Neglected Risks, Financial Innovation, and Financial Fragility

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Abstract

We present a standard model of financial innovation, in which intermediaries engineer securities with cash flows that investors seek, but modify two assumptions. First, investors (and possibly intermediaries) neglect certain unlikely risks. Second, investors demand securities with safe cash flows. Financial intermediaries cater to these preferences and beliefs by engineering securities perceived to be safe but exposed to neglected risks. Because the risks are neglected, security issuance is excessive. As investors eventually recognize these risks, they fly back to safety of traditional securities and markets become fragile, even without leverage, precisely because the volume of new claims is excessive.

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I. Introduction.

Many recent episodes of financial innovation share a common narrative. It begins with a strong demand from investors for a particular, often safe, pattern of cash flows. Some traditional securities available in the market offer this pattern, but investors demand more (so prices are high). In response to demand, financial intermediaries create new securities offering the sought after pattern of cash flows, usually by carving them out of existing projects or other securities that are more risky. By virtue of diversification, tranching, insurance, and other forms of financial engineering, the new securities are believed by the investors, and often by the intermediaries themselves, to be good substitutes for the traditional ones, and are consequently issued and bought in great volumes. At some point, news reveals that the new securities are vulnerable to some unattended risks, and in particular are not good substitutes for the traditional securities. Both investors and intermediaries are surprised by the news, and investors sell these "false substitutes," moving back to the traditional securities with the cash flows they seek. As investors fly for safety, financial institutions are stuck holding the supply of the new securities (or worse yet, having to dump them as well in a fire sale because they are leveraged). The prices of traditional securities rise while those of the new ones fall sharply.

A notorious recent example of this narrative is securitization of mortgages during the last decade. Various macroeconomic events, including sharp reductions in government debt during the Clinton administration and massive demand for safe US assets by foreigners, created a "shortage" of safe fixed income securities. By pooling and tranching mortgages and other loans, financial institutions engineered AAA-rated mortgage backed securities (MBS), as substitutes for US government bonds. The perception that these securities were safe, apparently shared by both buyers and intermediaries who engineered them, was justified by historically low default rates on mortgages in the US and by more or less continuously growing home prices since World War II. Trillions of dollars of mortgage and other asset backed securities were created and sold to investors.

Both the holders of these securities and financial intermediaries appeared to be caught by surprise in the summer of 2007, when the news that AAA-rated securities are not safe hit the market. It is not that investors failed to realize that there was a housing bubble, or that home prices could decline and mortgages could default. Yet two things came as rather substantial surprises. The first was how fast home prices declined, and defaults grew. Gerardi et al. (2008) show that few if any Wall Street professionals expected the housing bubble to deflate so rapidly. The second surprise was the sensitivity of the prices of AAA-rated securities engineered from mortgages, especially Collateralized Debt Obligations (CDO's), to home prices, a phenomenon largely overlooked by the models utilized by rating agencies (Jarrow et al. 2007, Coval et al. 2009). As these securities were downgraded, prices fell and new issuance stopped. The losses from MBS spread through the financial system, precipitating the market collapse in September 2008.

This recent episode is far from unique in recent US financial history. In the 1980s, investment banks began selling Collateralized Mortgage Obligations (CMOs), securities created out of mortgage portfolios and intended to substitute for government bonds. To avoid a possible risk to the value of CMOs resulting from mortgage prepayments by homeowners (which would occur if interest rates fell and people refinanced their homes) and consequent prepayments on the high-yielding bonds, intermediaries engineered CMOs nearly invulnerable to prepayment risk if historical patterns continued. In the early 1990s, however, as the Federal Reserve sharply cut interest rates, prepayments skyrocketed to levels unprecedented by historical standards, so even the values of CMO's most protected against prepayment risk declined sharply. The investors were caught by surprise and dumped the CMOs, turning back to government bonds (Carroll and Lappen 1994). Financial intermediaries were evidently caught by surprise as well, and many (particularly those who sold prepayment insurance) suffered substantial losses. Like the collapse of the housing bubble in 2007-2009, extreme prepayments appear to have been unanticipated by the market.

A similar narrative describes what happened to money market funds in 2008. The industry was originally created to offer investors a substitute for bank deposits, with slightly higher returns, instant liquidity, and no risk. Because investment in money market funds was not protected by deposit insurance, however, these funds were engineered never to "break the buck" – have their value per share drop below $1. To slightly raise returns, prime money market funds invested in generally safe non-government securities, such as commercial paper. The collapse of Lehman Brothers in September of 2008 led to its default on commercial paper, which caused one large holder of that paper, the Reserve Fund, to "break the buck" (Kacperczyk and Schnabl 2010). This event shocked investors and precipitated hundreds of billions of dollars in withdrawals not just from the Reserve Fund, but from the whole prime money market fund sector, and a return to traditional bank deposits and government securities only funds (Pozsar et al. 2010). Only government guarantees of prime money market funds saved the industry.

In this paper, we present a model that captures some key elements of this narrative. The model shares with the traditional accounts of financial innovation, such as Ross (1976) and Allen and Gale (1994), the view that innovation is driven by investor demand for particular cash flow patterns. This demand allows intermediaries to profitably engineer these patterns out of other cash flows. We add two assumptions to this standard story.

First, we assume that both investors and financial intermediaries do not attend to certain improbable risks when trading the new securities. This assumption captures what we take to be the central feature of the historical episodes we described: the neglect of potentially huge defaults in the housing bubble and of the sensitivity of AAA-rated securities to these defaults, the neglect of the possibility of massive prepayments in the early 1990s, or the neglect of the possibility that a money market fund can break the buck. We model the neglect of certain states of the world using the idea of local thinking, introduced by Gennaioli and Shleifer (2010), which is a formalization of the notion that not all contingencies are represented in the decision maker's thought process. The complete neglect of some states of the world in models used to assess the risks of CDO's is a good example (Jarrow et al. 2007).

Second, we make the preferred habitat assumption that investors have a very strong preference for safe cash flow patterns. We model this assumption through preferences, namely infinite risk aversion, but it can reflect psychological or institutional characteristics of demand. An alternative way to model such demand might be to consider investors who have lexicographic preferences with respect to particular characteristics of investments (e.g., AAA ratings). Yet another approach might be to stress regulatory requirements imposed on investors such as banks and insurance companies that favor safe assets. This assumption on demand is not strictly necessary for our results, but makes them much stronger.[1] We have obtained similar results in a model with finite risk aversion and Epstein-Zin preferences.

We then examine a standard model modified by these two assumptions, and obtain three main results. First, as in the standard model, there is room for financial innovation to offer investors cash flow streams that are not available from traditional securities in sufficient supply. However, when some risks are neglected, securities are over-issued relative to what would be possible under rational expectations. The reason is that neglected risks need not be laid off on intermediaries or other parties when manufacturing new securities. Investors thus end up bearing risk without recognizing that they are doing so.

Second, markets in new securities are fragile. A small piece of news that brings to investors' minds the previously unattended risks catches them by surprise, causes them to

[1] The demand for riskless debt can also come from the preference for information-insensitive claims (Gorton and Pennacchi 1990, Demarzo and Duffie 1999).

drastically revise their valuations of new securities, and to sell them in the market. The problem occurs precisely because new securities have been over-issued: there are not enough cash flows in the neglected states of the world to make promised payments in full. When investors realize that the new securities are "false substitutes" for the traditional ones, they fly to safety, dumping these securities on the market and buying the truly safe ones[2].

Third, in equilibrium financial intermediaries buy back many of the new securities. But their wealth might be much smaller than that of investors as a whole, which limits their ability to absorb the huge supply of the new securities (see point 1). As a consequence, the prices of these false substitutes fall sharply, even without traditional fire sales due to leverage (Shleifer and Vishny 1992). Prices of traditional securities rise as investors fly to safety.

The model thus delivers the basic patterns of financial innovation and financial fragility in a new way. The most important contribution is to connect financial innovation, the glut of new securities, surprise about risk, and corresponding financial fragility through a unified model of belief formation. We show that a model in the spirit of Allen and Gale (1994), even modified by a preferred habitat formulation of preferences but without neglect of certain risks, can deliver some aspects of the narrative, but not over-issuance and the fragility it entails. Without a deviation from rational expectations, one cannot get the basic idea of false substitutes: securities investors believe to be riskless turn out to be risky.

Our model of financial innovation is related to the behavioral finance idea of security issuance catering to investor demand as in Baker and Wurgler (2002) and Greenwood, Hanson, and Stein (2010)[3]. Henderson and Pearson (2009) study equity derivative products called SPARQS, which they argue are introduced to capitalize on investor misunderstanding of equity payoff patterns. Shleifer and Vishny (2010) apply the idea of catering to the

[2] Caballero and Krishnamurthy (2008) alternatively model the flight to safety as a response to Knightian uncertainty. Our model accounts for investor optimism and flight to safety in the same framework. Reinhart and Rogoff (2009) present a historical perspective on the neglect of low probability risks in financial markets.

[3] Also related is the idea that consumers ignore some attributes of products they buy (Gabaix and Laibson 2006).

financial crisis, but simply assume optimism as the stimulus for security issuance, and pessimism as the shock precipitating a crisis. Here we present a unified model of belief formation that accounts for the whole story.

Our paper is also related to an important theme in the literature on financial fragility, namely that both banks and the shadow banking system create "private money" or liquidity that investors demand (Gorton and Metrick 2010, Stein 2010). Such creation of liquidity is usually seen as socially valuable, but entailing systemic risks due to leverage and resulting asset fire sales (Shleifer and Vishny 2010, Stein 2010). While we recognize the benefits of financial innovation, we take a more skeptical view about the social value of liquidity creation when investors neglect certain risks. In such a system, security issuance can be excessive and lead to fragility and welfare losses, even in the absence of leverage. In this respect, our paper is closer to Rajan's (2006) prescient analysis of the risks of financial innovation, although we emphasize neglect of unlikely events leading to over-issuance of securities rather than incentive problems as a source of instability.

In the next section, we present a benchmark rational expectations model of financial innovation in a pure exchange economy. Section 3 modifies this model to allow for local thinking, and derives our main results on financial innovation and fragility. In Section 4, we study a production economy, in which innovation under local thinking can lead to investment distortions. In Section 5, we discuss welfare in both the exchange and the production economies. In the exchange economy, innovation under local thinking may benefit intermediaries and harm investors; in a production economy, because innovation distorts investment, it can leave everyone worse off. Section 6 examines the case of fully rational intermediaries dealing with locally-thinking investors. Section 7 discusses some implications of our work for the recent financial crisis. All proofs are collected in the Appendix.

2. The Model

There are three dates t = 0, 1, 2 and two assets, B and A, which pay off at t = 2. The assets stand for cash flows from projects. Asset B pays $R > 1$ for sure. Asset A pays y_i with probability π_i where $i = g$ (for growth), d (for downturn), r (for recession). We assume:

A1: $y_g > 1 > y_d > y_r$, *and* $\pi_g > \pi_d > \pi_r$.

Growth is the most likely outcome and the downturn is more likely than a recession.

There is a representative intermediary, who is patient and risk neutral. At t = 0, the intermediary owns both assets and sells claims on their returns. These "traditional" claims are a riskless bond on B that yields R at t = 2, and risky shares in A, which yield y_i at t =2. There is a measure 1 of investors, each endowed with wealth w and maximizes utility:

$$U = E[C_0 + C_1 + \theta\cdot\min(C_{2g}, C_{2d}, C_{2r})], \tag{1}$$

where C_t is consumption at t = 0,1 and C_{2i} denotes consumption in state i at t = 2. Investors are infinitely risk averse with respect to C_2 but, since $\theta > 1$, wish to postpone consumption to t = 2. To do so, investors must buy claims on A and B. Investors can however freely transfer resources from t = 0 to t = 1 without purchasing claims, so t = 0 and t = 1 should be viewed as being close together. Formally, the initial endowment perishes right after t = 1. Our results only become stronger if resources cannot be transferred from t = 0 to t = 1.

