Risk Premia in the Repo Market

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Abstract

This papers studies movements in short-term repurchase agreement (repo) interest rates. The term structure of U.S. Treasury, agency, and mortgage-backed security repos are analyzed from 1997-2012, and the general factor representation is common across all of the markets. We also analyze the term structure of spreads between U.S. Treasury and mortgage-backed security repo rates and find unique dynamics, as these spreads are capturing a term structure of relative collateral risk. When we turn to the issue of risk premia, we find that excess holding period returns are predictable with R^2's higher than 0.2. Additionally, looking at excess holding period returns in the spread market, we find that while the term structure factors do provide some predictive power, other measures of macroeconomic and financial stress provide additional predictive power. This result provides insight into the type(s) of risk premia being captured in this short-term credit market.

Keywords: Credit spreads; repurchase agreement; risk premia; term structure

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1 Introduction

Studying the time variaton 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 macro-financial 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 (overnight), the idea has always been that movements on the short end can, in normal times, provide corresponding, desired movements for longer-term rates.

The question of whether time-variation in risk premia, or better yet time-variation in excess returns, for long-term U.S. Treausry rates exists and if it is predictable has been asked time and time again. A major contribution to this literature is Cochrane and Piazzesi (2005), which 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 excess returns with an R^2 as high as 0.4. This finding was monumental, since standard predictability regressions that often used 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, but further work by Cochrane and Piazessi (2008) has shown that, indeed, these term structure factors provide explanatory power above and beyond a single factor for prediction of excess returns on longer-term Treasuries.[1]

The contribution of this paper is three-fold. First, we study the term structure properties 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 their credit 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. 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 will address this when we study the term structure of repo spreads between rates of mortgage-backed security and U.S. Treasury repos.

Our next contribution is to document the factor structure of these repo markets. 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. However, the shape of the factor loadings differ slightly from their more long-term bond market counterparts. In addition, we analyze the factor structure of the term structure of repo spreads (using mortgage-backed security less U.S. Treasury repo rates), and show that while this factor structure still contains its own level, slope, and curvature components, the shape

[1] 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).

of the factor loadings associated with these is different, leading to contrasting economic interpretations.

Lastly, we assess the predictability of excess returns in repo markets. We begin by discussing the definition of excess returns in these markets, since the construction relies on a strategy of rolling over short-term debt. As a starting point for our predictability regressions, we use the simple term structure factors as our predictive variables. At the quarterly investment horizon, we find R^2's as high as 0.27. When we analyze predictability of excess returns of spreads between mortgage-backed security and U.S. Treasury repo rates, we find that using just the repo term structure factors does not provide much predictive power. However, this result 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 risk across markets. Because of this, we feel as if other variables that reflect macroeconomic and/or financial risk might provide predictability power for this spread term structure. 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 by a factor of four 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 Description of the Data

Before diving into the analysis of the repo market and its potential risks, it will be of service to describe 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 in the type of collateral used for the loan. Since the financial crisis, the literature on repo markets has exploded. Some work on repo markets and risk in the repo market via haircuts, particularly during the financial crisis, includes Gorton and Metrick (2012), Jurek and Stafford (2010), and Krishnamurthy, Nagel, and Orlov (2012). We do not analyze haircuts in this analysis as we are using aggregate repo data, so please reference these papers for a discussion of haircut volatility during the crisis. We look at overnight, one-week, two-week, three-week, one-month, two-month, and three-month maturities.[2]

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 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

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

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 given the inherent default risks of the underlying mortgages. However, the crisis saw a wave of value losses in the underlying collateral of these repos, and the market seized for quite a bit of time, even though they were ex-ante rated with high credit ratings. Even now, the current mortgage-backed repo market is noticeably smaller as a fraction of overall repos.[3]

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.

