Rollover Risk and Market Freezes*

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Abstract

We consider the debt capacity of a risky asset when debt is being rolled over and there is a liquidation cost in case there is default and the lender seizes the asset. We show that debt capacity depends on how information reveals itself. When information structure is based on "optimistic" expectations, no news about the asset is good news; under this structure, debt capacity does not depend upon rollovers and liquidation cost, and is simply equal to expected cash flows from the asset. In contrast, when information structure is based on "pessimistic" expectations, no news about the asset is bad news; under this structure, debt capacity of the asset decreases in the frequency of rollovers and in liquidation cost. In the limit as the rollovers become unbounded, debt capacity goes to zero even for an arbitrarily small amount of risk of the asset. Our model explains why markets for rollover debt such as asset-backed commercial paper experience sudden freezes. The model also provides an explicit formula for the haircut in borrowing against an asset as a function of its credit risk, rollover risk and liquidation cost.

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1 Introduction

One of the many striking revelations from the sub-prime crisis of 2007 and 2008 has been the sudden freeze in the market for rollover of short-term debt. While rationing of firms in the unsecured borrowing market is not uncommon and has a long-standing theoretical underpinning (see, for example, the seminal work of Stiglitz and Weiss, 1981), what has been somewhat puzzling is the almost complete inability of financial institutions to borrow (or roll over) short-term debt against assets that have relatively low credit risk. From a theoretical standpoint, this is puzzling since the ability to pledge assets and provide collateral has been considered one of the most important tools available to firms in order to get around credit rationing (Bester, 1985). From an institutional perspective, the inability to borrow overnight against high-quality assets has been among the most important market failures that has effectively led to the demise of a substantial part of investment banking in the United States. More broadly, this has led to the collapse in other countries too (such as the United Kingdom) of banks and financial institutions that had relied on the rollover of short-term wholesale debt in the asset-backed commercial paper (ABCP) and overnight secured repo markets. The failure of Bear Stearns in mid-March 2008 presents a classic illustration of this market freeze.[1]

As an intrinsic nature of its business, Bear Stearns relied day-to-day on its ability to obtain short-term financing through borrowing on a secured basis. Beginning late Monday, March 10, 2008 and increasingly through that week, rumors spread about liquidity problems at Bear Stearns, which eroded investor confidence in the firm. Even though Bear Stearns continued to have high quality collateral to provide as security for borrowing,[2] counterparties became less willing to enter into collateralized funding arrangements with Bear Stearns. This

[1]The discussion that follows is based on the Security and Exchange Commission's Chairman Christopher Cox's Letter to the Basel Committee in Support of New Guidance on Liquidity Management, available at: http://www.sec.gov/news/press/2008/2008-48.htm

[2]This high quality collateral mainly consisted of highly rated mortgage-backed assets which had low but not inconsequential credit risk by this time in the sub-prime crisis.

resulted in a crisis of confidence late in the week, where counterparties to Bear Stearns were unwilling to make *even* secured funding available to Bear Stearns on customary terms. This unwillingness to fund on a secured basis placed enormous stress on the liquidity of Bear. On Tuesday, March 11, the holding company liquidity pool declined from $18.1 billion to $11.5 billion (see Figure 1.). On Thursday, March 13, Bear Stearns' liquidity pool fell sharply, and continued to fall on Friday. The market rumors about Bear Stearns' liquidity problems became self-fulfilling and led to the near failure of the firm. Bear Stearns was adequately capitalized at all times during March 10 to 17, up to and including the time of its agreement to be acquired by J.P. Morgan Chase. Even at the time of its sale, Bear Stearns' capital and its broker dealers' capital exceeded supervisory standards. In particular, the capital ratio of Bear Stearns was well in excess of the 10% level used by the Federal Reserve Board in its well-capitalized standard.