These preferences conveniently pin down the gains from trade in assets. Because of their greater desire to postpone consumption ($\theta > 1$), investors seek to buy assets from intermediaries. Because they are infinitely risk averse, investors want to buy riskless bonds. With only traditional claims, however, some beneficial trades do not occur. Financial innovation improves trading opportunities by splitting up the cash flows of asset A.

At t = 0, financial claims on A and B are traded and consumption-savings decisions are made. Competition in financial markets pins down the price p_A of a share in A and the price p_B of a bond issued on B. At t = 1, after portfolios are formed and consumption has taken place at t = 0, agents observe a noisy signal $s \in \{\underline{s}, \overline{s}\}$ of payoff y, where $\overline{s} > \underline{s}$. After observing s, agents can reassess their portfolio and consume. At t = 2 asset payoffs are realized and distributed to the holders of the financial claims, and consumption takes place. The signal is characterized by $\Pr(\underline{s}|\, y_g) = 1 - \gamma$, $\Pr(\underline{s}|\, y_d) = \delta$, and $\Pr(\underline{s}|\, y_r) = \rho$, where $\rho > \delta > \gamma \geq 1/2$. That is, $\underline{s}$ reduces the probability of growth and is a stronger signal of a recession than of a downturn. The latter feature is captured by $\rho > \delta$ and plays a central role in our analysis. Our results are starkest when the signal is mildly informative, i.e. $\rho \approx 1/2$. .

The timing of the financial markets is graphically represented in Figure 1:

t = 0	**t = 1**	**t = 2**
financial claims are traded, prices p_B and p_A are set	signal s is observed, financial claims re-traded and new prices p_{B1} and p_{A1} are set.	asset returns are realized and distributed to claimants

Figure 1

2.1 Rational Expectations Equilibrium with Traditional Claims

In choosing how many bonds b and shares a to buy at t = 0 (and thus implicitly the initial and future consumption levels C_0, C_1, C_2), each investor solves:[4]

$$\begin{aligned} \max_{b,a} \quad & w - p_A a - p_B b + \theta(Rb + y_r a) \\ s.t. \quad & w - p_A a - p_B b \geq 0 \end{aligned} . \tag{2}$$

The infinitely risk averse investor cares about his time 2 consumption only in the worst state, a recession. In contrast, at t = 0 the intermediary supplies b bonds and a shares to maximize:

$$\max_{a,b} \quad \Pi \equiv p_A a + p_B b + R(1-b) + Ey(1-a) . \tag{3}$$

When b (or a) are negative, intermediaries are buying bonds (shares). This possibility never arises in equilibrium, but it uniquely pins down equilibrium prices. To find these prices,

[4] As it will soon be clear, in our model under rational expectations there is no re-trading at t = 1, so the agent's portfolio problem can be formulated as one where assets are held to maturity until t = 2.

consider agents' reservation values for different assets. From program (2), the investor's reservation prices are equal to θR for bonds and θy_r for shares. Due to infinite risk aversion, shares are valued at their lowest payoff. Whenever the price of one or both securities is lower than the respective reservation price, the investor saves all of his wealth (setting $C_0 = C_1 = 0$) and purchases securities, starting with the one with the lowest price to reservation value ratio.

Program (3) implies that the intermediary's reservation prices are equal to R for bonds and E(y) for shares. The intermediary then sells all securities whose price is above the reservation value and keeps the remaining ones. We assume for simplicity that:

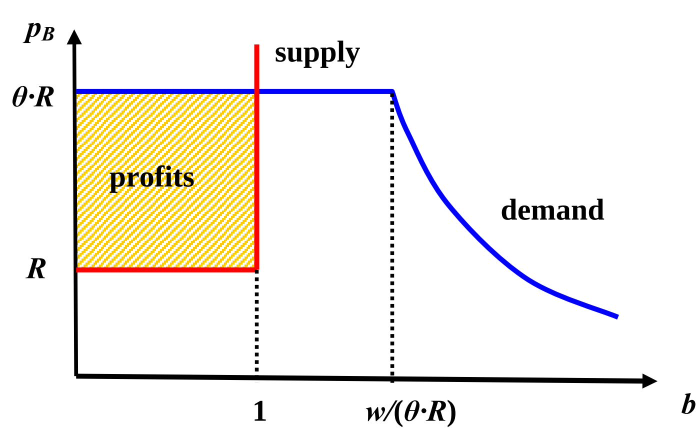
A2: $E(y|\underline{s}) > \theta \cdot y_d$ and $w > \underline{w} \equiv \max[\theta(R + y_r),(R + y_d)]$.

The first part of A.2 ensures that, even after observing a low signal $\underline{s}$, the intermediaries value shares substantially more than investors. This implies that there is no trade in shares either at $t = 0$ or at $t = 1$, and that the portfolios formed at $t = 0$ will not be rebalanced after observing s. The second part of A.2 ensures that investors are wealthy enough to absorb the total supply of bonds even at their reservation price $p_B = \theta \cdot R$ [formally, A.2 implies that $w/(\theta \cdot R) > 1$]. We can show that under A.2 the equilibrium at $t = 0$ is described by:

Lemma 1: Under rational expectations and a traditional claim structure, the financial markets equilibrium at $t = 0$ is characterized by $a = 0$, $b = 1$, $p_A = Ey$, $p_B = \theta \cdot R$.

In this equilibrium, displayed in Figure 2, investors absorb all bonds, their price is maximal, and shares do not trade ($p_A = Ey$ assures there are no trades among intermediaries).

Figure 2



Intermediaries' supply of bonds is initially flat at $p_B = R$ but becomes vertical after all available bonds are sold. Investors' demand is initially flat at $p_B = \theta R$ but begins to slope down after all of their wealth is used to buy $w/\theta R$ bonds, so p_B must drop below θR for them to absorb a larger supply. A.2 directly implies that there is a "shortage" of a safe store of value; this shortage keeps p_B at θR, allowing intermediaries to earn a unit profit $(\theta-1)\cdot R$ from bond sales. Investors' payoff at $t = 0$ is $U_{\mathrm{I}} = w$, intermediaries' payoff is $\Pi = \theta\cdot R + Ey$.

After a signal s is observed at $t = 1$, nothing happens to portfolios and consumption. Investors keep the bonds purchased at $t = 0$, the price of which stays constant at $p_B = \theta\cdot R$. Share prices fluctuate with the expected return of asset A since Ey is affected by the signal s, but no trading in shares takes place. In this equilibrium, it is irrelevant how consumers and intermediaries divide their $t = 0$ income between C_0 and C_1.

2.2 Rational Expectations Equilibrium with Financial Innovation

We view financial innovation as the repackaging by intermediaries of the payoff on A so as to relax the "shortage" of bonds. The intermediary carves out of the risky asset a new claim having the same cash flow pattern as a riskless bond, namely promising to repay R in all states of the world. The amount of these new riskless claims the intermediary can issue is limited by the lowest possible return y_r of A, since the maximum aggregate repayment the intermediary can pledge in all states of nature under the new claims is precisely y_r. As a consequence, the volume f of the new riskless claims issued in this way must satisfy:

$$f \leq f^{RE} = y_r / R\,. \tag{4}$$

If $f > y_r/R$, the new claim is risky because in a recession intermediaries cannot pay out the promised return R to all claim-holders. If $f \leq y_r/R$, the new claim is riskless: even in the worst state, intermediaries can repay R to all claimants. Unlike the bond, which is necessarily riskless because it pledges B's riskless return, the new claim is paid out of a risky return, and is therefore riskless only if issued in a sufficiently low volume. We thus model financial innovation as the creation of substitute securities mimicking exactly the cash flows of bonds that are demanded by investors but are in short supply. It is optimal for intermediaries to introduce a safe claim because infinitely risk-averse investors do not value the upside of risky claims. This innovation can also be interpreted as issuing riskless debt against the cash flow of risky asset A. After having issued f new claims, the residual risky return $y - fR$ from A is pledged to the shareholders.

Consider now the market equilibrium. Denote the t=0 price of the new claim by p_N. The new claim must fetch the same price as a bond (i.e. $p_N = p_B$), since the two securities have identical cash flows. Financial innovation boosts the supply b of bonds by the amount y_r/R. The new equilibrium in the market for riskless claims is shown in Figure 3.

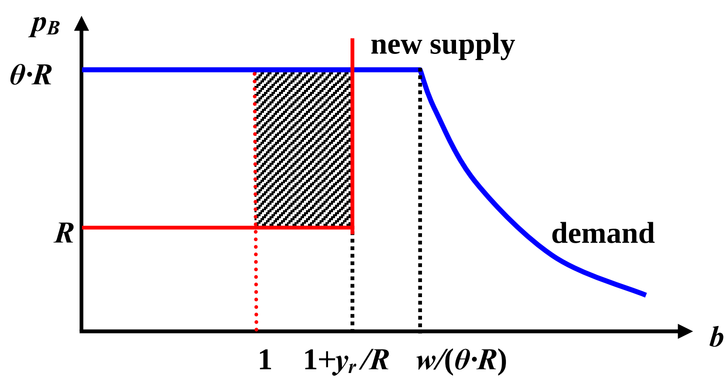


Figure 3

Under A.2, the boost in the supply of riskless claims triggered by financial innovation reduces but does not eliminate this shortage, because $\underline{w}/\theta R > 1 + y_r / R$. It is therefore still the case that the price of safe claims is equal to investors' reservation price, namely $p_N = p_B = \theta{\cdot}R$. The wealth of investors is sufficiently high to absorb all new claims at that price. Share prices are now equal to $p_A = Ey - y_r$ because the volume of innovation is maximal and so the risky asset's lowest payout is pledged to the holders of the new claim. In the equilibrium depicted in Figure 3, the intermediary's profit from innovation is equal to:

$$f^{RE} \times (\theta - 1)R \equiv y_r(\theta - 1)\,. \tag{5}$$

The intermediary's profit rises when y_r is higher, since more securities can be issued, and when investors' time preference θ is stronger, since the price of the new securities is higher.

To summarize the analysis thus far, under A.2 the financial markets equilibrium at t = 0 under rational expectations and financial innovation is described by:

Lemma 2: Under rational expectations, equilibrium at t = 0 with financial innovation is characterized by $a = 0$, $b = 1 + y_r/R$, $p_A = Ey - y_r$, $p_N = p_B = \theta \cdot R$.

At t = 1, financial innovation does not affect the reaction of markets to the signal s. Regardless of the signal, the price of riskless claims does not change and neither do portfolios or consumption. Only p_A fluctuates with the expected return on A. In this equilibrium, it does not matter whether consumption takes place at t = 0 or t = 1. As we will see, neither of these facts remains true with local thinking.

Finally, consider the welfare consequences of innovation. With innovation, the total payoff of investors as of t = 0 stays at $U_{\mathrm{I}} = w$ while the intermediary's payoff becomes $\Pi_{inn} = \theta \cdot R + (\theta - 1)y_r + Ey$, which is the no-innovation profit Π plus the profits from innovation. Social welfare at t = 0 is thus higher with innovation, just as in Allen and Gale (1994). The social benefit of financial innovation here consists of relaxing the aggregate shortage of riskless bonds. This benefit in our model accrues entirely to the intermediaries because, in the market equilibrium, investors purchase riskless claims at their reservation price.

Our model builds on the idea that a key feature of financial innovation is to allow intermediaries to cater to investors' demand for particular claims, namely riskless bonds. The initial excess demand for such bonds gives intermediaries the incentive to manufacture an identical riskless security out of a risky cash flow. With infinitely risk-averse investors, the model literally describes securitizations expanding the supply of AAA securities. With rational expectations, financial innovation allows gains from trade to be realized, and is strictly beneficial. Although this effect of financial innovation shows up in the case of local thinking as well, in that world it can also lead to excessive innovation and financial fragility.