Another repurchase agreement we use as a measure of a risk-free repo rate for part of our analysis is the U.S. Treasury general collateral repo rate. This repo is similar the U.S. Treasury repo rate, with the exception being that any form of general U.S. Treasury collateral is accepted. Duffie (1996) formalizes how these repo contracts control for the specialness that some issues of U.S. Treasuries might face that affects the value of the underlying collateral, and thus the repo rate itself. We use the overnight general collateral repo rate when calculating our daily excess returns. For other maturities, we use one-month,

[3] See the previously-mentioned literature on repo markets for a more detailed analysis on this phenomenon.

three-month, and one-year U.S. Treasury strips calculated from Bloomberg.[4]

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 term structures of repos 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.[5] 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).[6] 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.

3.1 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

[4] 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/.

[5] The factor analysis was done with more factors, and we will be using the fourth factor in regressions later in the paper.

[6] 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).

of each factor is derived, as is common in the fixed income literature. Each repo loads with a magnitude of approximately 0.4 on the level factor. Turning to the slope factor, Figures (5) to (6) plot the factor loadings of the agency and mortgage-backed security repo markets, respectively, from the estimation using the full time series of data. At first glance, it should be obvious that yields in all three markets load onto the level, slope, and curvature factors with similar magnitudes. The loading on the level factor is around 0.4 across all maturities and markets, as evidenced by the solid line in each figure. The slope factor loadings are upward-sloping, and the curvature factor loadings have a hump shape. The shapes of these loadings are also in line with the previous literature on longer-term bond markets, as in Cochrane and Piazzesi (2005) and (2008), with the exception being that the slope factor loads onto each maturity in a decreasing fashion. Therefore, increases in the slope factor in each of these markets is associated with a flattening (or inversion) of the yield curve for these repos.[7] 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).

3.2 Spread Term Structure Factor Loadings

Now we move to the factor structure of the mortgage-backed security repo minus 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

[7] The correlation of the level factor with other measures of general interest rate movements (i.e. the Federal Funds rate, short-term Treasury rates) is over 0.9 in all cases. As expected, this level factor is capturing the up-and-down movements of all yields in the term structure. Similarly, the slope and curvature factors (barring the sign of the slope) are capturing the similar movements as their counterparts in the longer-term Treasury market, albeit with a slight change in interpretation for the slope factor given the short-term maturities we study here.

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. Given that the only difference between these repos is the underlying collateral, the spread is most likely being driven by fundamental risk differences in the underlying collateral. It is not a surprise that mortgage-backed securities carry much more credit risk than U.S. Treasuries, and there may also be subtle liquidity differences across the markets, as well. Regardless of where the risk is coming from, we see the spread between these repo rates as a measure of financial risk in the repo market.[8]

It is not common to see a factor analysis performed on a spread term structure, 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. We call them level, slope, curvature for a reason: they share a similar shape to the factor loadings we have observed previously. 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.

What 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 risk in these repo markets. As discussed above, this relative risk is predominantly capturing the differential risk in the underlying collateral. An increase in this level risk causes spreads to increase at the same magnitude across all maturities.

The slope and curvature factors remain a bit of a mystery in terms of their economic

[8]We could also look at the difference between agency and U.S. Treasury repo markets, and the appendix provides results for this analysis.

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 making 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, it is of interest that more study 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. 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.

To summarize, the factor loadings for the spread term structure have stark contrasts to the factor loadings of both of the mortgage-backed security and U.S. Treasury repos. There is a large open question as to what these spread factors represent, but in general they are capturing movements in relative collateral risk across the two markets.

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.[9] From the expectations hypothesis, any time variation in this excess log holding period return is capturing time-varying risk premia, and the goal of this section is to understand if it is predictable.

This analysis is appropriate when we are looking at bonds whose maturity is longer than the investment horizon (holding period). What about when bonds mature before the end of

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

the investment horizon? For this, we must determine how to calculate excess log holding period 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 the return from these two strategies must be the same, namely that:

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

If this equation does not hold, then the expectations hypothesis is violated, and any time variation in the difference is capturing time-varying risk premia. The log holding period return is being captured by the right-hand side of equation (5), and thus the excess log holding period return is captured by the difference of the righthand side and lefthand side of equation (5).

While it may not seem obvious, equation (2) and (4) are capturing the same excess holding period return. However, it is important to remember how it is calculated, and to note that studying the behavior of time-varying risk premia via equation (5) is not commonplace in the literature since risk premia are not studied in such short-term markets frequently.[10] 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).

