Mobile Collateral versus Immobile Collateral*

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Abstract

The financial architecture prior to the recent financial crisis was a system of mobile collateral. Safe debt, whether government bonds or privately-produced bonds, i.e., asset-backed securities, could be traded, posted as collateral, and rehypothecated, moving to its highest value use. Since the financial crisis, regulatory changes to the financial architecture have aimed to make collateral immobile, most notably with the BIS "liquidity coverage ratio" for banks. We evaluate this immobile capital system with reference to a previous regime which had this feature: the U.S. National Era.

1   Introduction

In the thirty years prior to the 2007-2008 financial crisis, the global financial system evolved away from a system of immobile collateral into a system of mobile collateral. In this new system bank loans, instead of remaining passively immobile on bank balance sheets, were securitized into bonds which could be traded, used as collateral in repo, posted as collateral for derivatives positions, and rehypothecated, moving to the location of their highest value use. In short, U.S. banks' loans, which had been sitting passively on bank balance sheets, were transformed into bonds, making them mobile. Since the financial crisis of 2007-2008, regulatory initiatives have been aimed at making collateral once again immobile. In this paper, we evaluate the recent policy of again making collateral immobile. We have two main arguments in our evaluation. The first is that there is a cost to making this collateral immobile because it ties up safe debt. The second is that we find weak support for the idea that making collateral immobile has large benefits – namely that it makes the financial system safer and reduces panics. Instead we find that other forms of bank debt increase when safe collateral becomes immobile, possibly making the system riskier.

The transformation of the U.S. financial system towards mobile collateral is shown in Figure 1 (from Gorton, Lewellen and Metrick (2012)). The figure shows the different forms of privately-produced safe debt as a percentage of total privately-produced safe debt. In the 1950s and 1960s demand deposits of banks were 80 percent of the privately-produced safe debt. Demand deposits were backed by bank loans, essentially the collateral. Demand deposits then go into a downward trend for the next thirty years. At the same time, the categories of privately-produced safe debt that are growing were money market instruments (specifically, repo, commercial paper and money market funds), as well as AAA mortgage-backed securities (MBS) and other AAA asset-backed securities (ABS). By the start of the financial crisis, this "shadow banking system" was as large as the amount of demand deposits (though much of the ABS and MBS ended up as collateral backing repo and asset-backed commercial paper). This shadow banking system is funding the very same bank loans in a different way.

At the same time that this transformation of the financial system was going on, another important, related, trend was developing. This is shown in Figure 2. Figure 2 shows the holders of outstanding U.S. Treasury debt (excluding Treasuries held by the federal, state and local pensions; social se-

curity is also not counted). Again, there is a steady downward trend for U.S. banks, as the banks no longer need Treasuries as a component of their portfolios backing demand deposits. Coincidentally, the Rest of the World shows a sharply upward trend in holdings of U.S. Treasury debt. The Rest of the World has a demand for safe, liquid, debt. In other words, Treasury debt has a convenience yield. Krishnamurthy and Vissing-Jorgensen (2012a,b) show empirically that investors value the money-like properties of liquidity and safety of these bonds. Furthermore there is a negative correlation between outstanding U.S. Treasury debt and the production of privately-produced safe debt (see Krishnamurthy and Vissing-Jorgensen (2012a,b) and Gorton, Lewellen and Metrick (2012)). When Treasuries outstanding (as a percentage of GDP) declines, privately-produced safe debt increases to fill the gap. More specifically, Xie (2012) shows, using daily data, that asset-backed security (ABS) and mortgage-backed security (MBS) issuance occurs when there is a high convenience yield on Treasuries. In other words, when Treasuries are scarce, more ABS and MBS are issued (85 percent of an issue is AAA). Sunderam (2014) shows that a high convenience yield results in the endogenous response of more asset-backed commercial paper (ABCP) being issued.

The private response to create more privately-produced safe debt when there is a scarcity of U.S. Treasuries is partly the focus of the literature on the "global savings glut". This literature argues that increased capital flows into the United States from countries with an excess of savings may have been an important reason that U.S. interest rates were low (see, e.g., Bernanke (2005, 2007), Bernanke, Bertaut, De Marco and Kamin (2011)). Foreign investors have a demand for safe assets and focused their investments on U.S. Treasuries (see Caballero and Krishnamurthy (2009)). Maggiori (2013) argues that this as a form of insurance; the U.S. can (almost uniquely) produce safe debt, which is demanded by foreign investors in countries which cannot produce safe debt (China and the oil-producing countries; see Bertaut, De Marco and Kamin (2011)).

The creation of privately-produced safe debt is in part a response to a scarcity of government-produced safe debt. Both types of safe debt—government-produced and privately-produced– are used as collateral for short-term bank money, i.e., repo, ABCP and money market funds (MMF). The response to scarcity was not only increased private production of safe debt, but also increased mobility of the debt. In the past, when U.S. Treasuries or bank loans backed demand deposits, the backing loans were immobile. Indeed, since demand deposits were the dominant form of inside money, there

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was no need for mobility. The bank loans sat on bank balance sheets and were not traded. As the need for demand deposits receded, and foreign investors demanded U.S. Treasuries, the financial system transformed the immobile bank loan collateral into forms of mobile collateral via securitization. Privately-produced safe debt became a product to be used as mobile collateral.

In Section 2 of this paper we provide evidence of the extent to which the financial system became a system of mobile collateral, indeed, stretching the available mobile debt to meet demands. To do this we study the determinants and extent of repo fails. We show that repo fails were increasing because of the scarcity of U.S. Treasuries and Agency bonds. Another manifestation of system morphing was that repo was significantly expanding beyond the primary dealers prior to the crisis. And, fails were caused in significant part by a demand for liquidity in a world with insufficient safe debt. This was, and remains, a problem. Krishnamurthy and Vissing-Jorgensen (2012b) argue empirically that when the ratio of privately-produced safe debt goes up relative to Treasuries, financial crises are more likely. Also see Gourinchas and Jeanne (2012). This scarcity appears to persist today. For example, Bertaut, Tabova and Wong (2014) show that since the financial crisis U.S. investors have invested in sovereign debt of Australia and Canada because of the shortage of safe debt since securitization collapsed.

New regulations do not address potential scarcities of safe debt. In fact, since the financial crisis, new regulations aim at returning to a financial system of immobile collateral. For example, under Dodd-Frank and similar European legislation collateral must be posted to central clearing parties (CCP) (regardless of the private party's net position), while the CCP does not post collateral to participants. CCPs will only accept highly liquid, high grade collateral. Variation margin has long been part of the bilateral swap market, but importantly, initial margin is new and will increase substantially the amount of collateral required. Not all swaps trades will be cleared through a CCP. For those that are not, initial and variation margin for each trade must be held by a third party. Further, collateral posted to banks by clients cannot be rehypothecated. And, most importantly, the BIS Liquidity Coverage Ratio (LCR) requires that (net) short-term bank debt be backed by (essentially) Treasuries ("high-quality liquid assets").[1] See BIS (2013).

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[1]Throughout the paper, we will refer to "high-quality liquid assets" as Treasuries and we will refer to net short term debt as repo.

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In other words, short-term bank money (repo and CP) and Treasuries, both of which have a convenience yield, must be combined. One kind of money must be backed by another kind of money, a kind of narrow banking.

The LCR is the leading example of the move back towards an immobile collateral system. In effect, it attempts to reverse thirty years of change. As such an important change, how should we evaluate the LCR (or any new policy for that matter)? Because of the Lucas (1976) critique, a general equilibrium model would be needed, one which currently does not exist. There have, of course, been numerous more or less ad hoc forecasts of how much collateral the new system will need given the LCR, but these numbers vary a lot and are subject to the Lucas critique, i.e., there is no accounting for the general equilibrium effects that might occur ("unintended consequenfes"). In fact, we know from the above studies that privately-produced money grows when there is a scarcity of Treasuries.

We are not interested here in forecasting the amount of collateral needed.[2] Rather, in this paper we evaluate the LCR *structure* by analyzing a financial system that had the same structure of requiring that U.S. Treasuries back the issuance of privately-issued bank money: the U.S. National Banking Era, 1863-1914.[3]Under the National Banking System, national banks could issue distinct "national bank notes" by depositing eligible U.S. Treasury bonds with the U.S. Treasury, which would then print the bank's notes. Originally, the idea was to create a demand for U.S. Treasuries so as to finance the U.S. Civil War. But, a by-product did not go unnoticed, namely, the belief that backing private money with Treasuries would prevent banking panics. Prior to the National Banking Era, U.S. banks issued their own distinct notes, backed by state bonds (in Free Banking states) or backed by portfolios of bank loans (in chartered banking states). There were systemic banking crises in 1814, 1819, 1837 and 1857. It was expected that the National Banking System would eliminate panics. Similarly, the explicit purpose of the liquidity coverage ratio (LCR) is to make the financial system safer. BIS (2013) labels the LCR as one of the key reforms "to develop a more resilient banking sctor" (p. 1).

However, this stability did not occur under the National Banking Era. Banking panics were not prevented, but merely shifted from one form of bank

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[2]On this topic see Heller and Vause (2012), Sidanius and Zikes (2012), Fender and Lewrick (2013) and Duffie, Scheicher and Vuillemey (2014).

[3]On the National Banking Era see Noyes (1910), Friedman and Schwartz (1963), and Champ (2011c).

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money to another. During a panic, instead of requesting cash for private bank notes, debt holders demanded national bank notes for their demand deposits. By the time the National Bank Acts were passed demand deposits had become a sizeable form of privately-produced bank money and we show that they continued to grow substantially throughout this period (Figure 9). But, economists did not understand this for decades. Bray Hammond (1957), in his Pulitzer Prize-winning book *Banks and Politics in America*, wrote: ". . . the importance of deposits was not realized by most American economists . . . till after 1900" (p. 80). Hammond goes on to discuss why the growing importance of demand deposits was overlooked. Economist Charles Dunbar (1887) wrote in the inaugural volume of the *Quarterly Journal of Economics*: "The ease with which we ignore deposits as a part of the currency seems the more remarkable, when we consider that few men in business fail to recognize the true meaning of this form of bank liability" (p. 402). And Russell C. Leffingwell, the Assistant Secretary of the Treasury wrote as late as 1919: "All of these people who believe in the quantity theory of money . . . choose to call bank deposits money, but bank deposits are not money" (Leffingwell letters, quoted by Wicker (1966, p. 21). Regulators and economists were conceptually confused.What seems so obvious now was not obvious then. Forms of short-term bank debt change and this was not immediately recognized. Worse, the new forms of bank debt and their risks tend to be misunderstood. It is possible that the system even contributed to panics by encouraging a different, less well understood form of bank debt to be created. This is a key point because a main benefit of the proposed system of immobile collateral is that it will make the system safer.

There was another problem with the National Banking System: too little money was issued and the system was inflexible or "inelastic". Too little money was issued even though it was apparently profitable to do so, an apparent riskless arbitrage opportunity. Economists have called this the "under issuance puzzle" or the "national bank note puzzle." First noticed by Bell (1912), this under issuance has been a puzzle ever since, for over a century! The puzzle is that national banks never fully utilized their note-issuing powers even though it appears that it was profitable to do so. As Kuehlwein (1992) put it: ". . . through the turn of the century and into the 1920s banks devoted a significant fraction of their capital to direct loans . . . despite the fact that national bank notes appeared to be more profitable" (p. 111). Friedman and Schwartz (1963, p. 23) reached the same conclusion. There is a large literature on this; see Calomiris and Mason (2008) and the

citations therein.

Because the LCR is structurally the same as the National Banking System, this puzzle is important. In this paper, we show that the reason that "riskless arbitrage profits" persisted during the National Banking Era was that the calculations of the arbitrage profit done to date ignored the fact that there was a convenience yield to Treasuries and a cost to bank capital. Banks held Treasuries on their balance sheets but, in principle, could have raised capital to buy Treasuries.[4] But, for the system as a whole, there appears to have been a shortage of safe debt. Simply put, banks had other important uses for Treasuries and bank capital was expensive. We show that the "arbitrage profits" are essentially a proxy for the "convenience yield" on Treasuries or the cost of bank capital or likely both. This suggests that backing one kind of money (National Bank notes) with another kind of money (Treasuries) may not be such a good idea. By linking the two forms of money, another form of private-produced money is likely to appear or grow. This is strongly shown in the data – as the share of Treasuries to GDP declined over this period, deposits grew. And a shortage of safe debt is associated with financial instability. This too is consistent with the data as banking panics occurred frequently throughout the period (1873, 1884, 1890, 1893, 1896, and 1907).

Of course, it will be objected that the two systems—the current LCR and the historical National Banking Era– are different and that the National Banking Era is not relevant. Indeed, there are important differences. Nevertheless, it seems useful to analyze a system which is structurally identical to the LCR. In terms of policy evaluation, there seems no real alternative.

