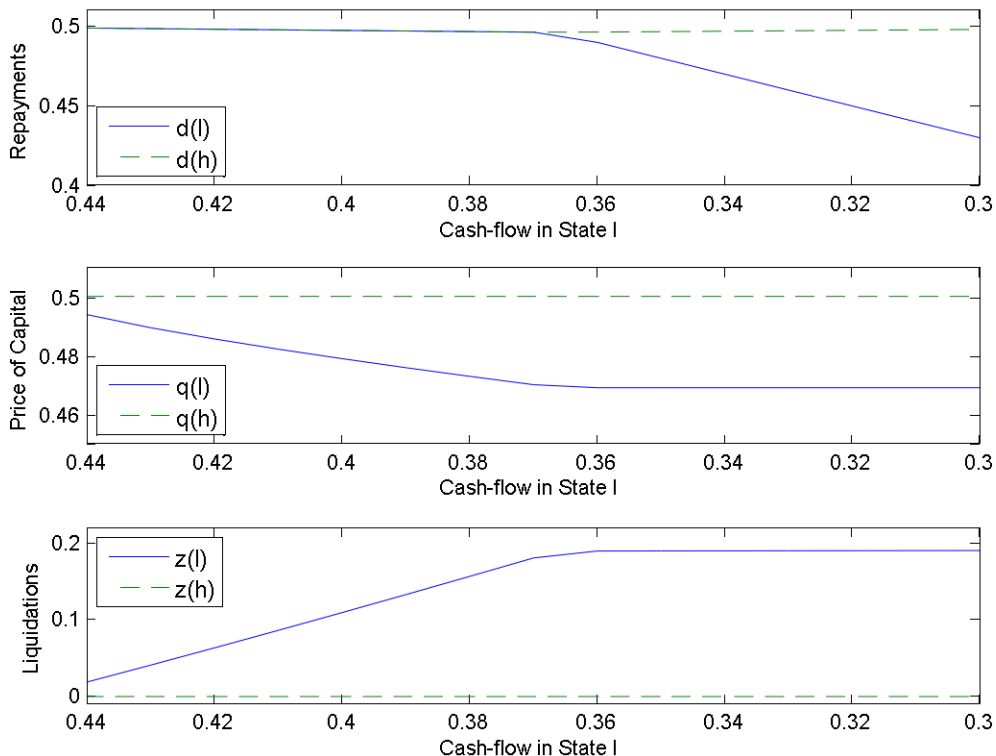


Figure 3: **Equilibrium Fluctuations (b)**

**Calibration:**  $\chi(k) = \frac{\chi}{\alpha} k^\alpha$  with  $(\chi, \alpha) = (1, 2)$ ;  $g(k) = Ak - \frac{g}{\beta} k^\beta$  with  $(g, \beta) = (0.1, 1.7)$ ;  $\theta = 0.1$  and  $(a(h), A) = (0.5, 0.5)$ ; prior:  $\pi(l) = 0.05$ , signal dispersion:  $\sigma = 0.15$ ; number of buyers:  $n = 10$ , liquidity needs:  $\lambda = 0.3$ .

across agents (either uninformative or fully informative signals), then contracts are always traded at their expected value: buyers agree on valuations and compete contract prices to their expected values. Furthermore, one can use the result known in auction theory as the ‘linkage principle’ to show that discounting of contingent claims and thus amplification effects are smaller when public signals are introduced.<sup>31</sup> Thus, it is the dispersion of signals across agents rather than the informativeness of these signals that drives the main results of the paper.

While the above results show that amplification effects will be bounded by the magnitudes of three ingredients introduced in the paper, the actual magnitude of amplification will also depend on the severity of the shock to the entrepreneurial sector, i.e. how low is  $a(l)$ . In Figure 3, I plot

<sup>31</sup>Milgrom and Weber (1982) show that a seller’s revenue increases when public signals are introduced. This is equivalent to  $\zeta^+$ , and thus the upper bound on  $V(q)$ , decreasing in my framework.

the optimal contractual repayments (top diagram), the equilibrium prices of capital goods (middle diagram), and equilibrium liquidations (bottom diagram) as a function of cash-flows  $a(l)$  in the low state. I parameterize signal dispersion to  $\sigma^2 = 0.15$ , search friction to  $n = 10$ , and liquidity needs to  $\lambda = 0.3$  as before. As can be seen, entrepreneurs borrow with non-contingent claims when the shocks to cash-flows are not severe (Type I). In this region, entrepreneurial liquidations become more severe and asset prices become more depressed the lower their cash-flows are. However, when cash-flows in the low state become sufficiently low ( $a(l) = 0.365$ ), introducing contingencies and bounding liquidations becomes optimal (Type III). In equilibrium, this also puts the lower bound ( $\underline{q} = .469$ ) on the price of capital in that state, which corresponds precisely to the percent fall in the price of capital for  $\sigma^2 = 0.15$  and  $n = 10$  depicted in Figure 2.

## 4.5 Discussion

The results presented in the previous section rationalize why macroeconomic risks may not be shared properly and thus why balance sheet recessions may occur even if borrowers and lenders are able to write contracts contingents on the aggregate state of the economy. The theory thus provides a potential rationale for the restriction of contractual incompleteness often exogenously imposed in much of the literature on the balance sheet channel. However, the model also predicts that amplification of aggregate shocks should be expected to be larger for risks about which there are larger informational disagreements and for which the secondary financial markets feature larger search frictions. Hence, while this restriction may be relevant for some risks where hedging markets are not very liquid (e.g. housing), it may be less so for risks where hedging occurs in well-organized competitive exchanges (e.g. energy). Furthermore, as I show in the next section, the model yields policy implications that would not be possible to obtain with exogenous restrictions on the contractual environment.

The model is also able to nest some of the alternative explanations provided in the literature. For example, Rampini and Viswanathan (2009) argue that borrowers may optimally choose to forgo risk-sharing opportunities if their funding needs are sufficiently high ex-ante. In my framework, this would also arise if financing needs are high - Type II contract in Proposition 3. However, the mechanism presented in this paper is applicable independent of the extremity of borrowers' financing needs. Krishnamurthy (2003) and Lorenzoni (2008), on the other hand, derive balance sheet amplification

by imposing limited commitment on lenders and supposing that write-downs are insufficient for risk-sharing. More precisely, while in my framework the state  $l$  repayment that eliminates fluctuations is given by  $d(l) = a(l) + \theta A$ , in their framework it is given by  $d(l) = a(l) + \theta A - w$ , where  $w$  is some additional expenditure that the entrepreneur must make in the intermediate period. The assumption of insufficiency of write-downs is then equivalent to  $a(l) + \theta A < w$ , i.e. cash-flows shocks are sufficiently severe so that even if entrepreneurs wrote down all of their liabilities ( $d(l) = 0$ ) they would still be unable to avoid liquidations. In contrast, my framework can explain periods of balance sheet amplification even when such write-downs suffice for risk-sharing. This result is of further interest in view of the recent policy discussions which stress that write-downs can go a long way in providing insurance to borrowers.

The magnitude of balance sheet amplification in my framework is tightly linked to the information dispersion and search frictions that I have introduced in the paper. While I have analyzed a stylized trading environment, the insight that information disagreements and limited competition allow buyers to earn rents is more general. In particular, the literature on common value auctions has shown that in a variety of trading mechanisms, sellers forgo informational rents when faced with buyers who disagree about the value of the object being offered for sale.<sup>32</sup> While in general the magnitude of rents may depend on the particular trading environment, the logic that drives costly contractual contingencies should extend well beyond the basic economic environment presented in this paper.

## 5 Policy Implications

In this section, I consider the policy-implications of the theory. I study the implications of the model for macro-prudential policy in Section 5.1, and I discuss the theory's implications for policies geared towards increasing transparency and competition in financial markets in Section 5.2.

### 5.1 Macro-Prudential Regulation

I now consider the implications of the theory for macro-prudential regulation. The question I ask

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<sup>32</sup>See Milgrom and Weber (1982) for this result in alternative trading mechanisms. Duffie and Manso (2009) analyze bilateral trading mechanisms where disagreements lead to probability of no-trade. While Cremer and McLean (1986) show the existence of mechanisms where buyers' rents are zero, such mechanisms are very complex and are unlikely to apply to trade in financial markets.

is whether atomistic entrepreneurs retain excessive risks in a decentralized economy. In particular, I study the problem of a social planner who can ex-ante coordinate entrepreneurs' contractual choices and whose objective is to maximize entrepreneurial welfare subject to leaving investors as well off as in the competitive equilibrium. The planner must still respect the financial constraints faced by economic agents (i.e. limited commitment constraints). In addition, the planner still allows economic agents to trade in capital goods markets and in secondary markets for financial contracts.

Note that if the planner modifies entrepreneurial contracts, she only affects investors' welfare through the changes in the equilibrium prices of capital  $\{q(s)\}$ . Thus, to ensure a Pareto improvement, the planner must compensate investors for any losses originating from these changes in prices.<sup>33</sup> To simplify the analysis, I suppose that the planner makes compensatory transfers to investors in state  $h$  of period 2. Furthermore, I consider the parameterizations of the model for which the financial constraints are loose in both states at the competitive allocation.

Let  $T \geq 0$  denote the transfer that the planner makes from entrepreneurs to investors in state  $h$  and let  $\Pi^{CE}(s)$  ( $\Pi(s)$ ) denote the profits of the traditional sector firms in period 2 and state  $s$  at the competitive (at the planner's) allocation. Since investors are ex-ante identical, the transfer  $T$  must satisfy

$$(1 - \pi(l))T \geq \sum_s \pi(s) (\Pi^{CE}(s) - \Pi(s))$$

i.e. the expected present value of the transfer to the investors must be at least as great as the expected present value of losses in profits. The transfers and the contract chosen by the planner are still required to satisfy the financial constraints

$$\begin{aligned} 0 &\leq b(s) + B(s) \leq (\theta a(s) + q(s))k - T \cdot 1\{s = h\} \\ 0 &\leq B(s) \leq \theta A(1 - z(s))k \end{aligned}$$

and, importantly, the planner internalizes the fact that her contractual choices affect equilibrium prices of capital, i.e. she faces the additional constraint  $q(s) = g'(z(s))k$ .

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<sup>33</sup>Transfers are necessary here because the economy is ex-post efficient. In an alternative setting, where increased risk-sharing benefits all agents in the economy ex-post, such transfers may not be needed for Pareto improvement. See, for example, Jeanne and Korinek (2012) for a model with technological externalities.