3. Financial Innovation under Local Thinking

We consider departures from rational expectations due to agents' limited ability to represent uncertainty. To do so, we follow Gennaioli and Shleifer's (2010) model of local thinking. This model, which provides a unified explanation of several "anomalies" in judgments but admits Bayesian rationality as a special case, builds on the notion that agents' inferences are made on the basis of a *selected* subset of possible events rather than on the entire state space. Intuitively, not all states of the world come to mind; the agent does not think of everything when imagining the future[5]. Crucially, the selection of events from the state space is shaped by their true underlying probabilities: more likely events are ceteris paribus easier to retrieve from memory than less likely ones. This feature allows one to consider how historical frequencies and news combine to create judgement biases, particularly news that change the agent's representations.

We model local thinking by assuming that an agent does not think of all three possible states $i = g, d, r$ of the risky asset's payoff but only the two most likely ones. The agent then conditions his inferences about the payoff of A on the two states that come to mind, ignoring the remaining state. To see how this works, consider a local thinker's representation of the future at $t = 0$. Since by assumption $\pi_g > \pi_d > \pi_r$, the states that come to mind are g and d, so the agent assesses $\Pr^L(y_g) = \Pr(y_g | y_g, y_d) = \pi_g/(\pi_g + \pi_d)$ and $\Pr^L(y_d) = \Pr(y_d | y_g, y_d) = \pi_d/(\pi_g + \pi_d)$, where superscript L stands for "local." At $t = 0$, the local thinker exaggerates the probabilities of growth and downturn and neglects the possibility of a recession.

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[5] Other models of unforeseen contingencies, surveyed by Dekel, Lipman, and Rustichini (1998) are less tractable and focus on studying how the awareness of being unaware of some states affects choice, rather than on how the set of contingencies that comes to mind is endogenously determined and updated.

After s is observed at $t = 1$, the agent's assessments are revised. What comes to mind at this point depends on the "true" posterior probabilities $\pi_i(s) = \Pr(y_i|s)$ for $i = g, d, r$. Since the prior probability of growth is fairly high and we focus on scarcely informative signals (formally $\rho \approx 1/2$), y_g is still the most likely outcome after s is observed. This implies that state g is always included in the agent's representation. Consider now the probability ranking of a downturn and a recession. If the signal is good, ($s = \bar{s}$), this ranking does not change as $\pi_d(\bar{s}) > \pi_r(\bar{s})$. Observing a good signal after a history of economic stability confirms the initial representations encoded in assumption A.1.

A bad signal $s = \underline{s}$ in contrast is generally informative of lower growth, but especially about a recession, as formally captured by the assumption that $\rho > \delta$. In this case, so long as:

A.3: $\rho > \hat{\rho} \equiv \delta \cdot \frac{\pi_d}{\pi_r}$,

we have that $\pi_r(\underline{s}) > \pi_d(\underline{s})$, namely a recession becomes more likely than a mere downturn. If the prior probabilities π_d and π_r are not far apart, A.3 is easily met and we henceforth assume that it is. This implies that after $s = \underline{s}$ the representation of uncertainty changes drastically: the agent now neglects the possibility of a mere downturn by including state r at the expense of d into his representation and thus forms his assessments conditional on y_g and y_r.

By formalizing the change in agents' representations, local thinking allows us to identify two general, distinct, effects of bad news. The first and most fundamental effect is to prompt the agent to consider the possibility of a recession. Initially, after a period of economic stability, limited representations lead the agent to neglect this unlikely risk. After observing a piece of bad news (such as a bank failure), the initially unattended-to possibility of a recession comes to the agent's mind. The second effect of news it that they may induce over-reaction. With limited representations, as the possibility of a recession comes to mind, other, more favourable, states are crowded out of agents' attention. This crowding out leads to over-weighting of the probability of recession, which may (but need not) induce a switch from the initial optimism to pessimism.[6]

Although over-reaction leads to stronger effects, the main results of our model rely merely on the neglect of the possibility of a recession at $t = 0$. In fact, as we formally show in Proposition 2, the "false substitute" effect arises even if the agent's assessment at $t = 1$ is rational, much as if agents were to learn the true distribution of states after observing $\underline{s}$.[7]

3.1 Local Thinking Equilibrium and Innovation at *t* = 0

We solve the model by assuming that investors and intermediaries are local thinkers holding the same beliefs. In Section 6 we consider rational expectations intermediaries.

If the intermediary does not innovate, the equilibrium at $t = 0$ is very similar to the rational expectations case in Lemma 1, except that the share price is now equal to $p_A = E^L y = \mathrm{E}(y|\ y = y_g, y_d)$, which is the value for asset A's cash flow expected by a local thinker. When the intermediary innovates, then given agents' representations at $t = 0$, the change from the rational expectations case is substantial. When state r is neglected, the number of new riskless claims that the intermediary can potentially issue is equal to:

$$f^L = y_d / R. \tag{6}$$

Since at $t = 0$ agents do not pay attention to the possibility of a recession, riskless claims can be issued until all cash flow y_d in a downturn is pledged to investors. The

[6]After observing $\underline{s}$ a local thinker estimates an average payoff of $\mathrm{E}(y|y_g,y_r,\underline{s})$, which is lower than the rational agent's estimate when $\mathrm{E}(y|y_g,y_r,\underline{s}) < y_d$. If $\mathrm{E}(y|y_g,y_r,\underline{s}) = y_d$ the local and rational thinker's assessments are identical (the local thinker is optimistic otherwise). Thus, the switch from optimism to pessimism arises when the recession is very bad, i.e. y_r is low. Pessimism may also arise in our model if the probability of growth is sufficiently low that after $\underline{s}$ state y_g is disregarded. None of our main results change under these alternative specifications. We have chosen the structure of A.1 in order to highlight the fact that the basic mechanism of our model does not require pessimism and may arise even if the local thinker's $t = 1$assessments are fully rational.

[7] More generally, although local thinking provides a model of probability distortions and over-reaction, the mere distortion of probabilities and updating is not sufficient for our results. For example, we would not get them in a model of under- and over-reaction along the lines of Barberis et al. (1998). The key cognitive problem our agents suffer from is the neglect of the possibility that y_r might happen. This assumption interacts with infinite risk aversion to cause assets to be priced based only on the worst case scenario that agents contemplate. But even if risk aversion is finite, the neglect of low payoff states plays an important role by creating the possibility that security issuance is excessive relative to the available cash flows.

potential volume of financial innovation with local thinking is higher than with rational expectations (formally $f^L > f^{RE}$ since $y_d > y_r$) because cash flows in a downturn rather than a recession can now be pledged to create a "substitute" for a riskless bond. If investors are sufficiently wealthy, the price of riskless claims stays at $p_N = p_B = \theta \cdot R$ and the extra profit from innovation obtained by the intermediary is equal to:

$$f^L \times (\theta - 1)R \equiv y_d(\theta - 1), \tag{7}$$

which is higher than the profit in Equation (5) under rational expectations. The reason for higher profits is the greater volume of innovation. If instead investors' wealth is not so high, innovation can boost the supply of the riskless claim to the point that p_B and p_N fall below θR, so the equilibrium lies in the downward portion of investors' demand curve as in Figure 4.

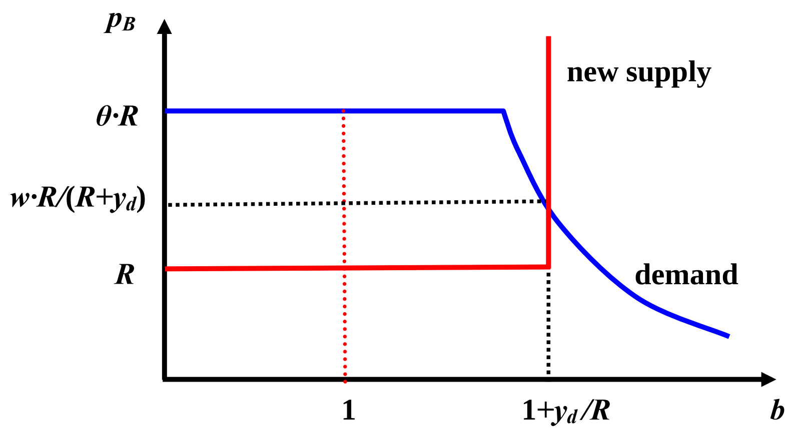

Figure 4

Here p_B may be so low that an intermediary's profit from innovation falls below the level in Equation (7).[8] If the price drops to $p_B = p_N = R$, intermediaries may be willing to supply fewer claims than f^L. A.2 simplifies the analysis by ruling out this case. In fact, $w > \underline{w}$ implies that, when f^L is issued, the equilibrium price $p_B = p_N = wR/(R + y_d)$ is above R.

[8] Under rational expectations this case could not occur by virtue of assumption A.2 which implies that investors' wealth is sufficiently large that they can absorb f^{RE} new claims at their reservation value $\theta \cdot R$.

Proposition 1 Under local thinking, the volume of innovation is $f^L = y_d / R$. We also have at t=0 that b=1+f^L, a=0, and p_A=E(y| y_g, y_d) − y_d. We have two cases: 1) If $\underline{w} < w < \theta(R + y_d)$, then $p_N = p_B = wR/(R + y_d) < \theta R$; 2) If $w \geq \theta(R + y_d)$, then $p_N = p_B = \theta \cdot R$.

When investors' wealth w is high relative to the supply of riskless claims, demand for new claims is high, and so is p_B. The reverse is true when investors' wealth is low relative to the amount of riskless claims issued. In this case, the boost in the supply of riskless assets triggered by innovation can reduce the price of all safe assets, including the traditional bond, below the no-innovation level. Note that that under local thinking the volume of new claims issued is higher (and the price p_B lower) than under rational expectations. This is so because locally-thinking intermediaries and investors see asset A as having a smaller downside risk than do their rational expectations counterparts. This encourages the supply of the new claim, which investors see as a riskless bond. The issuance "glut" created by local thinking has far-reaching implications for financial fragility.

As we show next, the intermediary's wealth at t = 1 also plays a key role in affecting fragility. To highlight this role, we allow the fraction σ of income carried by intermediaries to t = 1 to be anywhere in [0,1]. In this model σ is indeterminate, for the intermediary is indifferent between consuming the income obtained by selling claims at t = 0 or at t = 1.

3.2 Local Thinking Equilibrium and Innovation at *t* = 1

We just saw that local thinking boosts the volume of innovation relative to rational expectations. This profoundly alters the reaction of markets to the signal s at t = 1. These effects do not play out if the signal is good. In this case, representations do not change and the effect of news under local thinking is very similar to that under rational expectations. The price for riskless claims is unaffected by news because after observing $\bar{s}$ the new claim is still perceived to be riskless, while share prices rise to $p_A(\bar{s}) = E(y| y = y_g, y_d, \bar{s}) - y_d$.

When the signal is bad, matters are very different because now downside risk is represented as a recession with a payoff y_r rather than as a downturn with a payoff y_d. Investors now realize that the new claims are not riskless! This is so because the volume of new securities issued is $f^L = y_d / R$, so the total repayment promised to investors is equal to y_d, which exceeds the resources available in a recession. In a recession, intermediaries can repay to each holder of the new claim an amount equal to:

$$\frac{y_r}{y_d} \cdot R < R. \tag{8}$$

The large volume f^L of new securities issued under local thinking plays a critical role here. It is because f^L is large that in a recession the new securities become risky in the aggregate. The arrival of $s = \underline{s}$ reveals to investors that, contrary to their initial belief, the new claim is very different from the safe bond it sought to replicate, and drastically reduces their valuation of that claim. This is true even if the news is not very informative and investors realize that a recession is still quite unlikely (i.e., π_r is small), so that most of the times the new claim will in fact repay the promised amount R. The possibility of a recession destroys the very idea that made the new claim appealing to investors at $t = 0$, namely that it was just like a riskless bond. The new claims are not true substitutes for the traditional claims; they are false substitutes, severely affecting financial markets at $t = 1$.[9]

To see this, note that after seeing $\underline{s}$ investors' reservation price for the traditional bond is equal to $\theta \cdot R$ while that for the new claim drops to $\theta(y_r/y_d) \cdot R$, the present value of the latter claim's payout in a recession. In contrast, the intermediary's reservation price for traditional bonds is equal to R and that for the new claim is equal to:

[9] The new claim pays less than the traditional bond in y_r no matter what the $t = 1$ signal is, but investors recognize this at $t = 1$ if and only if the signal is $\underline{s}$, which is why markets are fragile only in that state.

$$\omega^L \cdot R \quad where \quad \omega^L \equiv \left[(y_r / y_d)\Pr^L(y_r|\underline{s}) + \Pr^L(y_g|\underline{s})\right]. \tag{9}$$

Risk neutral intermediaries value the new claim at their perceived expected repayment. Here $\omega^L < 1$ reflects the drop in the new claim's expected payout. Our analysis is general but our results are best appreciated in the case where $\underline{s}$ is barely informative about repayment even for a local thinker, namely $\omega^L \approx 1$ (once again, this requires π_r to be small).