We summarize with the following conclusions about the LCR or other systems that make collateral immobile. First, these systems have costs because they tie up safe assets and add to issues of scarcity. Second, we cast doubt on the systems supposed benefits – namely preventing crises. Historically, the National Banking Era had many panics. It is likely that a system of immobile collateral which restricts certain forms of bank debt creation simply encourages other forms of bank debt to be created. This is consistent with the growth in deposits during the National Banking Era. There is a remarkably strong correlation between Treasury supply and deposits (Figure 9). These new forms of bank debt are dangerous because they are typically

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[4]Also, average profit rather than marginal profit was calculated. This distinction is important, as we discuss below.

not well understood or acknowledged, as deposits were not well understood in the National Banking Era and as shadow money (repo, ABCP, etc.) were not understood until the recent crisis.

The paper proceeds as follows. In Section 2 we provide more evidence on the scarcity of safe assets in the period leading up to the financial crisis of 2007-2008 by looking at repo fails. Section 3 is devoted to the National Banking Era. We calculate the profitability of national bank note issuance and then show that even in the 19th and early 20th centuries U.S. Treasuries had a convenience yield. We then show that this can resolve the century-old national bank note paradox. Section 4 concludes with implications for the present day.

2 Collateral Mobility and Scarcity

Many authors have discussed the shortage of safe debt prior to the financial crisis, e.g., Caballero (2010), Gourinchas and Jeanne (2012), usually relating it to the global savings glut. But, it has proven difficult to provide evidence for this shortage. In this section we provide some evidence for this shortage, which was driving the growth of mobile collateral.

2.1 Repo Fails

There is said to be a "repo fail" if one side to the repo transaction does not abide by the contract at maturity, failing to deliver the collateral back (called a "failure to deliver") or failing to repay the loan (called a "failure to receive"). See Fleming and Garbade (2005, 2002) on fails. Repo fails can provide indirect evidence on scarcity and mobility. If collateral is scarce, then it can become more mobile via rehypothecation (re-use) chains, making it more difficult to find the bond to return to the borrower, i.e. a fail. There is no direct evidence on this, but we provide a variety of indirect evidence.

We examine data from the New York Federal Reserve Bank on primary dealers' fails.[5] The primary dealers are only a subset of all firms involved in the bilateral repo market, as we will see below. But, still it encompasses many large financial firms. The New York Federal Reserve Bank collects

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[5] "Primary dealers" are financial firms that are trading counterparties if the New York Fed in its implementation of monetary policy. There are currently 22 primary dealers; see http://www.newyorkfed.org/markets/pridealers_current.html .

data on only three asset classes used as collateral for repo: U.S. Treasuries, Agency bonds, and Agency MBS.[6]

Repo fails by asset class are shown in the three panels of Figure 3. From Figure 3 it is apparent that repo fails were increasing prior to the financial crisis. It is apparent from the figure that the period from January 2000 until January 2010 is more turbulent than the period before and the period after. The turbulence is not just the financial crisis. This is confirmed by Table 1 Panel A which shows the mean dollar amount of fails (in $ millions) in the 1990s compared to the period 2000-2007; also shown are the standard deviation of fails. We formally test for difference between subperiods below.

The data collected by the New York Fed is very limited. To get some sense of the narrowness of the primary dealer group, we can look at data from the Depository Trust and Clearing Corporation (DTCC) on fails. DTCC has hundreds of members that use DTCC for clearing and settlement.[7] In 2011 DTCC settled $1.7 quadrillion in security value. DTCC also has a large repo program. DTCC fails data is for the value of Treasury and Agency fails, that is the amounts that were not delivered to fulfill a contract. The DTCC data covers all fails of Treasuries and Agencies, not just repo fails. However, if there is a scarcity of safe debt, then there are likely fails in trades as well as repo. The DTCC series is not as long as the NY Fed's, but it shows the larger universe of players. The data are shown in Figure 4; looking at the scale of the y-axis it is clear that there are many more fails, suggesting that the size of the fails problem is an order of magnitude larger than the NY Fed data shows. Also, see Gorton and Metrick (2015).

Aside from operational issues that explain repo fails, there are two other possibilities. First, there is the possibility that a counterparty strategically defaults to retain the bonds or retain the cash, at least for a short period of time. Secondly, there can be multiple fails due to rehypothecation (the re-use of collateral) chains, i.e., several transactions are sequentially based on the same collateral. As explained by Fleming and Garbade (2002): " . . . a seller may be unable to deliver securities because of a failure to receive the same securities in settlement of an unrelated purchase. This can lead to a 'daisy chain' of cumulatively additive fails: A's failure to deliver bonds to B causes B to fail on a sale of the same bonds to C, causing C to fail on a

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[6] "Agency" refers to Fannie Mae, Freddie Mac or Ginnie Mae, government-sponsored enterprises that securitize and guarantee certain types of residential mortgages.

[7] See the DTCC membership list: http://www.dtcc.com/client-center/dtc-directories.aspx .

similar sale to D, and so on" (p. 43). We do not have the data, however, to distinguish between fails due to rehypothecation chains from other fails. We cannot distinguish between these possibilities, but the tests below strongly suggest that increasingly fails were not operational errors.

Collateral is mobile if it is in a form that can be traded and posted as collateral in repo or derivatives transactions. Rehypothecation is another form of collateral mobility. What is the extent of rehypothecation? There is some survey data from the International Swaps and Derivatives Association (ISDA). ISDA has an annual survey of its members that usually asks about the extent of rehypothecation using collateral received in OTC derivative transactions, in terms of the percentage of institutions that report that they do rehypothecate collateral. In 2001, the first survey, 70 percent or the respondents reported that they ". . . actively re-use (or 'rehypothecate') incoming collateral assets in order to satisfy their own outgoing collateral obligations" (p. 3). Over the years the percentage rises to 96 percent for large firms in 2011. In 2014, ISDA for the first time asked about which bonds were actually used for rehypothecation. Table 1 Panel C shows the results. In 2014 ISDA estimated that total collateral used in non-cleared OTC derivatives to be $3.7 trillion. It would appear that rehypothecation is sizeable. This does not address the question of the length of rehypothecation chains. Singh (2011) estimates that prior to the financial crisis, collateral velocity was three. Also see Singh and Aitken (2010).

This is not the only evidence on scarcity and mobility. The bilateral repo market was expanding significantly beyond the primary dealers in the 2000s. In the New York Fed data, if one dealer fails to deliver to another dealer, then the first dealer records a "fail to deliver" of $N, and the counterparty primary dealer reports a "fail to receive" of $N. So, fails and receives should be equal, unless the primary dealers are trading with firms that are not primary dealers.

To examine whether repo was expanding beyond the primary dealers we look at the difference between receive and fail by asset class. If all the fails are between primary dealers, then this number will be zero. So, if this number is positive, then it means that the party failing to deliver was not a primary dealer, the primary dealer records a "fail to receive". Figure 5 shows failure to receive minus failure to deliver by asset class. Again it is apparent that this number was near zero prior to 2000, meaning that all fails were with another primary dealer. But, after 2000 and prior to the crisis, Receive minus Deliver is clearly not zero. In this period there are significant fails by non-primary

dealer counterparties, suggesting that the bilateral repo market had grown significantly, consistent with collateral being mobile and scarce. (Also see Gorton and Metrick (2015).

This is confirmed in Table 1 Panel B, where it is clear that failure to receive minus failure to deliver increasingly differs from zero in the period 2000-2007, prior to the crisis. Moreover, note the sign difference between Treasuries and MBS during 2000-2007. For Treasuries receive minus fail is very large in 2000-2007, again meaning that non-primary dealers are not delivering Treasuries according to their repo contracts. But, in the case of MBS, the number is very negative, meaning that primary dealers are failing to deliver to non-primary dealer counterparties. This is also apparent in the figure.

The fails data on Agency MBS market is very different, likely because the repo fails number includes fails in the "to be announced" (TBA) market, although the data do not allow us to decompose the fails. (See Government Securities Dealers Reports (2015), Board of Governors of the Federal Reserve System). TBA contracts are forward contracts for the purchase of "to be announced" agency MBS. In this market, the MBS to be traded are not specified initially. Rather, the parties agree on six general parameters of the MBS (date, issuer, interest rate, maturity, face amount, price). The contracts involve a delayed delivery, typically an interval of several weeks. In the TBA market transactions are usually "dollar rolls," agreements involving the purchase or sale of an agency MBS with a simultaneous agreement to resell or repurchase MBS at a specified price. In a TBA dollar roll the securities returned need only be "substantially similar," unlike in a repo transaction. The TBA market is very large. Average daily fails in this market between December 31, 2009 and December 29, 2010, as reported by primary dealers, was $83.3 billion in fails to deliver and $73.8 billion in fails to receive (see Treasury Market Practices Group (TMPG) (2011)). On the TBA market, see Vickery and Wright (2013).

2.2 Fails and the Demand for Liquidity

We now turn to some formal evidence that collateral became increasingly mobile. We start the analysis by testing to see if there are significant breakpoints in the panel of fails (receive and deliver) data. To do this we follow Bai (2010). Bai (2010) shows how to find breakpoints in panels of data where a breakpoint is in the mean and/or the variance. Assuming a com-

mon breakpoint in a panel of data is more restrictive than assuming random breakpoints in the individual different series in the panel, but the method can be used on an individual series as well.

The method can be used to find other breakpoints subsequent to the first. The first breakpoint divides the panel into two sub-panels, on each side of the first breakpoint. To find the second breakpoint apply the procedure to each of the two subseries, on the two sides of the first breakpoint. The second breakpoint is the one that gives the larger reduction in the sum of squared residuals, when comparing the break found in each of the two subseries.

We examine a panel of four series: fail to deliver and fail to receive for Treasuries and for Agencies. We omit MBS for reasons discussed above. The sample period of weekly data runs from July 1991 to September 2014. The breakpoints are shown in Table 2. The table shows the 95% confidence intervals in the last two columns in terms of dates. From the figures above it is clear that fails are increasing, starting in the early 2000s. Consistent with this the first breakpoint is September 12, 2001, just after September 11, 2001. This is the start of a different regime and it extends until, not surprisingly, the second break chronologically just after Lehman. The third breakpoint is February 9, 2009.

Why were fails increasing? We will examine the proposition that fails increased as the demand for liquidity increased. We follow Xie (2012) in measuring the convenience yield by the spread between the rate on general collateral (GC) repo and the rate on the Treasury used as collateral for the repo. The maturity is one month. In GC repo, the lenders will accept any of a variety of Treasuries as collateral, i.e., it is general collateral rather than specific collateral. Xie shows that this spread has historically (1991-2007) been 36 basis points (see Xie (2012)), reflecting the fact that with GC repo the Treasury must be returned and the cash is tied up during the time of the repo Obtaining a Treasury via reverse repo is not as good as actual ownership of the Treasury.

To be clear, the GC repo to Treasury spread of 36 basis points means that the borrower is *losing* money to the lender for the cash lent. Take the more usual case, say with privately-produced collateral. Then, if this underlying collateral earned 6 percent and the repo rate was 3 percent, then the borrower would be earning the spread of six minus three. But with Treasuries as collateral, because of their safety and liquidity, the borrower is earning negative 36 basis points. The borrower is paying to own a Treasury financed in the repo market. The amount of repo supplied then is linked to

the convenience yield of Treasuries.

The basic idea we explore is whether an increase in the GC repo spread, i.e., an increase in the convenience yield, is associated with an increase in repo fails. In other words, if there is an increase in the demand for liquidity, then this spread will widen. A widening of the spread corresponds to an increased scarcity of Treasuries, and possibly other safe collateral as well, such as Agency bonds and Agency MBS.

We use differences-in-differences in seemingly-unrelated regression on the panel of the Treasuries and Agency bonds, where fails are normalized by fails in 2013. We indicate the three breaks discussed above. The first period is September 12, 2001 going until September 23, 2008 and the second is September 24, 2008 until February 10, 2009, followed by February 11, 2009 onwards. This means that there are four periods: prior to 2001, break 1, break 2 and break 3. We will look at specifications with and without lags. We also include the change in the one month T-bill since the level of the interest rate effects the incentive to fail. In a repo fail the implicit penalty is the interest that could have been earned elsewhere, so in a low interest rate environment the penalty is low.[8]

The regression results for fails to receive are shown in Table 3. The table for fails to deliver is in the Appendix. In both cases the interaction between the GC repo spread and regime 1 is significant. Break 1 is the period prior to the crisis up to September 24, 2008. In both cases the interaction of the spread with the period of Break 2 is also significant and these coefficients are larger. Break 2 runs from September 24, 2008 to February 11, 2009, the post-Lehman period. Changes in the convenience yield or the demand for liquidity appear to have driven repo fails in the period prior to the financial crisis and during the crisis. The first regime corresponds to the period of the scarcity of safe debt while the second regime corresponds to the flight to quality. This is true for both fails to receive and fails to deliver. The change in the one month T-bill rate is also significant, suggesting that the incentive to fail is related to the level of the interest rate. Finally, the three dummy variables for the three break regimes are not significant. This may be due to a combination of factors. The break points may be driven by the variance, and the interaction terms may be absorbing this effect.

