Collateral Value Risk in the Repo Market

Josephine Smith*

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Abstract

This papers studies movements in repurchase agreement (repo) interest rates as a measure of collateral value risk. We document the behavior of the term structures of U.S. Treasury, agency, and mortgage-backed security repo rates from 1997-2012. We also analyze the term structure of spreads between mortgage-backed security and U.S. Treasury repo rates as a measure of financial stress via relative collateral value risk and find unique dynamics. Calculating yield curve risk premia for repos is highlighted, and the risk premia associated with repos is predictable. Across the term structures of different repos and over various investment horizons, R^2 values are in excess of 0.5. Relative collateral value risk premia are also predictable, and are related to both macroeconomic and financial proxies for risk.

Keywords: Collateral value risk; repurchase agreement; risk premia; term structure

*Correspondence: Stern School of Business, New York University, 44 West 4th Street, Suite 9-86, New York, NY 10012. Email: jsmith@stern.nyu.edu. Phone: (212) 998-0171. I'd like to thank my colleagues at NYU Stern for the input, particularly Alexi Savov and Bruce Tuckman, as well as seminar participants at Stanford University and Tsinghua University. This paper was previously circulated as "Risk Premia in the Repo Market."

1 Introduction

Studying the time variation in risk premia of the term structure of interest rates is a research area that has been fruitful for decades. Two of the seminal papers in this line include Fama and Bliss (1987) and Campbell and Shiller (1991), which provided some of the first empirical documentation of the failure of the expectations hypothesis via forecasting excess returns. However, much of the research has been focused on U.S. Treasury securities at maturities of longer than one year for a variety of reasons. First and foremost there are data limitations, since the U.S. government does not issue extremely short-term debt (i.e. less than a month). Another reason has been the economic importance of long-term interest rates, as macroeconomists economists have stressed that these interest rates are crucial for understanding firm investment. While monetary policy is aimed at the short end of the yield curve for interbank lending (overnight), the idea has always been that movements on the short end can, in normal times, provide corresponding, desired movements for longer-term rates.[1]

The question of whether time-variation in risk premia, or better yet time-variation in excess returns, for long-term U.S. Treasury rates exists and if it is predictable has been asked time and time again. Cochrane and Piazzesi (2005) looks at rates of bonds with maturities between one and five years and finds that a single, tent-shaped factor constructed from forward rates can predict time-variation of annual excess returns on U.S. Treasury zero-coupon bonds for maturities out to five years with an R^2 as high as 0.4. This finding was monumental, since standard predictability regressions that often used level, slope, and curvature factors of the term structure as predictive variables failed to generate significant R^2's. Furthermore, these other papers relied on a theoretical framework of a stochastic discount factor that is capable of pricing all of these factors. The single factor was novel,

[1]A discussion of comparing short-term and long-term rates and monetary policy can be found in Smith and Taylor (2009).

but further work by Cochrane and Piazessi (2008) has shown that, indeed, these additional term structure factors provide explanatory power above and beyond the single tent factor for prediction of excess returns on longer-term Treasuries.[2]

The contribution of this paper is three-fold. First, we document stylized facts about the term structure of short-term repurchase agreement (repo) markets. Repurchase agreements, while complicated in the exact nature of how each market operates and the participants, are at the core just collateralized loans. The maturity structure we analyze runs from overnight to three months. Financial institutions are known to finance themselves using the short end of the yield curve and lend at the long end, so studying these very short-term lending markets is interesting from that perspective. In addition, if firms have long-term investment horizons but are potentially funding these investments by rolling over in short-term repo markets, this is of first-order importance for both financial markets and the macroeconomy.

We analyze three separate repo markets based on the type of underlying collateral: U.S. Treasuries, agency securities, and mortgage-backed securities. Figures (1) and (2) plot the repo rates for each particular type of collateral from 1997 and 2012 at the overnight and three-month maturity, respectively. Until the recent financial crisis, these repo rates moved nearly one-for-one with the Federal Funds rate. However, during the crisis, repos with mortgage-backed securities as collateral saw a spike in borrowing rates, being driven by the (potentially mis-priced) risk of the underlying collateral. We stress that this increase in interest rates for collateralized borrowing is not a measure of increases in counterparty credit risk. Rather, in Section 2, we will provide a description of the collateral value risk that these repo rates are capturing, in contrast to the credit or counterparty risk that other aspects of the repurchase agreement contracts control for. To advance our understanding even further beyond the unique collateral value risk for each type of repo collateral, we

[2]The breadth of research in this area is enormous. Other work focusing on predictability of bond excess returns with methodologies similar to this paper include Stambaugh (1988), Kim and Wright (2005), Kim and Orphanides (2005), and Smith (2012).

also examine the behavior of spreads between mortgage-backed security and U.S. Treasury repo rates as a measure of repo stress in the form of relative collateral value risk.

Second, using a standard principal component analysis, we show that these short-term repo markets share a very common underlying factor structure, with the standard level, slope, and curvature factors prevailing as they do in the more traditional bond market studies. These factors are not perfectly correlated with their counterparts in the longer-term U.S. Treasury bond market, potentially due to the risks embedded in repos as well as the maturity of the repo. In addition, we analyze the factor structure of the term structure of repo spreads (using mortgage-backed security repo rates minus U.S. Treasury repo rates), and show that while this factor structure still contains its own level, slope, and curvature components, they are capturing the relative collateral value risk factors across these two repo markets.

Lastly, we assess the predictability of risk premia in repo markets. We begin by discussing the definition of risk premia in these markets, since the construction relies on a strategy of rolling over short-term debt. We will be providing evidence on the predictability of yield curve risk premia, rather than return risk premia through the construction of holding period returns. As a starting point for our predictability regressions, we use the simple term structure factors as our predictive variables, including a control for any residual credit risk the reader may be concerned with by proxying with the TED spread. At the quarterly investment horizon, we find R^2's as high as 0.6 for mortgage-backed security repos. When we analyze predictability of risk premia of spreads between mortgage-backed security and U.S. Treasury repo rates, we find even stronger results, with R^2 values for the quarterly horizon peaking at nearly 0.7. These results does not shock us, since we interpret this spread term structure as fundamentally different from the simple repo term structures as it is reflecting relative collateral value risk across markets, and thus the factors themselves can potentially have differing explanatory power across different repo markets.

We conclude our analysis with an attempt to link these excess returns to other variables that reflect macroeconomic and/or financial risk, since we feel they might provide predictability power for any of the term structure analyzed in the paper above and beyond the principal components. Using the VIX as a proxy for financial risk and the Bloom et. al. (2012) policy uncertainty index as a proxy for macroeconomic risk, we see an increase in R^2's beyond 0.7 for the spread term structure. This helps to confirm our hypothesis that, indeed, these spreads are capturing relative risks, but we do find that it is a combination of macroeconomic and financial risks. One paper that has addressed short-term bond markets and risk premia with uncertainty is Mueller, Vedolin, and Zhu (2011), albeit looking at long-term bonds over short-term investment horizons.

The structure of the paper is as follows. Section 2 describes the data used in the analysis and the general structure of repurchase agreement markets. Section 3 documents the factor analysis of each repo market. Section 4 analyzes our excess return predictability regressions. Section 5 extends the excess return analysis to macroeconomic and financial risk. Section 6 concludes.

2 The Repurchase Agreement Market

Before diving into the analysis of the repo market and its potential risks, it will be of service to describe the structure of a repurchase agreement and the data used in this paper. Three different repo markets will be analyzed: U.S. Treasury repos, agency repos, and mortgage-backed security repos. These three repo markets differ primarily in the type of collateral used for the loan.

2.1 Repurchase Agreement Details

It is important to understand the specifics of the repurchase agreement market before analyzing any of its risks, since much confusion remains about what each component of a repurchase agreement is meant to capture. As pointed out in the introduction, a repo is just a collateralized loan, whereby the borrower sells the specified collateral to the lender at a price below its market value. The different between the market value of the collateral and the loan principal captures the *haircut* or margin of the repo. At the end of the repo, the lender returns the collateral to the borrower, and the borrower pays the lender back the principal plus any interest that accrues according to the specified *repo rate*.

Typical market participants for repurchase agreements vary. Borrowers, or net sellers of collateral, include securities dealers, thrifts, and bank portfolios. Lenders, or net buyers of collateral, include bank trust departments, money market funds, municipalities, and corporations.[3] The market participants can also vary based on the type of collateral used in the repurchase agreement.

U.S. Treasury repos are the safest form of repo transaction. The borrower must post collateral in the form of a pre-specified U.S. Treasury security. Given the low credit risk of the U.S. government, this type of repo is thought of as safe, and lenders require small haircuts and charge lower interest rates to borrow in this market. Since we don't have U.S. Treasury securities at a maturity of less than one-month, repo rates have provided practitioners with a measure of short-term, relatively riskless borrowing rates in U.S. fixed income markets. Agency repos are considered a slightly less safe form of major repo transactions. The collateral posted in this transaction takes the form of Federal agency and government-sponsored enterprise (e.g. Fannie Mae and Freddie Mac) securities. Given the potential risks underlying these institutions, agency repos are considered slightly less

[3] Hedge funds can act on either side of the market, depending on what type of leverage position they desire in the particular repo market.

safe compared to U.S. Treasury repos. However, the recent backing of these institutions via the federal government has driven some to the opinion that these repos are now much safer, though this issue remains a hot topic for discussion. We also consider mortgage-backed security repos. The collateral underlying these repos takes the form of high-grade mortgage-backed securities and related derivatives. Since their inception, these repos have traded at noticeably higher rates than their U.S. Treasury counterparts, which we believe is due to the higher collateral value risk of these repos.

2.2 Credit Risk in Repos

Since the financial crisis, the literature on repo markets has exploded. However, much of this work has focused on the haircut or margin of the repurchase agreement. Gorton and Metrick (2012) and Krishnamurthy, Nagel, and Orlov (2012) are some of the more prominent papers in this vein.[4] Lenders often require a haircut, or over-collateralization, to limit their credit exposure. Typically, this haircut amounts to between one and three percent of the market value of the collateral for high grade collateral. However, as shown in Gorton and Metrick (2012), haircuts on the bilateral repo market for low-grade collateral rose dramatically during the crisis, implying nearly complete shut down of these repo markets, or a "run on repo" (i.e. haircuts on the order of 50%-100%). This evidence on astronomical haircuts is in contrast to that provided by Krishnamurthy, Nagel, and Orlov (2012), who use tri-party repo haircuts derived from SEC filings for money market mutual funds. These authors find that for the tri-party repo market, haircuts were essentially flat during the financial crisis.

Because of the conflicting evidence on the level of haircuts and how they vary across bi-lateral vs. tri-party repurchase agreements, there is no real consensus on the perceived counterparty credit risk for repurchase agreements during the crisis as captured by the level

[4] Another paper is Jurek and Stafford (2010).

and time-variation of haircuts for different forms of repo collateral. We do not analyze haircuts in this paper as we are more interested in the collateral value risk of repos, which we discuss below.[5]

2.3 Collateral Value Risk in Repos

The quality of the underlying collateral of a repurchase agreement is the fundamental determinant of the interest rate associated with that particular repo. The easiest way to understand this is through a simple supply vs. demand argument for lending or borrowing in the repurchase agreement market with a given type of collateral. Suppose we are dealing in the repo market with U.S. Treasuries as the underlying collateral. While this market contains very little credit risk (haircuts are on the order of 2% historically), there is potentially quite a lot of collateral value risk of the yields (and thus prices) for U.S. Treasury bonds fluctuate during the term of the repo. Agents who wish to borrow in this repo market with U.S. Treasuries as collateral are faced with a set of potential lenders who vary in their desire to accept U.S. Treasuries as collateral. Where their supply and demand curves intersect will ultimately determine the repo rate. Due to the high liquidity of U.S. Treasuries, these rates are often capturing very safe, short-term investments, and thus low collateral value risk.

This analysis of repo rate determination might change if we move to the repo market where mortgage-backed securities are used as the underlying collateral. Evidence is mixed in the level of credit risk in this market before, during, and after the crisis (current tri-party repo haircuts are approximately 2%-4%), but the risk of large movements in the collateral value is what this paper will try to assess. Borrowers in this collateralized lending market will face potentially much higher repo rates than those borrowing using U.S. Treasuries as collateral, since the market for lenders will include only those who wish to accept collateral

[5]Lenders also reduce the credit exposure in repos by marking the repo to market on a regular basis, as well as by adjusting credit lines to borrowers whose perceived credit risk has increased.

with much higher risk in movements in its value (potentially related to the liquidity of the security itself), thus driving up the repo rates. Ultimately, the difference between repo rates on mortgage-backed security repos and U.S. Treasury repos will be our measure of relative collateral value risk, which could be capturing a variety of macroeconomic and financial risks that policy might speak to in a theoretical model.

2.4 Data on Repurchase Agreements

In this paper, we look at overnight, one-week, two-week, three-week, one-month, two-month, and three-month maturities of the repos with each specific type of collateral.[6] We will examine the term structure of the U.S. Treasury, agency, and mortgage-backed security repo rates separately; these rates capture the unique collateral value risk for each repo market collateral. The paper than turns to the spread between mortgage-backed security repo rates and U.S. Treasury repo rates as a measure of relative collateral value risk.