In his analysis of the failure of Bear Stearns, the Federal Reserve Chairman Ben Bernanke observed:[3] "[U]ntil recently, short-term repos had always been regarded as virtually risk-free instruments and thus largely immune to the type of rollover or withdrawal risks associated with short-term unsecured obligations. In March, rapidly unfolding events demonstrated that even repo markets could be severely disrupted when investors believe they might need to sell the underlying collateral in illiquid markets. Such forced asset sales can set up a particularly adverse dynamic, in which further substantial price declines fan investor concerns about counterparty credit risk, which then feed back in the form of intensifying funding pressures... In light of the recent experience, and following the recommendations of the President's Working Group on Financial Markets (2008), the Federal Reserve and other supervisors are reviewing their policies and guidance regarding liquidity risk management to determine what improvements can be made. In particular, future liquidity planning will have to take into account the possibility of a sudden loss of substantial amounts of secured financing."

[3]The quotes are based on Ben Bernanke's remarks to the Risk Transfer Mechanisms and Financial Stability Workshop at the Bank for International Settlements, May 29, 2008.

Our paper is an attempt to provide a simple theoretical model of debt capacity of an asset when (i) the debt is short-term in nature, and hence, needs to be rolled over, (ii) there is the risk of fire sale in case there is default and the current lender needs to seize and liquidate the underlying asset, and (iii) arrival of information about quality of the asset is "pessimistic" (as we explain below). These are essentially the features alluded to in the above discussion surrounding the collapse of Bear Stearns. A novel feature of our model is the assumption on the information structure. When debt is short-term in nature, it is natural to assume that uncertainty about credit risk of the underlying asset may not be fully revealed by the date of next rollover. That is, debt may have to be rolled over several times before information about the asset is completely revealed.

Does such rollover risk diminish the debt capacity of an asset? Consider an information structure in which at each date of rollover, either there is release of bad news and asset pays zero, or there is no news. This information structure is "optimistic" in that for a given likelihood of default on the asset until its maturity, the likelihood of bad news declines if no news is revealed over time. Under such an information structure, rollover risk and liquidation cost are irrelevant to the debt capacity of an asset, which is simply equal to the expected value of asset's cash flows at maturity. This conventional result, however, breaks down if the information structure is pessimistic in that at each date of rollover, either there is release of *good* news or there is no news. Or, in other words, for a given likelihood of default on the asset until its maturity, the likelihood of bad news *rises* if no news is revealed over time.

Under this pessimistic information structure, the debt capacity of an asset is declining in the number of debt rollovers required until maturity of the asset and in the liquidation cost. Strikingly, the debt capacity of an asset tends to zero as the number of debt rollovers until maturity becomes unbounded. What is remarkable is that this second result holds for an *arbitrarily small credit risk* of the underlying asset, capturing the scenario that Bear Stearns experienced during its failure in March 2008. A corollary to this result is that as credit risk increases, it takes fewer debt rollovers to have the debt capacity of an asset fall below some arbitrarily small threshold.

Hence, a switch in market's expectations about the quality of an asset from optimistic scenario to the pessimistic one can cause a sudden "market freeze" in the rollover of short-term asset-backed debt. What causes the freeze is an "adverse dynamic" (to borrow Bernanke's phrase) whereby at each date, the lender providing the rollover financing recognizes that there is the likelihood of no (good) news which will force her to liquidate the asset at a cost and reduced debt capacity accordingly. This reduced debt capacity at each rollover date feeds through backward induction diminishing the debt capacity of the asset to zero in the limiting case.