The following proposition provides the main result of this section. It states that the planner chooses to reduce liquidations and repayments in the low state, and it shows that the planner's allocation can be implemented by taxing (or capping) entrepreneurial borrowing against adverse states of the world. Let superscript  $\{SP\}$  denote the optimal allocations of the social planner and superscript  $\{CE\}$  denote the allocations in the competitive equilibrium, then we have that

**Proposition 6 (Prudential Regulation)** *The planner chooses to borrow and invest (weakly) less than entrepreneurs,  $k^{SP} \leq k^{CE}$ , and she strictly reduces repayments and liquidations in the low state,  $d^{SP}(l)k^{SP} < d^{CE}(l)k^{CE}$  and  $0 < z^{SP}(l)k^{SP} < z^{CE}(l)k^{CE}$ . At the planner's allocation, the prices of capital goods satisfy*

$$q^{CE}(l) < q^{SP}(l) < q^{SP}(h) = q^{CE}(h) = A$$

*The constrained efficient allocation can be implemented by a compensatory transfer  $T$  and a Pigouvian tax  $\tau$  on entrepreneurial repayments against state  $l$ .*

I provide a numerical illustration of the above result in Figure 5. For the same calibration as in the previous section, I plot the prices and allocations in the two economies (competitive equilibrium vs social optimum) as a function of entrepreneurial cash-flows in the low state (i.e. severity of the shock). As can be seen, when shocks are small, both the contract at CE and SP are non-contingent (top left), and the planner borrows less than entrepreneurs in both states. When shocks become larger, however, the planner makes her contract contingent sooner than the entrepreneurs, and the degree of contingency of the planner's contract is significantly greater. As a result, in the low state, the price of capital goods (bottom left) are lower and liquidations (top right) are smaller. Furthermore, while the planner tends to borrow and invest less overall (bottom right), much of the difference between the competitive and the planner's allocations derives from the degree of contingency of the financial contracts. Thus, the theory also implies that policies of limiting overall indebtedness (leverage) of borrowers may be sub-optimal.

The finding that the planner wants to reduce borrowing against the adverse state of the world is due to pecuniary externalities that arise at times of systemic distress. Here, entrepreneurs do not internalize the positive externality on other entrepreneurs of reducing repayments in the low state. The



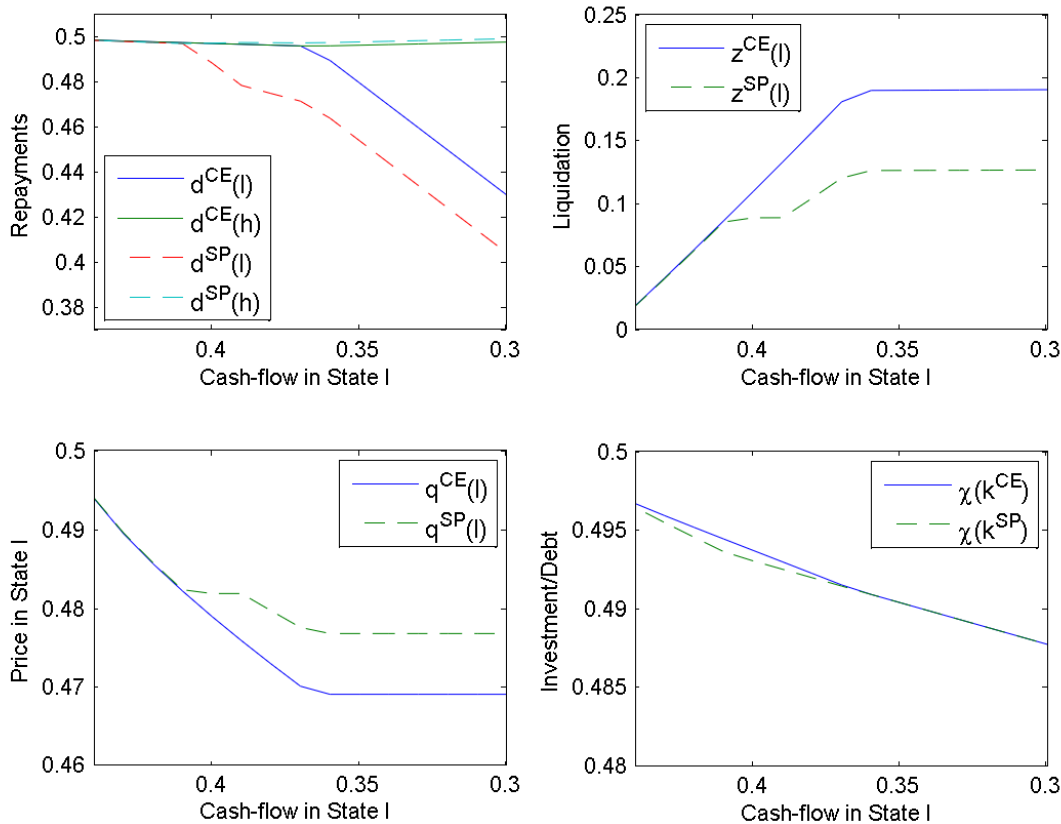


Figure 4: **Competitive Equilibrium vs. Social Optimum**

existence of these externalities in related settings has been pointed out by a number of researchers (e.g. Korinek (2009), Lorenzoni (2008), Stein (2010)). One of the interesting differences with the existing analyses is that my framework features the possibility that economic agents endogenously borrow with non-contingent claims but the planner wants to introduce contingencies into financial contracts. Thus, the model can also rationalize the recent policy proposals to introduce macro-contingencies into firms' and households' liabilities. Furthermore, the model suggests that policies targeting borrower leverage alone may be sub-optimal; this is in sharp contrast to implications drawn from models that exogenously restrict contracts to be non-contingent.

These findings thus lend support to some recent regulatory proposals. For example, in a congressional testimony on the role of household debt in the Great Recession, Mian (2011) states that, "mortgage principal can be automatically written down if the local house price index falls beyond

a certain threshold. [...] If we had such contingencies present in the current mortgage contracts, we could have avoided the extreme economic pain due to the negative deleveraging aggregate demand cycle.” These calls have also been echoed in the discussion of contingent capital requirements (CoCo) for financial institutions. For instance, Calomiris and Herring (2008) argue that, “If a CoCo requirement had been in place in 2007, the disruptive failures of large financial institutions, and the systemic meltdown after September 2008, could have been avoided.” Thus, in addition to explaining why macroeconomic contingencies may often be absent in borrower liabilities, my theory provides a rationale for why policy makers may want to intervene in order to subsidize such contingencies.

## 5.2 Transparency/Competition Policies

The theory also suggests that the recent policy measures intended to increase transparency and competition in financial markets can have the extra benefit of stabilizing macroeconomic fluctuations. As a result of the Dodd-Frank Act of 2010, many standardized products that were traded over-the-counter will now be required to be traded on regulated exchanges and be cleared centrally.<sup>34</sup> According to the Commodity and Futures Trading Commission, “Transparent trading will increase competition and bring better pricing of the marketplace. This will lower costs for businesses and consumers.”

The policy of transparency within the model can be thought of as essentially an introduction of informative public signals: for example, assume that a fraction of trades in the secondary markets is executed before others, and that policy makers mandate public reporting of the terms of trade of each transaction. A statistic of these terms of trade would then be informative about the future state of the economy, and traders in the second set of markets would thus be endowed with an additional public signal. By the ‘linkage principle’, this would lower the buyers’ rents and the costs of contingency to the entrepreneurs. The policy of increasing competition can instead be thought of as increasing the number  $n$  of buyers within each market. This would again have the effect of lowering the cost of contingency faced by entrepreneurs. The model thus predicts that these policies would indeed lead to lower costs of funding for borrowers by increasing the extent to which borrowers and lenders can share macroeconomic risks. Furthermore, the model points to the additional effect of these policies on macroeconomic stabilization.

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<sup>34</sup>Similar policies have been put in place in 2007 through Markets in Financial Instruments Directive in the European Union.

For a complete analysis of the effects of these policies, however, the potential costs associated with such policies must also be incorporated: presumably, there are reasons why trade in many financial assets occurs over-the-counter to begin with. For example, among other reasons, a typical rationale for trading OTC is that these markets allow economic agents to tailor financial contracts to their specific ‘tastes’ and that they are associated with lower transaction costs for traders. Biais et al. (2012) argue that the lower degree of anonymity in OTC markets allows economic agents to better search, screen, and monitor their counterparties. Some of these costs can be incorporated in the model simply by introducing a problem of adverse selection: a fraction of entrepreneurial collateral backing financial contracts is bad (never pays), but the quality of collateral can be screened only in OTC markets. The model would then predict that centralized trading would be dominated if this fraction is sufficiently large.

Furthermore, as shown in Dang et al. (2010), transparency may not always be beneficial. In my setting, public signals are always beneficial because signals about the aggregate state are always received by traders. However, this may not be the case if such information is costly to acquire: it may not pay agents to obtain costly signals when this state is believed unlikely to occur. Public signals that increase the public’s perception of the likelihood of the low state may then incentivize information acquisition, which will then introduce costs to contractual contingency and thus limit risk-sharing. While the study of endogenous market formation is beyond the scope of this paper, the theory does suggest an additional social benefit to transparent and competitive markets – macroeconomic stabilization – that should be considered when evaluating policies related to market design.

## 6 Extensions

In this section, I consider several extensions of the basic economic environment. In Section 6.1, I extend the model to the case where investor liquidity needs are unobservable and show that the main results of the paper remain robust to this case. In Section 6.2, I decouple the magnitude of investor liquidity needs from their frequency and show that the magnitude of implied balance sheet amplification will be increasing in the importance that investors attach to liquidity of financial claims. In Section 6.3, I discuss other directions in which the model can be fruitfully extended.

## 6.1 Unobservable Liquidity Needs

In this section, I generalize the main result of the paper to the case when investor liquidity needs are unobservable. In particular, I show that contingent contracts are as before discounted due to informational rents earned by buyers in secondary financial markets.

Consider financial contracts  $\mathcal{C} = \{d(s)k\}$  that are positively correlated with the state of the economy, i.e.  $d(h) > d(l)$ . The case of negatively correlated contract is similar, and non-contingent contracts are again priced at their 'fair' value as in Lemma 2. When liquidity needs are unobservable, pessimistic investors who have not experienced liquidity needs may also decide to sell their contracts. To this end, I restrict my attention to threshold posting strategies: while investors with liquidity needs,  $\beta = 1$ , will as before sell their contracts independently of their signals, investors without liquidity needs,  $\beta = 0$ , will sell if they receive signals below some threshold  $\hat{x} \in [\underline{x}, \bar{x}]$ , where  $\hat{x} = \underline{x}$  if these investors never sell.<sup>35</sup> An equilibrium in secondary markets is defined as before, except that now buyers cannot condition their offers on the liquidity need of the seller: a buyer with signal  $x$  submits an offer  $p(x, \mathcal{C}, \hat{x})$ , where  $\hat{x}$  appears in the argument because buyers will know the equilibrium threshold strategy.