Figure (3) plots the breakdown of the repo market as a function of all types of collateral as of July 2012. The data is provided by the Tri-Party Repo Infrastructure Reform Task Force at the Federal Reserve Bank of New York. The collateral value of the market totaled nearly $1.8 trillion dollars at the time of the latest data release. As you can see, U.S. Treasury securities make up a large piece of the repo market, but Agency MBS have begun to take a larger role in the market since the Federal Reserve began accepting these as collateral. At the peak of the repo market, nearly $4 trillion dollars of collateral were outstanding in repos. [7]

[6] Over 50% of repo transaction occur are overnight repos, though often they remain as open repos and are rolled over.

[7] All data is available from the author upon request. Except for the repo statistics reported in Figure (3), all available data was collected from Bloomberg. To collect the tri-party repo statistics, please visit http://www.newyorkfed.org/tripartyrepo/.

2.5 Description of Empirical Proxies

We also employ a set of empirical proxies for measures of credit risk, macroeconomic uncertainty, and financial uncertainty. As a proxy for credit risk, we use the TED spread, or the spread between the three-month LIBOR rate and the three-month U.S. Treasury bill rate. This series is useful since it covers our entire time sample and captures a measure of financial credit risk. It will not play a major role in our later regressions, since movements in excess returns are picking up factors outside of credit risk.[8]

We will be testing predictability of excess returns in various repo markets using proxies for both macroeconomic and financial uncertainty. As a laboratory for studying whether macroeconomic or financial risks are predictive of risk premia in repo markets, we use two different variables to proxy for risk. The first is an old standard: the S&P VIX. The VIX, or volatility index, is constructed to capture volatility in the stock market, and is often used as a proxy for uncertainty in the stock market. Even though it is meant to capture stock market volatility, it is without question that the fixed income and stock markets are correlated, and we believe that the VIX can provide particularly informative power for the short-end of the yield curve given its reliance on day to day fluctuations in market news and uncertainty.

The second variable we use to proxy for uncertainty is the newly-developed policy uncertainty index found in Bloom et. al (2012). This index is constructed using three types of information: newspaper articles covering policy-related economic news, federal tax code provisions nearing expiration, and dispersion among forecasters regarding policy-related forecasts. While this index is calculated ex-post, we are using it here to ascertain whether it has predicted power for future returns over varying investment horizons. Interestingly, this

[8]We could have also used other measures of credit risk, such as CDS spreads or the three-month LIBOR-OIS spread. However, these measures of credit risk do not exist for the full sample of the data we wish to analyze. Using the BBB-AAA corporate debt spread is also feasible. However, we believe this measure of credit risk is capturing movements in corporate credit risk, which may not necessarily be capturing potential systemic credit risk for all financial market participants.

index is constructed using what the authors believe is purely policy-related macroeconomic news, and thus it is in contrast to the VIX which is meant to capture high-frequency stock market volatility.[9] Figure (13) plots the movements in these two indices over our sample period. Table (1) displays summary statistics for all of the repo rates and empirical proxies used in the analysis.

3 Factor Analysis of the Repo Term Structure

As a starting point for the empirics, it is useful to perform a standard principal component analysis on each of the three repo rate term structures with varying collateral that were discussed previously. Models of the term structure in finance often aim to break down the movements of all yields into a small number of factors. The most common factors include level, slope, and curvature, named appropriately due to how the repo rates load onto each of the factors. While the pure finance literature links these factors to their implied movements in the yield curve, modern macro-finance literature has aimed to link these factors to macro-financial variables. As an example, Ang and Piazzesi (2003) found the relationship of similar factors to inflation, output, and monetary policy rates using an affine model developed theoretically in Duffie and Singleton (1999).[10] However, that analysis was done on the longer-term U.S. Treasury yield curve at a lower frequency of data collection. Here, our goal is simply to identify these factors at the short end of the repo yield curve using daily data. In the end, this analysis will prove fruitful when we move to the analysis of repo spread term structures, as well as using the estimated behavior to understanding general risk premia in short-term repo markets.

[9] This index has been used in as empirical tests for the importance of policy risk. See Pastor and Veronesi (2012) as an example of such an application.

[10] Other work linking the term structure to macroeconomics includes Ang, Dong, and Piazzesi (2007), Gallmeyer et. al. (2007), Rudebusch and Swanson (2008), and Smith and Taylor (2009).

3.1 Review: Construction of the Factor Loadings

At the risk of too much review, this section establishes some notation and language for the repo rates in each market and the corresponding spreads across repo markets, as well as how the factors are calculated. Let $i_t^{j,(n)}$ denote the repo rate at time t corresponding to collateral $j = \{\text{Treasury, Agency, Mortgage-Backed Security}\}$ for maturity n. The spread between repo rates on mortgage-backed security and U.S. Treasury repos will be denoted as $z_t^{(n)}$.

To construct the factors for each term structure, we perform an eigenvalue decomposition of the covariance matrix of each of the term structures. The eigenvalues are ordered from largest to smallest, and we can use these eigenvalues to back out the factors associated with the data on the term structure. The factors associated with the three largest eigenvalues (ranked in decreasing fashion) are the level, slope, and curvature factors, respectively. This factor decomposition essentially amounts to finding the best fit in a linear regression model of the term structure on the factors themselves; R^2 values on the order of 0.99 are not uncommon in these regressions. For the term structure of spreads $z_t^{(n)}$, the same decomposition is performed, and the discussion below will contrast these factors to the factors for the original repo term structures themselves.

3.2 Repo Term Structure Factor Loadings

Figure (4) plots how a U.S. Treasury repo with maturity from overnight to three-months loads onto each of the level, slope, and curvature factors. It is here we see where the name of each factor is derived, as is common in the fixed income literature. We also do a similar set of plots for the agency repos and mortgage-backed security repos, found in Figures (5) and (6), respectively. The main takeaway is that these factor loadings are nearly identical in shape and magnitude across markets, with slight differences in how the curvature factor loading peaks (at one-week or two-week maturity). We also know that the movements in these factors are positively correlated with the movements in the companion factors for the longer-term U.S. Treasury bond market. However, a back-of-the-envelope calculation of the correlation of these factors with the comparable factors using the entire term structure of U.S. Treasury securities highlights there are fundamental time series differences. The level factors correlate nearly perfectly, but the slope factors only correlate with a correlation coefficient of around 0.4, and the curvature factors correlate with a similar magnitude. These differences could be important, but this paper will not address the potential implications of these differences.

3.3 Spread Term Structure Factor Loadings

Now we move to the factor structure of the spreads between mortgage-backed security repo rates and U.S. Treasury repo term structure. At each maturity, we compute the spread between the repo rate on the mortgage-backed security repo and the repo rate on the U.S. Treasury repo. Figure (7) plots the spreads themselves at the overnight, one-month, and three-month maturities. As evidenced by the picture, these spreads have not always been zero. There was volatility in the late 1990s, in 2005, and during the recent financial crisis. The spreads have decreased since the end of the worst part of the crisis. The difference between these two types of repos is capturing both credit risk and collateral value risk, but the discussion in Section 2 highlighted the fact that haircuts are the credit risk dimension controlled by lenders, while the repo rates (and thus spreads) in Figure (7) are capturing the relative collateral value risk for mortgage-backed security repos vs. U.S. Treasury security repos. It is not a surprise that mortgage-backed securities carry much more collateral value risk than U.S. Treasuries. This is both of a function of the market participants for borrowing and lending in these markets, as well as the fundamental movements in collateral value.

Regardless of where the collateral value risk is coming from, we see the spread between these repo rates as a measure of both macroeconomic and financial risk.[11]

It is not common to see a factor analysis performed on a term structure of interest rate spreads, so it is useful to describe what the factors in this framework are capturing. Figure (8) plots the first three principal components of this spread term structure, and Figure (9) plots how the spreads with maturity from overnight to three-months load onto each of the level, slope, and curvature factors derived from a principal component analysis of the term structure of spreads. We call them level, slope, curvature for a reason: they share a similar shape to the factor loadings we observe for the term structure of U.S. Treasuries. The first factor loads at the same magnitude across maturities, the second factor loads in a monotonic fashion with maturity, and the third factor loads in a curved shape across maturities.

It is interesting is to think about the interpretation of these factors. We know that the level factor of both the mortgage-backed security and U.S. Treasury repos are highly correlated; they each have a correlation of 0.99 with the Federal Funds rate. However, the level factor of the spreads has a correlation of 0.09 with the Federal Funds rate. Therefore, the level factor here is not meant to capture the general level of interest rates, but rather the general level of relative risk across these repo markets; in particular, the level of relative collateral value risk. An increase in this level risk causes spreads to increase at the same magnitude across all maturities. To the contrary, an increase in the level factor for each repo market separately is predominantly capturing movements in monetary policy via the Federal Funds rate.

The slope and curvature factors remain a bit of a mystery in terms of their economic interpretation. An increase in the slope factor causes the shortest-term rates to fall and the longer-term rates to rise, in contrast to the slope factor for each of the individual repos mak-

[11] We could also look at the difference between agency and U.S. Treasury repo markets, and the author can, at request provide results for this analysis.

ing up the spread. This is an interesting phenomenon. While an increase in the slope factor of each of the mortgage-backed security and U.S. Treasury repos causes their individual yield curves to flatten (or invert), an increase in the slope factor of their spread causes its yield curve to become more upward-sloping. While a flattening of the yield curve for the level of interest rates can often signal worsening economic conditions, more study must be done on the flattening of the yield curve for spreads, since it is not necessarily capturing the flattening of the yield curve of the individual securities making up the spread. We will show that this slope factor has predictive power for excess returns on repos. Turning to the curvature factor, we again see a shift in the shape relative to the mortgage-backed security and U.S. Treasury repo factor loadings, which each had a hump shape. Here, the factor loadings for the curvature factor of the spreads is u-shaped. Increases in the curvature factor cause the shortest- and longest-term interest rates to rise and those in-between to fall.

Table (2) displays the correlations of level, slope, and curvature factors from each of the decompositions performed above, as well as for the empirical proxies used later in the analysis. These unconditional correlations point to the strong degree of correlation of the level factors across each of the repo markets. The slope factor of the U.S. Treasury repos has a correlation of approximately 0.7 with the slope factors in the other repo markets, while the slope factors of the agency and mortgage-backed security repo market are have a correlation coefficient of nearly 0.9. The small discrepancy in these coefficients may capture the level of collateral value risk in each market. The curvature factors are also highly correlated with each other, with correlation coefficients hovering around 0.7. Turning to the factors for the term structure of spreads between mortgage-backed security and US. Treasury repo rates, we see that these factors are essentially uncorrelated with their comparable factors in both the U.S. Treasury and mortgage-backed security repo markets. It is this lack of correlation that opens up the door for interpretation of what these slope factors are really capturing.

In an effort to look ahead, we compare all of these factors to our empirical proxies. As expected, the Federal Funds rate is highly correlated with the level factors in each of the repo markets, but not with the level factor of the spread of repo rates. The TED spread, our empirical proxy for credit risk, is correlated with a correlation coefficient of 0.7 with the level factor for the spreads between mortgage-backed security and U.S. Treasury repo rates. We are not surprised by this fact, since there is no reason to believe that credit risk is uncorrelated with the relative collateral value risk, which we think these spreads are capturing. In fact, our predictability regressions will show that there is a conditional correlation, but that credit risk is not what explains excess returns. We will control for this in our later predictability regressions for risk premia. The macroeconomic policy index is correlated with a correlation coefficient of approximately 0.5 with the level factors in each of the repo markets, while the VIX shows low, if any, correlation with these level factors. Also interesting is the 0.5 correlation coefficient associated with the TED spread and the policy index and VIX. While these results are all pinpointing unconditional correlations, they do provide some economic intuition going forward.

4 Excess Return Predictability

Before barraging the reader with excess return regressions, it is important to understand how excess returns are calculated in this framework. To do this, let us solidify some general notation. Though repos don't function exactly like zero-coupon bonds, we can borrow the notation since we are simply just formalizing theory for a shorter-term collateralized loan contract with no intermediate interest payments.

4.1 Excess Return Notation and Theory

Let $p_t^{(n)}$ denote the log price of a n-period discount bond at time t. The continuously-compounded yield of this n-period discount bond is therefore

$$i_t^{(n)} = -n^{-1} p_t^{(n)}. \tag{1}$$

It is important to keep track of n and t throughout the analysis. t represents the time sample, which is daily. n, on the other hand, represents the maturity of the repo, which ranges from overnight to three months.

Let's begin with a situation where we purchase a n-period bond (i.e. lend money) at time t and sell it one period later at time $t+1$ when it is now a $n-1$ period bond. The log holding period return from this strategy is given by

$$\begin{aligned} r_{t+1}^{(n)} &= p_{t+1}^{(n-1)} - p_t^{(n)} && (2) \\ &= n i_t^{(n)} - (n-1) i_{t+1}^{(n-1)}. && (3) \end{aligned}$$

We denote the excess log holding period return as

$$rx_{t+1}^{(n)} = r_{t+1}^{(n)} - i_t^{(1)}, \tag{4}$$

where $i_t^{(1)}$ is the market risk-free return over the holding period.[12] From the expectations hypothesis, any time variation in this excess holding period return is capturing time-varying return risk premia, and the goal of this section is to understand if it is predictable.