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[8]For this reason the Treasury Market Practices Group introduced a "dynamic fails charge" to provide an incentive for timely settlement. See Garbade, Keane, Logan Stokes and Wolgemuth (2010).

In the Appendix we examine the breakpoints for the absolute value of fails to deliver minus fails to receive in the Treasury and Agency MBS repo markets. This is the variable that measures the growth of the repo market beyond the primary dealers. The results in the Appendix show the seemingly unrelated panel regression results for the absolute value of fails to deliver minus fails to receive in the Treasury and Agency MBS repo markets. Not surprisingly this difference in the repo market is not driven by demands for liquidity. Instead the market is growing for other structural reasons, e.g., the rise of large money managers, and foreign investors (see Gorton and Metrick (2015)).

The Agency MBS breakpoints for the absolute value of the difference between fails to receive and fails to deliver are shown in Panel B of Table 1. The break points are a bit different from those for Treasuries and Agency MBS. The regressions for Agency MBS fail to receive and fail to deliver are in the Appendix. For both types of fails the liquidity demand, as captured by the GC repo-Treasury spread is significant for the second break period, from September 16, 2009 to December 27, 2011. Throughout the financial crisis there continued to be a significant amount of agency MBS issued. In 2008 and 2009 $2.89 trillion was issued (see Vickery and Wright (2013)). This was a period of a flight to quality, that is a desire to hold very liquid securities.

2.3   Summary

The evidence for collateral mobility is indirect because there are no data or limited data on rehypothecation, trading, and collateral posting for derivative positions and for clearing and settlement. Nevertheless, the size of the securitization market prior to the crisis and the evidence above, indicate the system of mobile collateral that had developed.

3   An Immobile Collateral System

Bolles (1902) described the U.S. National Bank Act as " . . . the most important measure ever passed by any government on the subject of banking." The National Bank Acts were passed during the U.S. Civil War; the first Act was passed in 1863 and this law was amended in 1864. The Act created a new national banking system. The Act was intended to create a demand for U.S. Treasury bonds because without the income tax it was the only way to

finance the North in the war. The Acts established a new category of banks, national banks, which were to coexist with state chartered banks. National banks could issue bank-specific national bank notes by depositing eligible U.S. Treasury bonds with the U.S. Treasury.[9] In this section we examine the U.S. National Banking Era. In subsection 3.1 we provide a very brief background on the banking system in the era, 1863-1914. In subsection 3.2 we introduce the "bank note paradox". We show the "arbitrage profits" that allegedly existed. The analysis of the profitability of note issuance and its relation to the convenience yield on Treasuries is in subsection 3.3. Subsection 3.4 summarizes the results of this section.

3.1   The U.S. National Banking System

During the U.S. National Banking Era banks were required to back their privately-produced money in the form of bank-specific national bank notes with U.S. Treasury bonds. One kind of money was required to back another kind of money—narrow banking. So, there was a collateral constraint on the issuance of money by banks. As with repo today, the interest on the bonds went to the banks. With national bank notes backed by U.S. Treasuries there was for the first time in the U.S. a uniform currency. Prior to the Acts, banks issued individual private bank notes which traded at discounts to face value when traded at a distance from the issuing bank. There were hundreds of different banks' notes, making transacting difficult. Initially, national bank note issuance was limited to 100 percent of a bank's paid-in capital, but this was changed to 90 percent by the act of March 3, 1865. Also, note issuance was limited to 90 percent of the lower of par or market value. This was changed to 100 percent by an act in 1900. See Noyes (1910), Friedman and Schwartz (1963), and Champ (2011c) for more information on the National Banking Era.

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[9]Eligible bonds were U.S. Treasury government registered bonds bearing interest in coupons of 5% or more to the amount of at least one-third of the bank's capital stock and not less than $30,000. The Act of July 12, 1870 eliminated the requirement that bonds bear interest of 5% or more. After that date eligible bonds were "of any description of bonds of the U.S. bearing interest in cash."

3.2 The Bank Note Issuance Puzzle

The National Banking Era has been puzzling for economists for well over a century. The puzzle is that there appears to have been high, allegedly sometimes infinite, profits from issuing national bank notes—riskless arbitrage profits—but this capacity to issue notes was never fully utilized. Friedman and Schwartz (1963, p. 23): ". . . despite the failure to use fully the possibilities of note issue, the published market prices of government bonds bearing the circulation privilege were apparently always low enough to make note issue profitable . . . The fraction of the maximum issued fluctuated with the profitability of issue, but the fraction was throughout lower than might have been expected. We have no explanation for this puzzle." They go on to write: "Either bankers did not recognize a profitable course of action simply because the net return was expressed as a percentage of the wrong base, which is hard to accept, or we have overlooked some costs of bank note issue that appeared large to them, which seems must more probable" (p. 24).[10]

Phillip Cagan (1963, 1965) determined whether it was profitable for banks to issue notes by examining the following formula:

$$
r = \begin{cases} \frac{r_b p - \tau \alpha \min(p,1)}{p - \alpha \min(p,1)} & if \quad p > \alpha \min(p,1) \\ \infty & if \quad p = \alpha \min(p.1) \end{cases}
$$

where: r is the annual rate of return on the issuance of national bank notes; p is the price of the bond held to back the notes (dollars), assuming a par value of one; r_b is the annualized yield to maturity on the bond held as backing; α is the fraction of the value of a given deposit of bonds that could be issued as notes; and τ is the annual expense in dollars of issuing $\alpha \min(p, 1)$ in notes. The term $\alpha \min(p, 1)$ refers to the amount of notes that are returned to the issuing bank by the U.S. Treasury from the deposit of a bond with price p. The variable τ includes the tax rate on note issuance, which was \$0.01 for \$1 prior to 1900 and \$0.005 on 2% coupon rate bonds after 1900). Also, miscellaneous costs are included here. For example, Cagan used an estimate of these costs of 0.00625 per one-dollar deposit in government bonds.[11]

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[10]Champ (2011b) also cites these Friedman and Schwartz passages. Friedman and Schwartz's mention of "the wrong base" refers to mistaken calculations by the contemporary Comptroller of the Currency.

[11]The Comptroller used \$62.50 for the costs associated with notes issued based on \$100,000 of bonds deposited. These costs included the cost of redemption, \$45; express charges, \$3; engraving plates for the notes, \$7.50; and agents' fees, \$7. See Champ

Champ (2011b) gives the following example. Consider a bank in 1890 (i.e, $\alpha=0.9$) that purchased a bond for \$1.10, with yield to maturity of 4 percent. Then, the total cost of note issuance is $\tau = 0.01 + \frac{0.00625}{0.09} \approx 0.01694$. So, in this case. the rate of profit for issuing notes backed by this bond sold be:

$$r \approx \frac{(0.04)(1.10) - (0.01694)(0.9)}{1.10 - 0.9} \approx 14.375\%$$

Cagan (1963) found very high profits rates for the 1870s, 20-30%. More importantly, Cagan and Goodhart (1965) found profit rates of infinity in the early 1900s. An infinite rate of profit occurs when $\alpha = 1$ after 1900 and the bond is selling below par. In that case, the notes the bank could issue based on using that bond as collateral would exactly equal the price paid for the bond, so no capital could be used and the bank could earn infinite profits. Figure 7 shows Cagan's profit series (as computed by Champ (2011b)). The figure shows the conundrum. The gaps in the figure are the instances where the rate of profit was alleged to be infinity; these are all cases where the prices of 2% coupon bonds fell below par. Note that the figure calculates the average rate of profit, not the marginal rate of profit. National banks did not take advantage of apparent profit opportunities.

Figure 8 shows our calculation of the profit series. We used Champ's more accurate representation of the costs of note issuance than the Comptroller of the Currency.[12] We also filled in all the bond prices that were missing from a Bruce Champ spreadsheet (provided to us by the Federal Reserve Bank of Cleveland). We also made further adjustments discussed below.

Why didn't banks take advantage of this arbitrage opportunity? After all, banks held U.S. Treasury bonds on their balance sheets (i.e., not including Treasuries held to back their notes). See Figure 6. Or, banks could have raised capital and used this to buy bonds for collateral for notes. To explain this puzzle, the literature has focused on hidden transactions costs or the risks of unpredictable redemptions; see Bell (1912), Cagan (1965), Goodhart (1965), Cagan and Schwartz (1991), Duggar and Rost (1969), Champ, Wallace and Weber (1992), and Wallace and Zhu (2004). None of these explanations are particularly persuasive; these explanations are reviewed by

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(2011b).

[12]Based on a spreadsheet of Bruce Champ, provided by the Federal Reserve Bank if Cleveland.

Champ (2011b) and Calomiris and Mason (2008).[13]

Prior explanations do not mention that there may be a convenience yield associated with U.S. Treasuries. This is, however, suggested by the work of Krishnamurthy and Vissing-Jorgensen (2012) who look at data over the period 1926-2008, and Krishnamurthy and Vissing-Jorgensen (2013) who analyze the period 1914-2011. Figure 6, showing that national banks held U.S. Treasuries on their balance sheets (i.e., the ratio of U.S. government bonds not on deposit at the Treasury to bank loans and discounts) suggests, by revealed preference, that there was a convenience yield associated with Treasuries during the National Banking Era.

At the time bankers also recognized the convenience yield on Treasuries. For example, *The Financier*, April 7, 1902, Volume LXXIX (The Financier Company): ". . . banks have always regarded high class bonds as an offset, so to speak, for risks incurred in discounts yielding a higher rate of interest. In this connection we cannot do better than to quote from a very valuable paper read by A.M. Peabody, of St. Paul, before the St. Paul Bank Clerks' Association, in which this feature is brought prominently forward. After explaining the classification of such investments, Mr. Peabody says: 'They have ever proved themselves the safeguards for banks under pressure of financial panics in times of great stringency, and when it would be impossible to borrow money on any form of security, railroad bonds with government bonds, are alone available as security for money' (p. 1258). And, *The Bond Buyers' Dictionary* (1907): ". . . it is possible to say that there is a better market in moments of extreme panic for the Government issues than there is for even the best class railroad bonds. There will not be by any means [be] the same volume of liquidation. For every dollar of Government bonds thrown into a panic market there will be $100 of railroad bonds. . . . Government bonds are undoubtedly the safest of all securities. . . " (p. 73).

But, even if banks wanted to keep these Treasuries on their balance sheets, why didn't they raise bank capital to buy Treasuries to back note issuance. That they did not suggests that bank capital was costly or that banks could not find the bonds. We will argue that bankers did not take advantage of opportunity to issue more national bank notes because it was *not* profitable to do so. We will show that the implicit profit from not issuing notes is

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[13]Calomiris and Mason (2008) show that there was ". . . substantial variation in the propensity to issue national bank notes traceable to county, state, and bank-specific characteristics related to the profitability of lending" (p. 340).

driven by measures of convenience yield.

We first return to the calculation of the profit rate from note issuance. As mentioned above, we filled in the missing bonds in Champ's original spreadsheet used for calculating the profit rate to note issuance.[14] We next eliminated bonds that would have been called in the next six months, since then the notes backed by these bonds will have to be returned, or new bonds will have to be purchased.[15]

However, there is another issue, namely that it is the *marginal* profit rates that are relevant not the average rate of profit. This is important because in the early 1900s, and possibly before that. U.S. government bonds were hard to find. And, even when banks could find bonds, they had to reverse repo in the bonds in at a high cost. Contemporary observers continually wrote about this shortage of safe debt. For example, Morris (1912): "Various reasons have been assigned for the decline in circulation which culminated in 1891, the most probable being the growing scarcity of U.S. bonds and their relatively high premium. It is also alleged that improved banking facilities, allowing a more extensive use of checks, reduced the demand for currency" (p. 492). Morris dates the start of the problem as 1891. It is also interesting that Morris points out that the cost of note issuance caused a further development of demand deposits, the shadow banking system of its time.

Borrowing bonds was costly. Francis B. Sears, vice president of the National Shawmut Bank of Boston, Mass. (1907-08): "There are two classes of banks—those outside of the large cities, that can get bonds only by buying them, and a few banks in a few large cities that can borrow them. I would like to add that insurance companies and savings banks are large bondholders, and undoubtedly arrangements can be made with them to get bonds for some large banks. The rate is $1\frac{1}{2}$ to 2 percent for borrowing bonds in that way" (p. 91). *Bankers Magazine* (March 1908): "Bond borrowings by the national banks have become an important feature of banking in recent years. Where a bank wishes to increase its circulation, or to procure public deposits, and does not happen to have the bonds which must be pledged with the Treasury, and finding the market price of bonds too high to make the

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[14]The missing bond prices/amounts were mostly during 1875-1879 plus one bond maturing in 1896. This did not affect the potentially infinite profits, but just added more observations in the earlier period.