Let  $\hat{x}$  denote the equilibrium posting strategy. Suppose as before that a seller of contract  $\mathcal{C}$  has been matched with buyers with signals  $x_1^B, \dots, x_n^B$ , and let  $y_1^+$  denote the maximal signal among the signals  $\{x_2^B, \dots, x_n^B\}$  received by the opponents of buyer 1. This buyer's valuation of the contract conditional on his signal being  $x_B^1 = x$  and conditional on receiving the contract is given  $\mathbb{E}\{d(s)k | x_1^B = x, y_1^+ < x, H(\hat{x})\}$ , where now buyer 1 also has to condition on the event that the investor has chosen to sell the contract rather than keep it,  $H(\hat{x}) \equiv (\{x^S < \hat{x}\} \cap \{\beta^S = 0\}) \cup \{\beta^S = 1\}$ . As I show in the Appendix, the derivation of buyers' offers  $p$  for a given threshold  $\hat{x}$  follows analogously to that in Proposition 2. Buyers first update their beliefs to adjust for the possible adverse selection on the side of the seller and then they submit offers just as before. The threshold  $\hat{x}$  is then determined by the marginal investor's indifference condition: investor with signal  $\hat{x}$  who does not experience a liquidity need is indifferent to whether to post his contract for sale.

The following proposition yields the main result of this section. It shows that the contract price schedule that results from the equilibrium in secondary markets takes a form analogous to that in Proposition 2,

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<sup>35</sup>I still maintain that there are sufficiently many buyers to have an exclusive matching of  $n$  buyers per seller; a sufficient condition for this is that  $\lambda$  is not too large.

**Proposition 7** *The price of a generic contract  $\mathcal{C} = \{d(s)k\}$  is given by*

$$\mathcal{L}(\mathcal{C}) = \mathbb{E}\{d(s)k\} - \widehat{\zeta} \cdot |d(h) - d(l)|k$$

where  $\widehat{\zeta} = \widehat{\zeta}^+ \cdot 1\{d(h) \geq d(l)\} + \widehat{\zeta}^- \cdot 1\{d(h) < d(l)\}$  and  $\widehat{\zeta}^+, \widehat{\zeta}^- > 0$ .

The reasoning behind why contingent contracts are discounted is the same as before: buyers first update their beliefs to take into account that the seller may be adversely selected, and then shade their offers below their conditional valuations in order to earn informational rents. The schedule  $\mathcal{L}(\mathcal{C})$  takes the same form as before again due to linearity of buyers' offer strategies. Thus, this result generalizes Proposition 2 to the case of unobservable liquidity needs and shows that the results of the paper also remain robust to this case.

## 6.2 Magnitude of Liquidity Needs

In the main analysis, I assumed that investors who are 'distressed' have the same marginal valuation of funds in  $t = 1$  as investors who are not 'distressed'. As a result, the value of liquidity to investors was captured by the probability  $\lambda$  of experiencing a liquidity need. In practice, however, the marginal valuation of funds is likely to be greater for 'distressed' investors. To incorporate this effect, consider modifying investor preferences to  $\mathbb{E}\{c_0 + c_1 + c_2\}$  if the investor is a 'late' type and to  $\mathbb{E}\{c_0 + \delta c_1\}$  if the investors is an 'early' types, where  $\delta > 1$  is the marginal valuation of funds to 'distressed' investors in  $t = 1$ . Thus, in period 1, a 'dollar' is valued at  $\delta > 1$  by early investors and only at 1 by the late investors. With these preferences, the ex-ante price of a generic contract  $\mathcal{C} = \{d(s)k\}$  is now given by

$$\mathcal{L}(\mathcal{C}) = (1 + \lambda(\delta - 1))\mathbb{E}\{d(s)k\} - \lambda\delta\zeta_{\mathcal{C}}|d(h) - d(l)|k$$

where  $\zeta_{\mathcal{C}}$  is given as in Proposition 2. Thus, the increased value of liquidity has two effects. First, the average cost of funds to the entrepreneurs is now lower because entrepreneurial claims enable investors to make welfare improving transfers at  $t = 1$ . Second, as resale value becomes a more important determinant of financial contract pricing, the cost to contractual contingency plays a more prominent role. In particular, the threshold price of capital given in Proposition 3 that determines

entrepreneurs' incentives to insure cash-flow fluctuations is now given by

$$\underline{q}(\delta) \equiv \left( \theta + (1 - \theta) \frac{\pi(l)}{1 - \pi(l)} \frac{1 - \pi(l) - \frac{\delta}{1 + \lambda(\delta - 1)} \lambda \zeta^+}{\pi(l) + \frac{\delta}{1 + \lambda(\delta - 1)} \lambda \zeta^+} \right) A$$

and is therefore decreasing in  $\delta$ . As a result, the upper bound on price fluctuations and balance sheet amplification given in Proposition 4 is also increasing in  $\delta$ . Thus, even if the probability  $\lambda$  of experiencing liquidity needs is small, their effect on risk-sharing may still be large if the magnitude  $\delta$  of these liquidity needs is large.

In the above example, I considered the case when investor liquidity needs are observable. With unobservable liquidity needs, when  $\delta > 1$ , we would also have additional discounting of claims due to informational rents earned by non-liquidity hit sellers. Because I have modeled the seller side of the economy monopolistically, however, discounting here would be indistinguishable from the standard models of adverse selection where private information is about idiosyncratic states. Incorporating competition on the seller side of the economy would be more realistic, and it would also allow to distinguish frictions that arise from *dispersed* information rather than information held exclusively by one party.

### 6.3 Other Extensions

**Informational Spillovers.** Information about the future state was assumed to arrive only once. In reality, however, investors may receive information repeatedly, perhaps through market based interactions with other investors. An interesting way to introduce information arrival is by supposing that not all trades are executed simultaneously and that buyers travel through markets sequentially and privately learn new information from each trade. This approach has been taken up in Duffie and Manso (2007). In a similar market setting, they study how information that is common across markets accumulates over time. Buyers infer each others' signals over time by trading and eventually dispersed information becomes aggregated. However, recall from Figure 2 that the costs of contingency are largest when signals are of intermediate informativeness (intermediate  $\sigma$ ). Hence, even if each investor's information set is initially uninformative, there would be periods in which disagreements among investors become large; as a result, the discount on financial contracts in these periods would also be large. Of course, eventually, information would be fully aggregated and the discount on

contingent contracts would converge to zero.

**Heterogeneity.** The model can also incorporate ex-ante heterogeneity among investors: some investors may face lower search frictions or may be better informed than others. Introducing such heterogeneity can have interesting implications for the allocation of macroeconomic risk in the economy. For example, the model would predict that risks should be concentrated more heavily in portfolios of investors who face lower search frictions and who have higher ability to process information. In this case, it would also be interesting to incorporate potential ‘capacity’ constraints (risk-aversion, financing constraints, etc.) that may endogenously limit the extent to which these risks can be concentrated in the portfolios of the more connected/informed investors.

**Insuring Liquidity Needs.** I have precluded contracting on investor liquidity needs by assuming that these are non-verifiable. If these liquidity needs were instead verifiable, then investors may be able to avoid the secondary market by contracting to exchange financial contracts for consumption goods at pre-agreed terms. Furthermore, there may be gains from re-trading between investors and entrepreneurs in period 1. For example, an investor who experiences a liquidity need may be willing to exchange his risky contract for a safer one at a cost in order to minimize trading losses in secondary markets. As a result, entrepreneurs may benefit from this exchange by reducing their overall repayments, but their exposures to cash-flow fluctuations may now increase when such an exchange occurs. This may then introduce interesting interactions between secondary market liquidity and entrepreneurial balance sheets; especially, if aggregate liquidity needs also fluctuate. Such an extension is left for future research because the (informational) heterogeneity among entrepreneurs and the multi-dimensional (liquidity and information) heterogeneity among investors make the problem considerably more complex.

**Cyclicalities of the Discount.** Incorporating fluctuations in secondary market ‘liquidity’ may also yield interesting implications. In particular, the three components (liquidity needs, info dispersion, and search frictions) that give rise to discounting of contingent contracts are likely to be subject to cyclical fluctuations as well. Furthermore, because it is the interaction of these three ingredients that gives rise to discounting of financial contracts, their co-variance will also be an important determinant of contract pricing. Incorporating such fluctuations is not only interesting theoretically, but it is also likely to yield cyclical predictions with regards to the extent of macroeconomic risk-sharing.

## 7 Conclusions

In this paper, I argued that balance sheet recessions can be rationalized as a result of informational and trading frictions in financial markets. I showed that information dispersion about the future states of the macroeconomy and search frictions in financial markets make issuance and trade of contracts contingent on the state of the economy costly. As a result, it was optimal for borrowers to sacrifice the risk-sharing benefits that such contracts provide and, in aggregate, such behavior allows for aggregate shocks to be amplified into balance sheet recessions. The magnitude of this amplification was shown to be closely linked to the level of informational and trading frictions introduced in this paper. I also studied the policy-implications of the model and found that active policy measures geared towards subsidizing contingent write-downs of borrowers' liabilities can be welfare improving. The theory also suggests that enhancing transparency and competition in financial markets may have an additional benefit of stabilizing macroeconomic fluctuations. While the economic environment presented in this paper is stylized, I argued that the basic mechanism that limits risk-sharing and leads to periods of balance sheet amplification should apply more generally. Further exploration of these ideas and their quantitative evaluation are left for future research.



## 8 Appendix

*Proof of Lemma 0.* Traditional sector firms set  $k^d(s) = 0$  if  $q(s) > A$  and  $k^d(s) = g'^{-1}(q(s))$  if  $q(s) \leq A$ . Since entrepreneurs will liquidate all of their capital if  $q(s) > A$  and entrepreneurs choose  $k > 0$ ,  $q(s) > A$  cannot be an equilibrium; hence,  $q(s) \leq A$ . Capital goods market clearing then implies that  $q(s) = g'(z(s)k)$  for some  $z(s) \in [0, 1]$  and  $k > 0$ . Finally, since  $(g'(x) - \theta A)x$  is increasing in  $x$ , we have  $(p(s) - \theta A)z(s)k = (g'(z(s)k) - \theta A)z(s)k > (g'(0) - \theta A)0 = 0$  if  $z(s)k > 0$ , and as  $g'(0) = A$ , we have that  $\theta A < q(s) \leq A$ .