Our results can alternatively be stated in terms of the so-called "haircut" of an asset. Measuring the haircut as the ratio of the debt capacity of an asset to its expected value (or its debt capacity for buy-to-hold debt), our model shows that the haircut can be calculated simply based on three inputs: the credit risk of the asset (per-period likelihood of default, or its overall likelihood of default assuming continuous release of information), the number of debt rollovers, and the fire-sale discount to be incurred in case of liquidation of the asset by a lender. Under the optimistic information structure, haircut is zero whereas under the pessimistic structure, haircut is 100% in the limiting case as rollover frequency becomes unbounded.[4]

In terms of institutional settings where our model of rollover risk and market freezes is applicable, the most natural candidate is the commercial paper market accessed primarily by financial institutions, but also by highly-rated industrial corporations, where rollover at short maturities is a standard feature. Another recent candidate is the practice of taking assets off-balance-sheet and putting enough capital with them to make them "bankruptcy-remote" and AAA-rated, and then borrow short-term against these assets. Such structures, characterized in essence by a maturity mismatch between assets and liabilities, were prevalent

[4]Shin (2008), for example, documents based on data from Bloomberg, that the typical haircuts on treasuries, corporate bonds, AAA asset-backed securities, AAA residential mortgage-backed securities and AAA jumbo prime mortgages are respectively, less than 0.5%, 5%, 3%, 2% and 5%, whereas, in March 2008, these haircuts respectively rose to between 0.25% and 3%, 10%, 15%, 20% and 30%. See also the discussion in Brunnermeier and Pedersen (2005) on widening of haircuts in stress times.

in many forms ("structured investment vehicle" or SIV, "conduits", among others) in the period leading up to the sub-prime crisis.[5] And yet another candidate is the entire balance-sheet of a financial institution (such as that of Northern Rock or of investment banks) when the funding model inherently resembles that of a SIV, that is, long-term risky assets such as mortgages funded by short-term asset-backed commercial paper. All these markets experienced severe stress during the sub-prime crisis and froze – 100% haircut – for many days at a stretch once the expectations about the quality of mortgage assets became pessimistic, even though prior to this period, they appeared to be the cheapest form of financing – zero haircut – available in the market.[6]

Before we proceed, it is in order to acknowledge that we take the short-term nature of debt and fire sales as given. That investment banks are (or used to be!) funded with rollover debt and that debt capacity can be higher with short-term debt under some circumstances for many underlying assets, are interesting facts in their own right. Indeed, there exist agency-based explanations in the literature (for example, Diamond, 1989, 1991, 2004, Calomiris and Kahn, 1991, and Diamond and Rajan, 2001a, 2001b) for the existence of short-term debt as optimal financing in such settings. Our model presents a caveat to this result on short-term debt maximizing debt capacity: when expectations are pessimistic, debt capacity through short-term debt may in fact be arbitrarily small, suggesting that institutions ought to arrange for this through alternative long-term financing. Providing a micro-foundation for debt maturity in a model where there is a switch between optimistic and pessimistic regimes is a fruitful goal for future research, but one that is beyond the scope of this paper.

Similarly, there is a large body of literature in finance and economics justifying, verifying or employing fire sales of assets during periods of industry- or economy-wide shocks. On the theoretical front, Williamson (1988) and Shleifer and Vishny (1992) link this to the notion

[5]See Crouhy, Jarrow and Turnbull (2007) for an excellent description of such off-balance-sheet vehicles.

[6]In fact, in the case of Northern Rock, other financial institutions such as HBOS, Bradford and Bingley, and Alliance and Leicester, that were heavily reliant on wholesale, short-term paper, also experienced a spillover (Yorulmazer, 2008) and have since the nationalization of Northern Rock in September 2008 been acquired, merged or nationalized.

of specificity of assets, that is, how fungible are assets across industries. On the empirical front, Pulvino (1998), Krugman (1998), Aguiar and Gopinath (2005), Coval and Stafford (2006), Acharya, Bharath and Srinivasan (2007), and Acharya, Shin and Yorulmazer (2007) have provided evidence of fire sales in real and financial markets in a variety of settings. And, on an application front, a large literature on financial crises (starting with Allen and Gale 1994, 1998) has employed fire sales as a key modeling device.