[10] 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 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. 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 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 magnitude 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 holding period returns are calculated using daily data at the daily, quarterly, and annual frequency.[11] While repos are not standard bonds, there is a natural interpretation of each of these returns. The holding period return at the daily frequency captures the return captured from unwinding a repo position after one day. It is more interesting to look at the holding pe-

[11] SInce we do not have repos at each continuous maturity, we use the Campbell-Shiller approximation:

$$aprx_{t+1}^{(n)} = ni_t^{(n)} - ni_{t+1}^{(n)} - i_t^{(1)}. \quad (6)$$

riod returns at the quarterly and annual frequencies. For example, let's use the one-month repo as our maturity of interest. What does it mean if we hold a one-month repo for one quarter? This holding period return is constructed to be the same as the return from rolling over a one-month repo each month for one quarter. Similarly, the annual holding period return of a one-month repo is constructed to be the same as the return from rolling over a one-month repo each month for one year. To construct excess returns, we must substract from the holding period return a measure of the riskless rate for that given return horizon. For the daily frequency, we use the overnight general collateral repo rate. For the quarterly frequency, we use the three-month U.S. Treasury strip. Lastly, for the annual frequency, we use the one-year U.S. Treasury strip.

The baseline regression of excess returns for maturity n on factors for the corresponding market will be of the form

$$aprx_{t+1}^{(n)} = \alpha^{(n)} + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \beta_4^{(n)} PC(4) + \varepsilon_{t+1}^{(n)}, \qquad (7)$$

where PC(1), PC(2), PC(3), and PC(4) are the first four 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.

4.2.1 U.S. Treasury Repos

Table (2) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)}\ \beta_3^{(n)}\ \beta_4^{(n)}\right]$ as a function of the maturity for the U.S. Treasury repo. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. To begin with Panel A, we can see that daily returns are high predictable using just the first four principal components of the U.S. Treasury repo term structure. The R^2's are falling with maturity with these daily excess returns, which is not surprising. The magnitude of the R^2's is promising, particularly for the one-, two-, and three-month repo daily excess returns.

Moving onto the quarterly returns, this will be the reader's first glimpse into excess return predictability when looking at a rollover holding period return strategy. For the sake of exposition, we abbreviate the results and display only the predictability results for the overnight, one-week, and one-month repos. There is strong predictive power for each type of repo over a quarterly return horizon with R^2's of approximately 0.2. Finally, with the annual returns, we still have noticeable predictability, with R^2's as high as 0.18 for the one-month repo. This implies that if one were to roll over one-month repos for a year and compare the return of that strategy to holding just a one-year bond, then 18% of the time-variation in that excess return is captured by the first four principal components of the repo term structure. While some of these R^2's may not be of the magnitude of those in Cochrane and Piazzesi (2005), we are looking at a much shorter-term market and rollover returns comparisons, and we believe these results are strong.

Looking at the coefficients themselves, we see that for each investment horizon, all maturities are loading on the first principal component with similar magnitude, though this factor does not carry much explanatory power for the annual returns in Panel C. For daily returns, this factor loads with a coefficient of around -0.4, while with quarterly returns the loading hovers around 0.9. Interestingly, the statistical significance of the term structure factors varies depending on the investment horizon. The third and fourth principal components are statistically significant for daily returns at various horizons (above and beyond that provided by the first principal component). For quarterly returns, the first two principal components provide statistically significant coefficients and predictive power. Lastly, for annual returns, we see that the second and third principal components are statistically significant, and the first principal component does not provide much predictive power for these regressions.

4.2.2 Agency Repos

Table (3) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)}\ \beta_3^{(n)}\ \beta_4^{(n)}\right]$ as a function of the maturity for the agency repo market. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. Starting again with daily returns, we see continued predictive power of the agency repo term structure factors, in line with those we saw for U.S. Treasury repos (though marginally lower at the three-month maturity). The magnitude of the coefficients is even the same across the U.S. Treasury and agency repo markets. At the quarterly return horizon, we have R^2's hovering around 0.23, and most of the action is coming from the first principal component. For annual returns, the predictive power drops, but interestingly the second and third principal components are again the drivers of predictive movements in excess returns.