*Proof of Proposition 1.* Entrepreneurial budget constraint and the consumption non-negativity constraints in period 2 are

$$\begin{aligned} c(s) &= (a(s) - d(s)k + z(s)q(s) + (1 - z(s))A)k \\ d(s) &\leq a(s) + \widehat{d}(s) + z(s)q(s) \end{aligned}$$

Since by Lemma 0, in equilibrium  $q(s) \in (\theta A, A]$  with  $q(s) < A$  if and only if  $z(s) > 0$ , in equilibrium entrepreneurs set  $z(s) > 0$  if and only if the consumption non-negativity constraint binds with  $z(s) = 0$ . Thus,  $z(s) > 0$  if and only if  $d(s) > a(s) + \widehat{d}(s)$ , for  $s \in \{l, h\}$ . From the consumption non-negativity constraint, entrepreneurial liquidations in state  $s$  are decreasing in  $\widehat{d}(s)$ . Suppose that entrepreneurs set  $\widehat{d}(h) = \theta A$ , then we have

$$\begin{aligned} a(h) - d(h) + \widehat{d}(h) &= a(h) - d(h) + \theta A \\ &\geq a(h) - (\theta a(h) + p(h)) + \theta A \\ &\geq a(h) - (\theta a(h) + A) + \theta A \\ &= (1 - \theta)(a(h) - A) \\ &\geq 0 \end{aligned}$$

where the first inequality follows from the financial constraint, the second inequality follows from Lemma 1, and the last inequality holds by Assumption 1.3. Thus, Lemma 2 implies that  $z(h) = 0$ . On the other hand, Lemma 4 also implies that entrepreneurs will liquidate capital in state  $l$  if  $d(l) > a(l) + \theta A$ . If the latter inequality holds, then entrepreneurs will liquidate the minimum possible units, i.e. set

$z(l) = \max\{0, \frac{d(l)-a(l)-\theta A}{q(l)-\theta A}\}$ , in which case the equilibrium price of capital in state  $l$  is  $q(l) = g'(z(l)k)$  by Lemma 1. Note that  $z(l) < 1$  because  $d(l) - a(l) - \theta A \leq \theta a(l) + p(l) - a(l) - \theta A < p(l) - \theta A$ .

*Proof of Lemma 1.* The result follows directly from the fact that buyers agree about the contractual payoffs and because  $n \geq 2$  buyers compete a la Bertrand.

*Proof of Lemma 2.* Suppose that buyers have matched with an investor with  $\beta = 0$  and believe that the investor has received signal  $x^S \in A$  where  $A$  is some measurable subset of  $[\underline{x}, \bar{x}]$ . Suppose also that the contract is positively correlated with the state of the economy. The payoff to buyer 1 who receives signal  $x$  but bids as if he has received signal  $z$  is given by

$$\Pi(z, x) = \int_{\underline{x}}^x (v^+(x, y, A) - p(z)) f_{y_1^+}(y|x, A) dy$$

where for  $x, y \in [\underline{x}, \bar{x}]$ ,  $v^+(x, y, A) \equiv \mathbb{E}\{d(s)k|x_1^B = x, y_1^+ = y, x^S \in A\}$  and  $F_{y_1^+}(\cdot|x, A)$  is the conditional distribution of the second highest signal among signals  $\{x_2^B, \dots, x_n^B\}$ , conditional on  $x_1^B = x$  and  $x^S \in A$  (I omit indexation by contract and liquidity needs for brevity). In particular, we have that

$$F_{y_1^+}(y|x, A) = \frac{\sum_s F_s^{n-1}(y) f_s(x) \pi_A(s)}{\sum_s f_s(x) \pi_A(s)}$$

$$f_{y_1^+}(y|x, A) = \frac{\sum_s (n-1) f_s^{n-2}(y) f_s(x) \pi_A(s)}{\sum_s f_s(x) \pi_A(s)}$$

where  $\pi_A(s) \equiv \Pr(s|x^S \in A)$ , i.e. all buyers bid as in a standard first-price common value auction only after adjusting their priors from  $\pi(l)$  to  $\pi_A(l)$ . Differentiation with respect to  $z$  and evaluation at  $x = z$  implies that the equilibrium strategy satisfies the ODE

$$p'(x) = (v^+(x, x, A) - p(x)) \frac{f_{y_1^+}(x|x, A)}{F_{y_1^+}(x|x, A)}$$

With the boundary condition  $p(\underline{x}) = v(\underline{x}, \underline{x}, A)$ , the solution to the above ODE is given by

$$p(x) = \int_{\underline{x}}^x v^+(z, z, A) dG^+(z|x, A) \tag{10}$$

for  $x \in [\underline{x}, \bar{x}]$ , and where for  $z \leq x$ ,  $G^+(z|x, A) = \exp\left(-\int_z^x \frac{f_{y_1^+}(t|t, A)}{F_{y_1^+}(t|t, A)} dt\right)$ . The boundary condition

holds since a buyer with signal  $\underline{x}$  earns a negative payoff if  $p(\underline{x}) > v^+(\underline{x}, \underline{x}, A)$ , and if  $p(\underline{x}) < v^+(\underline{x}, \underline{x}, A)$  then he can deviate and earn a positive payoff. The function  $v^+(x, x, A)$  is increasing in  $x$  and  $G^+(z|x') \geq G^+(z|x)$  for  $z \leq x$  and  $x' > x$ ; thus the strategy  $p(\cdot)$  is indeed increasing and differentiable. To show that  $p$  is a maximum, note that MLRP implies that

$$\frac{d\Pi}{dz} = F_{y_1^+}(z|x) \left[ (v^+(x, z, A) - p(z)) \frac{f_{y_1^+}(z|x, A)}{F_{y_1^+}(z|x, A)} - p'(z) \right]$$

is positive for  $z < x$ , negative for  $z > x$ , and it is zero at  $z = x$  by construction. This establishes that the strategy  $p$  is optimal for buyers. The derivation of buyers' offers for the case of a negatively correlated contract is analogous. The equilibrium offer strategy in that case is decreasing and is given by

$$p(x) = \int_x^{\bar{x}} v^-(z, z, A) dG^-(z|x, A) \quad (11)$$

for  $x \in [\underline{x}, \bar{x}]$ , where  $v^-(y, x, A) = \mathbb{E}\{d(s)k|x_1^B = x, y_1^- = y, x^S \in A\}$ , and where for  $z \geq x$ ,  $G^-(z|x, A) = \exp\left(-\int_x^z \frac{f_{y_1^-}(t|t, A)}{1-F_{y_1^-}(t|t, A)} dt\right)$ . To compute the off-equilibrium strategies, set  $A = \{\bar{x}\}$  for negatively correlated contracts, and  $A = \{\underline{x}\}$  otherwise.

That in equilibrium investors with  $\beta = 1$  sell their contracts is clear: contractual prices are always positive and these investors do not value consumption in period 2. Suppose now that investors with  $\beta = 0$  and signals in some measurable set  $A \subset [\underline{x}, \bar{x}]$  also sell their contracts in equilibrium, and consider buyers who have matched with a seller with  $\beta = 0$  and contract  $\mathcal{C}$  that is contingent on the state. Note that seller with  $\beta = 0$  is indifferent between selling a non-contingent contract and keeping it, and thus he will not sell it by the indifference-breaking assumption. Let  $p(\cdot, 0, \mathcal{C})$  denote an equilibrium offer strategy followed by buyers, and let  $p^{max}(0, \mathcal{C})$  denote the maximal offer implied by this strategy (as defined in Section 3.2). Then since buyers observe the seller's liquidity need, then for non-negatively correlated contracts we have that

$$\begin{aligned} p(x) &= \int_x^{\bar{x}} v^+(z, z, A) dG^+(z|x, A) \\ &\leq \int_x^{\bar{x}} v^+(x, z, A) dG^+(z|x, A) \end{aligned}$$

$$\begin{aligned}
&\leq \int_x^{\bar{x}} v^+(x, z, A) dF^+(z|x, A) \\
&= \mathbb{E}\{d(s)k|x_1^B = x, y_1^+ < x, x^S \in A\}
\end{aligned}$$

The same reasoning shows that  $p(x) \leq \mathbb{E}\{d(s)k|x_1^B = x, y_1^- > x, x^S \in A\}$  for negatively correlated contract. Using symmetry and integrating over buyers' signals, we have that

$$\mathbb{E}\{p^{max}(0, \mathcal{C})|x^S \in A\} \leq \mathbb{E}\{d(s)k|x^S \in A\}$$

But the payoff to a seller with  $\beta = 0$  and with signal  $x \in A$  is  $U^S(x, 1, \mathcal{C}) = \mathbb{E}\{d(s)k|x^S = x\} - \mathbb{E}\{p^{max}(0, \mathcal{C})|x^S = x\}$  and must be positive for all  $x \in A$  by the indifference-breaking assumption; integration over  $x^S \in A$  then implies that

$$\mathbb{E}\{p^{max}(0, \mathcal{C})|x^S \in A\} > \mathbb{E}\{d(s)k|x^S \in A\}$$

Hence, we have a contradiction, i.e. there is no equilibrium in which investors with  $\beta = 0$  post their contracts for sale.

*Proof of Proposition 2.* Since investors sell their contracts if and only if they experience  $\beta = 1$ , the expected present value of contract  $\mathcal{C} = \{d(s)k\}$  to an investor is given by

$$\begin{aligned}
\mathcal{L}(\{d(s)k\}) &= \mathbb{E}\{d(s)k\} + \lambda \mathbb{E}\{p^{max}(1, \mathcal{C})\} \\
&= \mathbb{E}\{d(s)k\} + \lambda (\mathbb{E}\{p^{max}(1, \mathcal{C})\} - \mathbb{E}\{d(s)k\})
\end{aligned}$$

where  $\mathbb{E}\{p^{max}(1, \mathcal{C})\}$  denotes the expected price at which an investor with  $\beta = 1$  sells his contract. From Proposition 2, we have that

$$\mathbb{E}\{p^{max}(1, \mathcal{C})\} = \begin{cases} \mathbb{E}\{\int_{\underline{x}}^{x_1^B} v^+(z, z, A) dG^+(z|x_1^B)|\{x_1^B > y_1^+\}\} & \text{if } d(h) \geq d(l) \\ \mathbb{E}\{\int_{x_1^B}^{\bar{x}} v^-(z, z, A) dG^-(z|x_1^B)|\{x_1^B < y_1^-\}\} & \text{otherwise} \end{cases}$$

where  $v^+(x, y) = \mathbb{E}\{d(s)k|x_1^B = x, y_1^+ = y\}$  and  $v^-(x, y) = \mathbb{E}\{d(s)k|x_1^B = x, y_1^- = y\}$  because investors with  $\beta = 1$  sell their contracts irrespective of signals received. Using the forms of the functions  $v^+(\cdot, \cdot)$

and  $v^-(\cdot, \cdot)$ , we have that

$$\mathcal{L}(\{d(s)k\}) = \mathbb{E}\{d(s)k\} - \lambda\zeta|d(h) - d(l)|k$$

where  $\zeta = \zeta^+ \cdot 1\{d(h) \geq d(l)\} + \zeta^- \cdot 1\{d(h) < d(l)\}$  with  $\zeta^+$  and  $\zeta^-$  given by

$$\begin{aligned}\zeta^+ &= \mathbb{E} \left\{ \int_{\underline{x}}^{x_1^B} \Pr(s = l | x_1^B = z, y_1^+ = z) dG^+(z | x_1^B) | \{x_1^B > y_1^+\} \right\} - \pi \\ \zeta^- &= \pi - \mathbb{E} \left\{ \int_{x_1^B}^{\bar{x}} \Pr(s = l | x_1^B = z, y_1^- = z) dG^-(z | x_1^B) | \{x_1^B < y_1^-\} \right\}\end{aligned}$$

That  $\zeta^+ > 0$  follows from the fact that  $\Pr(s = l | x_1^B = z, y_1^+ = z) > \Pr(s = l | x_1^B = x, y_1^+ = z)$  for all  $x > z$ , and from the fact that  $G^+(\cdot | x)$  is fbsd dominated by  $F_{y_1^+}(\cdot | x)$  for all  $x$ ,

$$\begin{aligned}\pi &= \mathbb{E} \left\{ \int_{\underline{x}}^{x_1^B} \Pr(s = l | x_1^B > y_1^+ = z) dF_{y_1^+}(z | x_1^B) | \{x_1^B > y_1^+\} \right\} \\ &< \mathbb{E} \left\{ \int_{\underline{x}}^{x_1^B} \Pr(s = l | x_1^B = y_1^+ = z) dF_{y_1^+}(z | x_1^B) | \{x_1^B > y_1^+\} \right\} \\ &\leq \mathbb{E} \left\{ \int_{\underline{x}}^{x_1^B} \Pr(s = l | x_1^B = y_1^+ = z) dG_{y_1^+}(z | x_1^B) | \{x_1^B > y_1^+\} \right\} \\ &= \zeta^+ + \pi\end{aligned}$$

The proof that  $\zeta^- > 0$  is analogous.