These reservation prices lead to two important observations. First, after seeing $\underline{s}$ investors value the new claim less than the bond, creating a force toward the segmentation of the previously unified market for safe claims. Second, investors' reservation price for the new claim may fall below intermediaries' reservation price [this occurs when $\theta(y_r/y_d) < \omega^L$]. In this case, investors wish to sell the new claims back to intermediaries, who – depending on their wealth σ – may or may not have the money to buy them.

To see how prices are set at $t = 1$, we focus on the case where the price of safe claims at $t = 0$ is below $\theta \cdot R$ and where investors' valuation of the new claim at $t = 1$ falls below intermediaries' valuation, namely when $\theta(y_r/y_d) < \omega^L$. This captures a scenario where innovation: a) is so extensive as to affect the bond market at $t = 0$ and b) induces a misallocation of the new claim at $t = 1$. The latter condition is crucial for it is precisely when innovation transfers a claim to the low valuation market participant that a "false substitute" effect arises. Proposition 2 deals with the other cases also.

One immediate consequence of our previous discussion is that after observing $\underline{s}$ the price of traditional bonds *rises* from its initial level $p_B = wR/(R + y_d) < \theta \cdot R$ to investors' reservation level, namely $p_{B1} = \theta \cdot R$. This rise is connected to the drop in investors' valuation of the new securities. After realizing that the new claim is risky, investors try to sell it in the market to increase current consumption and to purchase the truly riskless bonds. This boost in the demand for bonds encounters a limited supply, which causes bond prices to rise. At the same time, the price of the new claim must drop, for the maximal valuation $\omega^L R$ of that claim in the market is lower than its $t = 0$ price. As a consequence, once investors realize that the new securities are false substitutes for the old ones, there is a "flight to safety" causing bond prices to rise and the price of the new claim to fall.

The extent of the new claim's price drop crucially depends on the wealth of the intermediaries. Suppose that the intermediaries carry little or no wealth to $t = 1$, so that they do not have the resources to buy all of the new claims, even when the latter are priced at investors' valuation $\theta \cdot (y_r/y_d) \cdot R$. Figure 5 depicts the resulting equilibrium at $t = 1$:

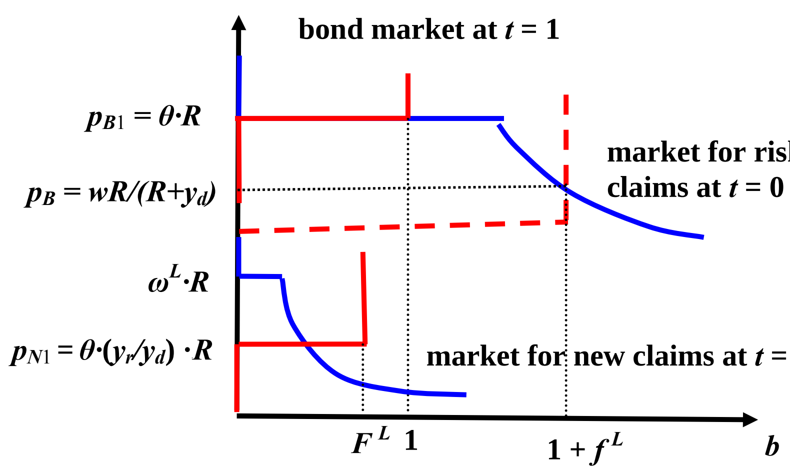

Figure 5

In equilibrium, the new claim's price drops to investors' valuation $\theta \cdot (y_r/y_d) \cdot R$ even though intermediaries are willing to buy it at a higher price. The problem is that intermediaries have little wealth and thus can absorb only some new claims. This low demand by intermediaries (the downward sloping curve in the bottom part of Figure 5) leads to a major price drop.

Intuitively, as the wealth σ of intermediaries increases, their demand also rises, potentially driving the equilibrium price of the new claim above $\theta \cdot (y_r/y_d) \cdot R$. In the extreme case of $\sigma = 1$, intermediaries carry all of their $t = 0$ income to $t = 1$ and thus have enough funds to buy all of the new claims at the *initial* equilibrium price p_B (after all, they obtained these resources by selling the new claims at $t = 0$). But then intermediaries can *a fortiori* afford to buy all of the new claims at their reservation price $\omega^L \cdot R$, which is below the initial price p_B. When σ = 1, the equilibrium price must thus settle at p_{N1} = $\omega^L \cdot R$ to make intermediaries willing to absorb precisely the amount of new claims held by investors.

This discussion allows us to decompose the drop in the new claim's price into two parts. The first is the difference between the initial price $p_B = wR/(R+y_d)$ and intermediaries' reservation price $\omega^L \cdot R$. This price drop represents the elimination of any premium paid for the new claim over and above its expected payoff. Investors initially paid this premium because they wrongly believed the new claim to be a substitute for the riskless bond in short supply. The second part is the drop from $\omega^L \cdot R$ to $\theta \cdot (y_r/y_d) \cdot R$. Even if the new claim is only mildly risky, it is not what investors wanted (given their infinite risk aversion). Thus, they dump it on the market. Since intermediaries cannot absorb this claim in large volumes given their limited wealth, its equilibrium price settles at investors' reservation price, which is below the expected payoff. Here over-issuance exacerbates fragility by boosting the supply of new claims that must be held by disgruntled investors (shifting out the upward sloping supply in the bottom part of Figure 5).

These broad patterns of market segmentation and financial fragility, as well as the role of intermediaries' wealth, extend to other parameter constellations.

Proposition 2 After news $\underline{s}$, the traditional bond trades at $p_{B1} = \theta \cdot R$, the price of the new claim drops to $p_{N1} < p_N$. there are two cases:

1. If $\omega^L \leq \theta \cdot (y_r / y_d)$ then $p_{N1} = \theta \cdot (y_r/y_d) \cdot R$ and new claims are not traded.
2. If $\omega^L > \theta \cdot (y_r / y_d)$ then $p_{N1} = p_{N1}(\sigma)$, where $p_{N1}(\sigma)$ is an increasing function with $p(0) = \theta(y_r / y_d)R$, $p(1) = \omega^L \cdot R$. When $\sigma > 0$ some new claims are re-traded. For a given σ, the price drop $(p_B - p_{N1})$: i) decreases (weakly) in y_r and ii) increases (weakly) in y_d if and only if $y_d < y_d^*$ for some threshold y_d^*.

It is a general feature of the model that the bond price at t=1 is equal to its maximum possible value $\theta \cdot R$. Bond prices thus rise at t=1 when their initial price p_B is below $\theta \cdot R$, as in case 1) of Proposition 1. The price of the new claim always falls below its t = 0 level. If $\theta(y_r/y_d) \geq \omega^L$, this price drops to investors' reservation level and no re-trading occurs. In this case, the intermediaries' wealth does not matter because they are the low valuation market participants. In the most interesting case where $\theta(y_r/y_d) < \omega^L$, intermediaries wish to buy back some new claims, thus helping to support their price. However, if their wealth σ is insufficient, they are unable to do so, creating a large price drop.[10,11] Given the key role of intermediaries' wealth in shaping price fluctuations, in sections 4 and 6 we pin down σ by introducing production and rational intermediaries, respectively.

Proposition 2 shows how, for a given σ, parameters y_r and y_d determine financial fragility, viewed as the drop in the new claim's prices after $\underline{s}$ is observed. A milder recession (a higher y_r) reduces fragility by rendering the new claim less risky, which raises the reservation prices of investors and intermediaries at t = 1. By boosting the supply of new claims at t = 0, a milder downturn (a higher y_d) exerts two opposite effects on fragility. On the one hand, the higher supply at t = 0 reduces the price of new claims at t = 1 by increasing the quantity that intermediaries must absorb and by rendering these claims more risky. These effects enhance fragility. On the other hand, higher supply of new claims at t = 0 reduces their equilibrium price at t = 0, which dampens fragility. In this way, financial innovation

[10] We have implicitly assumed that there is no innovation at t=1 after $\underline{s}$ is observed. In practice, investors (rather than intermediaries) may repackage new claims, keeping the safe portion $(y_r/y_d)R$ for themselves and selling off the risky portion to intermediaries. Such re-tranching might improve risk allocation in the economy but it would only marginally attenuate financial fragility when intermediaries' wealth is low. Indeed, low-wealth intermediaries would be able to pay very little for the risky portion of new claims, keeping their price low.

[11] One could consider innovations that, rather than replicating the bond's cash flow, supply Arrow-Debreu securities. If intermediaries supply two such securities, one paying 1 dollar if the state is y_g, the other if the state is not y_g (i.e. if the economy slows-down), investors could replicate the safe asset by purchasing an equal amount of them. This form of innovation also leads to over-issuance: all of the cash flow y_d available in a downturn is sold under the security paying out in the slowdown as local thinking investors and intermediaries identify such slowdown with cash flow y_d, not y_r. As the economy's slowdown is revised downward to y_r, however, this security cannot be repaid in full and its price drops. The only difference with our current setup is that Arrow-Debreu claims automatically allow investors to implement the outcome attained under retranching by selling the securities that pay out in y_g until the investor's portfolio pays the same in all future states.

creates an inverted-U shaped relationship between fragility and agents' optimism (as measured by y_d). When agents are very optimistic, the supply of new assets expands, reducing these assets' prices today as well as the price decline after $\underline{s}$ is observed.

Having explored the fragility of the new claim, we turn to the impact of innovation and the neglect of risks on aggregate financial markets. We measure financial activity by the market value $p_B \cdot b + p_N \cdot f + p_A \cdot a$ of all claims, which depends on whether or not innovation occurs and on market participants' information. Let $V_z^{I,L}$ denote the market value obtained under innovation and local thinking (as denoted by the superscript I,L). Index z captures market participants' information, and takes a value in $\{0, \bar{s}, \underline{s}\}$, where $z = 0$ denotes the information at $t = 0$, $z = \underline{s}$ the information at $t = 1$ after a bad signal is realized, and $z = \bar{s}$ the information at $t = 1$ after a good signal. Let V_z^L denote the market value of claims prevailing under no innovation with information z. Let $V_z^{I,RE}$ and V_z^{RE} denote the corresponding values under rational expectations. Focusing for simplicity on the case where $\sigma = 0$ we show:

Corollary 1 If $\theta(y_r/y_d) < \omega^L$, innovation boosts market volatility under local thinking but not under rational expectations. Formally, we have that $\left|V_0^{I,L} - V_z^{I,L}\right| \geq \left|V_0^L - V_z^L\right|$ while $\left|V_0^{I,RE} - V_i^{I,RE}\right| = \left|V_0^{RE} - V_z^{RE}\right|$ for $z = \underline{s}, \bar{s}$.