From the standpoint of our paper, these two features imply that market freezes due to changes in expectations about credit risk of an asset are most likely when borrowing and/or lending horizon becomes short-term and underlying assets are "crowded" in the sense that most financial institutions that also provide short-term debt are on one side of the market for underlying assets. The first feature generates rollover risk and the second feature generates fire sales in asset liquidations.[7]

The rest of the paper proceeds as follows. Section 2 presents a discrete-time binomial example that illustrates our main result on rollover risk and market freezes. Section 4 generalizes the example to continuous-time case. Section 3 discusses implications of the model. Section 5 relates the model and results to existing literature. Section 6 concludes with some ideas for further work. The appendix extends the continuous-time model to allow for random rollovers and random arrival of information.

[7]Indeed, the sub-prime crisis of 2007 and 2008 features both. Inter-bank borrowing has in fact switched from three-month unsecured to overnight secured and unsecured as a number of borrowers have been rationed in the longer maturity buckets. There has also been evidence of substantial discounts in sale of assets in SIVs and conduits. See, for instance, and "SIV restructuring: A ray of light for shadow banking," *Financial Times, June 18 2008*; and "Creditors find little comfort in auction of SIV Portfolio assets," *Financial Times, July 18 2008*, which both report that net asset values due to asset fire sales have fallen below 50% of paid-in capital. As the first article reports: "[W]hen defaults on US subprime mortgages rose last summer, ABCP investors stopped buying [short-term ABCP] notes – creating a funding crisis at SIVs. . . . This situation prompted deep concern about the risk of a looming firesale of assets. The prospect was deemed so alarming that the US Treasury attempted to organize a so-called "super-SIV" last autumn, which was supposed to purchase SIV assets."

2 Binomial example

2.1 The basic idea

Suppose that a SIV is set up with a collection of indivisible assets as collateral. We want to determine the maximum amount that can be borrowed by the SIV using only the assets as collateral. The SIV issues commercial paper with maturity normalized to equal the length of one time period. For simplicity, we assume that current yield of the assets is zero and the terminal value is either 0 or $V > 0$. We also assume for simplicity that the asset has zero yield, the current risk-free interest rate is zero, and the market is risk neutral.

If the SIV is forced to default and liquidate the assets, we assume that the recovery rate is $\lambda \in [0, 1]$, that is, the assets fetch a fraction λ of the *maximum amount of finance that could be raised by the SIV as a going concern.* [ADD SOME JUSTIFICATION HERE.]

Information becomes available in each period just before the debt must be rolled over. For simplicity, we assume that there is a public signal that takes two values, H and L, with probabilities p and $1 - p$ respectively. We can think of the signal H as "good news" and the signal L as "no news." If good news arrives in any period, it means that the value of the assets with be V. Hence, the value of the assets is 0 if and only if there is "no news" in every period an event that occurs with probability $(1 - p)^n$ when there are n periods left before the assets mature. This information structure, which we referred to in the introduction as the "pessimistic" information structure, is illustrated in Figure 2.

— Figure 2 about here —

We want to calculate the maximum amount of debt that can be issued by the SIV. We can do this by backward induction, beginning with the period before the asset matures.

There are two possible situations that must be considered. Either (i) good news has arrived, in which case the value of the asset is V for certain, or (ii) good news has not yet arrived, in which case the value of the asset remains uncertain.

Suppose that goods news has not yet arrived. In the penultimate period, the SIV issues debt with a face value of D. If $D > V$, the SIV defaults in both states, i.e., regardless of the value of the asset and the expected value of the debt is

$$p\lambda V + (1-p) \times 0 = p\lambda V.$$

On the other hand, if $D \leq V$, then the expected value of the debt is

$$pD + (1-p) \times 0 = pD.$$

Then the value of debt is

$$\max\{p\lambda V, pD\},$$

which is maximized by setting $D = V$. Let $D_0 = pV$ denote the maximum value of debt.