4.2.3 Mortgage-Backed Security Repos

Table (4) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)}\ \beta_3^{(n)}\ \beta_4^{(n)}\right]$ as a function of the maturity for the mortgage-backed security repo market. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. In the end, much of the same predictability results remain as for U.S. Treasury and agency repos, with slightly better predictive performance at the quarterly return horizon.

To sum up these excess returns regressions, we have found significant predictive power of the principal components in each repo market for the excess returns in that repo market at the daily, quarterly, and annual investment horizon. At the daily return horizon, predictability is decreasing in maturity of the underlying repo. For the quarterly and annual horizons, however, the predictability content is rather stable. Recall that these last two investment horizons were taking account of the fact that the excess returns were from a rolling over strategy of short-term debt for the length of the investment horizon.

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. In an effort to assess whether excess returns are predictable, we choose to link this term structure of spreads to the term structure of our safest type of repo, the U.S. Treasury repo.[12] 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 long-term bond, the way in which excess returns are computed is identical. For spread maturities longer than the investment horizon, the holding period return is derived from holding a portfolio of the spread between mortgage-backed security repos and U.S. Treasury repos for a given maturity and then selling it at the end of the investment horizon. For spread maturities 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 these holding period returns from the return one would derive from holding the spread with a maturity equal to the investment horizon.

Table (5) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)}\ \beta_3^{(n)}\ \beta_4^{(n)}\right]$ as a function of the maturity for spreads between mortgage-backed security and U.S. Treasury repo rates, and the predictive

[12]Interestingly, there is very little predictability derived from the principal components of the spread term structure itself, which provides a new set of questions for future research.

variables are the first four principal components of the U.S. Treasury repo term structure used in Table (2). Panel A captures the coefficients for daily returns, Panel B captures the coefficients for weekly returns, and Panel C captures the coefficients for quarterly returns.[13] Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. The R^2's for these regressions are substantially lower than those for the level term structures, with a peak of 0.11 for the daily excess return on one-month repo. However, moving to the quarterly investment horizon sees the R^2's cut in half. While these results are not as exciting as the previous predictability results, we will discuss in more detail the interpretation of excess returns in this market in the next section and show that other macro-financial indices provide more predictive power.

4.4 Sharpe Ratios of the Repo Term Structure

An interesting statistic commonly used to understand average risk premia in bond markets is the Sharpe ratio. The Sharpe ratio in this environment is going to capture constant risk premia, or risk premia on average over the sample period addressed. The formula for computing the Sharpe ratio is given by:

$$SR^{(n)} = \frac{\mathbb{E}[arx_{t+1}^{(n)}]}{\sigma[arx_{t+1}^{(n)}]}, \tag{8}$$

i.e., it is the mean of the excess return divided by its standard deviation. Sharpe ratios are most commonly used in portfolio optimization analysis to determine how one can maximize portfolio performance via the mean-variance frontier. A standard benchmark is that the market stock portfolio has a Sharpe ratio of approximately 0.5.

Table (6) provdes a breakdown of Sharpe ratios using excess returns of both the U.S.

[13] We only go out to the quarterly return horizon since we want to benchmark to the quarterly spread as the comparable security.

Treasury repos and the spread between mortgage-backed security and U.S. Treasury repos. We also compute the Sharpe ratios over different subsamples to provide the reader a glimpse into how Sharpe ratios might have changed after the start of the recent financial crisis. Panel A looks at Sharpe ratios computed from quarterly returns of U.S. Treasury repos, while Panel B looks at annual returns of U.S. Treasury repos. The first column is the maturity of the underlying repo. Columns 2 through 4 provide the mean $\mu^{(n)}$ of the excess returns, the standard deviation $\sigma^{(n)}$ of the excess returns, and the Sharpe ratio for the entire sample period. Columns 5 through 7 do the same, but just for the period of 12/01/1997-12/31/2006. The last three columns focus on the period that includes the financial crisis, and thus this period starts on 01/02/2007 and ends at the end of our full sample.