The *combination* of local thinking and financial innovation amplifies the market's response to news. Without innovation, market fluctuations are entirely due to changes in the price of claims that everyone understands are risky (the magnitude of such fluctuations depends on whether agents are rational or not). When expectations are rational, this remains true under innovation as well, since the risky claim still bears all of the fundamental risk. Matters are very different under local thinking. To see this, consider Figure 6, which is drawn for $w > \theta(\mathrm{R}+y_d)$ [i.e. Case 2) of Proposition 1]:

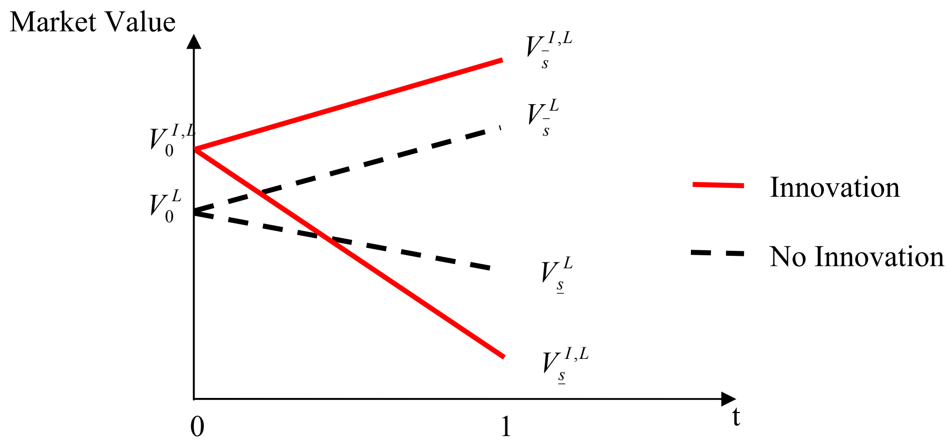

Figure 6

As the upper branches in the figure show, in good times (i.e., at t = 0 and in state $\bar{s}$) financial innovation allows intermediaries to expand financial assets by manufacturing new, apparently safe claims that risk averse investors are eager to buy. When bad news arrives and the neglected risk becomes manifest, this innovation entails extreme fragility. Although the revelation of neglected risks also causes the market to drop in the absence of innovation, the price drop is much larger with innovation because the neglected risk has now been loaded more heavily onto investors through their holdings of new, supposedly safe, claims. Since investors are inefficient risk bearers and intermediaries have limited wealth, the market collapses. In sum, when some risks are neglected, financial innovation enhances the volatility of financial markets. This is again due to the "false substitutes" effect, which entails a market boom in good times and a market collapse after bad news arrives.

3.3 Innovation, Local Thinking and Financial Fragility: Discussion

Our model places the demand for new claims at the heart of the link between financial innovation and fragility. Investors' initial excess demand for safe claims encourages intermediaries to manufacture new claims out of risky cash flows that are perceived to be equally safe. As investors realize that the new claims are a false substitute for the old ones, their reluctance to hold on to these claims triggers a sharp price drop even after marginally bad news. These marked shifts in the demand for the new safe claims are intimately connected to financial innovation.

The pressure to create new safe claims is strong precisely when investors disregard specific risks such as a possible collapse of home prices in light of favourable recent history. This optimism boosts intermediaries' ability to sell new claims and thus their incentive to innovate. The issuance glut renders the new claim vulnerable to the arrival of bad news that bring to mind previously neglected risks and thus the critical fact that the new claims are not as safe as the assets they sought to replicate. Because of their preferred habitats, investors try to rebalance their portfolios in favour of the truly safe traditional claims, triggering massive sales of the new claims and price drops. Such sales are not driven by leverage or liquidation demands, as in standard fire sales models, but by the fall in demand that arises as investors realize that these new securities are false substitutes for the old ones.

The general message of our model is that when investors neglect certain risks, financial innovation creates a false substitutability between the new and traditional claims. This false substitutability explains both the excessive volume of innovation ex-ante and the ex-post flight to quality occurring as investors come to realize that the new claim exposes them to previously unattended to risks. Although the motives for financial innovation are the same in our model as in Allen and Gale (1994), the consequences are very different. In our model, innovation benefits intermediaries who earn large profits selling securities at $t = 0$, but hurts investors, who are lured into an inefficient risk allocation and suffer from ex-post price drops. Investors' losses depend on the liquidity of intermediaries and their ability to provide backstop insurance against price drops at $t = 1$. As we show in Section 5, in an economy with production both investors and intermediaries might lose from innovation.

4. Innovation and Local Thinking in a Production Economy

Suppose that instead of owning assets, the intermediaries have exclusive access to production technologies (or activities) *B* and *A*. Activity *B* yields *R* at $t = 2$ for any unit invested at $t = 0$. The return of activity *A* is stochastic, equal to y_i with probability π_i, where as before $i = g, d, r$. The riskless activity is in limited supply, in the sense that investment I_B in activity *B* cannot exceed 1. Investment I_A in activity *A* is in principle unbounded.

The intermediary has initial wealth $w_{\text{int}} < 1$ but can raise additional funds from investors by selling claims on *A* and *B*. The traditional claim to finance *B* is a riskless bond priced at p_B at $t = 0$ and yields R at $t = 2$; the traditional claim to finance *A* has a unit cost p_A and yields y_i at $t = 2$. The difference from the pure exchange economy of Sections 2 and 3 is that now the supply of claims must be consistent with the intermediary's optimal investment decisions. For brevity, we study this production economy only under local thinking, but we later discuss the role of limited representations. In the absence of innovation, the intermediary chooses investment levels I_B and I_A, and issues volumes *b* and *a* of traditional claims to solve:

$$\max_{b,a,I_A,I_B,i_A,i_B} \quad \Pi \equiv R(I_B - b) + E^L y(I_A - a) - I_B - I_A + bp_B + ap_A + w_{int} \tag{10}$$

$$\text{s.t.} \quad I_B = bp_B + i_B, \tag{11}$$

$$I_A = ap_A + i_A, \tag{12}$$

$$i_B + i_A \leq w_{int}, \tag{13}$$

$$b \leq I_B \leq 1, \quad a \leq I_A. \tag{14}$$

In Equation (10), the intermediary's payoff is equal to the output generated by *A* and *B* net of investors' repayment, minus investment costs, plus the revenue from security sales at $t = 0$. Constraints (11) and (12) say that investment in *A* or *B* is equal to the intermediary's own investment in the activity (i_A, i_B) plus the funds raised from investors. Constraint (13) says that the intermediary's own investments cannot exceed his wealth w_{int}; the constraints in (14) limit total investment and the supply of claims.

By substituting Equations (11) and (12) into the objective function (10) and in the constraints in (14) we can rewrite the intermediary's problem as:

$$\max_{b,a,i_A,i_B} \Pi \equiv R[(p_B - 1)b + i_B] + \mathrm{E}^{\mathrm{L}}y[(p_A - 1)a + i_A] - i_A - i_B + w_{int} \tag{15}$$

$$\text{s.t.} \qquad i_B + i_A \leq w_{int}, \tag{16}$$

$$-(p_B - 1)b \leq i_B \leq 1 - p_B b, \quad -(p_A - 1)a \leq i_A \,. \tag{17}$$

The objective function (15) shows that the intermediary is willing to issue a claim only if its price is higher than 1. In this case, the revenue generated by each unit of security issued is higher than the investment cost of creating the promised return. We assume:

A.4: $\theta \cdot y_d < 1$ and $w > w^* = \theta \cdot \left[R + y_d(w_{\text{int}} - 1)\right]/(1 - \theta \cdot y_d)$

The first part of A.4 says that investors' reservation price for the risky claim is less than one, which implies that in equilibrium $p_{\mathrm{A}} < 1$ and thus the risky claim is not issued ($a = 0$). The second part of A.4 says that the investors' wealth is sufficiently high that, even with innovation, the price of riskless claims is $p_B = \theta \cdot R$. This restriction, which is stronger than the one in A.2, simplifies the equilibrium analysis but can be relaxed. Under A.4 it is immediate to see that the equilibrium at $t = 0$ works as follows:

Lemma 3 In the absence of innovation, no risky claim is issued ($a = 0$) and $p_{\mathrm{A}} \leq 1$. The bond is issued for an amount $b = 1$ and $p_B = \theta \cdot R$. The intermediary withdraws profits from the sale of b from activity B by setting $i_B = -(\theta \cdot R - 1)$. If $\mathrm{E}^{\mathrm{L}}y \geq 1$ the intermediary invests these resources in A by setting $i_A = w_{int} + \theta \cdot R - 1$, and $p_{\mathrm{A}} = 1$. If $\mathrm{E}^{\mathrm{L}}y < 1$ the intermediary sets $i_A = 0$, consumes $w_{int} + \theta \cdot R - 1$ before $t = 2$, and $\mathrm{E}^{\mathrm{L}}y \leq p_{\mathrm{A}} < 1$.

The main features of the pure exchange equilibrium of Lemma 1 also obtain in the production economy. There is a shortage of riskless bonds, and their entire supply is sold to investors at their reservation price. No risky claims are issued. The only difference from the pure exchange economy is that now the risky activity is only operated if its expected return is higher than the cost of investment (i.e., $E^{L}y \geq 1$).

4.1 Innovation, Equilibrium and Reaction to News

As in Section 3, the intermediary creates new riskless claims by pledging the lowest possible output level generated by A. The maximum quantity of new claims that can be created in this way is equal to:

$$f^{LP} = y_d \cdot \mathrm{I}_A/R. \tag{18}$$

The ability to create new claims increases in the amount of investment in activity A. Taking this effect into account, with innovation the intermediary solves:

$$\max_{b,f,i_A,i_B} \Pi \equiv R[(p_B - 1)b + i_B] + (p_B E^L y - R)\cdot f + E^L y\, i_A + w_{int} - i_B - i_A \tag{19}$$

$$\text{s.t.} \qquad i_B + i_A \leq w_{int}, \tag{20}$$

$$f \leq f^{LP} = i_A\, [y_d / (R - p_B\, y_d)], \tag{21}$$

$$-(p_B - 1)b \leq i_B \leq 1 - p_B\, b, \quad 0 \leq i_A. \tag{22}$$

Constraint (21) directly follows from substituting into (18) the definition of investment $\mathrm{I_A} = fp_B + i_A$, where we have once more imposed $p_B = p_N$. One important implication of (21) is that new claims can only be issued if the intermediary invests some of his wealth in A by setting $i_A > 0$. This is due to assumption A.4, which implies that y_d is sufficiently small that the intermediary must insure investors against the bad state by committing some of its wealth to the project. We also assume:

A.5 $\theta \cdot E^L y > 1$.

A.5 implies that, in order to maximize objective (19) at $p_B = \theta \cdot R$, the intermediary always wants to issue the maximum possible volume of new bonds f^{LP} because the price the intermediary obtains for these bonds is higher than the ratio between the promised return R and *A*'s average return $E^L y$. We then have:

Proposition 3 Under A.4 and A.5, there are two possible equilibrium configurations:

1) If $E^L y + (\theta - 1) \cdot y_d < 1$, innovation does not occur and the equilibrium described in Lemma 3 arises.

2) If $E^L y + (\theta - 1) \cdot y_d > 1$, innovation occurs. The price of riskless claims is $p_B = \theta \cdot R$, the intermediary sets $I_B = b = 1$ and $i_B = -(\theta \cdot R - 1)$. This allows the intermediary to set $i_A = w_{\text{int}} + \theta \cdot R - 1$, and to sell the new security in volume $f^{LP} = [w_{\text{int}} + \theta \cdot R - 1]\ [y_d / R\ (1 - \theta \cdot y_d)]$.

Compared to Proposition 1, here a cost of financial innovation arises endogenously when the physical return to capital in *A* is lower than the investment cost, i.e. $E^L y < 1$. In this case, creating new securities requires the intermediary to invest in the risky technology, which entails a private cost. If however the unit profit $(\theta - 1) \cdot y_d$ obtained by the intermediary from each new "riskless" claim is large enough to more than compensate for the cost [formally if $E^L y + (\theta - 1) \cdot y_d > 1$], then innovation takes place. As we shall see, through this effect financial innovation can be a source of investment inefficiencies because at $t = 0$ the intermediary may decide to invest in *A* and sell new claims even when he would not invest absent the possibility of financial innovation.