Computing risk premia as in (4) is appropriate when we are looking at bonds whose maturity is longer than the investment horizon (holding period), which is the case is nearly

[12] Admittedly, this notation ignores approximation results from using logs, but we will rely on convenience for this framework.

all of the current literature on excess return predicability in bond market.[13] What about when bonds mature before the end of the investment horizon? For this, we must determine how to calculate excess returns from rolling over short-term debt. For the sake of an example, suppose our investment horizon is n. There are two ways of getting money from time t to time $t+n$: either invest in the n-period bond, or roll over one-period bonds until the $n-1$-maturity bond matures. The expectations hypothesis states that any difference between these two strategies must be capturing risk premia, namely that:

$$i_t^{(n)} = \frac{1}{n}\mathbb{E}_t\left[i_t^{(1)} + i_{t+1}^{(1)} + \cdots + i_{t+n-1}^{(1)}\right] + rp_t^{(n)}. \tag{5}$$

The risk premia term $rp_t^{(n)}$ in this equation is capturing *yield curve risk premia*, unlike the risk premia coming from (4) which is capturing *return risk premia*. These two types of risk premia are not the same, but we are constrained in this framework to the latter since we are working at the very short end of the yield curve and may not be interested in, say, daily excess returns (which would allow us to compute return risk premia). Yield curve risk premia are measuring the expected future return premia. We are not going to decompose the risk premia in (5) into how comes from each expected future return premia, but rather try to identify factors that predict it. We find it important to understand if risk premia are indeed predictable when calculated in this way, since we are now capturing the risk of rolling over short-term debt (one of the main uses of the repo market), and this is a very uncommon exercise in the fixed income literature on excess return predictability.

Turning back to the notation relevant for this paper, we will be computing excess returns for each of our repo market term structures

[13] An exception to this is the work of Smith (2012), who studies risk premia in the LIBOR-OIS term structure and finds evidence of predictable time variation in risk premia at a weekly investment horizon.

4.2 Are Excess Returns for Repos Predictable?

With the yield curve factors in hand for each repo market, the next logical question is whether or not these factors can predict time-varying risk premia in these markets, using the definition of risk premia coming from yield curve risk premia. There are two immediate concerns with this. First, the markets we are analyzing have a maximum maturity of three months, truly capturing the short end of the yield curve. Most of the previous work on fixed income risk premia looks at longer-term bonds, and it is sometimes difficult to predict time variation in risk premia in these markets. One obvious exception to this observation is Cochrane and Piazessi (2005), who identify a single tent-shaped factor comprised of forward rates that explains up to 44% of the variation in risk premia. However, we are trying to assess whether or not time-varying yield risk premia exist in these short-term markets and if, indeed, they are predictable.

A second issue is that fact that, conditional on the existence of time-varying risk premia in bond markets, it is not often the case that standard yield curve factors like level, slope, and curvature provide much predictive power. Intuitively, general movements in yields (captured by the factors) are not necessarily correlated with general movements in risk premia. This intuition is not new, but the results below will show that the previously published magnitudes of predictive power of yield curve factors using longer-term bond yields differs when we looks at short-term yields from the repo market.

For the U.S. Treasury, agency, and mortgage-backed security repos, excess returns are calculated using daily data at the monthly, quarterly, and annual investment horizon. The risk free rate we use in the calculation comes from Bloomberg-derived zero-coupon STRIPS with a maturity equal to the investment horizon. The baseline regression of excess returns for maturity n on factors for the corresponding market will be of the form

$$rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0^{(n)} TED_t + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \varepsilon_{t+1}^{(n)}, \tag{6}$$

where TED is the TED spread, and PC(1), PC(2), and PC(3) are the first three principal components of the term structure in each of the three repo markets. We will run this regression for each maturity *n* in each individual repo market. Later, we will ask the question of whether other financial variables have predictive power. This regressions does control for any residual credit risk showing up in our definition of excess returns; any additional predictive power after controlling for this credit risk through the TED spread will capture our predictability of excess returns.

4.2.1 U.S. Treasury Repos

Table (3) displays the coefficients from equation (6) as a function of the maturity for the U.S. Treasury repos. Panel A captures the coefficients for monthly returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported.[14] There are a variety of interest results in this table worth mentioning. First, there is not a systematic relationship between predictability of these excess returns with respect to the level, slope, and curvature factors. For the one-month investment horizon, excess returns are only marginally correlated with our proxy for credit risk, and much of the explained variation in these risk premia is coming from the curvature factor. The R^2 figures peak at 23% for the daily repo excess return. For the quarterly horizon, we find that the level factor is explaining the majority of the predictable variation in risk premia, as the credit risk proxy only proves to be significant for one-month repo excess returns. R^2 values are slightly higher at this investment horizon, peaking at 0.34 for the one-month repo excess

[14] At request, the author can provide many more summary statistics of these regressions that were deemed superfluous for the current version of the paper. In particular, breakdowns of the R^2's controlling for each factor separately can be provided.

return. Finally, at the annual investment horizon, we see credit risk showing up as a conditional predictor of these excess returns, but it is not the main player; the slope and curvature factors are explaining the majority of the predictable variation in these returns, and R^2 values max out at 0.24 for the one-month repo. Our main takeaway from this exercise is that, even after controlling for credit risk that may be correlated with this excess return, there is significant predictability coming from the level, slope, and curvature factors of the U.S. Treasury repo market.

4.2.2 Agency Repos

Table (4) displays the coefficients from equation (6) as a function of the maturity for the agency repos. Panel A captures the coefficients for monthly returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported. The results do change a bit for the agency repos as compared with U.S. Treasury repos. At the one-month horizon, there is almost zero predictability, with R^2 values on the order of 0.05. At the quarterly investment horizon, there is more promise; the R^2 peaks at the nearly 0.5 for the one-month repo. Controlling for credit risk is important in these regressions, but this is not explaining the majority of the variation in the excess returns; the level factor is doing most of the work. The slope and curvature factors also do provide some explanatory power. At the annual horizon, R^2 values again peak for the one-month repo at a level of approximately 0.24. For this horizon, credit risk must be controlled for, but predictability is coming from the slope and curvature factors, as well. The increase in R^2 values could be coming from the fact that, all else equal, collateral value risk is higher in the agency repo market than in the U.S. Treasury repo market, and the level, slope, and curvature factors do a better job of predicting it.

4.2.3 Mortgage-Backed Security Repos

Table (5) displays the coefficients from equation (6) as a function of the maturity for the mortgage-backed security repos. Panel A captures the coefficients for monthly returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported. The results continue to be different for the predictability of mortgage-backed security repo excess returns. At the monthly horizon, R^2 values peak at 0.26 for the two-week repo, but most of the predictability can be explained by credit risk, and very little is actually coming from the other controls. This changes at the quarterly and annual investment horizons. While credit risk does show up statistically significant, a large portion of the predictability comes from the level factor and slope factor at the quarterly horizon, with a peak in the R^2 of 0.63 for the one-month repo! For the annual return horizon, R^2 values are more muted, but we see importance of credit risk, slope, and curvature controls for these repos. In summary, predictability of excess returns varies in its level across the repo markets, and those markets which we think have more inherent collateral value risk exhibit excess returns with higher predictability coming from the level, slope, and curvature factors.

4.3 Excess Return Predictability for Repo Spreads

We now turn to the term structure of spreads between mortgage-backed security repo rates and U.S. Treasury repo rates. To begin, it is important to understand what we mean by an excess returns on a strategy involving investment in an interest rate spread. While this trade is not as natural in interpretation as for a bond, the way in which excess returns are computed is identical. For spread $z_t^{(n)}$ with maturity n shorter than the investment horizon, the holding period return is derived from rolling over a portfolio of the spread between mortgage-backed security repos and U.S. Treasury repos. We compare this return to that of holding the spread whose maturity is equal to the investment horizon. Because of this, we only compute excess returns over the one-month and three-month investment horizon. The spread itself captures the relative collateral value risk across the two markets, and thus the excess return, net of any credit risk, would be capturing risk premia associated with trading on this proxy for relative collateral value risk.

Table (6) displays the coefficients from equation (6) as a function of the maturity for the spread. Panel A captures the coefficients for monthly returns and Panel B captures the coefficients for quarterly returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported. At the one-month horizon, credit risk plays no role in explaining excess returns. The level factor is the main driver of predicability here, and R^2 values max out around 0.28. At the quarterly investment horizon, credit risk does explain a small portion of the excess returns (the R^2 increases by one to three percentage points), but each of the three factors explains the majority of the predictable component of excess returns. R^2 values here skyrocket to 0.5 and above using only these factors, which is supportive evidence towards predictability of risk premia associated with collateral value risk.

In summary, there are differences across the three markets in terms of the level of predicability and the source of the predictability. It is important to control for credit risk to alleviate any concerns about these excess returns solely capturing movements in credit risk, and not risk premia. However, for the majority of this analysis, we find that the factors outside of credit risk do provide potentially much predictive power for excess returns or repo rates themselves, but the results are much stronger for the repo spreads.

5 Macroeconomic vs. Financial Risks and Repo Markets

With a barrage of risk premia predictability results, we now turn to the bigger picture of understanding if there are other macroeconomic or financial measures of risk or uncertainty that provide additional predictive power for excess returns in the repo markets as well as the spread repo market. Our motivation for this analysis comes from the fact that macroeconomic and/or financial market uncertainty plays a role in explaining risk premia in short-term fixed income markets.[15]

We discussed in Section 2 the proxies we will be using for macroeconomic and financial risk. Our macroeconomic risk proxy is the policy uncertainty index found in Bloom et. al (2012), while our measure of financial risk will be the S&P volatility index, or VIX. Using these new variables, we run a set of regressions similar in spirit to (6) with a slight adjustment:

$$rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0^{(n)} TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_4 PI_t + \beta_5 VIX_t + \varepsilon_{t+1}^{(n)}, \tag{7}$$

where now we have added in both the policy index PI and the S&P volatility index VIX as part of the predictability regression. While these two indices are correlated (our sample correlation is approximately 0.5), our prior is that they are capturing fundamentally different types of uncertainty.

[15] That is not to say that it doesn't also play a role in longer-term fixed income markets. Some papers addressing this topic include Buraschi and Whelan (2010) and Hsu (2011).

5.1 U.S. Treasury Repo Excess Returns and Uncertainty

Our first set of excess returns regressions looks at the U.S. Treasury repo market.[16] Table (7) displays the coefficients from equation (7) as a function of the maturity for the U.S. Treasury repo market, where we include the additional explanatory variables. Panel A captures the coefficients for monthly returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported. The results of these regressions highlight that our measures of macroeconomic and financial risk provide only marginal (1-2 percentage points) increases in the R^2 values for these regressions compared to Table (3).

5.2 Repo Rates Spreads and Macroeconomic vs. Financial Risks

Table (8) displays the coefficients from equation (7) as a function of the maturity for the repo spreads, where we include the additional explanatory variables. Panel A captures the coefficients for monthly returns and Panel B captures the coefficients for quarterly returns. Under each coefficient estimate, we provide T-statistics computed using a Newey-West adjustment with 18 lags and a Hansen-Hodrick adjustment with 12 lags, with the former located in parentheses above the latter. Adjusted R^2 values are also reported. There is more than a marginal increase in the already substantial R^2 values for these regressions. At the one-month return horizon, both the overnight and one-week repo spreads see increases in the R^2 being attributed to the inclusion of the macroeconomy policy index. The same can

[16]Regression results for the agency and mortgage-backed security repos are available on request. Here, we will just highlight the results for the U.S. Treasury repos and the spread between mortgage-backed security and U.S. Treasury repo rates.

be said for the quarterly return horizon. At its peak for the one-week repo spread, we can predict quarterly returns with an R^2 of nearly 0.75. In fact, in unreported results, we run these regressions with just the TED spread, the macroeconomic policy index, and the VIX. We find R^2 values drop to approximately 0.2, but this is still a substantial R^2 for a quarterly return horizon regression with daily data using only these macroeconomic and financial risk proxies. So, while it may be the case that the level, slope, and curvature factors of this market do provide predictive power, they are not completely subsuming the power of the macroeconomic and financial risk variables. This is promising, since the literature is always searching for an economic interpretation of these factors. Regardless, the collateral value risk premia identified in these regressions is predictable.

6 Conclusion

We study the term structure of short-term repo markets with varying types of collateral from 1997-2012. We find that the term structure of repos have unique qualities above and beyond their extremely short maturity. Computing returns, we assess that predictability of these excess returns is possible using standard level, slope, and curvature factors from the repo markets. As a measure of repo stress, we look at the term structure of the spread between mortgage-backed security and U.S. Treasury repo rates. The underlying factor structure of this market differs substantially to that of each of the underlying repos, mostly due the fact that these spreads are, in and of themselves, capturing relative risk of the underlying collateral. Using repo factors, as well as measures of macroeconomic and financial risk, we are able to show meaningful predictability of risk premia in this spread term structure, as well.

There are a variety of open questions and further avenues of research coming from these results. An obvious extension is to use a more theoretical framework to model the behavior these term structures, such as an affine model, in an effort to use no-arbitrage restrictions to back out time varying risk premia. It is also important to understand exactly which type of risks we are capturing in these markets. Is the risk macroeconomic, financial, or both? Is there ever a hope of distinguishing between the two? We feel that the identification of short-term risk premia is crucial for our understanding of the linkages between macroeconomic and financial risk due to the prevalence of financing activity by major financial institutions using repo markets and the correlation of these short-term rates with policy rates in the U.S. and globally.