*Proof of Proposition 3.* That it suffices to consider contracts with  $d(l) \leq d(h)$  follows because contingent contracts are costly to issue regardless of the contract's correlation with the state and because entrepreneurs value insurance against state  $l$ . I derive the results in Proposition 3 in several steps.

First I show that Assumption 3 implies that  $a(l) + \theta A \leq d(l)$ . Suppose to the contrary that at the optimum  $d(l) < a(l) + \theta A$ . Then entrepreneur's marginal utility of wealth in state  $l$  is also 1 and thus  $d(h) = d(l) = d$  because  $\zeta > 0$ . Now, consider increasing  $d$  by a small amount  $\epsilon k$ . For  $\epsilon$  small, the marginal cost of this increase is  $\epsilon k$ , while the marginal benefit is given by  $\frac{\sum_s (a(s) + A) - d}{\chi'(k) - d} \cdot \epsilon k$  where  $k$  satisfies  $\chi(k) = (d + \epsilon)k < (a(l) + \theta A)k$ . Assumption 3 then implies that  $\chi'(k) < \sum_s (a(s) + A)$  and that thus such an increase is optimal for the entrepreneur. Since this argument applies for any  $d(l) < a(l) + \theta A$ , the result follows. Using the previous result, the entrepreneurial objective can be

re-written as

$$\max_{\{k, d(l), d(h)\}} \left[ \pi(l)(a(l) + \theta A - d(l)) \frac{(1-\theta)A}{q(l) - \theta A} + (1 - \pi(l))(a(h) + \theta A - d(h)) + (1 - \theta)A \right] k$$

subject to

$$\begin{aligned} \chi(k) &= \left( \sum_s \xi(s)d(s) \right) k \\ d(l) &\leq \theta a(l) + q(l) \\ d(h) &\leq \theta a(h) + A \\ a(l) + \theta A &\leq d(l) \\ d(l) &\leq d(h) \end{aligned}$$

where  $\xi(l) \equiv \pi(l) + \lambda \zeta^+$  and  $\xi(h) \equiv 1 - \xi(l)$ . Let  $\nu, \mu(l), \mu(h), \omega(l), \omega(h) \geq 0$  denote the multipliers on the above constraints in order as they appear. The entrepreneur's first order conditions with respect to  $k, d(l), d(h)$  are then given by

$$\begin{aligned} \nu &= \frac{\pi(l)(a(l) + \theta A - d(l)) \frac{(1-\theta)A}{q(l) - \theta A} + (1 - \pi(l))(a(h) + \theta A - d(h)) + (1 - \theta)A}{\chi'(k) - \sum_s \xi(s)d(s)} \\ \nu(1 - \xi(l)) &= 1 - \pi(l) + (\mu(h) - \omega(h))k^{-1} \\ \nu\xi(l) &= \pi(l) \frac{(1-\theta)A}{q(l) - \theta A} + (\mu(l) - \omega(l) + \omega(h))k^{-1} \end{aligned}$$

The complementary slackness conditions are given by

$$\begin{aligned} \mu(h)(\theta a(h) + A - d(h)) &= 0 \\ \mu(h)(\theta a(l) + q(l) - d(l)) &= 0 \\ \omega(l)(d(l) - a(l) - \theta A) &= 0 \\ \omega(h)(d(h) - d(l)) &= 0 \end{aligned}$$

These conditions together with the period 0 budget constraint and the inequality constraints for the

repayments fully characterize the solution to the entrepreneurial problem.

- Type I: Note that  $q(l) > \underline{q} \implies \frac{\pi(l)}{\xi(l)} \frac{(1-\theta)A}{q(l)-\theta A} < \frac{1-\pi(l)}{1-\xi(l)}$ . Therefore, from the foc's we have that

$$\frac{(\mu(l) - \omega(l) + \omega(h))k^{-1}}{\xi(l)} > \frac{(\mu(h) - \omega(h))k^{-1}}{1 - \xi(l)}$$

If the contract satisfies  $d(l) = d(h)$ , then we are done (part (i)). If, on the other hand,  $d(l) < d(h)$ , then we have  $\omega(h) = 0$ , and thus  $\mu(l) > 0$ ; otherwise, we have that  $\mu(h) < 0$  since  $\omega(l) \geq 0$ , a contradiction. Thus,  $d(l) < d(h) \implies d(l) = \theta a(l) + p(l)$ .

- Type II: Note that  $q(l) < \underline{q} \implies \frac{\pi(l)}{\xi(l)} \frac{(1-\theta)A}{q(l)-\theta A} > \frac{1-\pi(l)}{1-\xi(l)}$ . Therefore, from the foc's we have that

$$\frac{(\mu(l) - \omega(l) + \omega(h))k^{-1}}{\xi(l)} < \frac{(\mu(h) - \omega(h))k^{-1}}{1 - \xi(l)}$$

If the contract satisfies  $a(l) + \theta A = d(l)$ , then we are done (part (i)). On the other hand,  $a(l) + \theta A < d(l) \implies \omega(l) = 0 \leq \mu(l)$  and thus  $\mu(h) > 0$ ; otherwise,  $\omega(h) < 0$  because  $\mu(l) - \omega(l) + \omega(h) \geq 0$ . Thus,  $d(l) < d(h)$  implies  $d(h) = \theta a(h) + A$ .

- Type III: Note that  $q(l) = \underline{q} \implies \frac{\pi(l)}{\xi(l)} \frac{(1-\theta)A}{q(l)-\theta A} = \frac{1-\pi(l)}{1-\xi(l)}$  and thus the bank is indifferent about what contract to issue.

*Proof of Proposition 4.* Part 1) To show that  $d(l) > a(l) + \theta A$  and  $q(l) < A$ , suppose to the contrary that at the optimum  $d(l) = a(l) + \theta A$  and thus  $q(l) = A$ ; note that foc's w.r.t.  $d(h)$  and  $d(l)$  then imply that  $d(h) = d(l) = d = a(l) + \theta A$ . Then we must have that

$$\begin{aligned} \nu &= \frac{\pi(l)(a(l) + A - d) + (1 - \pi(l))(a(h) + A - d)}{\chi'(\underline{k}) - d} \\ &= \frac{\mathbb{E}\{a(s) + A\} - d}{\chi'(\underline{k}) - d} > 1 \end{aligned}$$

where the last inequality follows from Assumption 3. Adding the foc's with respect to  $d(l)$  and  $d(h)$ , we have

$$\nu = \pi(l) \frac{(1-\theta)A}{q(l) - \theta A} + 1 - \pi(l) - \omega(l)k^{-1} < 1$$

since  $\mu(l) = 0 < \omega(l)$  and  $q(l) = A$ , a contradiction. Thus, since the unique  $q(l)$  that solves  $q(l) = g' \left( \frac{d(l) - a(l) - \theta A}{q(l) - \theta A} \right)$  is continuous in  $d(l)$ , and  $\nu$  is continuous in  $d(l)$  and  $q(l)$ , we must have that  $d(l) > a(l) + \theta A$  and thus  $q(l) < A$ . The remaining characterization of the financial contract follows from the financial constraints and Proposition 3. Part 2) That investment is below first-best follows from the result in Part 1) which implies that  $\nu > 1$  and thus

$$\left[ \chi'(k) - \sum_s \xi(s)d(s) \right] \nu = \pi(l)(a(l) + q(l) - d(l)) \frac{(1-\theta)A}{q(l) - \theta A} + (1 - \pi(l))(a(h) + A - d(h))$$

$\implies$

$$\chi'(k) - \sum_s \xi(s)d(s) < \pi(l)(a(l) + q(l) - d(l)) \frac{(1-\theta)A}{q(l) - \theta A} + (1 - \pi(l))(a(h) + A - d(h))$$

$\implies$

$$\chi'(k) < \pi(l)(a(l) + A) + (1 - \pi(l))(a(h) + A) + \sum_s (\xi(s) - \pi(s)) d(s)$$

$$\leq \pi(l)(a(l) + A) + (1 - \pi(l))(a(h) + A) = \chi'(k^{fb})$$

and the convexity of schedule  $\chi(\cdot)$ . The expression for liquidations follows from the beginning of period 2 budget constraint, and liquidations are positive by Part 1). Part 3) That the price of capital in state  $l$  is below  $A$  follows from Part 2) and Proposition 1. The bounds on asset price fluctuations follow from combining Proposition 1 with the foc's w.r.t.  $d(l)$  and  $d(h)$  by setting  $\mu(h) = 0$ .