[15]Eliminating these bonds removed some spikes in the profit series, one of which was during the period of high profits (1907). But otherwise it has no significant effect on the post-1902 series.

transaction profitable if the bonds must be bought, resort is had to borrowing. Bond dealers, savings banks or private holders may have 'Governments' which they are willing to lend to national banks for a consideration" (p. 321).[16] The *Rand-McNally Bankers' Monthly* (September, 1902) quoting "a banker": "There is not much profit in issuing circulation on government bonds, but some of the larger banks are willing to take out notes, if they can borrow bonds for that purpose from their friends—not being disposed to buy them for temporary use. . . . The real trouble is to find the bonds. Many of them are held by institutions and estates, who cannot legally loan the bonds to National Banks, and as their prices are too high to justify any large purchases of bonds by banks for the purpose of taking out circulation. . ."(p. 157-158). Gannon (1908), speaking of Treasury bonds: ". . . such bonds are not easy to buy in quantity, and the greater part of the recent expansion, some \$80,000,000 since the panic [of 1907], was accomplished by borrowing bonds"(p. 338)

The situation was summarized by *The Financial Encyclopedia* (1911, p. 119):

> When the banks borrow, either to secure banknote circulation or Government deposits, they make private arrangements with the actual owners of the bonds, including insurance companies, for the use of these securities. The rates banks pay vary, but in general lenders of bonds secure a very substantial profit from this employment of them, in addition to the interest which the bonds themselves carry.

> Borrowed bonds were first itemized separately in the national banks' returns under the Comptroller's call of November 25, 1902. At that time the total 'borrowed bonds' reported by national banks of the whole country were \$39,254,256 of which New York banks were credited with \$21,199,000. In the return of December 3, 1907, the banks of the United States reported bonds of \$166,073,021, more than half, or \$88,274,330, being held by the forty national banks of this [New York] city. These are by far the largest holdings ever reported by New York banks.

> When a bank borrows Government, municipal, or other bonds,

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[16]Government deposits in national banks had to be backed by bonds also, but there was a slightly larger list of eligible bonds for this purpose.

from an insurance company, for instance, which are pledged as security for public (Treasury) deposits, it either gives the lender a check for the face value, with a contract stipulating to buy back the bonds at a certain price, or the bank gives the lender other collateral as security for the loan.

In the case of life insurance companies, the collateral offered in exchange for the bonds has often represented bonds in which the lending corporations are allowed to invest, but which were not in the so-called 'savings bank list,' and for that reason were not eligible as security for public deposits. While one or two of the life companies have never consented to lend their bonds, many others, as well as various fire insurance companies, have done so, on the theory that it was a good business transaction, since it yielded them 1 or $1\frac{1}{2}\%$ in addition to the regular interest return.

The scarcity of bonds meant that the *marginal cost* of conducting the "arbitrage" was higher than the average cost. While the Comptroller started publishing data on bank bond borrowings in 1902, it seems that this problem started earlier. At a meeting of the American Economic Association held in Cleveland, Ohio in December 1897, it was voted to appoint a committee of five economists to consider and report on currency reform in the United States.[17] They turned in a report in December 1898. One point they made was this:"Now it is commonplace that our bank circulation is not a very profitable one." See *The Bankers' Magazine*, February 1899, p.221.

Note issuance profit series that are the average rate of profit are misleading. To adjust the profit calculations to reflect the scarcity and associated high cost of reversing in bonds, we set α in the above calculation of the profit rate to 0.99 instead of 1. Now, there are no instances of infinite profits. We discuss below why this does not greatly affect regression results. Figure 8 shows the series of profit rates in this case.

There is also the issue of the cost of bank capital. This cost is hard to quantify, as it is today. Bank stock during this period was illiquid, trading on the curb market. And there is some evidence that it was held in blocks by insiders. See Gorton (2013). There is no data on bank stock issuance. Contemporaries described the return to bank stock as low, partly due to double

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[17]The economists were a very distinguished group: F.M. Tayor, University of Michigan; F.W. Taussig, Harvard; J.W. Jenks, Cornell; Sidney Sherwood, Johns Hopkins; and David Kinley, University of Illinois.

liability.[18] For example, Frank Mortimer, cashier of the First National Bank, Berkeley. Ca.; in an address delivered before the San Francisco Chapter of the American Institute of Banking, *American Institute of Banking Bulletin* "When one takes into consideration the risk involved, the capital invested, and the double liability attached to stockholders in national banks, the profit from an investment in bank stock is small, indeed, when compared to the profit accruing from other lines of business." (p. 236; reprinted in the *Journal of the American Bankers Association*, vol. 6, July 1913-June 1914.).

3.3 The Convenience Yield on Treasuries and the Cost of Bank Capital

In this section we turn to an analysis of the rate of profit on note issuance. We show that the rate of profit on note issuance is highly related to the convenience yield on Treasuries. We measure convenience yield in two complementary ways. First, we use the supply of Treasuries divided by GDP. Krishnamurthy and Vissing-Jorgensen (2012) show that this measure strongly drives the convenience yield on Treasuries from 1926-present. When the supply of those assets is low, that is safe assets are relatively scarce, then the convenience yield for safe assets increases. Therefore, Treasury supply should be negatively related to the convenience yield. We take two measures of Treasury supply: (US government debt)/GDP (as in Krishnamurthy and Vissing-Jorgensen (2012)), and (available Treasuries)/GDP, where available Treasuries excludes those already held to back bank note issuance and thus captures the remaining supply. Second, we also measure the convenience yield as the spread between high grade municipal bonds from New England and Treasuries. Municipal bond yields are from *Banking and Monetary Statistics* (1976).

Table 4 gives the results of a regression of issuance profits on these measures of the convenience yield from 1880-1913. The results match our intuition. The profit measure is high exactly when the convenience yield to Treasuries is large. We find that a 1% increase in the muni spread is associated with a 15% increase in average profit. As demand for Treasuries increases, the apparent profits also increase. As the supply of available Treasuries decreases, profits also increase. Both the supply variables and the muni spread are highly significant independently. However, we would suspect that

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[18]On double liability see Macey and Miller (1992) and Grossman (2001).

they likely measure similar economic forces though each is measured with noise. Consistent with this, when we include both the supply of Treasuries and muni spread together the coefficients on each decrease in absolute value though they remain statistically significant. This suggests that both are imperfect but overlapping measures of the convenience yield.

We show the results when we use the average profit series as well as the log average profit series. Recall that profit is given by $\frac{r_b p - \tau \alpha \min(p,1)}{p - \alpha \min(p,1)}$. A possible concern is that the profit series is highly non-linear due to the denominator becoming small later in the sample. To mitigate this concern, we also report the results using log profits, which largely alleviates the strong non-linearity in the denominator (see Figure 8 which plots profits on a log scale). Our results do not change drastically with the log transformation, highlighting that non-linearities in the latter half of the sample aren't driving the result. In unreported results we also obtain the same basic findings for alternative values of α.

All variables in this regression are persistent which can potentially confound inference. We deal with this in several ways. First, in our main specifications we estimate standard errors using Newey-West with 10 year lags (specifically, we use 10 lags for annual data and 40 lags for quarterly data). Second, we run GLS assuming the error term follows an AR(1). This suggests transforming both our x and y variables by $1 - \rho L$ where ρ is the error auto-correlation and L is a lag operator. We find ρ by running OLS as in specification (4) in the Table and computing the sample auto-correlation of the residuals. This does not substantially change the point estimates or inference in terms of what is statically significant. As mentioned by Krishnamurthy and Vissing-Jorgensen (2012), however, coefficients do decrease somewhat in absolute value. A likely reason is that these are noisy measures of convenience yield and measurement error will become more pronounced in the transformed data. This follows from the fact that when x is persistent the variance of x will be dominated by low frequency components. In contrast, in the transformed data measurement error likely accounts for more of the variance of the right hand side variable, resulting in a larger degree of attenuation bias.

Finally, while the results appear fairly strong, we also acknowledge that we are working with a fairly small subsample of data which is a limitation of our analysis. Higher frequency data (e.g., monthly data on debt/GDP) won't be particularly helpful here in overcoming the fairly small sample because the variables are highly persistent.

We hypothesize that a third variable – the cost of capital for banks – likely plays a role in explaining the profits on note issuance as well. If the cost of raising capital for banks is high, then banks would find it costly to take advance of note issuance and may leave a puzzlingly large profit on the table. For this conjecture, we can only offer suggestive evidence from Figure 8 which plots the profit series along with NBER recession bars. It is likely that the cost of raising capital for banks increases during recessions, and especially at the onset of recessions, and these are times when we do in fact see increases in the profit series. Thus, there is some suggestive evidence of the cost of capital for banks being positively associated with the profits on note issuance as well.

Taken together, our results indicate that the profits to note issuance fluctuate with the convenience yield on Treasuries, and our evidence is consistent with the idea that profits are related to the cost of bank capital.

3.4 Proposals for Reform during the National Banking Era

Despite the creation of a uniform currency, the monetary system of the National Banking Era was increasingly unpopular. Reform of the currency system was increasingly discussed because of the problems of inelasticity and banking panics. "Inelasticity" meant that the quantity of money was not sensitive to the business or seasonal cycles. There were spikes in seasonal interest rates and the money supply could not be increased to alleviate bank runs. Following the Panic of 1893 calls for reform of the banking system became louder. All the reforms sought to sever the link between bank notes and Treasuries. This link was viewed as the problem. Replacement proposals were for an "asset-based" system, meaning that currency would be allowed to be backed by bank loans or commercial paper (depending on the party proposing this system).

The first proposal for an asset-backed currency came from the American Bankers' Association in 1894. It was called the "Baltimore Plan" (the Association's meeting was in Baltimore that year). The plan envisioned banks issuing circulating notes under federal supervision, where the notes would be secured by (1) a first lien upon the assets of the issuing bank; (2) the double liability of shareholders; (3) the 5 percent redemption fund; and (4) a 5 percent guaranty fund (to be used to repay note holders of a failed bank).

Treasury Secretary Carlisle (1894) modified the Baltimore Plan to create more security for the noteholders. He proposed (1) a deposit of 30 percent of the circulation in legal money with the government; (2), the safety fund of 5 percent; (3) a requirement upon all other banks to cover any losses beyond the two funds of any failed bank; (4) a lien upon all assets; and (5) a further lien on the shareholders' liability. In addition, both plans wanted to limit note issuance to 50 or 75 percent of paid-up capital.

There were other subsequent proposals as well, including plans from Eckels (1894a,b) and the Indianapolis Monetary Commission (1900), see Taylor (1898). All of these plans were similar in spirit to the Baltimore Plan. See Wicker (2005), West (1974) and Laughlin (1920) for more detailed discussions of the various plans.

The asset-based monetary proposals sought to separate the two forms of money: Treasuries and bank notes. And they did recognize that bank runs on demand deposits were related to perceptions of the "safeness" of the loans backing the demand deposits. Backing private bank notes with loan portfolios would have created the risk of runs on notes as well as demand deposits, although seniority of notes, guarantee funds, reserves, etc. were aimed at this problem. But, the proposals embedded the view that an "elastic" currency would alleviate panics. Laughlin (1920): "In all these plans we were really aiming to prevent the difficulties experienced in [the Panic of] 1893..." (p. 30-31).

It is interesting that the proposed reforms during the period all aimed to break the link between bank notes and Treasuries.

4   Discussion

Of course, the National Banking System is not exactly like the LCR. There are obvious differences. But, like the National Banking Era, the logic of the LCR seems to be that if short-term debt is backed by Treasuries, then bank runs will be avoided. Fundamentally the two systems enforce a correspondence between two types of debt instruments, each with a convenience yield. The input for making one kind of money, bank notes or money market instruments, is Treasuries. Such a system is fragile because by forcing two kinds of money together it is likely that there will be a shortage of one kind of money, leading to its private production elsewhere, which creates fragility in the system.

The National Banking System did succeed in introducing a uniform currency where the national bank notes of different banks all traded at par, unlike the pre-Civil War period. This was because banks' national bank notes were backed by U.S. Treasury debt. We have focused on the fact that Treasuries have a convenience yield. In the recent period, a measure of that convenience yield is the GC repo to Treasury spread. This spread is a driver of repo fails when agents want to keep the Treasuries (or the cash) in repo transactions.

This was the same core issue during the National Banking Era. In the National Banking Era, a measure of the convenience yield (and the cost of bank capital) is the implied profitability of issuing bank notes. There is no under issuance puzzle once this is recognized. If Treasuries have a convenience yield, then they provide safety and liquidity to the agents who demand this. But, these agents or other agents also have a demand for bank notes.