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PANEL A: MOMENTS OF REPO RATES BY COLLATERAL TYPE

	U.S. Treasury		Agency		Mortgage-Backed Security	
Maturity	Mean	Variance	Mean	Variance	Mean	Variance
Overnight	2.7858	4.7323	2.8370	4.7365	2.8629	4.7876
One-Week	2.7864	4.6787	2.8445	4.7008	2.8726	4.7475
Two-Week	2.7857	4.6707	2.8480	4.6957	2.8779	4.7424
Three-Week	2.7885	4.6665	2.8503	4.6923	2.8843	4.7333
One-Month	2.7882	4.6626	2.8621	4.6900	2.8951	4.7309
Two-Month	2.8001	4.6688	2.8743	4.6843	2.9106	4.7133
Three-Month	2.8119	4.6801	2.8906	4.6869	2.9272	4.7118

PANEL B: MOMENTS OF OTHER KEY VARIABLES

Variable	Mean	Variance
Federal Funds Rate	2.8716	4.7653
TED Spread	0.4851	0.2146
Policy Index	105.0795	6085.6991
VIX	22.6825	80.6024

Table 1: This table reports summary statistics on the repo rates and other key variables used in the analysis. Panel A reports the mean and variance for the repo term structures by collateral type: U.S. Treasury, agency, and mortgage-macked securities. Panel B reports the mean and variance for other key variables used in the analysis: the Federal Funds rate, the TED Spread (Three-month LIBOR over Three-month U.S. Treasury bill), the macroeconomic policy index, and the volatility index (VIX) for the S&P 500. For all interest rate and spreads, units are in percentage points. The policy index and VIX are in their standardized units. The full time sample is December 2, 1997 through January 30, 2012.

Correlations	L: U.S. Treas	S: U.S. Treas	C: U.S. Treas	L: Agency	S: Agency	C: Agency	L: MBS	S: MBS	C: MBS	L: Spreads	S: Spreads	C: Spreads	FF Rate	TED	PI	VIX
L: U.S. Treas	1.000	0.000	0.000	0.998	-0.002	-0.012	0.998	0.016	-0.008	0.055	-0.051	-0.086	0.997	0.138	-0.507	-0.231
Slop: U.S. Treas	0.000	1.000	0.000	-0.011	0.749	-0.102	-0.014	0.654	-0.103	-0.206	0.390	-0.016	0.023	-0.161	-0.023	-0.017
C: U.S. Treas	0.000	0.000	1.000	0.012	0.191	0.698	0.017	0.088	0.653	0.253	-0.072	0.402	0.009	0.230	0.187	0.243
L: Agency	0.998	-0.011	0.012	1.000	0.000	0.000	0.999	0.012	-0.003	0.106	-0.062	-0.088	0.997	0.165	-0.498	-0.225
S: Agency	-0.002	0.749	0.191	0.000	1.000	0.000	-0.007	0.891	-0.008	-0.067	-0.200	0.082	0.029	-0.215	0.060	0.017
C: Agency	-0.012	-0.102	0.698	0.000	0.000	1.000	0.001	-0.087	0.736	0.185	0.013	-0.045	-0.008	0.172	0.194	0.235
L: MBS	0.998	-0.014	0.017	0.999	-0.007	0.001	1.000	0.000	0.000	0.123	-0.052	-0.086	0.997	0.185	-0.493	-0.211
S: MBS	0.016	0.654	0.088	0.012	0.891	-0.087	0.000	1.000	0.000	-0.244	-0.438	0.000	0.040	-0.409	-0.054	-0.185
C: MBS	-0.008	-0.103	0.653	-0.003	-0.008	0.736	0.000	0.000	1.000	0.105	-0.082	-0.377	-0.010	0.030	0.121	0.115
L: Spreads	0.055	-0.206	0.253	0.106	-0.067	0.185	0.123	-0.244	0.105	1.000	0.000	0.000	0.096	0.708	0.169	0.275
S: Spreads	-0.051	0.390	-0.072	-0.062	-0.200	0.013	-0.052	-0.438	-0.082	0.000	1.000	0.000	-0.056	0.275	0.047	0.206
C: Spreads	-0.086	-0.016	0.402	-0.088	0.082	-0.045	-0.086	0.000	-0.377	0.000	0.000	1.000	-0.085	0.157	0.080	0.128
FF Rate	0.997	0.023	0.009	0.997	0.029	-0.008	0.997	0.040	-0.010	0.096	-0.056	-0.085	1.000	0.158	-0.504	-0.228
TED	0.138	-0.161	0.230	0.165	-0.215	0.172	0.185	-0.409	0.030	0.708	0.275	0.157	0.158	1.000	0.171	0.494
PI	-0.507	-0.023	0.187	-0.498	0.060	0.194	-0.493	-0.054	0.121	0.169	0.047	0.080	-0.504	0.171	1.000	0.535
VIX	-0.231	-0.017	0.243	-0.225	0.017	0.235	-0.211	-0.185	0.115	0.275	0.206	0.128	-0.228	0.494	0.535	1.000

Table 2: This table displays the contemporaneous correlations between the level, slope, and curvature factors for the term structure of repo markets conditional on the type of collateral, the level slope and curvature factors for the term structure of repo spreads (between mortgage-backed security and U.S. Treasury repo rates), the Federal Funds (FF) rate, the TED spread, the macroeconomic policy index PI, and the volatility index VIX. The full time sample is December 2, 1997 through January 30, 2012.

PANEL A: ONE-MONTH RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.032	0.101	-0.0014	0.062	0.5749	0.232
	(-2.1748)	(2.8181)	(-1.2851)	(0.7792)	(5.8017)	
	(-1.9512)	(2.5348)	(-1.1416)	(0.7304)	(5.4211)	
One-Week	-0.0051	0.0379	0.0001	0.0555	0.3876	0.1473
	(-0.5258)	(1.7523)	(0.1017)	(0.8425)	(5.3731)	
	(-0.4959)	(1.6886)	(0.0944)	(0.7986)	(5.1681)	
Two-Week	0.0004	0.0203	0.0002	0.0379	0.2881	0.1057
	(0.0554)	(1.527)	(0.4152)	(0.6105)	(4.8364)	
	(0.054)	(1.7292)	(0.4398)	(0.5941)	(4.7353)	

PANEL B: QUARTERLY RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.043	-0.0545	-0.0155	0.0803	0.2879	0.1828
	(-1.8205)	(-0.9314)	(-7.0388)	(1.1164)	(2.1336)	
	(-1.5852)	(-0.8117)	(-6.1357)	(1.0735)	(1.9133)	
One-Week	-0.0211	-0.1067	-0.0142	0.0606	0.2039	0.2316
	(-0.9382)	(-1.9734)	(-7.026)	(0.9389)	(1.6992)	
	(-0.8163)	(-1.7188)	(-6.1248)	(0.8993)	(1.5221)	
One-Month	-0.0158	-0.1445	-0.0145	-0.0032	0.0066	0.3398
	(-0.8315)	(-3.1213)	(-8.3497)	(-0.0688)	(0.0703)	
	(-0.7261)	(-2.725)	(-7.2928)	(-0.0672)	(0.0641)	

PANEL C: ANNUAL RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	0.1603	0.3703	0.003	0.8012	1.4122	0.2277
	(3.8147)	(5.256)	(0.4694)	(5.2407)	(5.7552)	
	(3.3449)	(4.6241)	(0.4091)	(4.9029)	(5.2449)	
One-Month	-0.0546	0.3566	-0.0209	0.9641	1.6878	0.2336
	(-1.1443)	(4.7017)	(-2.7702)	(5.3075)	(5.9656)	
	(-1.0019)	(4.1268)	(-2.4149)	(4.9623)	(5.4363)	
Three-Month	0.1459	0.2566	-0.0016	0.6475	1.1023	0.1741
	(3.818)	(4.0504)	(-0.2746)	(4.7092)	(4.9625)	
	(3.3389)	(3.5492)	(-0.2393)	(4.3786)	(4.4933)	

Table 3: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given U.S. Treasury repo, TED is the TED spread, and $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure. Column 1 is the maturity of the repo, columns 2 through 6 display the coefficient estimates, and column 7 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

PANEL A: ONE-MONTH RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.0431	0.0178	-0.0021	-0.0576	0.2927	0.0507
	(-2.7093)	(0.4174)	(-1.6951)	(-0.8373)	(4.1588)	
	(-2.4367)	(0.3747)	(-1.5056)	(-0.758)	(3.7723)	
One-Week	-0.0237	-0.0441	-0.0006	-0.0197	0.1273	0.0267
	(-2.0953)	(-1.4415)	(-0.6471)	(-0.3416)	(2.1285)	
	(-1.9718)	(-1.3429)	(-0.5819)	(-0.3103)	(1.9619)	
Two-Week	-0.0133	-0.0805	-0.0002	-0.0076	0.029	0.0753
	(-1.3743)	(-3.2177)	(-0.2378)	(-0.1495)	(0.3923)	
	(-1.3135)	(-3.0734)	(-0.2159)	(-0.1352)	(0.3832)	

PANEL B: QUARTERLY RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.0574	-0.1317	-0.0164	-0.1299	0.2851	0.2877
	(-2.3444)	(-2.1298)	(-7.5194)	(-1.5021)	(2.8481)	
	(-2.0447)	(-1.8597)	(-6.5603)	(-1.3299)	(2.5522)	
One-Week	-0.0455	-0.1775	-0.0152	-0.1111	0.2328	0.366
	(-2.1256)	(-3.3165)	(-7.7185)	(-1.3882)	(2.7176)	
	(-1.8552)	(-2.8984)	(-6.735)	(-1.2243)	(2.4401)	
One-Month	-0.0307	-0.2429	-0.0148	-0.1688	0.0757	0.4877
	(-1.5617)	(-4.9828)	(-8.5431)	(-2.5668)	(1.0291)	
	(-1.3627)	(-4.3486)	(-7.4512)	(-2.2626)	(0.954)	

PANEL C: ANNUAL RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	0.0914	0.4049	-0.0007	0.9836	0.9529	0.2106
	(2.2635)	(5.6876)	(-0.1137)	(5.8617)	(4.3143)	
	(2.0048)	(5.1082)	(-0.0992)	(5.1513)	(3.9738)	
One-Month	-0.1635	0.412	-0.0252	1.2588	1.2118	0.2397
	(-3.5263)	(5.2612)	(-3.4822)	(6.3428)	(4.7632)	
	(-3.118)	(4.7219)	(-3.0391)	(5.5682)	(4.4128)	
Three-Month	0.0764	0.2332	-0.0035	0.7972	0.8641	0.1492
	(2.0056)	(3.5218)	(-0.6203)	(4.668)	(4.3255)	
	(1.7639)	(3.1234)	(-0.541)	(4.0899)	(3.9486)	

Table 4: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given agency repo, TED is the TED spread, and $PC_t(i)$ is the i^{th} principal component of the agency repo term structure. Column 1 is the maturity of the repo, columns 2 through 6 display the coefficient estimates, and column 7 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

Panel A: One-Month Returns

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.0527	-0.0155	-0.0037	-0.0828	0.2189	0.0559
	(-3.3569)	(-0.3706)	(-3.2056)	(-1.1828)	(2.5242)	
	(-2.9733)	(-0.3291)	(-2.8367)	(-1.066)	(2.4378)	
One-Week	-0.027	-0.0952	-0.0019	-0.0121	0.0766	0.1237
	(-2.4096)	(-3.1564)	(-1.9951)	(-0.1993)	(0.8879)	
	(-2.2324)	(-2.9117)	(-1.7885)	(-0.1781)	(0.8129)	
Two-Week	-0.0135	-0.1416	-0.0013	0.0045	-0.0296	0.2583
	(-1.3604)	(-5.3194)	(-1.4397)	(0.0832)	(-0.3711)	
	(-1.2707)	(-4.9493)	(-1.2999)	(0.0751)	(-0.3379)	

Panel B: Quarterly Returns

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	-0.067	-0.1642	-0.0181	-0.1715	0.193	0.3495
	(-2.5748)	(-2.5226)	(-8.2765)	(-1.9639)	(1.9819)	
	(-2.2432)	(-2.198)	(-7.2142)	(-1.737)	(1.9086)	
One-Week	-0.05	-0.226	-0.0166	-0.1513	0.1531	0.444
	(-2.267)	(-4.2019)	(-8.453)	(-1.8337)	(1.7576)	
	(-1.9763)	(-3.6644)	(-7.372)	(-1.6138)	(1.6139)	
One-Month	-0.0154	-0.3442	-0.0152	-0.1946	-0.0414	0.6309
	(-0.859)	(-7.8625)	(-9.0681)	(-3.039)	(-0.6085)	
	(-0.7519)	(-6.8827)	(-7.9254)	(-2.6676)	(-0.5437)	

Panel C: Annual Returns

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	0.0341	0.4736	-0.0042	0.7787	1.0116	0.1804
	(0.7867)	(6.097)	(-0.665)	(4.2216)	(4.4447)	
	(0.6896)	(5.362)	(-0.5798)	(3.6819)	(3.97)	
One-Month	-0.2198	0.4599	-0.0292	0.9606	1.224	0.1969
	(-4.3642)	(5.3257)	(-3.9031)	(4.2905)	(4.3794)	
	(-3.8189)	(4.6724)	(-3.4023)	(3.7413)	(3.8924)	
Three-Month	0.0525	0.212	-0.0056	0.6001	0.8541	0.1016
	(1.2898)	(2.8613)	(-1.0005)	(3.3817)	(4.1381)	
	(1.1269)	(2.5028)	(-0.8719)	(2.9482)	(3.6788)	