*Lemma (non-binding constraint in state  $h$ ).* Let  $\bar{k}$  be implicitly defined by  $\chi(\bar{k}) = \xi(l)(a(l) + \theta A)\bar{k} + (1 - \xi(l))(a(h) + A)\bar{k}$ . Then a sufficient condition for the collateral constraint to be loose in state  $h$  is that  $\chi'(\bar{k}) \geq \sum_s \xi(s)(a(s) + A)$ . To show this, suppose to the contrary that in equilibrium  $d(h) = a(h) + A$  and recall that in equilibrium  $d(l) > a(l) + \theta A$  and  $q(l) < A$ . Hence, the entrepreneur's foc's yield

$$\nu(1 - \xi(l)) \geq 1 - \pi(l)$$

$$\nu \xi(l) \geq \pi(l) \nu(l)$$



$$\begin{aligned}\nu &= \frac{\pi(l)\nu(l)(a(l)+q(l)-d(l))+(1-\pi(l))(a(h)+A-d(h))}{\chi'(k)-\sum\xi(s)d(s)} \\ &< \frac{\xi(l)\nu(a(l)+A-d(l))+(1-\xi(l))\nu(a(h)+A-d(h))}{\chi'(k)-\sum\xi(s)d(s)}\end{aligned}$$

Now, note that  $d(l) > a(l) + \theta A$  implies that  $k > \bar{k}$  and thus

$$\begin{aligned}1 &< \frac{\xi(l)\nu(a(l)+A-d(l))+(1-\xi(l))\nu(a(h)+A-d(h))}{\chi'(k)-\sum\xi(s)d(s)} \\ &< \frac{\sum\xi(s)(a(l)+A)-\sum\xi(s)d(s)}{\chi'(k)-\sum\xi(s)d(s)} < 1\end{aligned}$$

where the last inequality follows from  $\chi'(k) > \chi'(\bar{k}) \geq \sum\xi(s)(a(s)+A)$ , a contradiction. Note that this assumption holds if the cost schedule is not too convex. Alternatively, in place of a technological assumption, if entrepreneurs had an endowment  $w$  in period 0, then non-binding constraint in state  $h$  can be ensured by assuming that  $w$  is not too low.

*Proof of Proposition 5.* It suffices to show that  $\lambda\zeta^+$  goes to 0. That  $\lambda\zeta^+$  goes to 0 as  $\lambda$  goes to 0 is clear. The proof for when  $n$  goes  $\infty$  is contained in Kremer (2002), Theorem 3. To show the result as  $\psi$  goes to 0, note that the resale value of financial contracts is always bounded below by the offer of the buyer who is most pessimistic about contract's payoffs, i.e. buyer with signal  $\underline{x}$  when  $d(h) \geq d(l)$  and with signal  $\bar{x}$  when  $d(h) < d(l)$ . Thus, it suffices to show that as  $\psi \downarrow 0$ , we have

$$\Pr(s=l|x_1^B = \underline{x}, y_1^+ = \underline{x}) \uparrow \Pr(s=l)$$

$$\Pr(s=l|x_1^B = \bar{x}, y_1^- = \bar{x}) \downarrow \Pr(s=l)$$

But note that

$$\Pr(s=l|x_1^B = \underline{x}, y_1^+ = \underline{x}) = \frac{1}{\Pr(s=l) + (1 - \Pr(s=l)) \left(\frac{f_h(\underline{x})}{f_l(\underline{x})}\right)^n} \cdot \Pr(s=l)$$

$$\Pr(s=l|x_1^B = \bar{x}, y_1^- = \bar{x}) = \frac{1}{\Pr(s=l) + (1 - \Pr(s=l)) \left(\frac{f_h(\bar{x})}{f_l(\bar{x})}\right)^n} \cdot \Pr(s=l)$$

and since  $\psi \downarrow 0$  implies that  $\frac{f_h(\underline{x})}{f_l(\underline{x})} \rightarrow 1$  and  $\frac{f_h(\bar{x})}{f_l(\bar{x})} \rightarrow 1$ , the result follows.

*Proof of Proposition 6.* I prove this proposition in several steps.

*Claim 1.*  $a(l) + \theta A < d^*(l) \leq d^*(h)$  Since increasing borrowing also reduces the transfer that the planner must make to the investors, it suffices to show that the planner will choose to liquidate capital even in the absence of transfers. Suppose that  $d(l) = d(h) = d = a(l) + \theta A$  and consider increasing  $d$  by  $\epsilon$ . The entrepreneurial consumption in period 2 is now given by

$$\left[ \pi(l) (a(l) + \theta A - d - \epsilon) \frac{(1 - \theta)A}{p_\epsilon(l) - \theta A} + (1 - \pi(l))(a(h) + \theta A - d - \epsilon) + (1 - \theta)A \right] k_\epsilon$$

where  $k_\epsilon$  denotes the new scale of investment which satisfies  $\chi(k_\epsilon) = (d + \epsilon)k_\epsilon$ . Let  $dk$  and  $dq(l)$  denote the change in the investment and price of capital resulting from this increase in borrowing. Then, for  $\epsilon$  near 0, the change in consumption is given by

$$(\mathbb{E}\{a(s) + A\} - d) \frac{dk_\epsilon}{d\epsilon} - k$$

where I use the fact that  $q(l)$  is close to  $A$  and  $k_\epsilon$  is close to  $k$  for  $\epsilon$  small. Note that the change in price does not enter the above expression because its effect on consumption is proportional to liquidations which are close to 0 for  $\epsilon$  small. Similarly, using the budget constraint, we get that

$$\frac{dk}{d\epsilon} = \frac{k}{\chi'(k) - d}$$

Hence, the total change in consumption is given by

$$\left( (\mathbb{E}\{a(s) + A\} - d) \frac{1}{\chi'(k) - d} - 1 \right) k$$

Assumption 3 then implies that at  $k$  satisfying  $\chi(k) = (a(l) + \theta A)k$ , the above expression is strictly positive. Hence, increasing  $d(l), d(h)$  above  $a(l) + \theta A$  is welfare improving. Since  $\zeta^+ > 0$ , a similar argument shows that increasing  $d(l)$  above  $a(l) + \theta A$  is welfare improving.

*Planner's Problem.* Using the previous result, the planner's problem is given by

$$\max_{\{k, d(l), d(h), \tau(h)\}} \left[ \pi(l) (a(l) + \theta A - d(l)) \frac{(1 - \theta)A}{q(l) - \theta A} + (1 - \pi(l))(a(h) + \theta A - d(h) - \tau(h)) + (1 - \theta)A \right] k$$

subject to

$$\chi(k) = \left( \sum_s \xi(s)d(s) \right) k$$

$$d(l) \leq \theta a(l) + q(l)$$

$$d(h) \leq \theta a(h) + A - \tau(h)$$

$$d(l) \leq d(h)$$

$$0 \leq \tau(h)$$

$$\pi(l) (\Pi^{CE}(l) - g(z(l)k) + q(l)z(l)k) \leq (1 - \pi(l))\tau(h)k$$

where  $q(l) = g'(z(l)k)$ ,  $z(l) = \frac{d(l) - a(l) - \theta A}{q(l) - \theta A}$ , and  $\tau(h) \equiv \frac{T(h)}{k}$ . Let  $\hat{\nu}, \mu(l), \mu(h), \omega(l), \omega(h), \gamma(h), \lambda$  denote the multipliers on the constraints of the planner's problem in the order as they appear. The planner's first order condition w.r.t.  $k$  is given by

$$\hat{\nu} \left[ \sum_s \xi(s)d(s) - \chi'(k) \right] + \left[ \sum_s \pi(s)\nu(s)(a(s) + \theta A - d(s) - \tau(s)) + (1 - \theta)A \right] + \lambda [(1 - \pi(l))\tau(h) - \pi(l)(z(l)k)p_k(l)] + \mu(l)p_k(l) + \pi(l)\nu(l)(z(l)k)p_k(l) = 0$$

where  $\nu(h) = 1 < \frac{(1-\theta)A}{q(l) - \theta A} = \nu(l)$ , and where  $p_k(l)$  denotes the derivative of the equilibrium price of capital w.r.t.  $k$ . The planner's first order conditions with respect to  $d(l)$  and  $d(h)$  yield

$$\hat{\nu}\xi(l)k - \pi(l)\nu(l)k - \omega(h) - \mu(l) + \pi(l)\nu(l)(z(l)k)p_d(l) + \mu(l)p_d(l) - \lambda\pi(l)(z(l)k)p_d(l) = 0$$

$$\hat{\nu}(1 - \xi(l))k - (1 - \pi(l))k + \omega(h) - \mu(h) = 0$$

where  $p_d(l)$  denotes the derivative of the equilibrium price of capital w.r.t.  $d(l)$  and thus satisfies  $kp_k(l) = (d(l) - a(l) - \theta A)p_d(l)$ . Her first-order conditions w.r.t.  $\tau(h)$  is

$$-(1 - \pi(l))k - \mu(h) + \gamma(h) + (1 - \pi(l))\lambda k = 0$$

Finally, we have the complementary slackness conditions

$$\begin{aligned}
\mu(h)(\theta a(h) + A + \tau(h) - d(h)) &= 0 \\
\mu(h)(\theta a(l) + q(l) - d(l)) &= 0 \\
\omega(h)(d(h) - d(l)) &= 0 \\
\gamma(h)\tau(h) &= 0 \\
\lambda [(1 - \pi(l))\tau(h)k - \pi(l) (\Pi^{CE}(l) - g(z(l)k) + q(l)z(l)k)] &= 0
\end{aligned}$$

These conditions fully characterize the solution to the planner's problem. For  $s \in \{l, h\}$ , define  $\widehat{\nu}(s)$  by

$$\begin{aligned}
\widehat{\nu}(l) &= \nu(l) + (\lambda - \nu(l)) z(l)p_d(l) - \mu(l)p_d \\
\widehat{\nu}(h) &= \nu(h) = 1
\end{aligned}$$

and note that then the foc w.r.t.  $k$  becomes

$$\widehat{\nu} \left( \chi'(k) - \sum_s \xi(s)d(s) \right) = \left( \sum_s \pi(s)\widehat{\nu}(s)(a(s) + \theta A - d(s)) + (1 - \theta)A \right) + (1 - \pi(l))(\lambda - \nu(h))\tau(h)$$

The foc's w.r.t.  $d(l)$  and  $d(h)$  then become

$$\begin{aligned}
\widehat{\nu}\xi(l) &= \pi(l)\widehat{\nu}(l) + (\mu(l) + \omega(h))k^{-1} \\
\widehat{\nu}(1 - \xi(l)) &= 1 - \pi(l) + (\mu(h) - \omega(h))k^{-1}
\end{aligned}$$

*Claim 2.* The planner sets  $k^* \leq k^{CE}$  and  $d^*(l)k^* < d^{CE}(l)k^{CE}$ . Note that the foc's w.r.t.  $d(l)$  and  $d(h)$  become

$$\pi(l)\widehat{\nu}(l) = \xi(l)\widehat{\nu} - (\omega(h) + \mu(l))k^{-1}$$

$$1 - \pi(l) = (1 - \xi(l)) \widehat{\nu} + (\omega(h) - \mu(h)) k^{-1}$$

and plugging these into the foc w.r.t.  $k$ , we get

$$\begin{aligned} \widehat{\nu} \chi'(k) = \sum_s \xi(s) \widehat{\nu} (a(s) + \theta A) + (1 - \theta) A - (\omega(h) + \mu(l)) k^{-1} (a(l) + \theta A - d(l)) + \\ (\omega(h) - \mu(h)) k^{-1} (a(h) + \theta A - d(h)) + \mu(h) \tau(h) k^{-1} \end{aligned}$$

Conjecture that  $\mu(l) = 0$  at the planner's allocation. Thus

$$\begin{aligned} \widehat{\nu} \chi'(k) = \sum_s \xi(s) \widehat{\nu} (a(s) + \theta A) + (1 - \theta) A + \\ [1 - \pi(l) - (1 - \xi(l)) \widehat{\nu}] (1 \{\omega(h) > 0\} (a(h) - a(l)) + 1 \{\mu(h) > 0\} (1 - \theta) (a(h) - A)) \end{aligned}$$

which defines  $k$  as a decreasing function of  $\widehat{\nu}$ . Note that an identical expression holds in the competitive equilibrium, with  $\nu^{CE}$ ,  $k^{CE}$ ,  $\omega^{CE}(h)$ , and  $\mu^{CE}(h)$  in place of those corresponding to the planner's solution. An immediate conclusion is that if the entrepreneur issues a contingent contract, then the planner does as well. Suppose that  $d^{CE}(l) < d^{CE}(h)$  and thus

$$\nu^{CE} = \pi(l) \nu^{CE}(l) + 1 - \pi(l)$$

and note that at the competitive allocation, we have  $\widehat{\nu}^{CE} = \nu^{CE}$  and  $\widehat{\nu}^{CE} > \nu^{CE}(l)$ . If the planner issues a non-contingent contract, then it must be the case that

$$\widehat{\nu} = \pi(l) \widehat{\nu}(l) + 1 - \pi(l) \leq \frac{1 - \pi(l)}{1 - \xi(l)} = \pi(l) \nu^{CE}(l) + 1 - \pi(l) = \nu^{CE}$$

But then it follows that the planner borrows liquidates strictly less in state  $l$ . Hence, we have that  $k^* \geq k^{CE}$  and  $d^*(l) = d^*(h) < d^{CE}(l) < d^{CE}(h)$ , a contradiction.