If there were enough Treasuries (high-quality liquid assets) to meet the global demand for safe debt and to back short-term bank debt, then the LCR and related immobile collateral requirements would not be a problem. One potential argument is that in the National Banking Era the supply of Treasuries was low (debt to GDP was in the range of 10-30%) so that scarcity was more of an issue in that period then it is today where the supply of government debt is much larger. However, this ignores that the demand for safe US government debt now is also global, which can add to issues of scarcity. The likelihood of such a satiation of the global economy with Treasuries today seems remote. Gorton, Lewellen and Metrick (2012) show that the sum of U.S. government debt outstanding and privately-produced safe debt outstanding has been 32 percent of total assets in the U.S. since 1952. See Figure 10. The figure shows that the bulk of safe debt has never been Treasuries, but has mostly been privately produced debt. (Figure 1 shows the composition of this privately produced safe debt.) There has never remotely been enough U.S. Treasuries to make up the 32 percent and given the debt burden of issuing enough to accomplish that, there is never likely to be enough. Furthermore, Treasuries outstanding is a function of fiscal policy not a function of the demands for collateral.

When Treasuries have a convenience yield, and short-term bank debt must be backed by Treasuries, there is a tradeoff between the two types of money. More short-term debt means fewer Treasuries for alternative uses. This tradeoff is common to the two systems. We saw this in the National Banking Era. The tradeoff is evident in the data. Noyes (1910): "A heavy

decrease in the outstanding public debt would naturally, at some point, cause a reduction in the bank-note circulation, independently of other influences. A large increase in the government debt would necessarily cause an increase in the supply of bank notes" (p. 4). Noyes then traces this out over the National Banking Era. It is the same statement that was formalized by Krishnamurthy and Vissing-Jorgensen (2012a,b) for the modern era. The convenience yield is negatively related to Treasuries (divided by GDP) outstanding.

One way out of this tradeoff, if it is binding, is to privately produce another kind of debt. In the recent period this was ABS and MBS, which could be used in place of Treasuries to back repo, ABCP, and MMF. In the National Banking Era, it was demand deposits using portfolios of loans as the backing. During the National Banking Era, Treasuries outstanding to GDP fell secularly (see Figure 6, panel C). And, from the start of the National Banking System, the ratio of bank notes to demand deposits fell, from just over 60 percent in the early part of 1865 to 14 percent by 1909, as shown in Figure 9. Demand deposits were privately-produced safe debt or money, the shadow banking system of its time. So, while the immobile collateral system ended bank runs on bank notes, there were bank runs on demand deposits, another form of bank money. The biggest problem of the National Banking Era was that there were banking panics.

It is difficult to prove causally that demand deposits grew relative to bank notes because of collateral requirements. However, the growth in deposits does line up remarkably well with the decline in Treasury supply and hence the supply of safe assets that could be used to back notes. This accords with the evidence in Krishnamurthy Vissing-Jorgensen (2012b) that the supply of Treasury crowds out privately produced bank debt. The ratio of national bank notes to demand deposits fell from over 60% to less than 20% over the period and this ratio co-moves strikingly with the debt to GDP ratio as shown in Figure 9. The correlation of the ratio of notes to deposits with the supply of Treasuries to GDP is 0.96. As the supply of Treasuries falls over this period, deposits grow. Demand deposits were conceptually misunderstood during the National Banking Era, although it was clear that demand deposits were the issue in banking panics. This highlights that the system of immobile collateral in the National Banking Era was not successful in mitigating panics and that it likely contributed to the growth of other forms of bank debt.

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5 Tables and Figures

Table 1: We present summary statistics on fails and rehypothecation. Sources: Panels A & B, Federal Reserve Bank of New York. Panel C, ISDA.

Panel A: Fails, $ Millions

	Fail to Receive			Fail to Deliver	
	1990-99	2000-07		1990-99	2000-07
Mean	31,676	154,600		11,812	122,363
Std Dev	3,771	6,372		4,105	163,564

Panel B: Receive fails minus deliver fails, $ Millions

	Treasuries		Agencies		MBS	
	1990-99	2000-07	1990-99	2000-07	1990-99	2000-07
Mean	5,169	16,624	-123	338	207	-8,073
Std Dev	3,947	18,268	739	3,696	2,615	22,283

Panel C: Amount of collateral received eligible vs actually rehypothecated (12/31/2013)

	Treasuries	Other
Total Received ($ Millions)	179,366	123,915
Eligible for Rehypothecation	85%	55%
Actually Rehypothecated	55%	30%

Table 2: We report breakpoints for our fails data panel for both failures to receive and deliver along with 95% confidence intervals. The methodology for finding breaks in panels follows Bai (2010).

Panel A: Treasury and Agency Bonds

	Break Date	Lower Bound	Upper Bound
First Break	12-Sep-01	2-May-01	16-Jan-02
Second Break	24-Sep-08	11-Jun-08	31-Dec-08
Third Break	11-Feb-09	14-Jan-09	4-Mar-09

Panel B: Agency MBS

	Break Date	Lower Bound	Upper Bound
First Break	16-Oct-02	18-Sep-02	6-Nov-02
Second Break	16-Sep-09	26-Aug-09	30-Sep-09
Third Break	28-Dec-11	23-Nov-11	25-Jan-12

Table 3: We run seemingly unrelated regressions of Treasury and Agency fails to receive.

	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec
GC Repo-1m T-bill	6.963***	0.695	7.303***	0.640	7.509***	0.620
	(5.57)	(0.41)	(5.78)	(0.38)	(5.91)	(0.36)
L1.GC Repo-1m T-bill			2.609*	0.818	2.951*	0.648
			(2.07)	(0.48)	(2.31)	(0.38)
L2.GC Repo-1m T-bill					2.495*	0.316
					(1.96)	(0.19)
GC Repo-1m T-bill x Break 1		13.35***		13.96***		13.35***
		(5.14)		(5.26)		(5.03)
L1.GC Repo-1m T-bill x Break 1				2.492		1.894
				(0.95)		(0.71)
L2.GC Repo-1m T-bill x Break 1						-2.164
						(-0.82)
GC Repo-1m T-bill x Break 2		39.57***		45.66***		44.08***
		(7.36)		(8.46)		(8.20)
L1.GC Repo-1m T-bill x Break 2				33.27***		37.98***
				(6.55)		(7.46)
L2.GC Repo-1m T-bill x Break 2						32.26***
						(6.43)
GC Repo-1m T-bill x Break 3		-1.485		-1.878		-1.185
		(-0.13)		(-0.16)		(-0.10)
L1.GC Repo-1m T-bill x Break 3				4.103		4.818
				(0.36)		(0.41)
L2.GC Repo-1m T-bill x Break 3						3.120
						(0.27)
Break 1 (9/2001-9/2008)		-8.852		-8.269		-6.430
		(-0.23)		(-0.21)		(-0.17)
Break 2 (9/2008-2/2009)		75.43		153.1		193.5
		(0.57)		(1.16)		(1.48)
Break 3 (2/2009)		11.00		9.994		7.266
		(0.26)		(0.24)		(0.17)
D. 1m T-Bill		-13.08***		-11.39***		-9.288***
		(-6.41)		(-5.53)		(-4.48)
Constant	0.879	-11.81	1.104	-10.05	1.092	-7.817
	(0.05)	(-0.48)	(0.07)	(-0.41)	(0.06)	(-0.32)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.013	0.055	0.015	0.076	0.016	0.095

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: We run regressions of profits on two measures of the convenience yield: Treasury supply and the Municipal bond - Treasury spread. We measure Treasury supply as either debt / GDP or Treasuries available / GDP. Treasury supply variables are annual which reduces the number of observations. The muni spread is quarterly. T-stats are Newey-West with 10 lags for annual regressions and 40 lags for quarterly regressions. The column "GLS" assumes errors follow an AR(1) and hence transforms the x and y variables by $1 - \rho L$ where ρ is the autocorrelation of the error term in (4) using OLS and L is a lag operator.

Profit on Convenience Yield, 1880-1913

$$y_t = a + b \times x_t + \varepsilon_t$$

Panel A: $y =$ profit

	(1)	(2)	(3)	(4)	GLS (5)
ln(Debt/GDP)	-43.4 [-2.05]				
ln(Avail/GDP)		-31.8 [-3.51]		-24.4 [-4.03]	-19.3 [-4.33]
Muni spread			54.5 [3.06]	14.9 [3.59]	18.3 [3.20]
AdjR^2	0.28	0.65	0.50	0.76	0.61
N	34	34	137	34	34

Panel B: $y = \ln(\text{profit})$

	(1)	(2)	(3)	(4)	GLS (5)
ln(Debt/GDP)	-1.78 [-2.35]				
ln(Avail/GDP)		-1.18 [-4.85]		-1.03 [-6.81]	-0.81 [-5.49]
Muni spread			1.81 [3.83]	0.44 [4.49]	0.38 [2.05]
AdjR^2	0.36	0.67	0.48	0.74	0.54
N	34	34	137	34	34

Figure 1: Composition of Privately-Produced Safe Debt (% of Total Privately-Produced Safe Debt)