The second message of Proposition 3 is that when the creation of new claims requires investment, an intermediary's desire to create new claims introduces a strong force for it to commit all of his initial wealth and income to investment so as to expand the volume of innovation. As a consequence, when at $t = 1$ bad news arrives, the intermediary does not have spare wealth to buy any of the new claims back. The result below formally shows the consequences of this logic:

Proposition 4 In the equilibrium with innovation of Proposition 3, after the arrival of a bad signal $s = \underline{s}$ at $t = 1$, the price of the traditional bond stays constant at $p_{B1} = \theta \cdot R$, while the price of the new claim drops to $p_{N1} = \theta \cdot (y_r / y_d) \cdot R$ and new claims are not traded at $t = 1$.

The key difference from the result obtained in the pure exchange economy is that now the equilibrium price of the new claim drops to investors' valuation regardless of whether the intermediary's reservation price $\omega^L \cdot R$ for the same claim is higher than $\theta \cdot (y_r / y_d) \cdot R$. Intermediaries have no spare wealth to buy back the new claims at $t = 1$ because they have optimally invested the totality of their $t = 0$ resources to boost the volume of innovation. As a consequence, the local thinker's neglect of the possibility of a recession leads to substantial price drops even when intermediaries barely react to news. The idea that intermediaries tie up their capital in innovation, and have no spare liquidity in a crisis, is also present in Shleifer and Vishny (2010). In that model, intermediaries had to co-invest with outsiders to keep some "skin in the game." Here the mechanism is different: profit maximizing intermediaries need to commit their capital at $t = 0$ to provide insurance to investors, but doing so deprives them of liquidity in a crisis.

This analysis reinforces the message of the exchange model with respect to the role played by the shifting demand for new securities in generating financial fragility. The issuance "glut" fostered by investors' demand for riskless claims creates the room for severe price drops not only by inducing investors to recognize the claim as risky upon the arrival of bad news, but also by reducing the liquidity of intermediaries and thus their ability to support the new claim's price. The initial boost in the issuance of the new securities, and their ex-post price decline, are just two sides of the same coin.

5. Welfare Analysis

Section 2 showed that under rational expectations financial innovation is socially beneficial: it boosts intermediaries' profits while leaving investors' welfare unchanged.[12] With local thinking, the welfare analysis is more complex. From the viewpoint of agents' beliefs at t=0, financial innovation is beneficial, just as under rational expectations. However, since agents' initial beliefs are incorrect, this welfare level is illusory because it does not account for the riskiness of new claims. Behavioural economists have long stressed that this tension between reality and incorrect beliefs raises important conceptual issues for defining a normative welfare metric. We do not aim to resolve these issues in this section.

Instead we consider how the "false substitute" effect created by financial innovation affects the average payoff realized by market participants, computed using the true distribution of states (and signals) as of t=0. For brevity, we focus on the most interesting case where $\omega^L > \theta \cdot (y_r / y_d)$. We also assume that in the exchange economy the new claim receives its maximal price $p_B = \theta \cdot R$ at $t = 0$, which facilitates the comparison between exchange and production, as in the latter case it is also true that $p_B = \theta \cdot R$.

5.1 Welfare in the Pure Exchange Model

Without financial innovation, the average welfare of investors as of $t = 0$ is trivially equal to E(U) = w, while that of intermediaries to E(Π) = $\theta \cdot R + E(y)$, where U and Π denote the utility of the investor and intermediary, respectively. To gauge the effect of financial innovation, suppose for a moment that there is no trading at $t = 1$. Then the expected welfare of investors as of $t = 0$ is equal to $E(U_{inn}) = w - \theta \cdot (y_d - y_r)$, that of intermediaries is equal to $E(\Pi_{inn}) = \theta \cdot R\ (1 + f^L) + E(y) - (\pi_g + \pi_d) y_d - \pi_r y_r$. Relative to the no innovation case, investors

[12] In the model of Section 2 intermediaries obtain the full benefit of innovation because assumption A.2 ensures that investors buy the new claim at their reservation price. If A.2 does not hold, the price of the new claim drops below $\theta \cdot R$, investors also benefit from innovation, and the creation of the new claim makes everybody better off.

lose because they bear the risk of a recession and intermediaries gain because they sell more overpriced safe claims at $t = 0$. Of course, the possibility of trading at t = 1 allows investors to undo at least in part their original portfolio and thus to reduce their losses under innovation.

Lemma 4 With financial innovation, if $\sigma = 0$ investors lose $\theta \cdot (y_d - y_r)$ and intermediaries gain $\theta \cdot y_d - (\pi_g + \pi_d) y_d - \pi_r y_r$ relative to the no innovation case. If instead $\sigma = 1$, investors lose $\Pr(\bar{s})\theta \cdot (y_d - y_r) + \Pr(\underline{s})(\theta - \omega^L) y_d$ and intermediaries gain $\Pr(\bar{s})\{\theta \cdot y_d - [\pi_g(\bar{s}) + \pi_d(\bar{s})] y_d - \pi_r(\bar{s}) y_r\} + \Pr(\underline{s})(\theta - \omega^L) y_d$ relative to the no innovation case.

Innovation benefits the intermediary by allowing it to sell more claims while it hurts investors by enabling them to buy a claim that is more risky than they think. If intermediaries do not carry wealth to $t = 1$ then – given that $\omega^L > \theta \cdot (y_r / y_d)$ – the loss to investors is larger than intermediaries' gain because investors inefficiently bear risk in equilibrium.[13] If in contrast intermediaries carry wealth to $t = 1$ there is a net loss from innovation after $\bar{s}$ but there is no "net loss" after $\underline{s}$: by buying back the new claims, intermediaries allow investors to increase current consumption, preventing them from bearing any future risk.

This analysis illustrates that, besides creating market fragility, false substitutability adds a countervailing cost to the standard "market completing" benefit of financial innovation. Here the cost of innovation always dominates its benefits due to investors' infinite risk aversion, but with more moderate preferences the net effect would be ambiguous.

5.2 Welfare in the Model with Production

One key change in the production model is that because the intermediary does not carry any wealth to $t = 1$, there is no trading at $t = 1$. With innovation, the welfare of

[13]This follows from the fact that $(\pi_g + \pi_d) y_d + \pi_r y_r > \theta \cdot y_r$ if and only if $(\pi_g + \pi_d) + \pi_r(y_r/y_d) > \theta \cdot (y_r/y_d)$, which always holds if $\omega^L > \theta \cdot (y_r/y_d)$ because $(\pi_g + \pi_d) + \pi_r(y_r/y_d) > [\pi_g(\underline{s}) + \pi_d(\underline{s})] + \pi_r(\underline{s})(y_r/y_d) > \omega^L > \theta \cdot (y_r/y_d)$.

investors as of $t = 0$ is equal to $\mathrm{E}(\mathrm{U}_{\mathrm{inn}}) = w - \theta{\cdot}R{\cdot} f^{LP}\,[1 - (y_r/y_d)]$, where $f^{LP} = [w_{\mathrm{int}} + \theta{\cdot}R - 1]\,[y_d\,/\,R\,(1 - \theta{\cdot}y_d)]$ is the volume of innovation occurring with production. Since the intermediary invests all of its wealth in A, it carries no wealth to $t = 1$. As a consequence, in the spirit of Lemma 4, investors lose $f^{LP}\theta{\cdot}R\,[1 - (y_r/y_d)]$ from innovation.

Consider now the intermediary's welfare in the production model. Now innovation and local thinking may induce the intermediary to undertake unprofitable investments.

Proposition 5 When $E^L y + (\theta - 1)y_d > 1$, the intermediary innovates and two cases arise:

1) If $E^L y < 1$, the intermediary gains in the case of innovation if and only if:

$$\mathrm{E}(y) + \{\theta - [(\pi_g + \pi_d) + \pi_r(y_r/y_d)]\}\cdot y_d > 1. \tag{23}$$

2) If $E^L y \geq 1$, the intermediary gains in the case of innovation if and only if:

$$\theta\,\mathrm{E}(y) > [(\pi_g + \pi_d) + \pi_r(y_r/y_d)]. \tag{24}$$

In the model with production, not only investors, but also intermediaries might lose from financial innovation. As Equations (23) and (24) illustrate, intermediaries may lose from innovation when the true expected return from activity A is sufficiently low that manufacturing new claims is not profitable to begin with (not even by taking into account the fact that these claims do not repay in full in a recession). Formally, this means that $\mathrm{E}(y)$ must be sufficiently lower than 1. In this case, optimism about the profitability of the new claim at $t = 0$ encourages the intermediary to over-invest in an unproductive activity, eventually triggering a loss. The most interesting case in this respect occurs when $E^L y < 1$. Now the return to A is perceived to be sufficiently low that investment in A occurs only if new securities can be engineered, so financial innovation bears sole responsibility for unproductive investment. The expansion in the supply of housing in the decade prior to 2007 might have been an example of such inefficient investment needed to meet the growing demand for securitization of mortgages (Mian and Sufi 2009, Keys et al. 2010).

In sum, while under rational expectations financial innovation improves social welfare by reducing the shortage of riskless claims, under local thinking it can reduce both investors' and even intermediaries' welfare by distorting the allocation of risk and investment in the economy.

6. Rational Intermediaries

We have assumed so far that intermediaries and investors share the same incorrect beliefs. We now show that the "false substitutes" effect holds even if the intermediaries hold rational expectations. Rationality of the intermediaries introduces two changes into our previous setting. First, the intermediaries evaluate returns correctly, which influences their investment and issuance decisions. Second, intermediaries may try to profit from the possible drop in prices of the new securities by carrying some liquid wealth to $t = 1$. This second effect (emphasized by Diamond and Rajan 2010) may offset an intermediary's incentive to commit its wealth to the risky project so as to expand the supply of new claims.

When deciding at $t = 0$ what volume f of new securities to issue, what amount of own wealth i_A to invest in A, and what amount of own wealth l to leave liquid for $t = 1$, a forward looking intermediary solves:

$$\max_{b,a,i_A,i_B} \quad \Pi \equiv R[(p_B - 1)b + i_B] + [p_B Ey - (1-\pi_r)R - \pi_r(y_r/y_d)R]\cdot f + Ey\, i_A +$$

$$+ w_{int} - i_B - i_A + l\cdot \Pr(\underline{s})(\omega^{rational} \cdot R - p_{N1})/ p_{N1} \tag{25}$$

$$\text{s.t.} \qquad i_B + i_A + l \le w_{int}, \tag{26}$$

$$f \le i_A\, [y_d / (R - p_B\, y_d)], \tag{27}$$

$$-(p_B - 1)b \le i_B \le 1 - p_B\, b, \quad 0 \le i_A,\ 0 \le l \tag{28}$$

In the above program, $\omega^{rational}$ denotes the new claim's repayment expected by the rational intermediary [formally, $\omega^{rational} \equiv \Pr(y \ge y_d | \underline{s}) + \Pr(y_r | \underline{s})(y_r / y_d)$], which is always higher than the repayment expected by a local thinker [i.e. $\omega^{rational} > \omega^{L}$ for all $\pi_r > 0$]. The rational intermediary anticipates, in the second term of the objective function in (25), the possibility that in a recession the new claim pays only $(y_r/y_d)R$. Additionally, the last term in Equation (25) illustrates that the intermediary expects to obtain a capital gain of $(\omega^{rational} \cdot R - p_{N1})/p_{N1}$ by leaving some liquid wealth l for the event that the signal turns out to be low, which occurs with ex ante probability $\Pr(\underline{s})$.[14]