Table 5: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given mortgage-backed security repo, TED is the TED spread, and $PC_t(i)$ is the i^{th} principal component of the mortgage-backed security repo term structure. Column 1 is the maturity of the repo, columns 2 through 6 display the coefficient estimates, and column 7 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

PANEL A: ONE-MONTH RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	0.0186	0.0004	0.1504	0.1615	-0.2752	0.2899
	(1.1405)	(0.0133)	(3.0374)	(1.9433)	(-3.179)	
	(1.0547)	(0.0125)	(2.787)	(1.7862)	(-2.897)	
One-Week	0.0139	-0.0089	0.1285	0.1242	-0.0295	0.2745
	(1.2297)	(-0.4373)	(3.6389)	(1.8236)	(-0.3821)	
	(1.1972)	(-0.4508)	(3.4074)	(1.7504)	(-0.3732)	
Two-Week	0.0067	-0.0064	0.0759	0.1052	0.108	0.137
	(0.687)	(-0.3689)	(2.5188)	(1.5313)	(1.4884)	
	(0.6982)	(-0.3906)	(2.4476)	(1.4912)	(1.4847)	

PANEL B: QUARTERLY RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	R^2
Overnight	0.0481	-0.0307	0.2537	0.4227	0.1256	0.6134
	(3.9379)	(-1.3273)	(5.9829)	(5.36)	(1.4304)	
	(3.4825)	(-1.1699)	(5.3685)	(4.761)	(1.2671)	
One-Week	0.0452	-0.0446	0.2558	0.4319	0.2141	0.6614
	(4.2978)	(-2.1953)	(6.9538)	(6.0095)	(2.5677)	
	(3.7905)	(-1.924)	(6.2478)	(5.3587)	(2.2886)	
One-Month	0.0467	-0.0668	0.1908	0.406	0.1863	0.4745
	(4.6012)	(-2.8503)	(6.2994)	(5.079)	(1.8738)	
	(3.9865)	(-2.4608)	(5.6614)	(4.5963)	(1.6624)	

Table 6: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given spread between mortgage-backed security and U.S. Treasury repo rates, TED is the TED spread, and $PC_t(i)$ is the i^{th} principal component of the term structure of the spreads between mortgage-backed security and U.S. Treasury repo rates. Column 1 is the maturity of the repo, columns 2 through 6 display the coefficient estimates, and column 7 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions and Panel B reports quarterly excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

PANEL A: ONE-MONTH RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	PI	VIX	R^2
Overnight	-0.0858	0.0731	0.0009	0.0542	0.5325	0.0181	0.2124	0.2493
	(-4.4168)	(1.5768)	(0.5305)	(0.7023)	(5.5513)	(1.3618)	(1.5411)	
	(-4.043)	(1.3995)	(0.4718)	(0.6517)	(5.2198)	(1.2788)	(1.3612)	
One-Week	-0.0622	0.0084	0.0026	0.0474	0.342	0.0203	0.2204	0.1861
	(-4.159)	(0.299)	(1.8988)	(0.7515)	(5.1974)	(1.5435)	(2.4793)	
	(-3.899)	(0.2788)	(1.7268)	(0.7032)	(5.1186)	(1.4499)	(2.2477)	
Two-Week	-0.0393	0.0006	0.0023	0.0329	0.2533	0.0201	0.1239	0.1379
	(-2.9542)	(0.0288)	(1.7354)	(0.5501)	(5.1212)	(1.4549)	(2.0623)	
	(-2.8787)	(0.029)	(1.6223)	(0.5297)	(5.4285)	(1.3883)	(1.9495)	

PANEL B: QUARTERLY RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	PI	VIX	R^2
Overnight	-0.106	-0.0859	-0.0123	0.0723	0.2327	0.0314	0.1987	0.1981
	(-2.636)	(-1.2686)	(-4.4965)	(1.0199)	(1.6681)	(3.1538)	(0.8708)	
	(-2.3036)	(-1.1057)	(-3.9254)	(0.9675)	(1.4951)	(2.8412)	(0.7611)	
One-Week	-0.0998	-0.147	-0.0105	0.0498	0.1388	0.0318	0.2858	0.2578
	(-2.6791)	(-2.5205)	(-4.4627)	(0.7939)	(1.1364)	(3.4391)	(1.4504)	
	(-2.3408)	(-2.1978)	(-3.9006)	(0.7494)	(1.0183)	(3.1046)	(1.2706)	
One-Month	-0.063	-0.1683	-0.0122	-0.0094	-0.0337	0.0216	0.1588	0.3514
	(-1.8487)	(-3.6305)	(-6.2773)	(-0.1998)	(-0.3441)	(2.3321)	(0.9797)	
	(-1.6221)	(-3.1915)	(-5.5398)	(-0.193)	(-0.314)	(2.1069)	(0.8656)	

PANEL C: ANNUAL RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	PI	VIX	R^2
Overnight	0.0925	0.3429	0.0092	0.7989	1.3239	0.0907	-0.0591	0.2361
	(1.1337)	(3.6247)	(1.1827)	(5.4914)	(5.6604)	(3.0944)	(-0.1289)	
	(0.9924)	(3.1803)	(1.0337)	(5.0909)	(5.1858)	(2.8653)	(-0.1128)	
One-Month	-0.18	0.3003	-0.0118	0.9546	1.549	0.1194	0.1253	0.2471
	(-1.9886)	(2.9371)	(-1.3217)	(5.6531)	(5.8139)	(3.5044)	(0.2429)	
	(-1.741)	(2.5747)	(-1.1556)	(5.2304)	(5.3345)	(3.2387)	(0.2125)	
Three-Month	0.0534	0.2139	0.0046	0.6394	1.005	0.078	0.1409	0.1852
	(0.7436)	(2.5377)	(0.676)	(4.8891)	(4.7248)	(3.0356)	(0.348)	
	(0.6505)	(2.2222)	(0.5904)	(4.5014)	(4.3007)	(2.7898)	(0.3046)	

Table 7: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given U.S. Treasury repo, TED is the TED spread, $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure, PI_t is the macroeconomic policy index, and VIX_t is the S&P volatility index. In the regression, we divide both the macroeconomic policy index PI and the volatility index VIX by 100 to report comparably-sized coefficients. Column 1 is the maturity of the repo, columns 2 through 8 display the coefficient estimates, and column 9 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

PANEL A: ONE-MONTH RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	PI	VIX	R^2
Overnight	-0.0025	-0.011	0.1525	0.158	-0.2819	0.0033	0.1023	0.3571
	(-0.1304)	(-0.3106)	(3.0107)	(1.928)	(-3.2215)	(2.5175)	(1.0198)	
	(-0.1191)	(-0.2901)	(2.7639)	(1.7854)	(-2.9509)	(2.5133)	(0.9011)	
One-Week	0.0093	-0.0114	0.129	0.1234	-0.031	0.0007	0.0219	0.3184
	(0.7662)	(-0.4574)	(3.5694)	(1.8013)	(-0.3924)	(2.1369)	(0.3115)	
	(0.7557)	(-0.4582)	(3.3515)	(1.7303)	(-0.3828)	(2.1389)	(0.2865)	
Two-Week	0.0099	-0.0066	0.0772	0.1056	0.1105	-0.0042	0.0058	0.1377
	(1.0481)	(-0.2896)	(2.5058)	(1.5288)	(1.5014)	(-1.7412)	(0.0876)	
	(1.1205)	(-0.2931)	(2.4457)	(1.4823)	(1.4949)	(-1.8195)	(0.0817)	

PANEL B: QUARTERLY RETURNS

Maturity	Intercept	TED	PC(1)	PC(2)	PC(3)	PI	VIX	R^2
Overnight	-0.0085	-0.064	0.2611	0.4136	0.1105	0.0041	0.302	0.6951
	(-0.5163)	(-2.2885)	(6.269)	(6.6387)	(1.4404)	(2.9057)	(3.2664)	
	(-0.4547)	(-2.0117)	(5.6391)	(5.9428)	(1.2862)	(2.8276)	(2.8594)	
One-Week	-0.0071	-0.0766	0.2636	0.4233	0.2011	0.0013	0.2933	0.7447
	(-0.5279)	(-3.1526)	(7.3181)	(7.5284)	(2.7622)	(2.3168)	(3.6579)	
	(-0.4634)	(-2.7635)	(6.5872)	(6.7745)	(2.4819)	(2.2932)	(3.2102)	
One-Month	-0.0086	-0.1039	0.2016	0.3969	0.1751	-0.0047	0.3451	0.5229
	(-0.6611)	(-3.8168)	(6.9743)	(6.2307)	(1.9804)	(-1.1037)	(4.1743)	
	(-0.5812)	(-3.3091)	(6.2739)	(5.6965)	(1.7635)	(-1.0545)	(3.7024)	

Table 8: This table displays the results from the regressions $rp_{t+1}^{(n)} = \alpha^{(n)} + \beta_0 TED_t + \sum_{i=1}^{3} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $rp_{t+1}^{(n)}$ is the excess return over holding period n at time $t+1$ for the given spread between mortgage-backed security and U.S. Treasury repo rates, TED is the TED spread, $PC_t(i)$ is the i^{th} principal component of the term structure of the spreads between mortgage-backed security and U.S. Treasury repo rates, PI_t is the macroeconomic policy index, and VIX_t is the S&P volatility index. In the regression, we divide both the macroeconomic policy index PI and the volatility index VIX by 100 to report comparably-sized coefficients. Column 1 is the maturity of the repo, columns 2 through 8 display the coefficient estimates, and column 9 is the R^2 of the regression. Below each coefficient estimate is a t-statistic with a Newey-West correction with 18 lags, followed by the t-statistic with a Hansen-Hodrick correction with 12 lags. Panel A reports one-month excess returns regressions and Panel B reports quarterly excess returns regressions. The sample period is daily from December 2, 1997 through January 30, 2012.

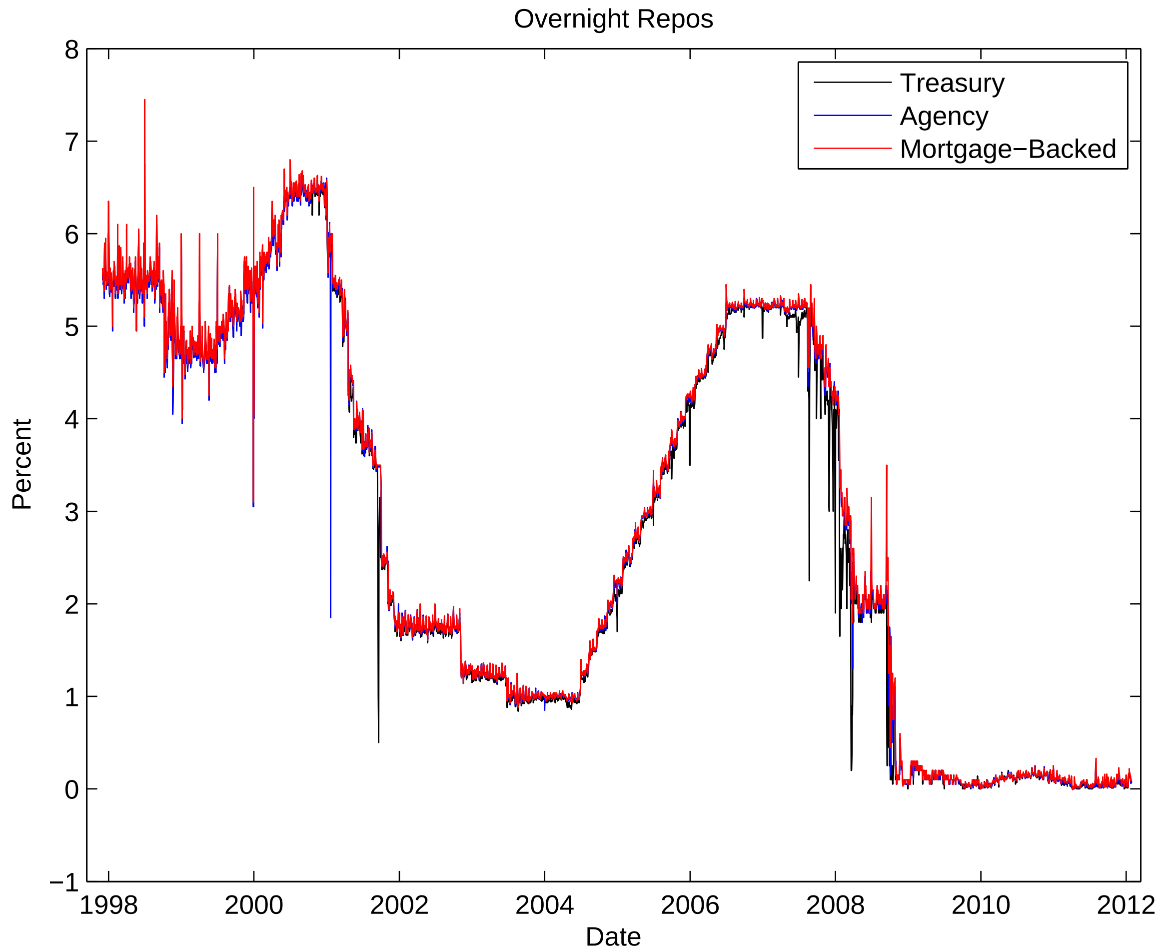

Figure 1: This figure plots the overnight repo rates for U.S. Treasury (black), agency (blue), and mortgage-backed security (red) repos. The sample period is daily from December 2, 1997 through January 30, 2012. Data is collected from Bloomberg.