Deposits   Money-like debt

MBS/ABS Debt   Corporate Bonds and Loans

Other Liabilities
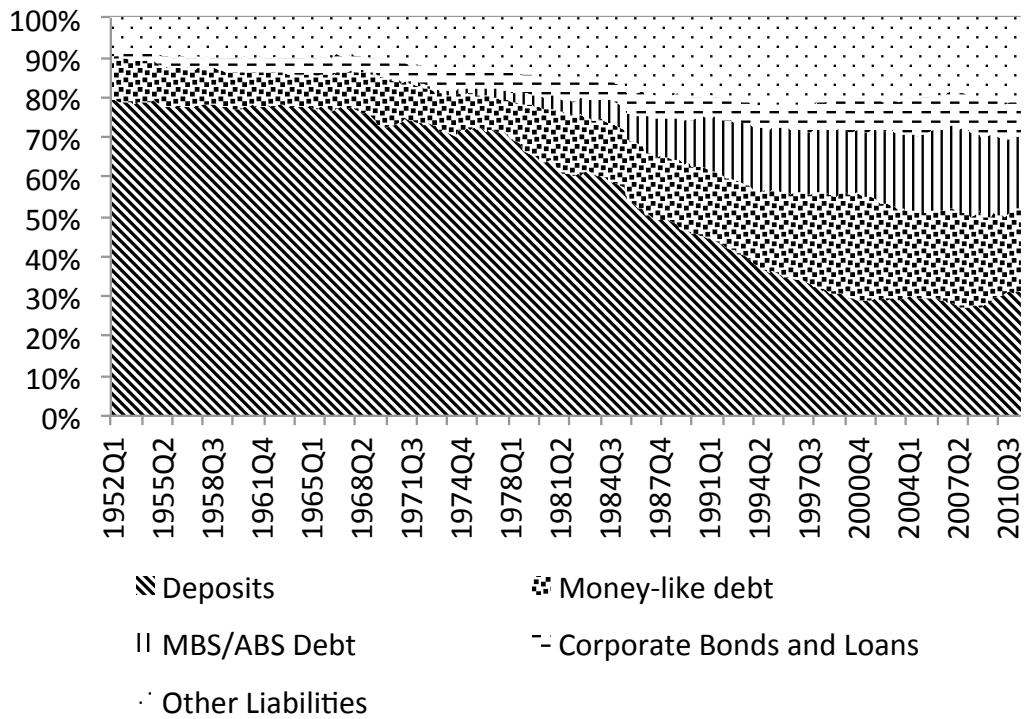
Figure 2: Holders of U.S. Treasury Securities (percent of total outstanding).
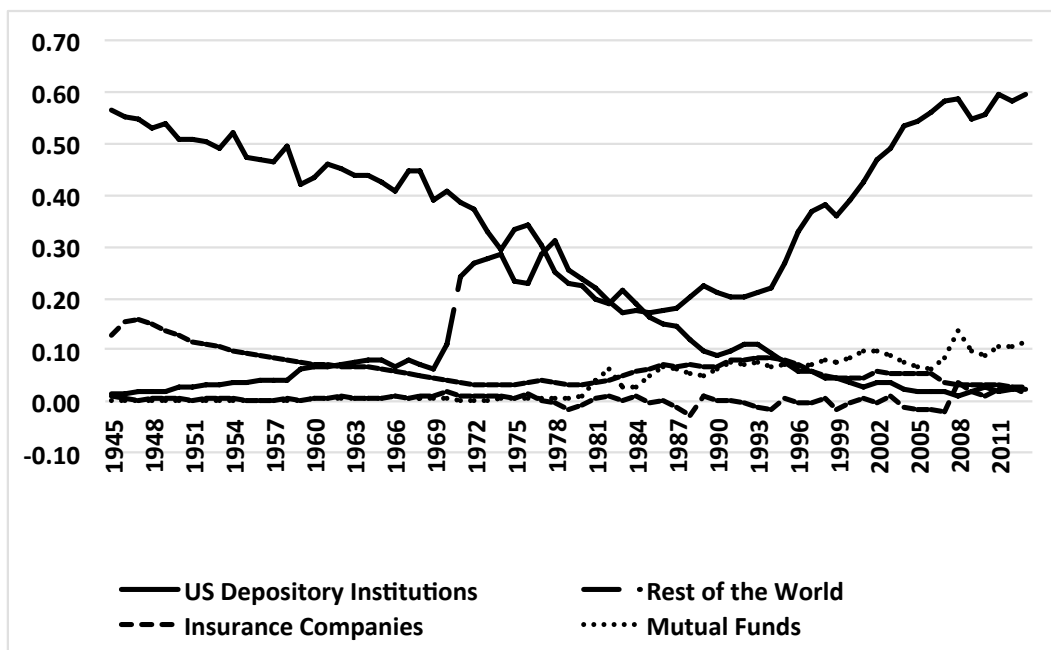
Figure 3: Fails by type.
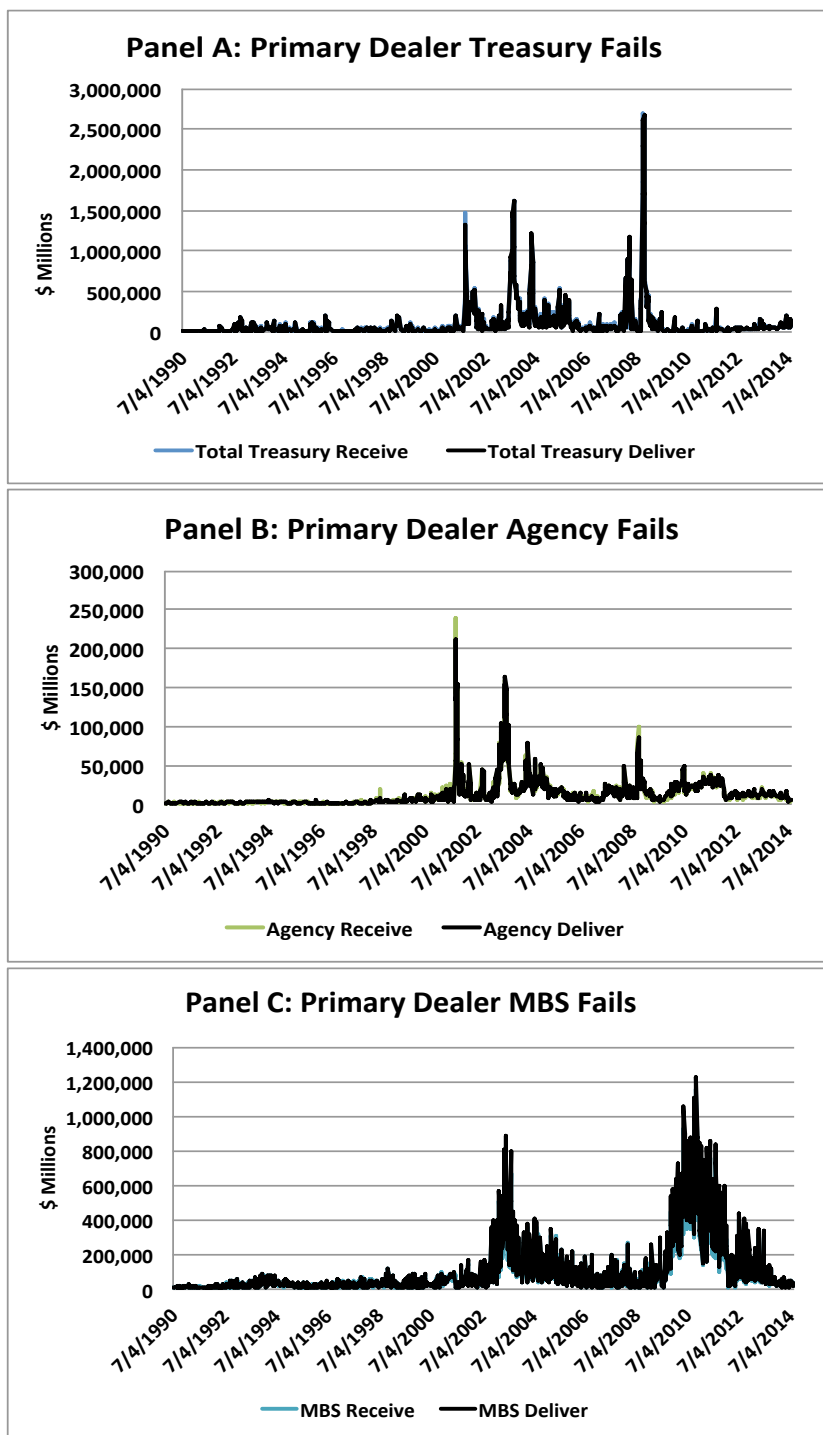
Figure 4: DTCC Fails ($100 million).
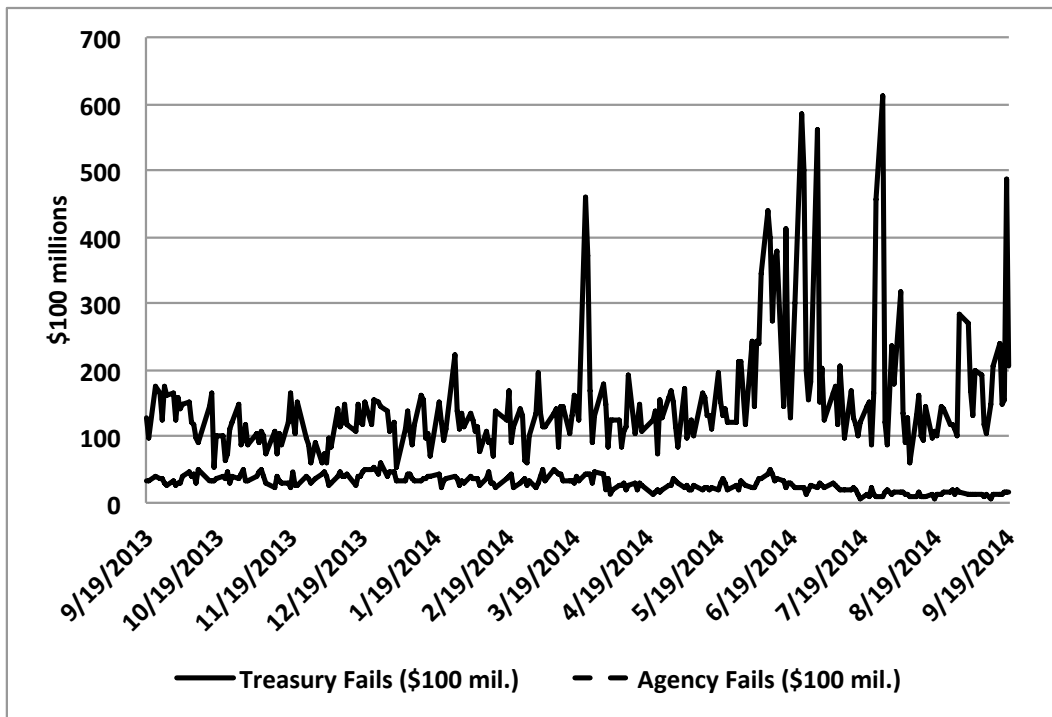
Figure 5: Difference between fail to receive and failure to deliver by type.
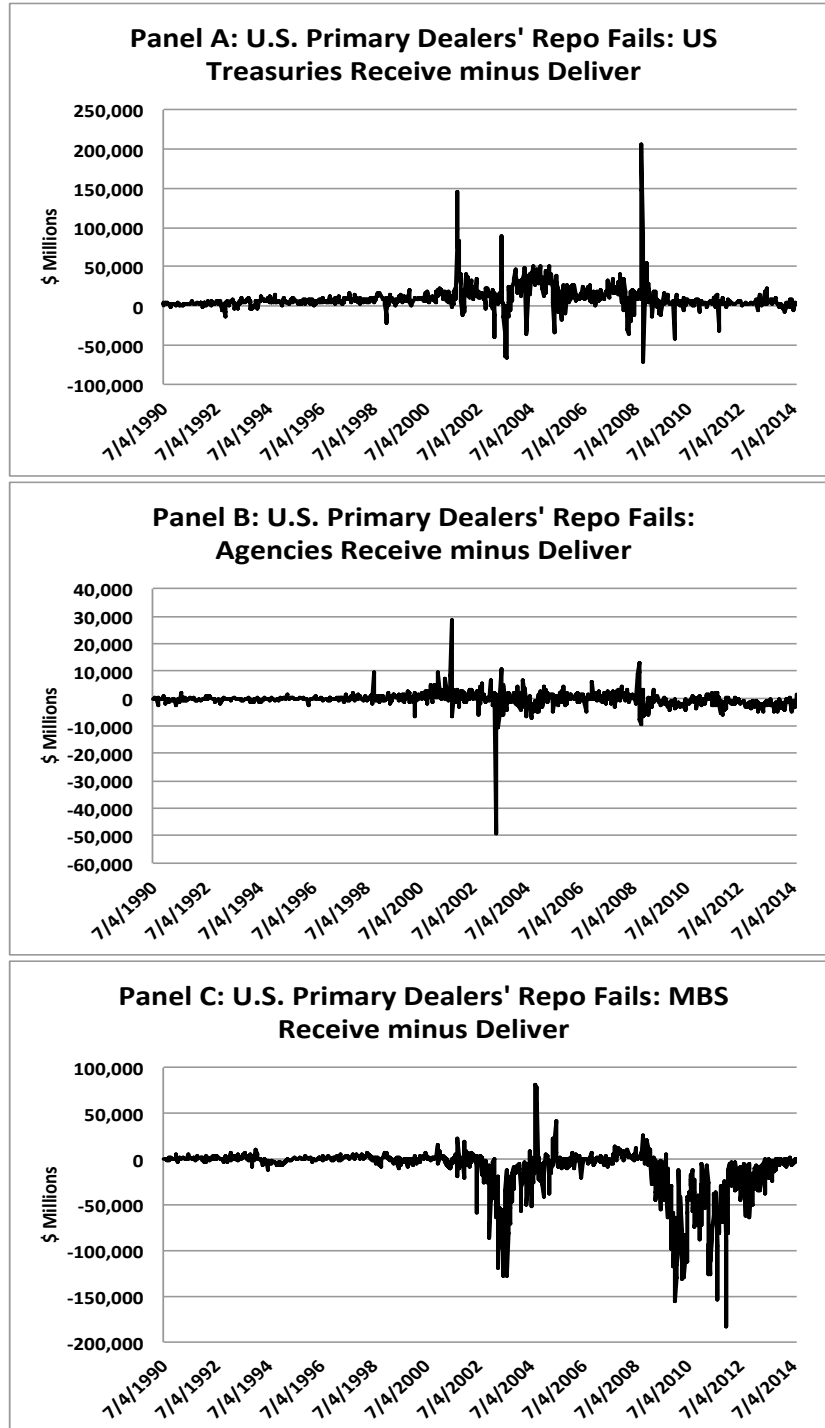
Figure 6: Panel A plots the fraction of Treasuries held to back notes and hence is informative about how aggressively banks were taking advantage of note issuance. Panel B plots the fraction of bonds on hand to loans and discounts. Panel C plots total Debt/GDP outstanding for the US and gives a sense of the total supply of government debt.