As in Section 4, under A.5 the intermediary issues – for a given amount of capital i_A committed to A – the maximum possible amount of new claims at $t = 0$, implying that constraint (27) is binding. Since the equilibrium price of riskless claims at $t = 0$ is still equal to $p_B = \theta \cdot R$, the intermediary invests up to capacity in B and sets $i_B = -(\theta \cdot R - 1)$. The new choice that the rational intermediary must make is whether to invest his wealth $w_{\text{int}} + \theta \cdot R - 1$ into A so as to expand the supply of new claims at $t = 0$ or to store liquidity until $t = 1$ by setting $l > 0$. From objective (25) and constraint (27), it is easy to check that at the equilibrium price $p_B = \theta \cdot R$ the return the intermediary obtains from increasing i_A is higher than that from increasing l, so that it is optimal for the intermediary to set $l = 0$, provided:

$$[\theta\, Ey - (1 - \pi_r) - \pi_r(y_r/y_d)]\ \frac{y_d}{1 - \theta y_d} + Ey > \Pr(\underline{s})\left(\frac{\omega^{rational} \cdot R - p_{N1}}{p_{N1}}\right), \qquad (29)$$

which can be rewritten as:

$$\frac{\pi_g (y_g - y_d)}{1 - \theta y_d} > \Pr(\underline{s}) \cdot \left(\frac{\omega^{rational} \cdot R - p_{N1}}{p_{N1}}\right). \qquad (30)$$

Even a rational intermediary invests all of its wealth in A when each unit invested in the risky project generates a sufficiently large upside (which the intermediary keeps for himself). The return from investing \$1 in A is multiplied by the factor $1/(1 - \theta y_d)$, which

[14] One implicit restriction in the above problem is that at $t = 1$ the intermediary cannot issue deposits to investors to buy the new claims. However, when the intermediary's own liquidity at $t = 1$ is zero, the infinitely risk averse investors are not wiling to lend more that their own valuation of these claims, which undermines the intermediary's ability to support the price of the new claim by borrowing ex-post.

captures the intermediary's ability to profit by creating new claims from such investment, realize a profit on them, to reinvest that profit in A to create more new claims and so on.

Condition (30) is hardest to satisfy when the probability that the new claim defaults is negligible (in the extreme when $\omega^{rational} = 1$) and the price of the new claim at t = 1 is the lowest, namely when $p_{N1} = \theta \cdot (y_r/y_d) \cdot R$. In this case, the rational intermediary invests all of its wealth in A at t = 0 provided:

$$\frac{\pi_g (y_g - y_d)}{1-\theta y_d} > \Pr(\underline{s}) \cdot \left(\frac{y_d - \theta y_r}{\theta y_r} \right), \tag{31}$$

which is satisfied for a broad range of parameter values. If Condition (31) does not hold, then the intermediary restricts the supply of new claims up to the point where the capital gain on the new claims is sufficiently small to use some but not all of his wealth to innovate, and to transfer the rest to t = 1.

7. Discussion

We have proposed a new approach to modeling financial markets, one that emphasizes the central role of the neglect of low probability risks in accounting for the nature of financial innovation and financial fragility. We have motivated the model using several examples in which the neglect of risks appears important, including the recent financial crisis. In conclusion, it might be useful to return to the crisis, and to explain some of the ways in which our model offers a novel perspective on the events.

We would argue that both the sharp decline in home prices and the sensitivity of the prices of some AAA-rated MBS to home prices and mortgage defaults came as a substantial surprise to the market in the summer of 2007. Indeed, one can date the beginning of the financial crisis to July-August 2007, when the markets first recognized these risks. During this short period, Bear Stearns liquidated two hedge funds investing in mortgage-backed securities, the French bank BNP-Paribas halted redemptions in three investment funds supposedly investing in AAA-rated assets, and the LIBOR-OIS spread exploded. Interestingly, bad news from the housing market and increases in risk premia on the risky (as opposed to AAA) tranches on MBS all arrived months before, with no noticeable market disruptions. It is only the realization that the debt which investors perceived to be completely safe was actually risky that created extreme fragility.

The sudden realization that AAA-rated securities were risky contributed to the freeze of the asset based commercial paper (ABCP) market in the summer of 2007. In our model, ABCP can be viewed as a loan collateralized by the senior tranch of the risky asset's cash flow. When this senior tranch is revealed to be more risky than originally thought, highly risk averse investors are no longer willing to hold the ABCP. If the clientele for ABCP consists largely of such highly risk averse investors, prices and issuance volume would fall substantially as these investors withdraw from the market.

We find it difficult to account for the crisis without incorporating the idea of a substantial surprise. The leading alternative explanation of the events holds that financial institutions speculated in AAA-rated securities using short term finance such as repo because they counted on a government bailout (Acharya et al. 2010, Gorton and Metrick 2010). The main argument in favor of this explanation is that banks and dealer banks themselves held enormous positions in these securities and sustained huge losses, leading to eventual bailouts. Since we believe that the banks have themselves neglected the risks of AAA-rated MBS and CDO's, we do not find their large exposure to these securities, for inventory reasons, as skin in the game, or even as a speculative "carry trade", to be inconsistent with our fundamental perspective. We would also question the view that the banks were aware of the risks, and just gambling on a bailout. After all, prior to the events of the summer of 2007, financial markets universally perceived AAA-rated MBS and CDO's to be safe, the banks' credit default swaps traded as if banks were totally safe, and banks provided repo financing to hedge funds using MBS as collateral with very low haircuts. We would argue that both the banks and the investors neglected the risks and were shocked by what happened: precisely the assumption we explore in this paper.

An alternative view of the crisis sees it as a perfectly well considered, but extremely rare event, a "perfect storm." Investors correctly considered the extremely low probability of a crisis, and priced securities accordingly, but this very low likelihood event nonetheless materialized. This view is inconsistent with the evidence we cited earlier that investors actually used the wrong models, not correct models with low probability extreme events (Jarrow et al 2007, Coval et al. 2009). It is also inconsistent with the evidence that financial crises in which investors accept too much risk without realizing that they are doing so are quite common. We have already discussed the episodes with CMO's and money market funds in the introduction; Reinhart and Rogoff (2009) enumerate multiple recent episodes of banking panics originating in excessive risk taking and leverage. A recent study by Greenwood and Hanson (2010) similarly shows that periods of expanding leverage are accompanied by a deterioration in the quality of borrowers, and are followed, on average, by negative returns on debt. The common thread in these studies is the neglect of risks, not the occurrence of low probability events.

Our paper offers a distinct normative perspective on the recent financial crisis as well, which may bear on some emerging policy proposals. Several economists, including Gorton and Metrick (2010) and Stein (2010) recognize the creation of safe securities, particularly short term ones, as an important function of the shadow banking system. In their view, the creation of such "private money" is in itself desirable, but exposes the financial system to the risks of financial meltdown due to socially excessive leverage. Desirable policies would thus seek to preserve the creation of liquidity by the banking system, but control leverage or improve mechanisms of reducing leverage and unwinding security holdings in distress.

Our model, then, is in agreement with the widely accepted prescription that greater capital and liquidity of financial intermediaries would lead to more stable markets (French et al. 2010). However, our model goes further by questioning the idea that all creation of private money by the banking system is necessarily desirable. We recognize the benefits of private supply of safe securities, but also note that, at least in some cases, such securities owe their very existence to neglected risks, and have proved to be false substitutes for the traditional ones. False substitutes by themselves lead to financial instability, and may reduce welfare, even without the effects of excessive leverage.

The financial fragility discussed in our model would interact, perhaps dangerously, with leverage. When investors or intermediaries perceive some securities to be safe, they would borrow using them as collateral, often with very low haircuts (Shleifer and Vishny 2010, Stein 2010). The realization that these securities are actually risky would lead to their sales by both investors and intermediaries trying to meet their collateral requirements, leading to additional fragility from fire sales. The stronger is the ex ante belief that securities are safe, the higher is the borrowing against them, and the more extreme the fire sales. Sales from unwinding levered positions and sales from disappointed expectations thus go in the same direction. As discussed by Shleifer and Vishny (2010) and Stein (2010), depressed security prices can have especially adverse welfare consequences ex post because they cut off lending to new investment. A financial crisis leads to an economic crisis. We do not discuss these welfare issues here because they have been analyzed elsewhere, but only emphasize the reinforcing influence of leverage and misunderstood risks on fragility.

If this perspective is correct, it suggests that recent policy proposals, while desirable in terms of their intent to control leverage and fire sales, do not go far enough. It is not just the leverage, but the scale of financial innovation and of creation of new claims itself, that might require regulatory attention. Such attention might be especially warranted when investors buy securities through an intermediary who makes either an explicit or an implicit guarantee backing them. Regulators may wish to require that intermediaries hold enough capital to make good on those guarantees or else refrain from making them. This might be a particularly significant issue when the safety of either securities or intermediaries is illusory.

For example, the innovation of prime money market funds has arguably created much instability by giving millions of investors the expectation of getting their money back on demand at par, even though it is invested in securities that are far from riskless. Our model suggests that it might be better to help investors form more realistic expectations by mandating that these funds be marked to market. With more realistic expectations of net asset value fluctuations, "breaking the buck" would no longer be a dramatic event that sparks a run on these funds and creates financial fragility.

8. Proofs

Proof of Lemma 1. The proof is straightforward but illustrates the basic logic behind several of our results. Given that $Ey > \theta \cdot y_d$, there exists no price $p_A \geq Ey$ at which intermediaries are willing to sell that also induces investors to buy. As a result, $p_A = Ey$ and each intermediary is happy to hold its endowment of shares, i.e. $a = 0$. If $p_B < \theta \cdot R$, investors demand more than 1 unit of bonds [because by A2 $w/\theta R > 1$] and – provided $p_B \geq R$ – intermediaries are willing to sell the full supply $b = 1$. As a result, in equilibrium it must be that $p_B = \theta \cdot R$ so that is optimal for investors to buy exactly $b = 1$.

Proof of Lemma 2. The result directly follows from the proof of lemma 1, with only two changes. First, the supply of bonds is now equal to $b = 1 + y_r/R$, but A2 implies that investors can absorb all of it at their reservation price, so in equilibrium $p_B = \theta \cdot R$. Second, $p_A = Ey\text{-}y_d$ and none of the risky claims are sold to investors (who value them zero).

Proof of Proposition 1. The result directly follows from the proof of lemma 1, with the only changes of replacing y_r with y_d. Since the supply of bonds is now $b = 1 + y_d/R$, if investors can absorb it at their reservation price, namely if $w/(\theta \cdot R) \geq 1 + y_d/R$, in equilibrium $p_B = \theta \cdot R$. If this is not the case, i.e. if $w < \theta \cdot (R + y_d)$, then investors spend all of their wealth to purchase the bonds and $p_B = wR/(R+y_d) > R$.

Proof of Proposition 2. Consider the market's reaction to a bad signal $\underline{s}$. To begin, note that the $t = 1$ equilibrium must have $p_{B1} = \theta \cdot R$. To see why, suppose that $p_{B1} < \theta \cdot R$ (as we have seen, $p_{B1} > \theta \cdot R$ is not an equilibrium because at this price investors sell their bonds but intermediaries are not willing to buy them). At this price, investors want to purchase as many bonds as possible provided $p_{N1} > (y_r /y_d)\ p_{B1}$. This cannot be an equilibrium because investors' demand for bonds does not encounter any supply. Consider instead the case where $p_{N1} \leq (y_r /y_d)\ p_{B1}$. Now the new claim is priced below investors' valuation $p_{N1} < (y_r /y_d)\theta \cdot R$. This cannot however be an equilibrium because all investors demand the new claim (or some of the bond as well) but nobody supplies it. As a result, it must be that $p_{B1} = \theta \cdot R$.