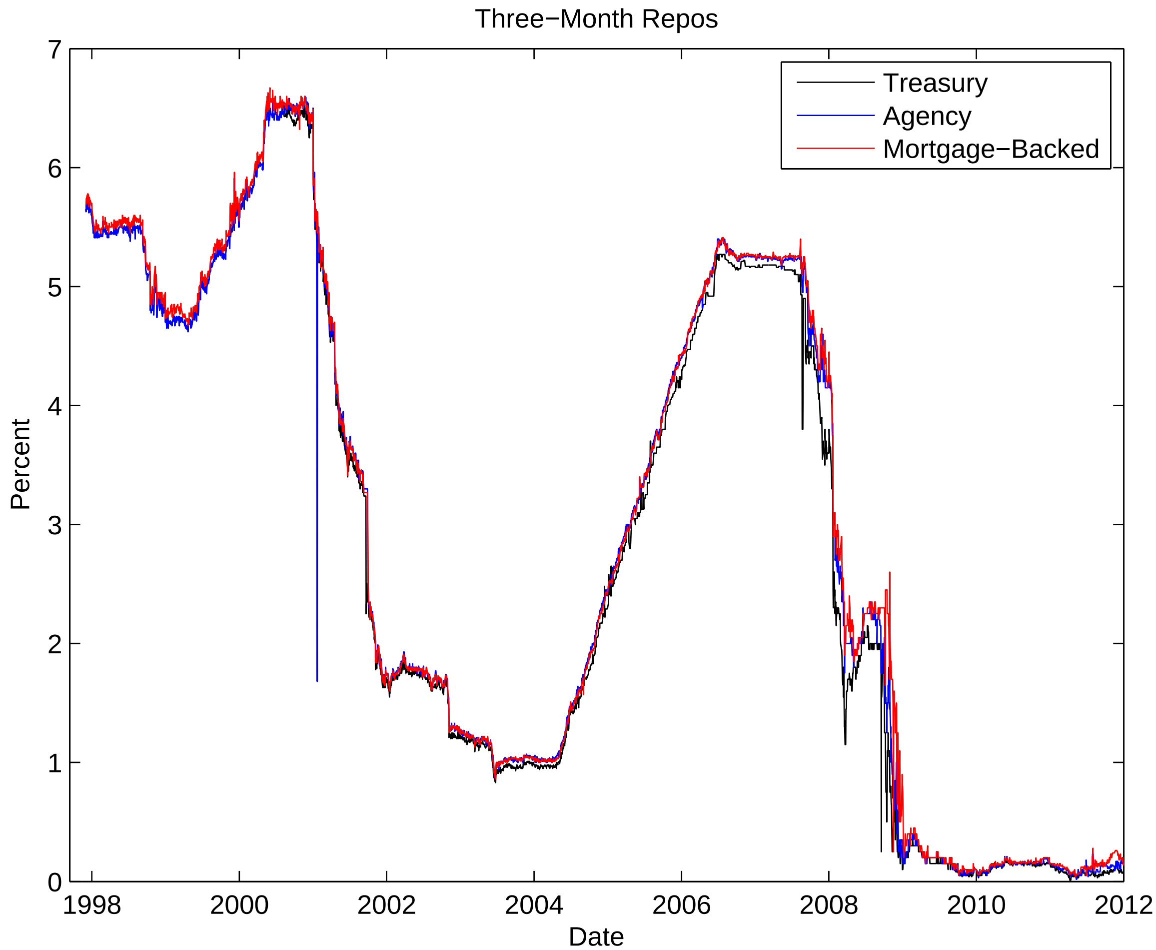

Figure 2: This figure plots the three-month repo rates for U.S. Treasury (black), agency (blue), and mortgage-backed security (red) repos. The sample period is daily from December 2, 1997 through January 30, 2012. Data is collected from Bloomberg.

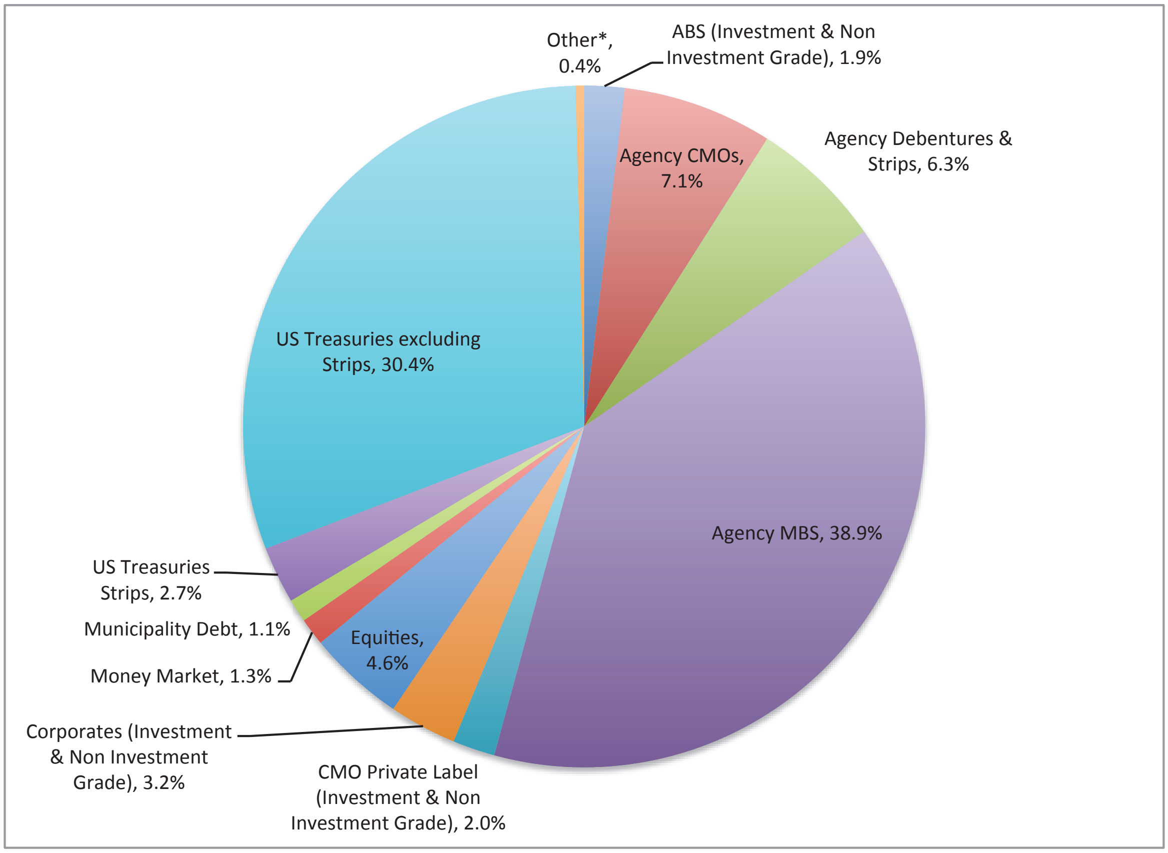

Figure 3: This chart breaks down the total tri-party repo market into the type of collateral underlying each repurchase agreement as of July 2012. Data is from the Federal Reserve Bank of New York.

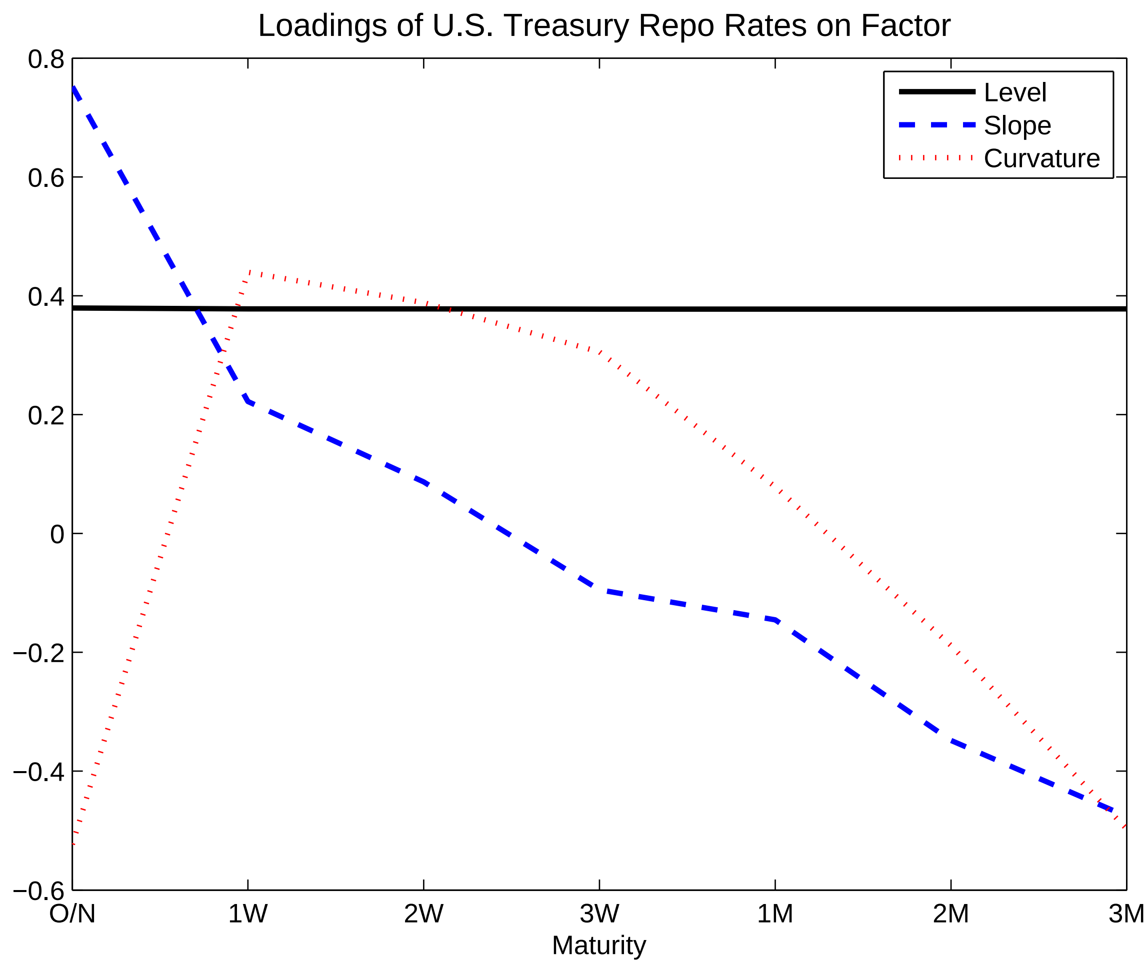

Figure 4: This figure plots how each of the first three principal components of the U.S. Treasury repo market load onto each individual U.S. Treasury repo. The *x*-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the level factor), the dashed blue line is the loadings on the second principal component (the slope factor), and the dotted red line is the loadings on the third principal component (the curvature factor).

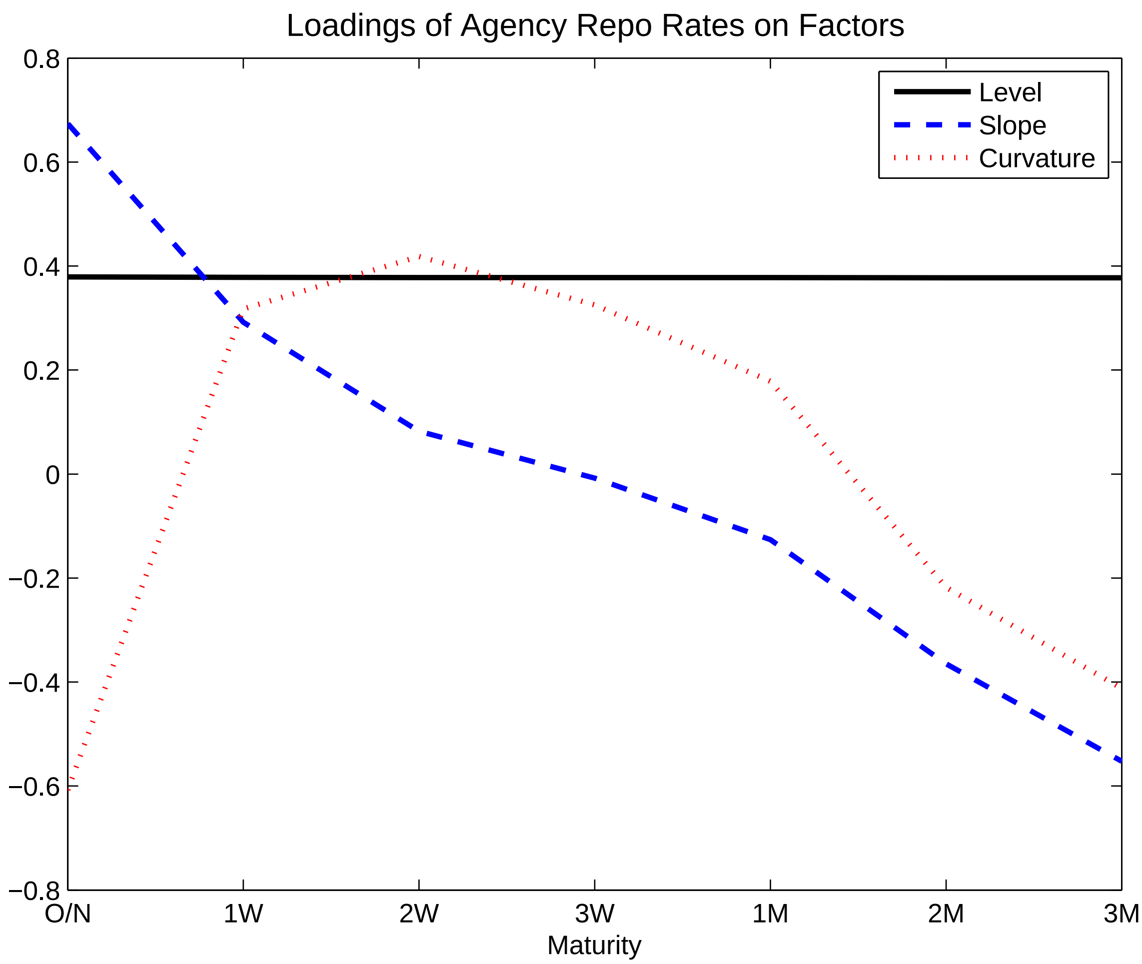

Figure 5: This figure plots how each of the first three principal components of the agency repo market load onto each individual agency repo. The x-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the level factor), the dashed blue line is the loadings on the second principal component (the slope factor), and the dotted red line is the loadings on the third principal component (the curvature factor).