Treasuries Held to Back Notes as a Percentage of Total U.S. Debt Outstanding

Ratio of U.S. Bonds on Hand to Loans and Discounts

US Debt/GDP

42
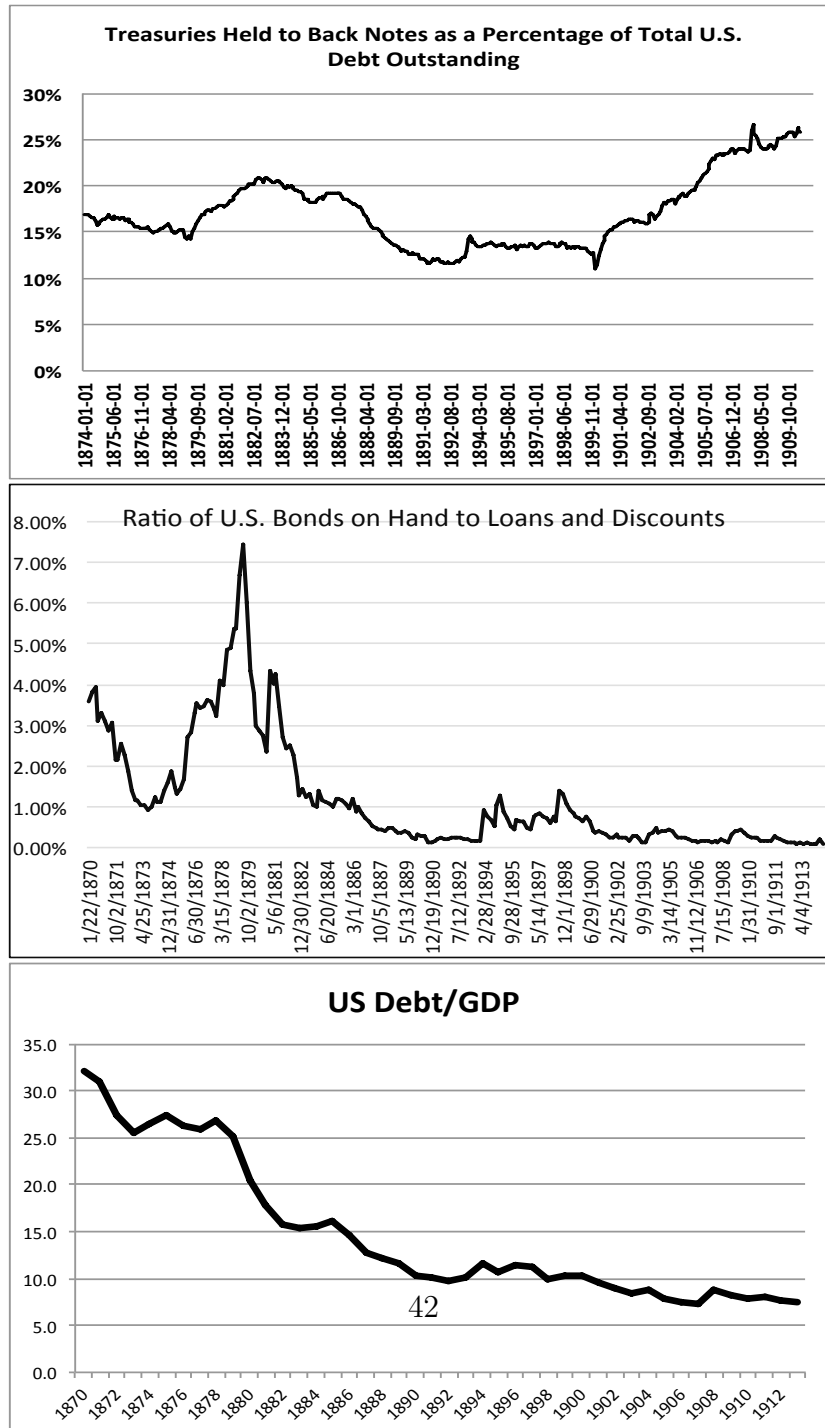
Figure 7: Original profit series as computed by Champ.
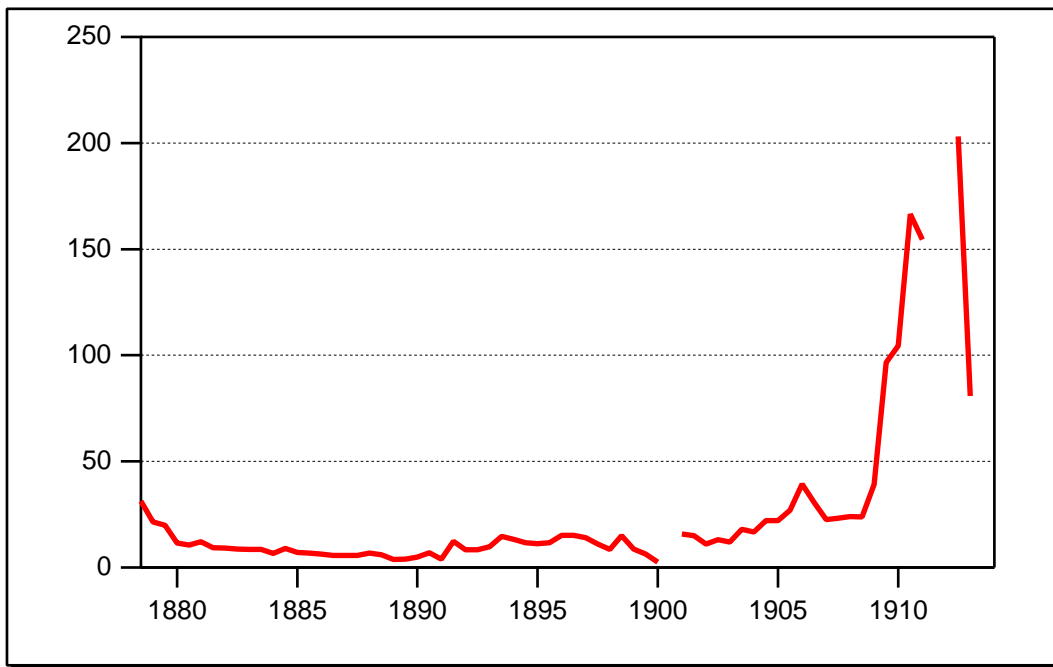
Figure 8: Profit series, plotted in standard (top) and log scale (bottom).
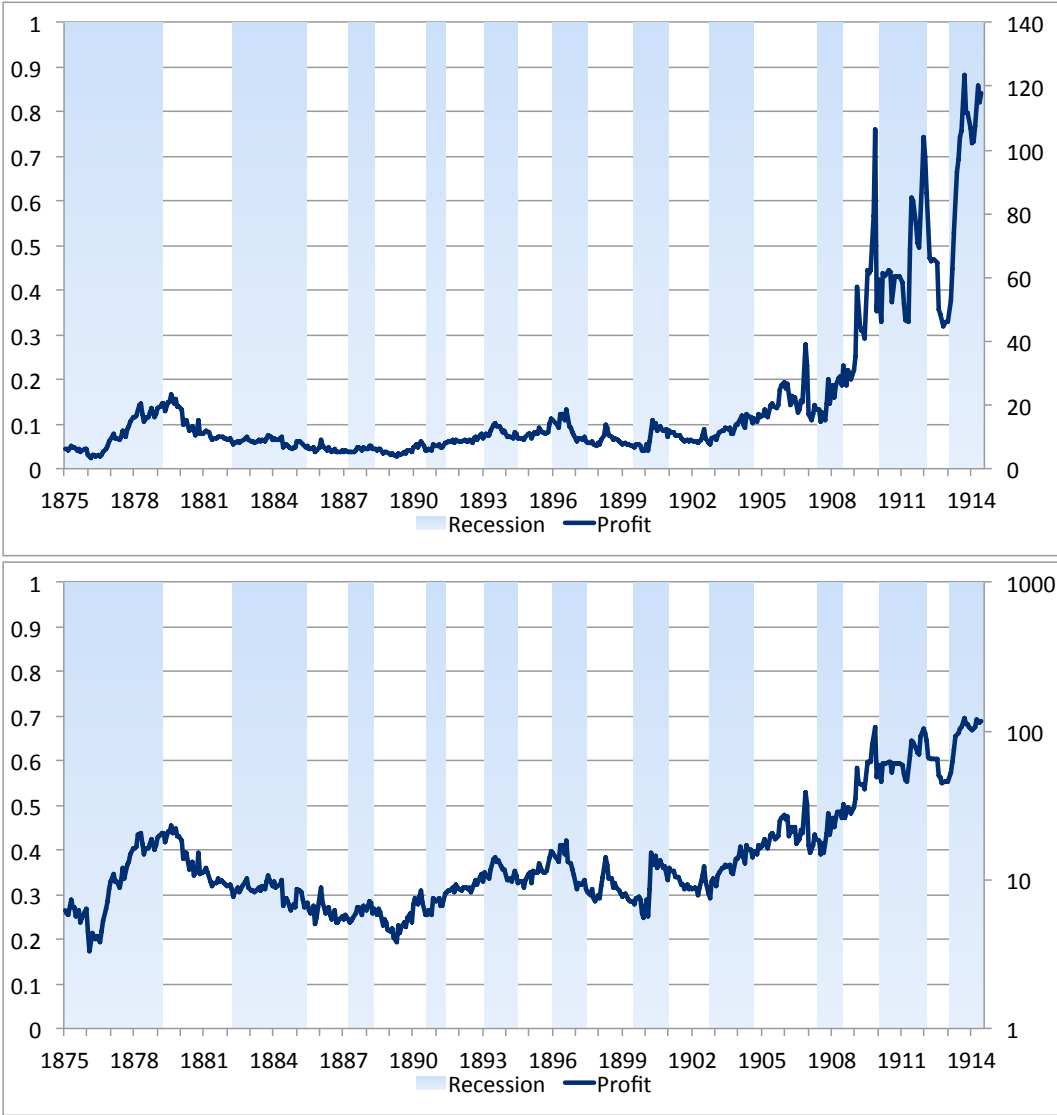
Figure 9: Ratio of notes to deposits. This figure plots the ratio of notes to deposits against US government debt to GDP. It shows that declines in government supply of Treasuries are strongly associated with increases in deposits.
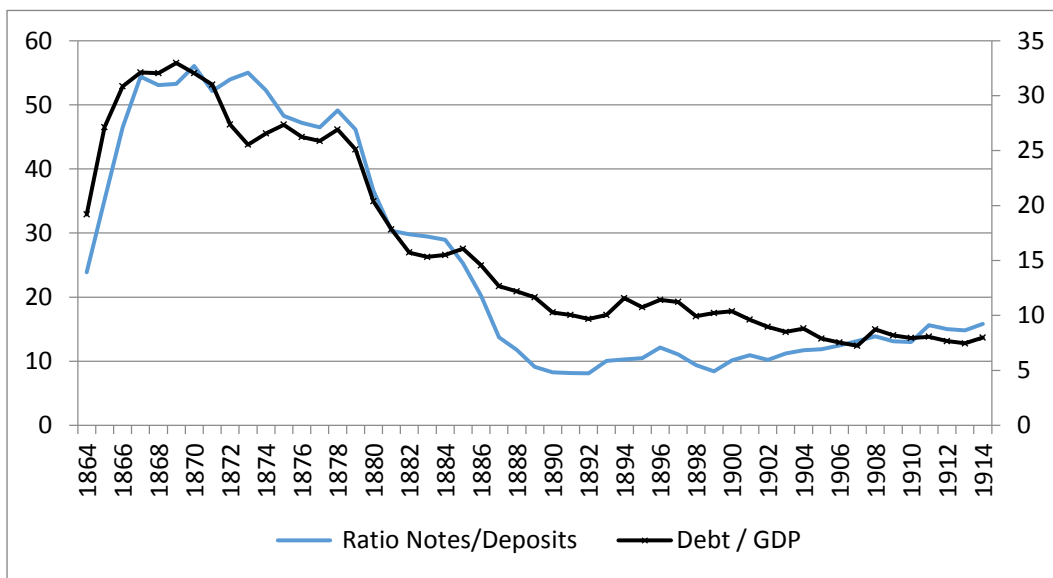
Figure 10: Safe asset share from Gorton Lewellen and Metrick 2012.
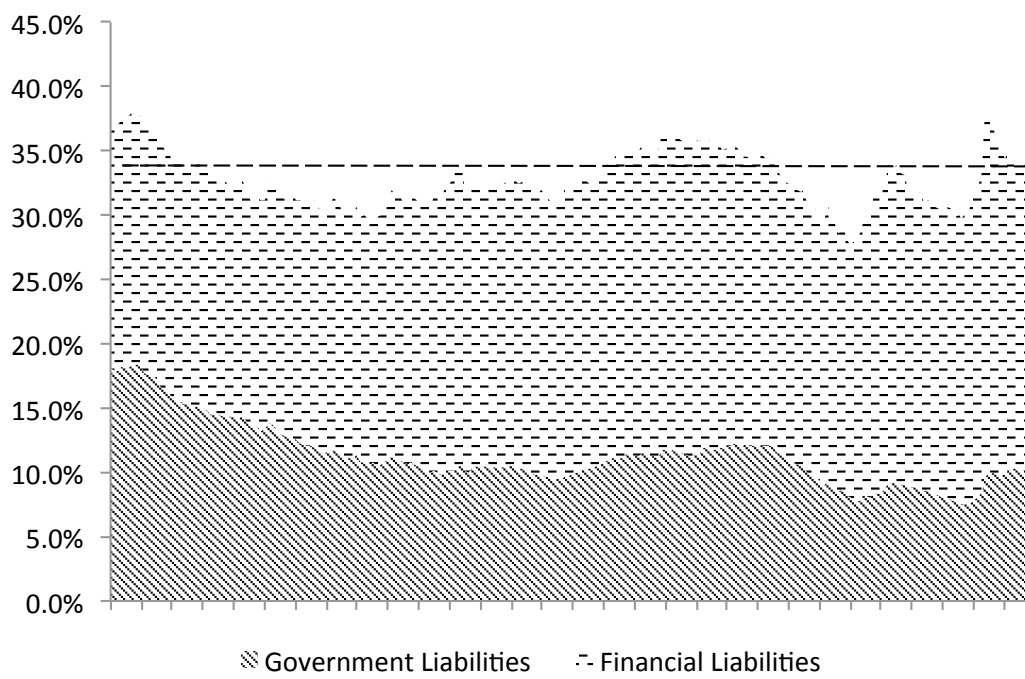
Appendices

Table 5: We report breakpoints for our fails data panel for the absolute value of the difference between fails to receive and fails to deliver along with 95% confidence intervals. The methodology for finding breaks in panels follows Bai (2010).