Consider now the market for the new claim. Given that $p_{B1} = \theta \cdot R$, if $p_{N1} < (y_r /y_d)\theta \cdot R$ all investors would demand the new claim at $t = 1$, which cannot be an equilibrium because investors hold the total supply of it. As a consequence, in equilibrium it must be that $p_{N1} \geq (y_r /y_d)\theta \cdot R$. If $p_{N1} = (y_r /y_d)\theta \cdot R$ investors are indifferent between holding and selling the claim; if $p_{N1} > (y_r /y_d)\theta \cdot R$ investors supply their total holdings f^L. If $\omega^L < (y_r /y_d)\theta$, the intermediary's valuation of the new claim is lower than investors' valuation. As a result, the equilibrium price is equal to $p_{N1} = (y_r /y_d)\theta \cdot R$. If instead $\omega^L > (y_r /y_d)\theta$, intermediaries are willing to buy at least some of the claims from investors and the equilibrium price p_{N1} depends on the share σ of t = 0 income carried by the intermediary to $t = 1$.

The intermediary's t = 0 income can take two values depending on whether the t=0 equilibrium falls in case 1) or 2) of proposition 1. If we are in case 1), namely $\theta \cdot (R+y_r) < w < \theta \cdot (R+y_d)$, the intermediary's $t = 0$ income is equal to w. As a result, the intermediary's wealth at t = 1 (and thus the demand for the new claim) is equal to $\sigma \cdot w$. By equalizing supply and demand for the new claim, one can easily find that the equilibrium price is equal to:

$$p_{N,1}(\sigma) = \begin{cases} \omega^L R & for \quad \sigma \geq \overline{\sigma}_1 \equiv \dfrac{\omega^L y_d}{w} \\ \sigma \dfrac{wR}{y_d} & for \quad \sigma \in (\underline{\sigma}_1, \overline{\sigma}_1) \\ \theta(y_r / y_d)R & for \quad \sigma \leq \underline{\sigma}_1 \equiv \theta \dfrac{y_r}{w} \end{cases} , \qquad (32)$$

Together with A2, equation (32) implies that $p_{N1}(\sigma) < p_B = wR/(R+y_d)$.

Consider case 2), namely $w > \theta\cdot(R+y_d)$. The intermediaries' $t = 0$ income is equal to $\theta(R+y_d)$. Now the intermediaries wealth at t = 1 is equal to $\sigma\cdot\theta(R+y_d)$. By equalizing supply and demand for the new claim one can easily find that the equilibrium price is now equal to:

$$p_{N,1}(\sigma) = \begin{cases} \omega^L \cdot R & for \quad \sigma \geq \overline{\sigma}_2 \equiv \omega^L \dfrac{y_d}{\theta(R+y_d)} \\ \sigma\cdot\theta\cdot R\cdot\dfrac{(R+y_d)}{y_d} & for \quad \sigma \in (\underline{\sigma}_2, \overline{\sigma}_2) \\ \theta(y_r/y_d)\cdot R & for \quad \sigma \leq \underline{\sigma}_2 \equiv \dfrac{y_r}{R+y_d} \end{cases}, \tag{33}$$

It is obvious that $p_{N1}(\sigma) < p_B = \theta R$.

Consider next the comparative statics of the price drop $(p_B - p_{N1})$ with respect to y_r and y_d. A higher y_r increases p_{N1} both in cases 1) and 2), as one can readily see from Equations (32) and (33). Indeed, a higher y_r increases investors' as well as intermediaries' reservation price, boosting p_{N1}. Since p_B does not depend on y_r, this softens the price drop in both cases. Consider the role of y_d. It is easy to see that in Equations (32) and (33) a higher y_d reduces p_{N1} by reducing both investors' and intermediaries' reservation prices. Thus, in case 2), which prevails when $y_d < w/\theta - R$, a higher y_d increases the price drop because here the initial price p_B does not change with y_d. In case 1), in contrast, the initial price p_B also falls in y_d, potentially allowing the price drop $(p_B - p_{N1})$ to fall with y_d. Take the first derivative of $(p_B - p_{N1})$ with respect to y_d in each of the three ranges of σ in Equation (32). After some algebra one can see that for each of these ranges there is a threshold $\hat{y}_d$ such that $(p_B - p_{N1})$ increases in y_d if an only if $y_d < \hat{y}_d$. Defining $y_d^* \equiv \max[\hat{y}_d, w/\theta - R]$ proves the proposition.

Proof of Corollary 1. Under rational expectations, Lemmas 1 and 2 imply that $V_z^{I,RE} = \theta R + \theta y_r + E(y - y_r|i)$ and $V_z^{RE} = \theta R + E(y|i)$, for $z = 0, \underline{s}, \overline{s}$. These formulas imply $\left|V_0^{I,RE} - V_z^{I,RE}\right| = \left|V_0^{RE} - V_z^{RE}\right| = \left|E(y|t=0) - E(y|z)\right|$ for $z = \underline{s}, \overline{s}$.

To consider local thinking, first note that in the absence of innovation we have $V_z^I = \theta R + E^L(y|z)$, for $z = 0, \underline{s}, \overline{s}$. This implies that $\left|V_0^L - V_z^L\right| = \left|E^L(y|t=0) - E^L(y|z)\right|$ for $z = \underline{s}, \overline{s}$. With innovation, consider first case 1) of Proposition 1, where the initial price of riskless bonds and of new claims is $p_B = wR/(R+y_d)$. Now $V_z^{I,L} = w + E^L(y - y_d|z)$ for $z =$

$0, \bar{s}$. If instead $z = \underline{s}$ we have $V_{\underline{s}}^{I,L} = \theta R + \theta y_r + E^L\left(\max[0, y - y_d]\middle|\underline{s}\right)$. It is immediate to see that $\left|V_0^{I,L} - V_{\bar{s}}^{I,L}\right| = \left|V_0^L - V_{\bar{s}}^L\right| = \left|E^L(y|t=0) - E^L(y|\bar{s})\right|$ while:

$$\left|V_0^{I,L} - V_{\underline{s}}^{I,L}\right| = \left|w - \theta(w - y_r) + E^L(y|t=0) - E^L(y|\underline{s})\right| > \left|V_0^L - V_{\underline{s}}^L\right| = \left|E^L(y|t=0) - E^L(y|\underline{s})\right|.$$

Consider case 2) of Proposition 1. Now $p_B = \theta R$ and $V_z^{I,L} = \theta R + \theta y_d + E^L(y - y_d|z)$ for $z = 0, \bar{s}$. If instead $z = \underline{s}$, we have $V_{\underline{s}}^{I,L} = \theta R + \theta y_r + E^L\left(\max[0, y - y_d]\middle|\underline{s}\right)$. Once more, $\left|V_0^{I,L} - V_{\bar{s}}^{I,L}\right| = \left|V_0^L - V_{\bar{s}}^L\right| = \left|E^L(y|t=0) - E^L(y|\bar{s})\right|$ while:

$$\left|V_0^{I,L} - V_{\underline{s}}^{I,L}\right| = \left|\theta(y_d - y_r) + E^L(y|t=0) - E^L(y|\underline{s})\right| > \left|V_0^L - V_{\underline{s}}^L\right| = \left|E^L(y|t=0) - E^L(y|\underline{s})\right|.$$

These inequalities prove Corollary 1.

Proof of Lemma 3. For investors to buy shares it must be that $p_A \leq \theta \cdot y_d$. By A4 this implies that investors only buy shares if $p_A < 1$. However, in objective (15) the intermediary issues shares only if $p_A \geq 1$. As a consequence, in equilibrium the intermediary does not issue any shares and $p_A \leq 1$. Since in equilibrium $p_B = \theta R \geq R$, the intermediary issues the maximal amount $b = 1$ of bonds because these yield at least as much as the intermediary's own investment i_B in B at the same unit investment cost. Thus, the intermediary withdraws from B the profits from bond sales by setting $i_B = -(\theta R - 1)$. The intermediary then invests these resources along with his wealth w_{int} in A if and only if $E^L y \geq 1$. When $E^L y \geq 1$ the equilibrium price of shares is $p_A = 1$ (if $p_A < 1$ intermediaries would prefer to buy shares than to invest). When $E^L y < 1$ the equilibrium price of shares is $E^L y < p_A < 1$ (so that no investment occurs, no shares are issued, and no shares are demanded).

Proof of Proposition 3. Assume for now that $p_B = \theta R$; we later show that in equilibrium it must be so. This has two consequences. First, under A5 it follows from objective (19) that the intermediary issues the maximum volume of new claims so that (21) is binding. Second, as in the proof of Lemma 3, the intermediary issues $b = 1$ bonds and sets $i_B = -(\theta R - 1)$. By substituting $p_B = \theta R$ and constraint (21) into the intermediary's objective (19), we see that up to an additive constant the objective becomes:

$$\left[\frac{E^L y + (\theta - 1)y_d - 1}{1 - \theta y_d}\right] i_A.$$

As a result, when $E^L y + (\theta - 1)y_d < 1$ the intermediary sets $i_A = 0$ and does not create any new claims. When instead $E^L y + (\theta - 1)y_d \geq 1$ the intermediary sets i_A at its maximum $w_{\text{int}} + (\theta R - 1)$ and issues new claims for the volume implied by Equation (21). It is easy to check that given A4 this volume is sufficiently low (relative to investors' wealth w) that the equilibrium price for riskless bonds is effectively equal to $p_B = \theta R$.

Proof of Proposition 4. The logic of the proof is identical to that of the proof of Proposition 2, except now the production structure pins down the intermediary's wealth at $t = 1$ at $\sigma = 0$.

Proof of Lemma 4. If the intermediary carries no wealth at $t = 1$, namely $\sigma = 0$, there is no trading at t=1. Suppose instead that the intermediary carries all of his wealth at t=1, namely $\sigma = 1$. Then, after observing $\bar{s}$ there is no trading anyway, implying that $E(U_{\text{inn}}|\bar{s}) = w - \theta\cdot(y_d - y_r)$ and $E(\Pi_{\text{inn}}|\bar{s}) = \theta\cdot R\ (1 + f^L) + E(y) - (\pi_g + \pi_d)y_d - \pi_r y_r$. After observing $\underline{s}$, investors sell all the new claims at $p_{N1} = \omega^L\cdot R$ so that they now obtain $E(U_{\text{inn}}|\underline{s}) = w - (\theta - \omega^L)R\cdot f^L$, while the welfare of intermediaries (who buy the claims at t=1) is equal to $E(\Pi_{\text{inn}}|\underline{s}) = \theta\cdot R\ (1 + f^L) - \omega^L R\cdot f^L + E(y)$. If $\sigma = 0$ then, innovation allows intermediaries to gain $\theta\cdot y_d - (\pi_g + \pi_d)y_d - \pi_r y_r$ and investors to lose. $\theta\cdot(y_d - y_r)$. If instead $\sigma = 1$, innovation allows intermediaries to gain on average $\Pr(\bar{s})\{\theta\cdot y_d - [\pi_g(\bar{s}) + \pi_d(\bar{s})]y_d - \pi_r(\bar{s})y_r\} + \Pr(\underline{s})(\theta - \omega^L)y_d$ and investors to lose $\Pr(\underline{s})\theta\cdot(y_d - y_r) + \Pr(\underline{s})(\theta - \omega^L)y_d$ if $\sigma = 1$.

Proof of Proposition 5. By Lemma 3, without innovation the intermediary obtains $E(\Pi) = w_{\text{int}} + \theta\cdot R - 1$ if $E^L y < 1$ and $E(\Pi) = E(y)\cdot[w_{\text{int}} + \theta\cdot R - 1]$ if $E^L y \geq 1$. By Proposition 3, the intermediary innovates when $E^L y + (\theta - 1)\cdot y_d > 1$. In the latter case, in the allocation of Proposition 3, the payoff obtained by the intermediary with innovation is on average equal to $E(\Pi_{\text{inn}}) = \{E(y) - [(\pi_g + \pi_d) + \pi_r(y_r/y_d)]y_d\}\,\dfrac{w_{\text{int}} + \theta\cdot R - 1}{1 - \theta y_d}$. By comparing this expression with the previous two equations describing the intermediary's welfare absent innovation, it is immediate to find the conditions of Proposition 5.

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