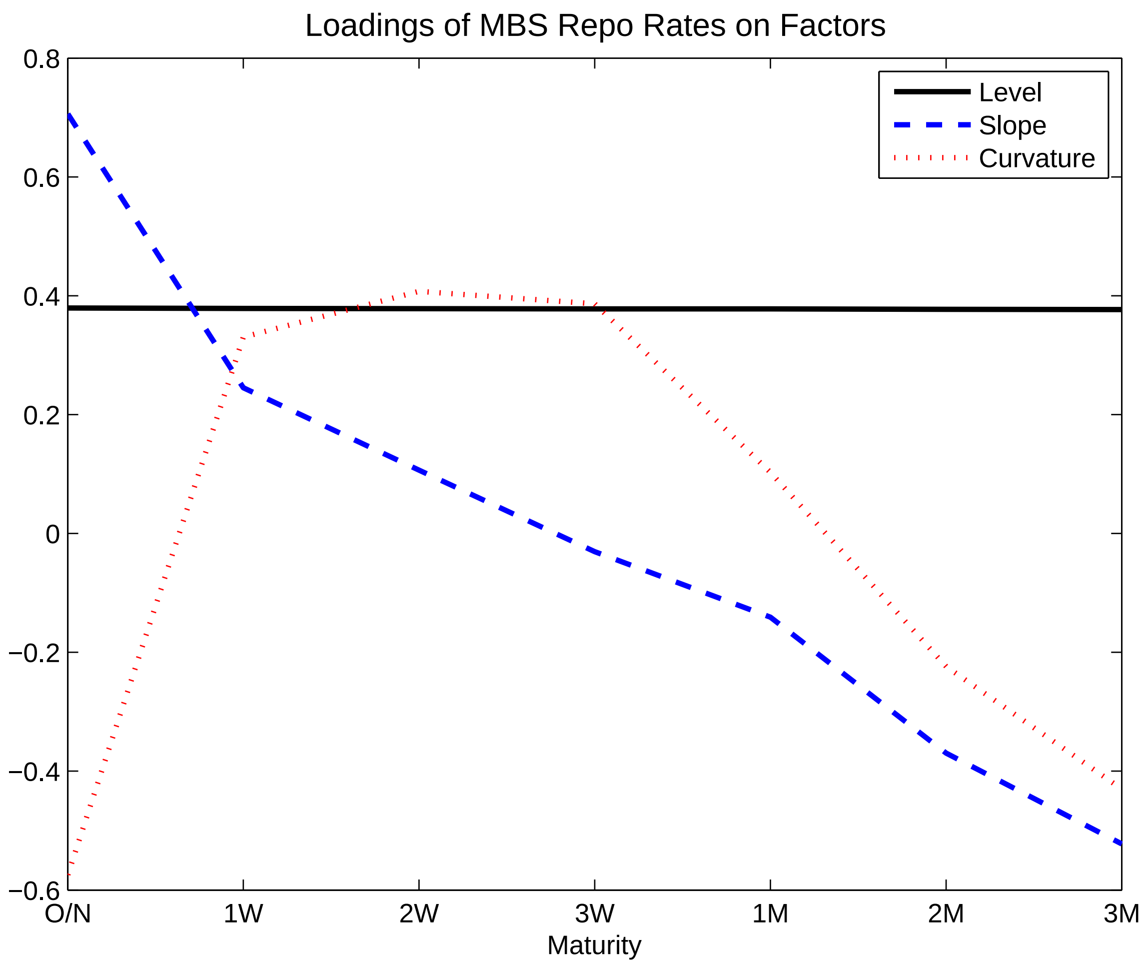

Figure 6: This figure plots how each of the first three principal components of the mortgage-backed security repo market load onto each individual mortgage-backed security repo. The *x*-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the level factor), the dashed blue line is the loadings on the second principal component (the slope factor), and the dotted red line is the loadings on the third principal component (the curvature factor).

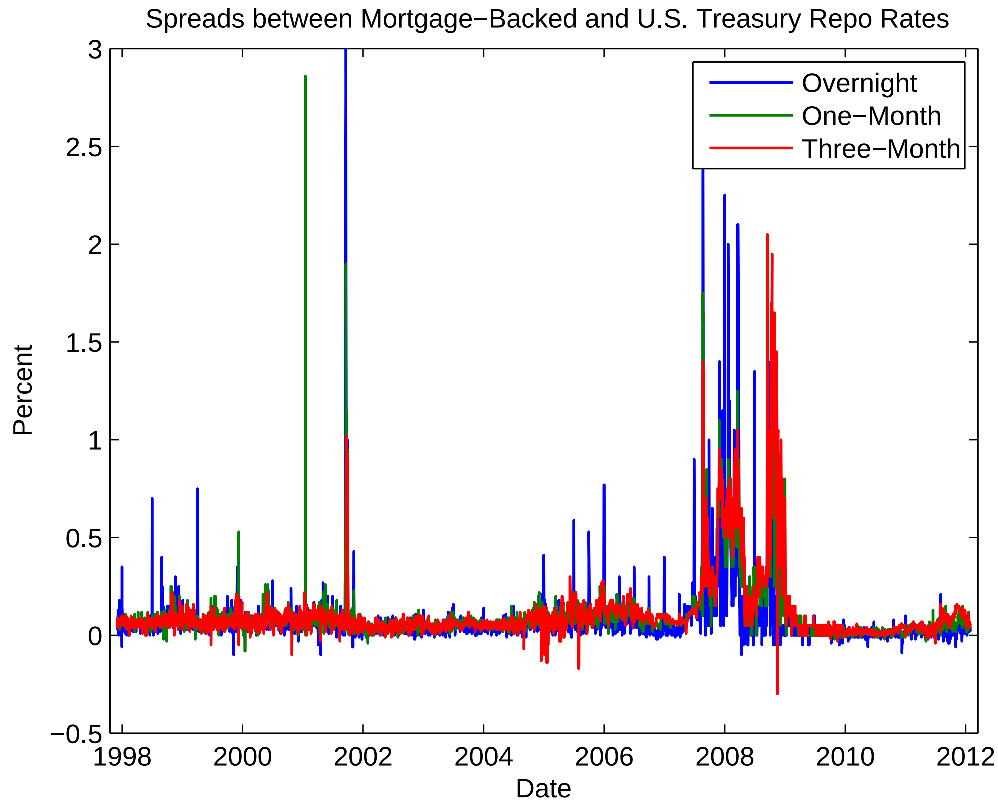

Figure 7: This figure plots the spreads between mortgage-backed security and U.S. Treasury repo rates at the overnight (blue), one-month (green), and three-month (red) maturities. The sample period is daily from December 2, 1997 through January 30, 2012. Data is collected from Bloomberg.

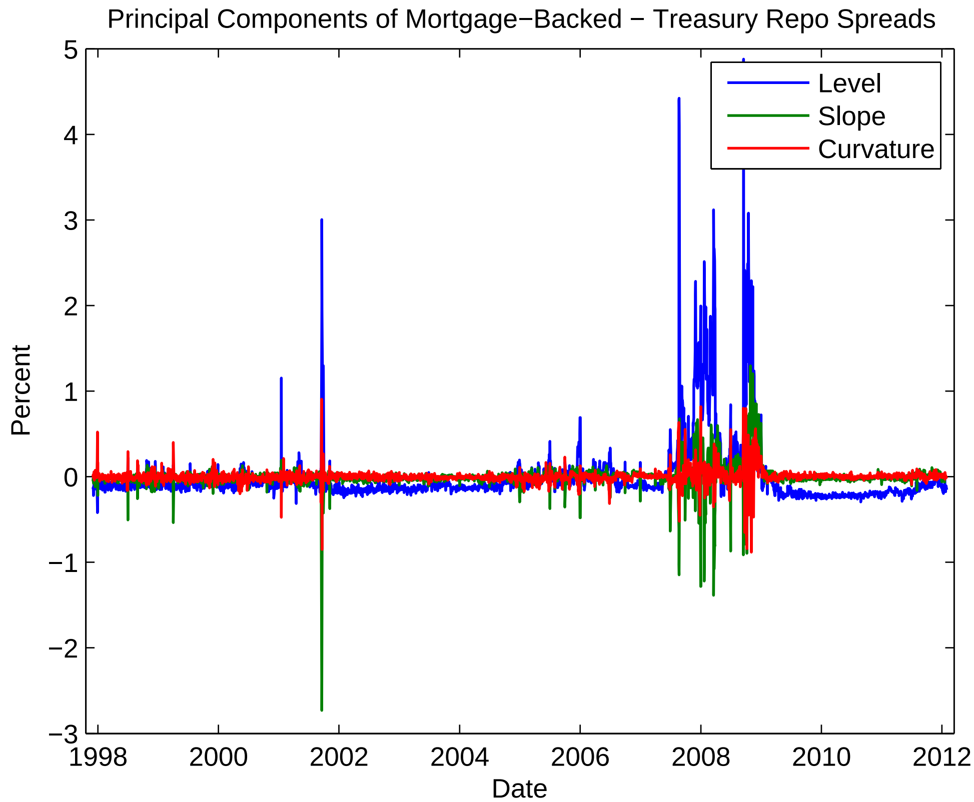

Figure 8: This figure plots the first three principal components of the term structure of the spreads between mortgage-backed security and U.S. Treasury repo rates. The blue line represents the first principal component (the level factor), the green line represents the second principal component (the slope factor), and the red line represents the third principal component (the curvature factor). The sample period is daily from December 2, 1997 through January 30, 2012. Data is collected from Bloomberg.

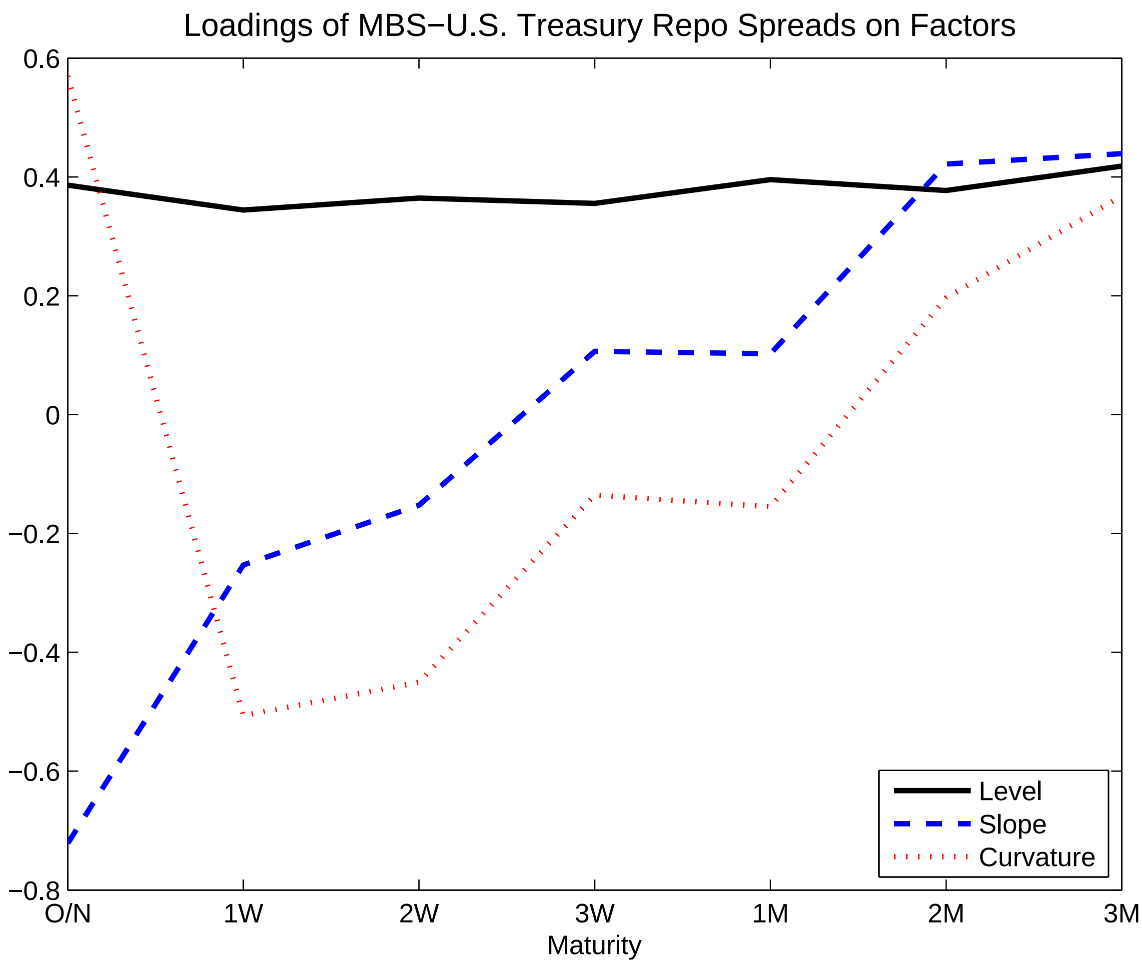

Figure 9: This figure plots how each of the first three principal components of the U.S. Treasury repo market load onto each spread between mortgage-backed security and U.S. Treasury repo rates. The x-axis is maturity of the underlying repo spread. The solid black line is the loadings on the first principal component (the level factor), the dashed blue line is the loadings on the second principal component (the slope factor), and the dotted red line is the loadings on the third principal component (the curvature factor).