Starting with Panel A at the quarterly investment horizon, we see that Sharpe ratios are small, particularly during the crisis period. In fact, there is a surprising drop in the level of the Sharpe ratio during the financial crisis, being driven by the fact that both the mean of the excess returns fell while the volatility of the excess returns rose. Turning to Panel B at the annual investment horizon, we see a shift in both the sign and magnitude of the Sharpe ratios. Almost all of the Sharpe ratios are negative, and during the crisis they are largely negative, on the order -1.25. This is not particulary surprising to us, since we are assessing a very risky strategy of rolling over short-term debt for a year. Particularly during the crisis, we might expect that the risk of such a strategy is further exacerbated by the high volatility of interest rates during the period.

Panels C and D report the results from a similar analysis for the weekly and quarterly returns, respectively, of spreads between mortgage-backed security and U.S. Treasury repo rates. Here, it is important to note that the Sharpe ratios are always negative and small, mostly driven by the fact that the mean of all of these excess returns is negative and small. It is important to note that the Sharpe ratios are, again, much higher during the financial crisis period than before the crisis. However, we provide these Sharpe ratio results as a method for the reader to understand average risk premia in these markets. Note that these strategies look awful by the investment horizon measures we entertain. Why in the world would investors ever roll over short-term repo instead of investing in the long-term? That is a fundamental question for a variety of financial institutions, as they perform this strategy every single day. One of the easiest ways to answer the question is that they simply don't care about mean and variance over these investment horizons, which is the stance that we also take. Also, these institutions, as discussed previously, can find rolling over short-term debt as ex-ante less costly if they face enormous credit risk when trying to issue long-term debt.

5 Macroconomic 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.[14]

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

[14]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).

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 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.[15] Figure (13) plots the movements in these two indices over our sample period.

We run a set of regressions similar in spirit to (7) with a slight adjustment:

$$aprx_{t+1}^{(n)} = \alpha^{(n)} + \sum_{i=1}^{4} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}, \tag{9}$$

where now we have added in both the policy index PI and the VIX VIX as part of the predictability regression. We will run these regressions in two stages: first, we include just the policy index, and then we add in both the policy index and the VIX. While these two indices are correlated (our sample correlation is approximately 0.5), our prior is that they are capturing fundamentally different types of risk.

[15] 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.

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 $\left[\beta_1^{(n)}\ \beta_2^{(n)} \cdots\ \beta_5\right]$ as a function of the maturity for the U.S. Treasury repo market, where we include just the policy index *PI* as an additional explanatory variable. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. The takeaway from this that the policy index does not help in predictability of excess returns at the daily investment horizon, there is slight improvement at the quarterly horizon, and there is predictability improvement at the annual investment horizon. At the annual horizon, R^2's increase by three percentage points for each repo maturity, peaking at an R^2 of 0.21 for the one-month maturity repo. While these changes are not large, we are, to our knowledge, the first to document the potential predictive power of this new policy index for longer-term excess returns using short-term financial assets.

Turning to our second set of excess returns regressions for the U.S. Treasury repo market, Table (8) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)} \cdots\ \beta_5\ \beta_6\right]$ as a function of the maturity for the U.S. Treasury repo market, where we include both the policy index *PI* and the VIX VIX as additional explanatory variables. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. Here, we only see slight or no increase in predictive power for these excess returns. Therefore, while the policy index does provide some noticeable predictability benefit for U.S. Treasury repos, the VIX is almost insignificant. Our general interpretation of this results is that movements in the U.S. Treasury repo

[16] Regression results for the agency and mortgage-backed security repos are available on request. The results are robust across these markets, as well.

term structure are picking up movements in policy uncertainty, predominantly due to their close linkage to movements in the Federal Funds rate over time. Risk premia of U.S. Treasury repos, as constructed here, is correlated with some elements of macroeconomic risk. However, we would not argue that there is not financial risk; it may just be picked up in the principal components used in the regression.