Thus we are left to consider the following cases:

- Case 1: Both contracts are non-contingent. This case follows immediately since at the competi-

tive allocation, we have

$$\widehat{\nu}^{CE} = \nu^{CE} = \pi(l) \nu^{CE}(l) + 1 - \pi(l) < \pi(l) \widehat{\nu}^{CE}(l) + 1 - \pi(l)$$

and therefore  $k^* < k^{CE}$  and  $d^*(l) = d^*(h) < d^{CE}(l) = d^{CE}(h)$ .

- Case 2: Both contracts are contingent. Suppose that  $\widehat{\nu} = \frac{1-\pi(l)}{1-\xi(l)}$ , then  $k^* = k^{CE}$  and we must have that  $\widehat{\nu}(l) = \nu^{CE}(l)$ , which implies that  $d^*(l) < d^{CE}(l)$ . On the other hand, if  $\widehat{\nu} > \frac{1-\pi(l)}{1-\xi(l)}$  then  $k^* < k^{CE}$ . Now suppose that  $d^*(l) = d^{CE}(l)$  and  $d^*(h) < d^{CE}(h)$ , and note that since  $\widehat{\nu} = \pi(l) \widehat{\nu}(l) + 1 - \pi(l)$ , the planner must strictly prefer to decrease  $d^*(l)$  and increase  $d^*(h)$ . Hence,  $d^*(l) < d^{CE}(l)$ .
- Case 3: If the contract is non-contingent in the competitive equilibrium, then we have that at the competitive allocation

$$\widehat{\nu}^{CE} = \nu^{CE} = \pi(l) \nu^{CE}(l) + 1 - \pi(l) < \pi(l) \widehat{\nu}^{CE}(l) + 1 - \pi(l)$$

Suppose that  $k^* \geq k^{CE}$ , then we have that  $\widehat{\nu} \leq \widehat{\nu}^{CE}$  and the planner's contract is therefore also non-contingent. Thus, also  $d^*(l) \geq d^{CE}(l)$  and  $\widehat{\nu}^{CE}(l) \leq \widehat{\nu}(l)$ , a contradiction. But if the planner issues a contingent contract, then it is also clear that  $d^*(l) < d^{CE}(l)$ , since otherwise  $d^{CE}(l) = d^{CE}(h) \leq d^*(l) < d^*(h)$  implies that  $k^* > k^{CE}$ , a contradiction. Thus, we conclude that  $k^* < k^{CE}$  and  $d^*(l) < d^{CE}(l)$ .

Note that the conjecture that  $\mu(l) = 0$  at the planner's allocation is verified. Thus, I proved that the planner (weakly) reduces borrowing and investment, and that she reduces repayments and liquidations in state  $l$ . Since, thus, we have that  $\widehat{\nu}(l) > \nu^{CE}(l)$ , we also conclude that the threshold price  $\underline{q}^*(\zeta)$  at which the planner decides to issue a contingent contract is strictly higher.

*Implementation.* To implement the planner's allocation set the transfer to satisfy  $(1 - \pi(l))T = \pi(l) (\Pi^{CE}(l) - g(z^*(l)k^*(l)) + p^*(l)z^*(l)k^*(l)) > 0$ . Let  $\tau$  denote the tax on entrepreneurial borrowing against state  $l$  and  $T_0$  denote the lump sum transfers of these taxes back to entrepreneurs, so that the

entrepreneur's period 0 budget constraint is given by

$$\chi(k) = \left( \sum_s \xi(s) d(s) \right) k - \tau \cdot d(l)k + T_0$$

If at the planner's allocation  $\mu(h) = 0 < \omega(h)$ , then set

$$\tau^* = 1 - \frac{\pi(l) \nu^*(l) + 1 - \pi(l)}{\pi(l) \widehat{\nu}^*(l) + 1 - \pi(l)}$$

where  $\nu^*$  denotes the entrepreneur's marginal utility of wealth in state  $l$  at the planner's allocation.

On the other hand, if  $\mu(h) \geq 0 = \omega(h)$ , then set the tax to

$$\tau^* = \xi(l) \left( 1 - \frac{\nu^*(l)}{\widehat{\nu}^*(l)} \right)$$

We only need to show that the entrepreneur's optimality conditions hold at the planner's allocation.

Now, note that at the planner's allocation, the entrepreneur's marginal utility of wealth  $\nu^*$  is equal to that of planner,  $\widehat{\nu}^*$ . If at the planner's allocation, we have  $\mu(h) = 0 < \omega(h)$ , then the entrepreneur's foc's at this allocation must satisfy

$$(1 - \tau^*) \nu^* = \pi(l) \nu^*(l) + 1 - \pi(l)$$

and this is verified by plugging the corresponding expression for  $\tau^*$  and using the fact the planner sets  $\widehat{\nu}^* = \pi(l) \widehat{\nu}^*(l) + 1 - \pi(l)$ . On the other hand, when  $\mu(h) \geq 0 = \omega(h)$ , the entrepreneur's foc's at the planner's allocation must satisfy

$$(\xi(l) - \tau^*) \nu^* = \pi(l) \nu^*(l)$$

which is also verified by plugging the corresponding expression for  $\tau^*$  and using the fact that the planner sets  $\xi(l) \widehat{\nu}^* = \pi(l) \widehat{\nu}^*(l)$ . Finally, note that since  $\nu^*(l) < \widehat{\nu}^*(l)$ , we have that  $\tau^* > 0$  and  $T^* > 0$ .

*Proof of Lemma 3.* The derivation of buyers' optimal offer strategies is analogous to the proof of Lemma 2, except that buyers' beliefs are augmented with the belief that the seller is in the set

$H^S = \{\beta = 1\} \cup (\{\beta = 0\} \cap \{x^S < \hat{x}\})$ , i.e. buyers' prior is updated to

$$\hat{\pi}(l) \equiv \Pr(s = l | H^S) = \frac{(\lambda + (1 - \lambda) F_l(\hat{x})) \pi_l}{(\lambda + (1 - \lambda) F_l(\hat{x})) \pi_l + (\lambda + (1 - \lambda) F_h(\hat{x})) (1 - \pi_l)}$$

and then buyers submit offers as if in a standard first-price common value auction. It suffices to show that there is a threshold such that non-liquidity hit investors with signals below that threshold post their contracts for sale. Let  $\hat{x}$  be the selling threshold, and let  $y^{max}$  be the maximal order statistic among signals  $x_1, \dots, x_n$  drawn independently from distribution  $F_s(\cdot)$ . Then for an investor with signal  $x$ , the buyers' optimal offer strategy (given in Lemma 7) implies a payoff from selling of

$$\begin{aligned} \mathbb{E}\{p^{max}(\mathcal{C}, \hat{x}) | x\} &= \int_{\underline{x}}^{\bar{x}} p(y, \hat{x}) f_{y^{max}}(y | x) dy \\ &= \int_{\underline{x}}^{\bar{x}} p(y, \hat{x}) \frac{\sum \pi(s) f_s^n(y) f_s(x)}{f(x)} dy \\ &= \int_{\underline{x}}^{\bar{x}} p(y, \hat{x}) \sum f_s^n(y) \frac{\pi(s) f_s(x)}{f(x)} dy \\ &= \int_{\underline{x}}^{\bar{x}} p(y, \hat{x}) \sum_s f_s^n(y) \Pr(s | x) dy \end{aligned}$$

First, I show that  $U(x, \hat{x}) = \mathbb{E}\{d(s) k | x\} - \mathbb{E}\{p^{max}(y, \hat{x}) | x\}$  is increasing in  $x$ . Let  $\hat{\pi}_l(y, \hat{x})$  denote the implied state  $l$  probability corresponding to the offer  $p(y, \hat{x})$ , then we need to show that

$$\int_{\underline{x}}^{\bar{x}} \hat{\pi}_l(y, \hat{x}) \sum_s f_s^n(y) \Pr(s | x) dy - \Pr(l | x)$$

is decreasing in  $\Pr(l | x)$ . Differentiation w.r.t.  $\Pr(l | x)$  yields

$$\int_{\underline{x}}^{\bar{x}} \hat{\pi}_l(y, \hat{x}) (f_l^n(y) - f_h^n(y)) dy - 1 = \int_{\underline{x}}^{\bar{x}} \hat{\pi}_l(y, \hat{x}) f_l^n(y) \left(1 - \frac{f_h^n(y)}{f_l^n(y)}\right) dy - 1$$

Now recall that signals are boundedly informative:  $\frac{f_h^n(y)}{f_l^n(y)} \geq \underline{\phi} > 0$  for all  $y \in [\underline{x}, \bar{x}]$ . There thus exists a  $\underline{\phi} \in (0, 1)$  such that the above expression is negative for all  $\hat{x} \in [\underline{x}, \bar{x}]$ . To show that there exists a threshold  $\hat{x}$ , consider the following two cases:

- Case 1: If  $U(\underline{x}, \underline{x}) \geq 0$ , then we have that  $\hat{x} = \underline{x}$  is an equilibrium because even the most pessimistic investor with  $\beta = 0$  does not want to sell when the threshold is  $\underline{x}$ . Since  $U(\cdot, \underline{x}) \geq 0$



is increasing, it follows that more optimistic investors will also not want to sell. Note that this equilibrium coincides with the equilibrium in the economy with observable liquidity needs.