Now let's move back one period and assume again that good news has not arrived. If the face value of the debt issued is D, the value of the debt in the ante-penultimate period is

$$\begin{cases} p\lambda V + (1-p)\lambda D_0 & \text{if } D > V \\ pV + (1-p)\lambda D_0 & \text{if } D_0 < D \leq V \\ pD & \text{if } D \leq D_0. \end{cases}$$

Noting that $V > D_0$, it is clear that the value of the debt issued is maximized by setting $D = V$.

Continuing in this way, we can calculate the maximum value of the debt that can be raised against the SIV's collateral for any number of future roll overs.

2.2 The general formula

Let n denote the number of rollovers required in the future and let D_n be the maximum amount that can be raised assuming that no news has been received in period n and the SIV is solvent. As an induction hypothesis, we assume that

$$D_n = \left(\sum_{i=0}^{n} (1-p)^i \lambda^i\right) pV. \tag{1}$$

Note first, that the maximum amount D_{n+1} must satisfy

$$D_{n+1} = \max\{pV + (1-p)\lambda D_n, D_n\},$$

depending on whether the face value of the debt is set equal to V or to D_n, and that

$$D_{n+1} = pV + (1-p)\,\lambda D_n \tag{2}$$

if and only if

$$pV + (1-p)\,\lambda D_n \geq D_n$$

which is equivalent to

$$\begin{aligned} D_n &\leq \frac{pV}{1-(1-p)\,\lambda} \\ &= \left(1+(1-p)\,\lambda+(1-p)^2\,\lambda^2+\cdots\right) pV \\ &= \left(\sum_{i=0}^{\infty}(1-p)^i\,\lambda^i\right) pV. \end{aligned}$$

Our induction hypothesis guarantees that this inequality is satisfied and hence that (2) is satisfied. Then using (2) and the induction hypothesis (1), we calculate

$$\begin{aligned} D_{n+1} &= pV + (1-p)\,\lambda D_n \\ &= pV + (1-p)\,\lambda\left(\sum_{i=0}^{n}(1-p)^i\,\lambda^i\right) pV \\ &= \left(\sum_{i=0}^{n+1}(1-p)^i\,\lambda^i\right) pV, \end{aligned}$$

as required.

Thus, we have proved by induction that,

Lemma 1 *Regardless of how many roll overs are required before the assets mature, the maximum amount of finance that can be raised is given by the formula (1).*

A straightforward consequence of formula (1) is that

Corollary 2 *The maximum amount of finance that can be raised against the assets is declining in the credit risk $(1-p)$, the fire-sale discount λ, and the rollover frequency n.*

2.3 Market freeze

We define the market to for short-term borrowing by the SIV to be experiencing a "freeze" if the maximum debt capacity of the SIV goes to zero. To characterize a market freeze, we examine the effect of the number of rollovers on the maximum finance that can be raised.

We can establish analytically that $D_n \to 0$ as we let $n \to \infty$, holding the fundamental value of the assets unchanged. In other words, we vary n holding constant the credit risk of the asset, $(1-p)^n$, constant, which implies that as $n \to \infty$, the likelihood of good news p goes to zero.

First, note that

$$\sum_{k=0}^{n} (1-p)^k \lambda^k \leq \sum_{k=0}^{\infty} (1-p)^k \lambda^k = \frac{1}{1-(1-p)\lambda} \leq \frac{1}{1-\lambda}.$$

Then substituting this inequality in the expression for D_n we find that

$$D_n = \left(\sum_{k=0}^{n} (1-p)^k \lambda^k \right) pV \leq \frac{1}{1-\lambda} pV.$$

Since $p \to 0$ as $n \to \infty$, the expression on the right converges to zero and the value of the debt becomes vanishingly small too. This yields our main result:

Proposition 3 *As long as there is credit risk on the asset ($p < 1$) and there is the risk of fire sale at rollover stage ($\lambda < 1$), the maximum debt capacity of the asset goes to zero as the frequency of rollovers becomes unbounded.*