5.2 Repo Rates Spreads and Macroeconomic vs. Financial Risks

In the previous section, we found that standard factors did not explain excess returns on spreads between mortgage-backed security and U.S. Treasury repos with meaningful R^2's. However, given that this spread is a measure of relative collateral risk, and the excess returns captures risk premia embedded in spreads, it is interesting to analyze whether the policy uncertainty index or VIX provide any insight into predictability of excess returns.

Table (9) displays the coefficients $\left[\beta_1^{(n)}\ \beta_2^{(n)} \cdots\ \beta_5\ \beta_6\right]$ as a function of the maturity for spreads between mortgage-backed security and U.S. Treasury repo rates, where we include both the policy index PI and the VIX VIX as additional explanatory variables. Panel A captures the coefficients for daily returns, Panel B captures the coefficients for quarterly returns, and Panel C captures the coefficients for annual returns. Under each coefficient estimate, we provide standard errors computed using a Newey-West adjustment with 18 lags. We do two sets of regressions, one with just the policy index and one with both the policy index and the VIX.

Looking at the first two rows of each panel, which report the results using the policy index as an additional explanatory variable and comparing to Table (5), we see that the R^2's do not change at the daily or weekly investment horizons, but there is a dramatic increase at the quarterly horizon. The R^2 doubles from around 0.05 using just the U.S. Treasury repo principal components to around 0.1 after including the policy index. Even more impressive, when we add in the VIX we see that the R^2 doubles yet again, ending with an R^2 of around 0.2. This leads us to two conclusions: first, the VIX carries much more explanatory power for these excess returns than the policy index, and second that both variables carry significant power in predicting excess returns over longer investment horizons. In contrast to the U.S. Treasury repo term structure, we believe that the spread term structure is picking up both macroeconomic and financial risks, though predominantly the latter.

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 excess holding period 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: U.S. TREASURY REPOS

	12/02/1997-01/30/2012		01/02/2007-01/30/2012	
Maturity	Mean	Standard Deviation	Mean	Standard Deviation
Overnight	2.79	2.18	1.33	1.91
One-Week	2.79	2.16	1.35	1.90
Two-Week	2.79	2.16	1.34	1.89
Three-Week	2.79	2.16	1.34	1.88
One-Month	2.79	2.16	1.34	1.87
Two-Month	2.80	2.16	1.34	1.86
Three-Month	2.81	2.16	1.34	1.86

PANEL B: AGENCY REPOS

	12/02/1997-01/30/2012		01/02/2007-01/30/2012	
Maturity	Mean	Standard Deviation	Mean	Standard Deviation
Overnight	2.83	2.18	1.41	1.97
One-Week	2.84	2.17	1.42	1.96
Two-Week	2.85	2.17	1.43	1.95
Three-Week	2.85	2.17	1.43	1.95
One-Month	2.86	2.17	1.44	1.95
Two-Month	2.87	2.16	1.45	1.94
Three-Month	2.89	2.16	1.46	1.93

PANEL C: MORTGAGE-BACKED SECURITY REPOS

	12/02/1997-01/30/2012		01/02/2007-01/30/2012	
Maturity	Mean	Standard Deviation	Mean	Standard Deviation
Overnight	2.86	2.19	1.43	1.97
One-Week	2.87	2.18	1.46	1.97
Two-Week	2.88	2.18	1.47	1.96
Three-Week	2.88	2.18	1.48	1.96
One-Month	2.90	2.18	1.50	1.95
Two-Month	2.91	2.17	1.51	1.95
Three-Month	2.93	2.17	1.53	1.94

Table 1: This table reports the mean and standard devation of each yield comprising the term structure of the U.S. Treasury, agency, and MBS repos. Panel A reports the summary statistics for the U.S. Treasury repo term structure, Panel B reports the summary statistics for the agency repo term structure, and Panel C reports the summary statistics for the MBS repo term structure. ColumN 1 reports the maturity of the repo. Columns 2 and 3 report the mean and standard deviation, respectively, of the repos over the full time sample 12/02/1997 - 01/30/2012. Columns 4 and 5 report the mean and standard deviation, respectively, of the repos over the late time sample 01/01/2007 - 01/30/2012. Units are in percentage points.