- Case 2: If  $U(\underline{x}, \underline{x}) < 0$ , then threshold  $\underline{x}$  cannot be an equilibrium because otherwise, by continuity of  $U(\cdot, \underline{x})$ , there would be a set of signals above  $\underline{x}$  for which investors with  $\beta = 0$  would want to sell. Consider the equation  $U(x^*, \hat{x}) = 0$ , which defines a map  $x^* : [\underline{x}, \bar{x}] \rightarrow [\underline{x}, \bar{x}]$  that, for a given threshold  $\hat{x}$ , gives the signal  $x^*(\hat{x})$  of the non-liquidity hit investor who is indifferent between selling his contract and keeping it. Note that  $x^*(\underline{x}) > \underline{x}$  by assumption that  $U(\underline{x}, \underline{x}) < 0$  and  $x^*(\bar{x}) < \bar{x}$  since the expected resale price is always strictly lower than the most optimistic valuation ( $x^*(\hat{x})$  is a singleton because  $U(\cdot, \hat{x})$  is increasing). In addition, since  $U(x, \hat{x})$  is continuous in both  $x$  and  $\hat{x}$ , we have that the map  $x^*(\cdot)$  is continuous on  $[\underline{x}, \bar{x}]$ . There thus exists an  $\hat{x}$  such that  $x^*(\hat{x}) = \hat{x}$ .

*Proof of Proposition 7.* Let  $\hat{x}$  be an equilibrium threshold and let  $H(\hat{x})$  denote the event that an investor sells contract  $\mathcal{C}$ , and note that

$$\Pr(H(\hat{x})) = \lambda + (1 - \lambda)F(\hat{x})$$

The contract price schedule is given by

$$\begin{aligned} \mathcal{L}(\{d(s)k\}) &= \mathbb{E}\{\gamma(x, \beta, \mathcal{C})\mathbb{E}\{p^{\max}(\mathcal{C}, \hat{x})|x\} + (1 - \gamma(x, \beta, \mathcal{C}))\beta\mathbb{E}\{d(s)k|x\}\} \\ &= \Pr(H(\hat{x}))\mathbb{E}\{p^{\max}(\mathcal{C}, \hat{x})|H(\hat{x})\} + (1 - \Pr(H(\hat{x})))\mathbb{E}\{d(s)k|H(\hat{x})^c\} \\ &= \mathbb{E}\{d(s)k\} + \Pr(H(\hat{x}))\mathbb{E}\{p^{\max}(\mathcal{C}, \hat{x}) - d(s)k|H(\hat{x})\} \end{aligned}$$

Finally, that  $\Pr(\hat{x})\mathbb{E}\{d(s) - p^{\max}(\mathcal{C}, \hat{x})|\hat{x}\} = \hat{\zeta} \cdot |d(h) - d(l)|k$  for some  $\hat{\zeta} > 0$  follows from the linearity of offer strategies and the fact that buyers earn informational rents. The proof that informational rents are positive is analogous to that of Proposition 2.

*Matching Function.* I construct a random matching function that maps each seller of a contract to  $n$  buyers randomly selected from the set of potential buyers, i.e. non-liquidity hit investors. Recall that investors' decision whether to post their contracts for sale is given by a measurable map  $\gamma$  :

$[\underline{x}, \bar{x}] \times \{0, 1\} \rightarrow \{0, 1\}$  that maps signals  $x \in [\underline{x}, \bar{x}]$  and liquidity needs  $\beta \in \{0, 1\}$  into sale or no sale decision  $\{0, 1\}$ . Investors' decision of whether to become buyers is simply given by their liquidity needs: an investor is a buyer if and only if he has  $\beta = 0$ . Let  $(\Omega, \mathcal{F}, \mathbb{P})$  be a canonical probability space. Fix a measure space  $(G, \mathcal{G}, \mu)$  of investors, where  $G = [0, 1]$ ,  $\mathcal{G}$  denotes the Lebesgue measurable subsets of  $[0, 1]$ , and  $\mu$  is the Lebesgue measure on  $[0, 1]$ . The random state of nature is given by  $s \in \{l, h\}$  and is assumed to satisfy  $\Pr(s = l) = \pi(l)$ . The stochastic processes for signals  $\{x_i\}$  and for liquidity needs  $\{\beta_i\}$  in turn satisfy

- Process  $\{\beta_i\}$  satisfies the following properties

- For all  $(i, \omega) \in G \times \Omega$ ,  $\beta_i(\omega) \in \{0, 1\}$  and  $\mathbb{P}(\omega \in \Omega : \beta_i = 1) = \lambda$ , and
- For any distinct  $i_1, \dots, i_k$  with  $k < \infty$  and  $s \in \{l, h\}$ ,  $\mathbb{P}(\omega \in \Omega : \beta_{i_1} = 1, \dots, \beta_{i_k} = 1) = \lambda^k$  (independence).

- Process  $\{x_i\}$  satisfies the following properties

- For all  $(i, \omega) \in G \times \Omega$ ,  $x_i(\omega) \in [\underline{x}, \bar{x}]$  and  $\mathbb{P}(\omega \in \Omega : x_i \leq x) = F(x) = \pi(l) F_l(x) + (1 - \pi_l) F_h(x)$ , and
- For any distinct  $i_1, \dots, i_k$  and any  $x_{i_1}, \dots, x_{i_k} \in [\underline{x}, \bar{x}]$  with  $k < \infty$ ,  $\mathbb{P}(\omega \in \Omega : x_{i_1} \leq x_1, \dots, x_{i_k} \leq x_k | s) = \prod_{l=1}^k F_s(x_l)$  for  $s \in \{l, h\}$  (independence).

- The processes  $\{\beta_i\}$  and  $\{x_i\}$  satisfy : for all  $i \in [0, 1]$ ,  $\mathbb{P}(\omega \in \Omega : x_i \leq x, \beta_i = 1) = F(x) \lambda$  for any  $x \in [\underline{x}, \bar{x}]$  (independence).

Given  $\omega \in \Omega$ , define the set of sellers by  $S(\omega) \equiv \{(i, \omega) \in [0, 1] \times \Omega : \gamma(x_i, \beta_i) = 1\}$ , and the set of buyers by  $B(\omega) \equiv \{(i, \omega) \in [0, 1] : \beta_i(\omega) = 0\}$ . These are measurable subsets of  $G$ , with the property that  $n \cdot \mu(S(\omega)) \leq \mu(B(\omega))$  holds  $\omega$  - almost surely. A sufficient condition for this inequality to hold is that  $n\lambda \leq (1 - \lambda)$  in the case with observable liquidity needs. In the case of unobservable liquidity needs,  $\lambda$  must satisfy  $n[\lambda + (1 - \lambda) F_l(\hat{x})] \leq (1 - \lambda)$ , and this is feasible because  $\hat{x}$  is decreasing with  $\lambda$  and is close to  $\underline{x}$  when  $\lambda$  becomes small. Let  $(\Omega', \mathcal{F}', \mathbb{P}')$  be an alternative probability space, and consider a map  $\pi : G \times \Omega \times \Omega' \rightarrow G^n \cup \{\emptyset\}$  that satisfies the following properties

- For  $i \notin S(\omega)$  and  $(\omega, \omega') \in \Omega \times \Omega'$ ,  $\pi(i, \omega, \omega') = \{\emptyset\}$ ,

- For  $i \in S(\omega)$  and  $(\omega, \omega') \in \Omega \times \Omega'$ ,  $\pi(i, \omega, \omega') = \{j_1, \dots, j_n\}$  where  $j_1 < \dots < j_n$ ,  $i \neq j_k$  for any  $k \in \{1, \dots, n\}$ ,
- For  $(\omega, \omega') \in \Omega \times \Omega'$ , the map  $\pi(\cdot, \omega, \omega')$  is injective when restricted to the set  $S(\omega)$ , and

The process  $\{\pi(i, \cdot, \cdot)\}_i$  satisfies

- For  $\omega \in \Omega'$  and for any distinct  $i_1, \dots, i_k \in S(\omega)$  and measurable sets  $A_1, \dots, A_{i_k} \in G^n$  with  $k < \infty$ ,  $\Pr(\omega' \in \Omega' : \pi(i_1, \omega, \omega') \in A_1, \dots, \pi(i_k, \omega, \omega') \in A_k) = \prod_{l=1}^k \Pr(\omega' \in \Omega' : \pi(i_l, \omega, \omega') \in A_{i_k})$  (independence).

Finally, the sigma algebras  $\mathcal{F}$  and  $\mathcal{F}'$  are assumed to be independent and the space  $\Omega \times \Omega'$  is endowed with the corresponding product sigma algebra  $\mathcal{F} \times \mathcal{F}'$  and product measure  $\mathbb{P} \times \mathbb{P}'$ . Thus, in state  $(\omega, \omega')$ , investor  $i \in S(\omega)$  is matched with  $n$  distinct investors  $j_1, \dots, j_n \in \pi(i, \omega, \omega')$  and investor  $i \notin S(\omega)$  remains unmatched; buyers are matched with at most one seller by the definition of the map  $\pi(\cdot, \omega, \omega')$  and no two sellers are matched with the same buyers by injectivity of the map  $\pi(\cdot, \omega, \omega')$ . Conditional on state  $\omega$ , a seller is matched with a random selection of buyers due to the independence assumption on the process  $\{\pi(i, \cdot, \cdot)\}_i$ . Finally, the independence of the two sigma algebras ensures that conditional on being a seller and being a buyer, no additional information is revealed by the match itself.

*Matching with Multiple Sellers.* Each seller can contact  $n$  buyers, and each buyer who is matched is assumed to be able to trade with  $m$  sellers, where  $m(1 - \lambda) \geq n$ . To ensure consistency, matching occurs by adjusting the fraction of buyers who are matched with sellers. Thus, if the measure of sellers is given by  $\mu$ , a fraction  $\omega = \frac{n}{m} \frac{\mu}{1 - \lambda}$  of buyers is matched with  $m$  sellers and the remaining buyers are matched with 0. This is a simple way to introduce noise into the matching process and ensure that the number of matches that a buyer gets does not fully reveal the state of the economy. Once buyers and sellers have matched, trades are assumed to be executed simultaneously. This latter assumption eliminates informational spillovers across markets; however, see Section 6. As in Section 4, consider the case of observable liquidity needs and conjecture that in equilibrium an investor is a seller if and only if he has a liquidity need, i.e. type  $\beta = 1$ . Then the fraction of buyers who are matched in state  $s$  is given by  $\omega_s = \frac{n}{m} \frac{\lambda}{1 - \lambda}$  for  $s \in \{l, h\}$  and is thus independent of the state. Thus, on equilibrium path, buyers do not make inferences about the state from the match and their offer strategies are the

same as in Section 4. For deviating investors of type  $\beta = 0$ , again suppose that buyers assign the most pessimistic belief. These off-equilibrium beliefs can then be shown to support the equilibrium with sorting solely on liquidity needs.

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