In other words, there is a "market freeze" when debt to be raised by the SIV has to be rolled over sufficiently frequently, *even for arbitrarily small amount of credit risk of assets.*

— Figures 3a, 3b about here (D_n for different n as p and λ vary) —

2.4 A formula for haircuts

Our results can alternatively be stated in terms of the so-called "haircut" of an asset. In markets, the haircut on an asset is the ratio of how much an investor can borrow against the asset as collateral to some notion of its fundamental value. We define the latter as the debt capacity of the asset for buy-to-hold debt. In other words, we can measure the haircut H_n in the model as the ratio of D_n to pV. The haircut then is given by the formula:

$$H_n = \left(\sum_{i=0}^{n} (1-p)^i \lambda^i \right).$$

Thus, the haircut can be calculated simply based on three inputs:

1. $(1-p)$, the credit risk of the asset;

2. n, the number of debt rollovers, or its rollover risk; and,

3. λ, the fire-sale discount to be incurred in case of liquidation of the asset by a lender.

A consequence of our earlier results is that

Corollary 4 *The haircut of an asset is increasing in its credit risk* $(1-p)$*, rollover risk* n*, and liquidation risk* λ*. In particular, the haircut of an asset approaches 100% as its rollover risk* n *becomes unbounded, as long as* $p < 1$ *and* $\lambda < 1$*.*

Brunnermeier and Pedersen (2005) and Shin (2008) discuss in detail the sharp widening of haircuts in stress times, even for relatively high quality assets such as AAA-rated asset pools. Our model provides an explanation for why stress times – when credit risk, rollover risk and liquidation risk rise – are associated with such large swings in haircuts. Figures 4a and 4b provide some illustrative calibrations to generate haircuts of the magnitude described by Shin (2008) and summarized in footnote 4.

— Figures 4a, 4b about here (H_n for different n as p and λ vary) —

Equally importantly, we explain in the next section why the second part of the corollary provides a potential explanation for Bear Stearns having experienced a complete inability in March 2008 to obtain *any* overnight rollover financing against its even high quality assets.

3 Factors driving market freezes

3.1 Investor expectations

3.2 Rollover frequency

3.3 Credit risk

3.4 Liquidation risk

4 Continuous time model

Suppose that time is continuous and represented by the interval $[0, 1]$ and that "good news" arrives according to a Poisson process with parameter α. The probability that some "good news" will have arrived by time t is $1 - e^{-\alpha t}$ and the probability that some "good news" arrives between times t and t', given that it has not arrived by time t, is $1 - e^{-\alpha(t'-t)}$. More generally, we can work with a stochastic process where the probability of delivering "good news" between t and t' that is denoted by $P(t, t')$. Suppose that the rollover dates are evenly spaced at times

$$t_n = \frac{N+1-n}{N+1}$$

for $n = 1, ..., N$. The probability that "good news" arrives between successive rollover dates is a constant

$$\begin{aligned} p &= P\left(\frac{n}{N+1}, \frac{n+1}{N+1}\right) \\ &= 1 - \exp\left\{\frac{-\alpha}{N+1}\right\}. \end{aligned}$$

The argument goes through as in the case of discrete time:

$$D(t_n) = \left(\sum_{i=0}^{n} [(1-p)\lambda]^i\right) pV.$$

as before. By induction, this shows that the maximum that can be raised at time 0 is

$$D(t_N) = \left(\sum_{i=0}^{N} [(1-p)\lambda]^i \right) pV.$$

And, in turn, as $N -> \infty$, the maximum debt capacity goes to zero, giving rise to a complete market freeze.

The advantage of the continuous time model is that it can handle more elegantly extensions such as random rollovers and random dates of information arrival. Since these are not central to our primary result on market freeze, we relegate them to the Appendix.

5 Related literature

Rosenthal and Wang (1993)

Huang and Ratnovski (2008)

6 Conclusion

[TO BE COMPLETED.]

Appendix

6.1 Random withdrawals

6.2 Random arrival of information

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