Panel A: Daily Returns

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
One-Week	-0.38	-0.33	1.07	-0.29	0.96
	(0.00)	(0.12)	(0.30)	(0.87)	
Two-Week	-0.38	-0.25	1.89	-0.39	0.89
	(0.00)	(0.16)	(0.45)	(1.02)	
Three-Week	-0.38	-0.30	2.15	-2.36	0.80
	(0.00)	(0.35)	(0.52)	(1.92)	
One-Month	-0.37	-0.44	2.84	10.35	0.62
	(0.00)	(0.51)	(0.86)	(5.57)	
Two-Month	-0.37	-0.92	3.71	-5.86	0.43
	(0.00)	(0.79)	(1.08)	(4.01)	
Three-Month	-0.37	-1.83	2.71	-10.13	0.25
	(0.01)	(0.99)	(2.05)	(5.80)	

Panel B: Quarterly Returns

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.02	-0.10	-0.23	0.03	0.17
	(0.00)	(0.06)	(0.15)	(0.10)	
One-Week	0.02	-0.10	-0.09	0.04	0.18
	(0.00)	(0.06)	(0.15)	(0.10)	
One-Month	0.02	-0.05	0.15	-0.10	0.23
	(0.00)	(0.05)	(0.13)	(0.09)	

Panel C: Annual Returns

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	-0.01	-0.65	-1.80	0.00	0.15
	(0.01)	(0.17)	(0.26)	(0.31)	
One-Month	0.02	-0.82	-2.06	0.09	0.18
	(0.01)	(0.19)	(0.30)	(0.36)	
Three-Month	-0.00	-0.55	-1.37	0.02	0.12
	(0.01)	(0.15)	(0.23)	(0.25)	

Table 2: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \beta_4^{(n)} PC_t(4) + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given U.S. Treasury repo and $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure. The first column is the maturity of the repo, the second through fifth columns display the coefficient estimates, and the sixth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
One-Week	-0.37	-0.14	0.95	-1.36	0.92
	(0.00)	(0.13)	(0.29)	(0.42)	
Two-Week	-0.37	0.04	2.52	2.71	0.73
	(0.00)	(0.21)	(0.88)	(2.05)	
Three-Week	-0.37	0.06	3.27	4.57	0.56
	(0.01)	(0.27)	(1.12)	(3.17)	
One-Month	-0.37	-0.11	2.83	-3.20	0.46
	(0.01)	(0.27)	(1.12)	(1.82)	
Two-Month	-0.36	-0.24	2.69	-0.62	0.20
	(0.01)	(0.56)	(1.17)	(0.73)	
Three-Month	-0.35	-0.21	2.77	-0.31	0.10
	(0.02)	(0.82)	(1.63)	(1.12)	

PANEL B: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.02	0.05	-0.17	-0.14	0.22
	(0.00)	(0.08)	(0.10)	(0.11)	
One-Week	0.02	0.01	-0.08	-0.12	0.23
	(0.00)	(0.07)	(0.09)	(0.09)	
One-Month	0.02	0.02	0.13	0.11	0.24
	(0.00)	(0.07)	(0.10)	(0.10)	

PANEL C: ANNUAL RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.00	-0.74	-1.29	-0.31	0.11
	(0.01)	(0.23)	(0.27)	(0.38)	
One-Month	0.02	-1.01	-1.56	-0.38	0.16
	(0.01)	(0.25)	(0.30)	(0.45)	
Three-Month	0.00	-0.66	-1.06	-0.31	0.10
	(0.01)	(0.19)	(0.23)	(0.30)	