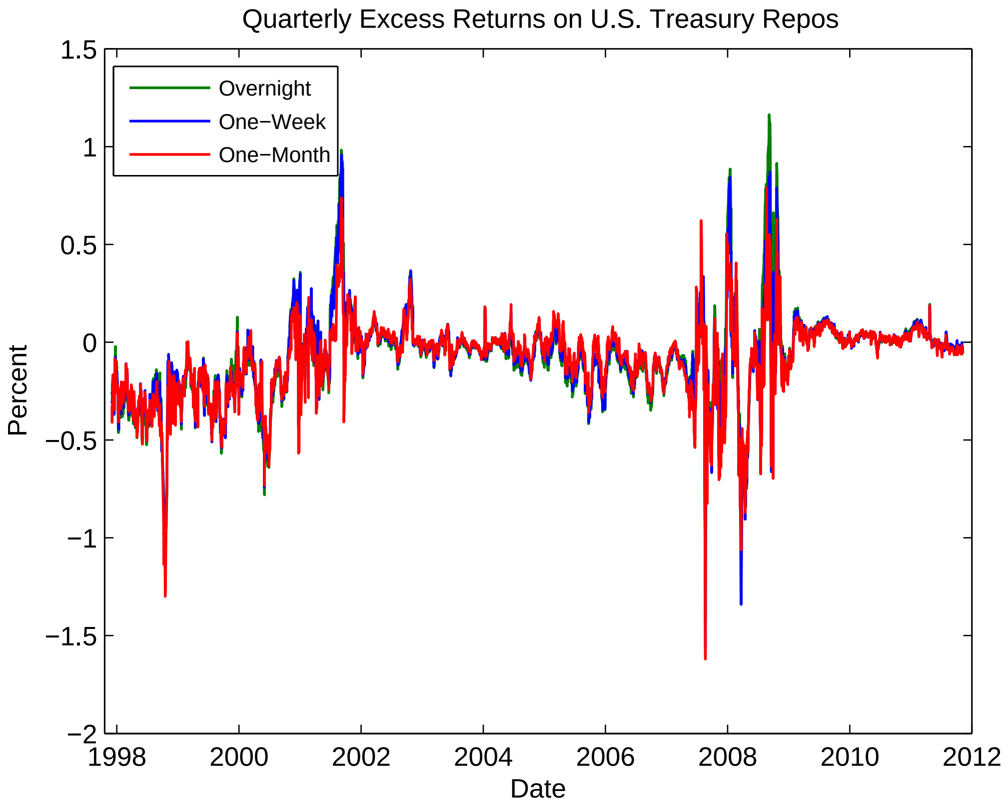

Figure 10: This figure plots quarterly excess returns on U.S. Treasury repos at the overnight (green), one-week (blue), and one-month (red) maturities.

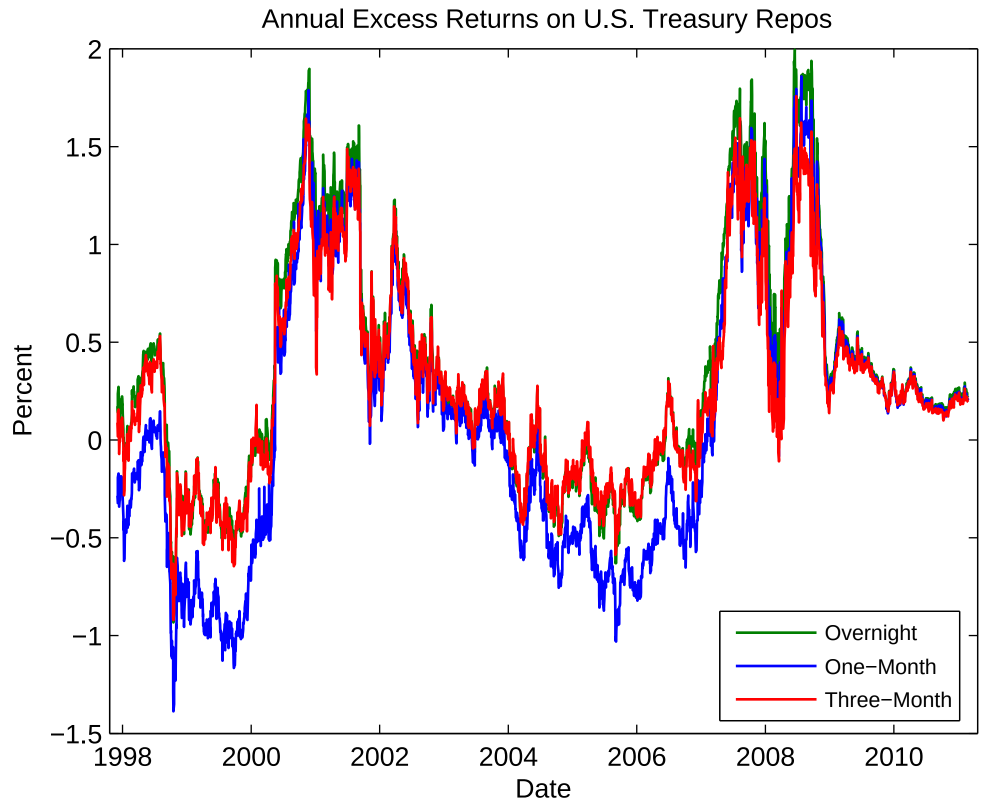

Figure 11: This figure plots annual excess returns on U.S. Treasury repos at the overnight (green), one-month (blue), and three-month (red) maturities.

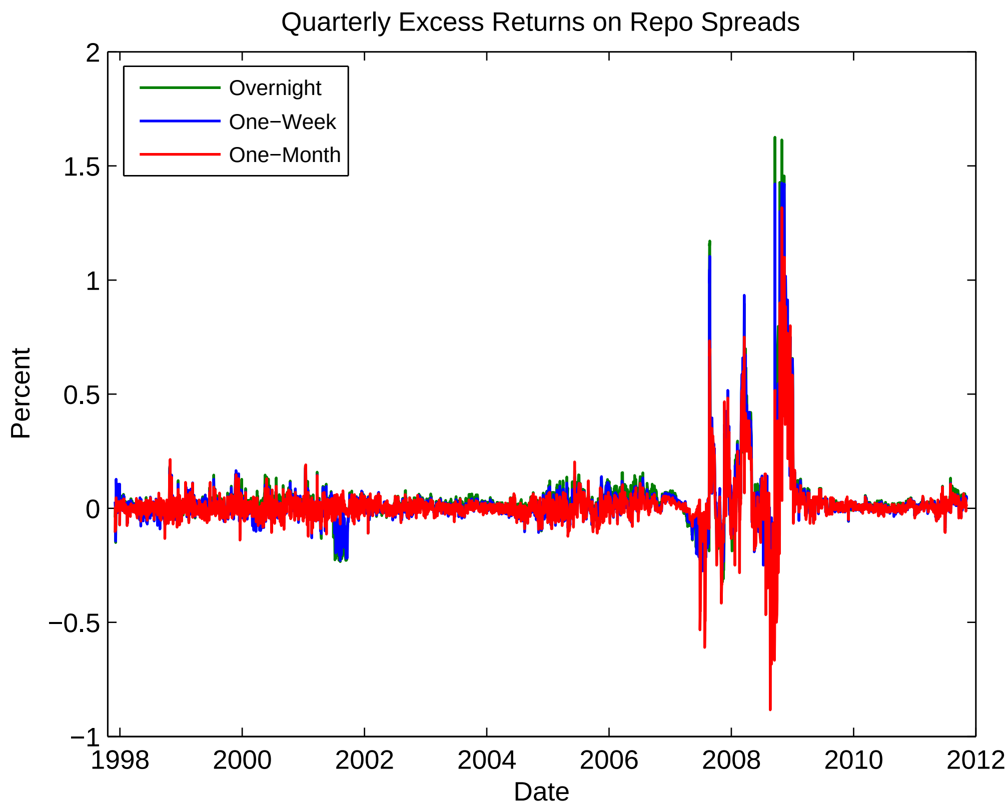

Figure 12: This figure plots quarterly excess returns on the spreads between mortgage-backed security and U.S. Treasury repo rates at the overnight (green), one-week (blue), and one-month (red) maturities.

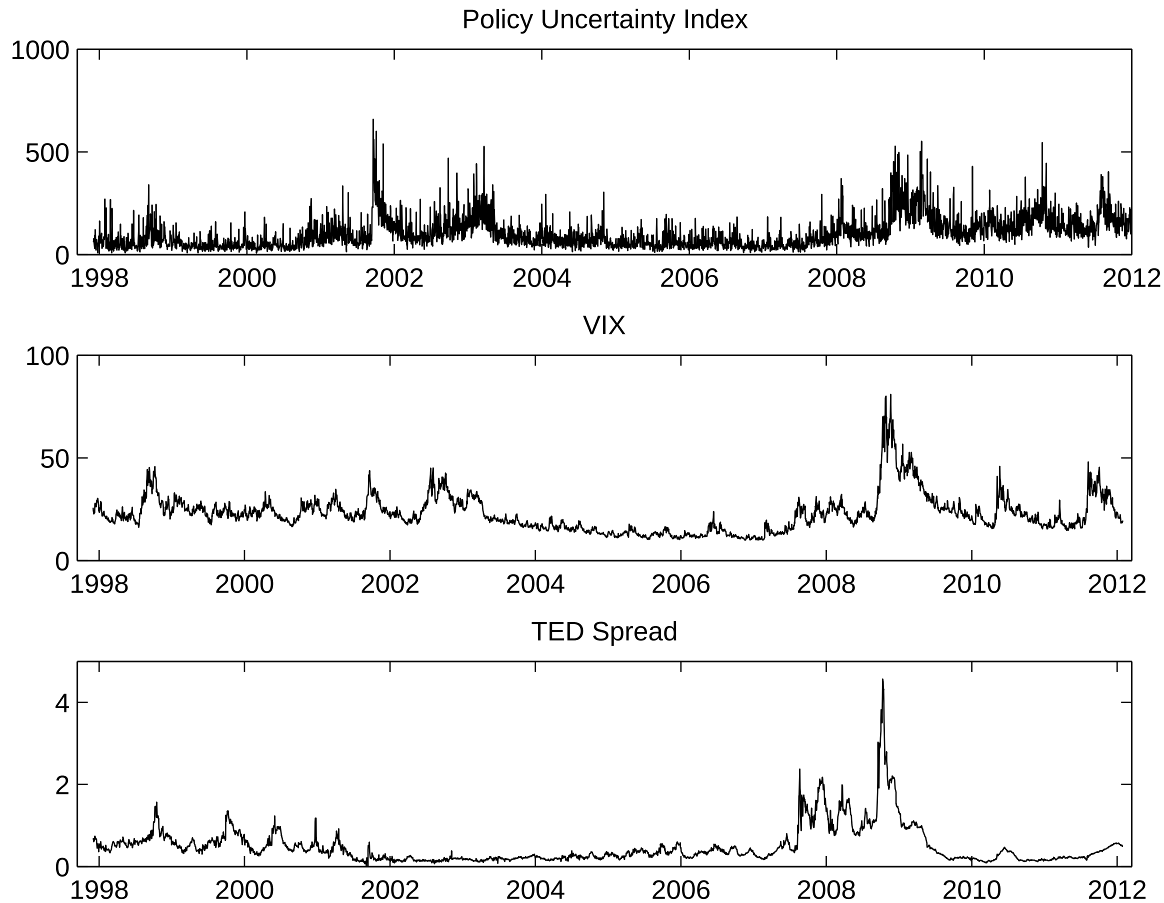

Figure 13: This first panel of this figure plots the Bloom et. al. (2012) policy uncertainty index from September 1997 to January 2012 at the daily frequency. The second panel of this figure plots the S&P VIX index from September 1997 to January 2012 at the daily frequency.