Panel A: All securities, $|\text{receive} - \text{deliver}|$			
	Break Date	Lower Bound	Upper Bound
First Break	12-Sep-01	25-Jul-01	24-Oct-01
Second Break	19-Aug-09	1-Jul-09	30-Sep-09
Third Break	1-Feb-12	23-Nov-11	4-Apr-12

Panel B: Treasury+Agency, $|\text{receive} - \text{deliver}|$			
	Break Date	Lower Bound	Upper Bound
First Break	6-Dec-00	31-May-00	6-Jun-01
Second Break	24-Sep-08	25-Jun-08	17-Dec-08
Third Break	11-Feb-09	17-Dec-08	1-Apr-09

Panel C: MBS, $|\text{receive} - \text{deliver}|$			
	Break Date	Lower Bound	Upper Bound
First Break	19-Jun-02	1-May-02	31-Jul-02
Second Break	19-Aug-09	1-Jul-09	30-Sep-09
Third Break	1-Feb-12	9-Nov-11	18-Apr-12

Table 6: We run seemingly unrelated regressions of Treasury and Agency fails to deliver.

	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del
GC Repo-1m T-bill	6.727***	0.598	7.002***	0.552	7.207***	0.562
	(5.43)	(0.35)	(5.58)	(0.33)	(5.72)	(0.33)
L1.GC Repo-1m T-bill			2.118	0.770	2.448	0.607
			(1.69)	(0.45)	(1.93)	(0.36)
L2.GC Repo-1m T-bill					2.417	0.406
					(1.92)	(0.24)
GC Repo-1m T-bill x Break 1		12.97***		13.54***		12.96***
		(5.02)		(5.11)		(4.88)
L1.GC Repo-1m T-bill x Break 1				2.172		1.673
				(0.83)		(0.62)
L2.GC Repo-1m T-bill x Break 1						-1.971
						(-0.75)
GC Repo-1m T-bill x Break 2		35.82***		40.87***		39.41***
		(6.69)		(7.57)		(7.32)
L1.GC Repo-1m T-bill x Break 2				27.47***		31.77***
				(5.42)		(6.24)
L2.GC Repo-1m T-bill x Break 2						29.20***
						(5.81)
GC Repo-1m T-bill x Break 3		-0.421		-0.979		-0.152
		(-0.04)		(-0.08)		(-0.01)
L1.GC Repo-1m T-bill x Break 3				2.129		2.970
				(0.19)		(0.25)
L2.GC Repo-1m T-bill x Break 3						3.371
						(0.29)
Break 1 (9/2001-9/2008)		-6.809		-6.450		-4.782
		(-0.18)		(-0.17)		(-0.12)
Break 2 (9/2008-2/2009)		62.38		126.5		163.3
		(0.47)		(0.96)		(1.25)
Break 3 (2/2009)		10.22		9.742		6.906
		(0.24)		(0.23)		(0.16)
D. 1m T-Bill		-11.20***		-9.827***		-7.917***
		(-5.52)		(-4.77)		(-3.81)
Constant	0.966	-10.30	1.273	-8.808	1.145	-6.793
	(0.06)	(-0.42)	(0.08)	(-0.36)	(0.07)	(-0.28)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.012	0.047	0.013	0.062	0.015	0.077

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: We run seemingly unrelated regressions of Treasury and Agency fails to deliver.

	Δ D-R	Δ D-R	Δ D-R	Δ D-R	Δ D-R	Δ D-R
GC Repo-1m T-bill	-0.0555	-0.0353	-0.0555	-0.0274	-0.0457	0.00581
	(-0.25)	(-0.12)	(-0.25)	(-0.09)	(-0.20)	(0.02)
L1.GC Repo-1m T-bill			0.0254	-0.0181	0.0472	-0.0198
			(0.11)	(-0.06)	(0.21)	(-0.07)
L2.GC Repo-1m T-bill					0.185	0.186
					(0.82)	(0.63)
GC Repo-1m T-bill x Break 1		0.118		0.327		0.307
		(0.27)		(0.71)		(0.66)
L1.GC Repo-1m T-bill x Break 1				0.606		0.726
				(1.34)		(1.55)
L2.GC Repo-1m T-bill x Break 1						0.184
						(0.40)
GC Repo-1m T-bill x Break 2		0.351		-0.00556		-0.0348
		(0.38)		(-0.01)		(-0.04)
L1.GC Repo-1m T-bill x Break 2				-1.920*		-1.933*
				(-2.19)		(-2.18)
L2.GC Repo-1m T-bill x Break 2						-0.280
						(-0.32)
GC Repo-1m T-bill x Break 3		0.957		0.618		0.464
		(0.48)		(0.30)		(0.22)
L1.GC Repo-1m T-bill x Break 3				-0.840		-1.049
				(-0.43)		(-0.52)
L2.GC Repo-1m T-bill x Break 3						-0.260
						(-0.13)
Break 1 (9/2001-9/2008)		89.87***		89.50***		89.39***
		(13.55)		(13.47)		(13.40)
Break 2 (9/2008-2/2009)		268.3***		263.4***		263.2***
		(11.88)		(11.61)		(11.56)
Break 3 (2/2009)		21.07**		21.40**		21.69**
		(2.92)		(2.95)		(2.97)
D. 1m T-Bill		-0.373		-0.544		-0.555
		(-1.07)		(-1.53)		(-1.54)
Constant	74.67***	37.40***	74.91***	37.34***	75.11***	37.37***
	(24.98)	(8.81)	(24.95)	(8.77)	(24.89)	(8.73)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.000	0.114	0.000	0.117	0.000	0.117

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: We run seemingly unrelated regressions of MBS fails to receive.

	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec	Δ Fails Rec
GC Repo-1m T-bill	6.963***	6.113***	7.303***	6.124***	7.509***	6.501***
	(5.57)	(3.59)	(5.78)	(3.60)	(5.91)	(3.76)
L1.GC Repo-1m T-bill			2.609*	-1.192	2.951*	-1.202
			(2.07)	(-0.70)	(2.31)	(-0.70)
L2.GC Repo-1m T-bill					2.495*	2.200
					(1.96)	(1.27)
GC Repo-1m T-bill x Break 1		5.348*		7.949**		7.532**
		(2.11)		(3.08)		(2.89)
L1.GC Repo-1m T-bill x Break 1				10.71***		11.75***
				(4.20)		(4.50)
L2.GC Repo-1m T-bill x Break 1						1.635
						(0.63)
GC Repo-1m T-bill x Break 2		-26.33		-26.27		-26.60
		(-1.03)		(-1.02)		(-1.04)
L1.GC Repo-1m T-bill x Break 2				-1.043		-1.480
				(-0.04)		(-0.06)
L2.GC Repo-1m T-bill x Break 2						11.23
						(0.44)
GC Repo-1m T-bill x Break 3		-0.995		-1.673		-0.807
		(-0.07)		(-0.11)		(-0.05)
L1.GC Repo-1m T-bill x Break 3				2.679		3.554
				(0.18)		(0.22)
L2.GC Repo-1m T-bill x Break 3						-0.644
						(-0.04)
Break 1 (10/2002-9/2009)		-19.14		-19.15		-19.33
		(-0.49)		(-0.50)		(-0.50)
Break 2 (9/2009-12/2011)		18.91		19.14		17.79
		(0.32)		(0.33)		(0.31)
Break 3 (12/2011)		11.41		12.42		10.48
		(0.20)		(0.22)		(0.18)
D. 1m T-Bill		-12.98***		-13.11***		-12.90***
		(-6.32)		(-6.37)		(-6.23)
Constant	0.879	-9.285	1.104	-9.406	1.092	-8.803
	(0.05)	(-0.39)	(0.07)	(-0.39)	(0.06)	(-0.37)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.013	0.030	0.015	0.040	0.016	0.043

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: We run seemingly unrelated regressions of MBS fails to deliver.

	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del	Δ Fails Del
GC Repo-1m T-bill	6.727***	5.459**	7.002***	5.464**	7.207***	5.908***
	(5.43)	(3.23)	(5.58)	(3.23)	(5.72)	(3.43)
L1.GC Repo-1m T-bill			2.118	-1.350	2.448	-1.358
			(1.69)	(-0.80)	(1.93)	(-0.80)
L2.GC Repo-1m T-bill					2.417	2.540
					(1.92)	(1.48)
GC Repo-1m T-bill x Break 1		5.776*		8.097**		7.629**
		(2.30)		(3.15)		(2.95)
L1.GC Repo-1m T-bill x Break 1				9.847***		10.68***
				(3.88)		(4.11)
L2.GC Repo-1m T-bill x Break 1						0.505
						(0.20)
GC Repo-1m T-bill x Break 2		-24.01		-23.83		-24.22
		(-0.94)		(-0.93)		(-0.95)
L1.GC Repo-1m T-bill x Break 2				-4.492		-5.109
				(-0.18)		(-0.20)
L2.GC Repo-1m T-bill x Break 2						15.98
						(0.63)
GC Repo-1m T-bill x Break 3		-1.485		-2.366		-1.309
		(-0.10)		(-0.15)		(-0.08)
L1.GC Repo-1m T-bill x Break 3				2.340		3.601
				(0.16)		(0.23)
L2.GC Repo-1m T-bill x Break 3						-0.467
						(-0.03)
Break 1 (10/2002-9/2009)		-17.26		-17.25		-17.50
		(-0.45)		(-0.45)		(-0.45)
Break 2 (9/2009-12/2011)		18.34		18.67		17.12
		(0.32)		(0.32)		(0.30)
Break 3 (12/2011)		9.075		10.96		8.271
		(0.16)		(0.19)		(0.14)
D. 1m T-Bill		-11.10***		-11.19***		-11.06***
		(-5.44)		(-5.47)		(-5.37)
Constant	0.966	-7.621	1.273	-7.690	1.145	-7.168
	(0.06)	(-0.32)	(0.08)	(-0.32)	(0.07)	(-0.30)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.012	0.026	0.013	0.034	0.015	0.036

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: We run seemingly unrelated regressions of MBS fails to deliver.

	Δ D-R	Δ D-R	Δ D-R	Δ D-R	Δ D-R	Δ D-R
GC Repo-1m T-bill	-0.0555	0.0792	-0.0555	0.0830	-0.0457	0.145
	(-0.25)	(0.27)	(-0.25)	(0.28)	(-0.20)	(0.48)
L1.GC Repo-1m T-bill			0.0254	0.114	0.0472	0.118
			(0.11)	(0.38)	(0.21)	(0.40)
L2.GC Repo-1m T-bill					0.185	0.362
					(0.82)	(1.20)
GC Repo-1m T-bill x Break 1		-0.201		-0.225		-0.282
		(-0.46)		(-0.50)		(-0.62)
L1.GC Repo-1m T-bill x Break 1				-0.201		-0.220
				(-0.45)		(-0.48)
L2.GC Repo-1m T-bill x Break 1						-0.419
						(-0.93)
GC Repo-1m T-bill x Break 2		1.635		1.674		1.620
		(0.37)		(0.38)		(0.36)
L1.GC Repo-1m T-bill x Break 2				-1.450		-1.549
				(-0.32)		(-0.35)
L2.GC Repo-1m T-bill x Break 2						2.371
						(0.53)
GC Repo-1m T-bill x Break 3		0.778		0.545		0.436
		(0.31)		(0.20)		(0.16)
L1.GC Repo-1m T-bill x Break 3				0.302		0.247
				(0.12)		(0.09)
L2.GC Repo-1m T-bill x Break 3						0.00159
						(0.00)
Break 1 (10/2002-9/2009)		81.37***		81.22***		81.10***
		(12.13)		(12.06)		(12.00)
Break 2 (9/2009-12/2011)		11.96		11.89		11.67
		(1.19)		(1.17)		(1.15)
Break 3 (12/2011)		0.403		0.629		0.843
		(0.04)		(0.06)		(0.08)
D. 1m T-Bill		-0.495		-0.509		-0.532
		(-1.39)		(-1.42)		(-1.47)
Constant	74.67***	48.45***	74.91***	48.58***	75.11***	48.65***
	(24.98)	(11.68)	(24.95)	(11.66)	(24.89)	(11.63)
Observations	2398	2398	2386	2386	2374	2374
R^2	0.000	0.065	0.000	0.065	0.000	0.065

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$