Table 3: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \beta_4^{(n)} PC_t(4) + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given agency repo and $PC_t(i)$ is the i^{th} principal component of the agency repo term structure. The first column is the maturity of the repo, the second through fifth columns display the coefficient estimates, and the sixth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
One-Week	-0.37	-0.40	0.66	-1.10	0.97
	(0.00)	(0.14)	(0.27)	(0.42)	
Two-Week	-0.37	-0.41	1.64	-0.87	0.93
	(0.00)	(0.20)	(0.49)	(0.41)	
Three-Week	-0.37	-0.50	2.12	0.96	0.87
	(0.00)	(0.27)	(0.51)	(0.65)	
One-Month	-0.37	-0.68	1.38	5.45	0.80
	(0.00)	(0.30)	(0.41)	(0.70)	
Two-Month	-0.37	-1.42	-0.47	4.67	0.42
	(0.01)	(0.66)	(1.28)	(1.69)	
Three-Month	-0.37	-2.23	-2.42	-7.63	0.26
	(0.01)	(0.90)	(2.29)	(4.15)	

PANEL B: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.02	0.01	-0.17	0.34	0.27
	(0.00)	(0.07)	(0.09)	(0.17)	
One-Week	0.02	-0.07	-0.12	0.33	0.27
	(0.00)	(0.06)	(0.09)	(0.16)	
One-Month	0.02	-0.14	0.09	0.45	0.27
	(0.00)	(0.06)	(0.11)	(0.20)	

PANEL C: ANNUAL RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.00	-0.32	-1.08	-1.01	0.06
	(0.01)	(0.26)	(0.26)	(0.59)	
One-Month	0.02	-0.51	-1.29	-1.12	0.11
	(0.01)	(0.30)	(0.31)	(0.66)	
Three-Month	0.00	-0.39	-0.88	-0.65	0.07
	(0.01)	(0.19)	(0.22)	(0.41)	

Table 4: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \beta_4^{(n)} PC_t(4) + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given mortgage-backed security repo and $PC_t(i)$ is the i^{th} principal component of the mortgage-backed security repo term structure. The first column is the maturity of the repo, the second through fifth columns display the coefficient estimates, and the sixth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
One-Week	0.00	0.36	-1.26	0.89	0.10
	(0.00)	(0.14)	(0.33)	(0.63)	
One-Month	-0.01	0.79	-2.10	-9.65	0.11
	(0.00)	(0.60)	(0.85)	(6.01)	

PANEL B: WEEKLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.00	0.05	0.33	-0.04	0.08
	(0.00)	(0.03)	(0.10)	(0.11)	
One-Month	0.00	0.02	-0.50	-2.67	0.11
	(0.00)	(0.16)	(0.26)	(0.84)	

PANEL C: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	R^2
Overnight	0.00	0.10	-0.22	0.06	0.05
	(0.00)	(0.08)	(0.10)	(0.13)	
One-Week	0.00	0.05	-0.28	0.06	0.06
	(0.00)	(0.07)	(0.09)	(0.12)	
One-Month	0.00	0.00	-0.21	0.15	0.05
	(0.00)	(0.06)	(0.07)	(0.15)	

Table 5: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \beta_1^{(n)} PC_t(1) + \beta_2^{(n)} PC_t(2) + \beta_3^{(n)} PC_t(3) + \beta_4^{(n)} PC_t(4) + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given spread between mortgage-backed security and U.S. Treasury repo rates and $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure. The first column is the maturity of the repo, the second through fifth columns display the coefficient estimates, and the sixth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports weekly excess returns regressions, and Panel C reports quarterly excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: U.S. TREASURY REPOS: QUARTERLY RETURNS

	12/02/1997-01/30/2012			12/01/2997-12/31/2006			01/02/2007-01/30/2012		
Maturity	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio
Overnight	0.07	0.23	0.31	0.11	0.20	0.55	-0.01	0.26	-0.02
One-Week	0.07	0.21	0.35	0.10	0.19	0.53	0.02	0.23	0.09
One-Month	0.09	0.20	0.45	0.11	0.44	0.59	0.05	0.21	0.23

PANEL B: U.S. TREASURY REPOS: ANNUAL RETURNS

	12/02/1997-01/30/2012			12/01/2997-12/31/2006			01/02/2007-01/30/2012		
Maturity	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio
Overnight	-0.35	0.60	-0.58	-0.19	0.55	-0.34	-0.69	0.55	-1.26
One-Month	-0.11	0.68	-0.17	0.10	0.65	0.16	-0.58	0.48	-1.20
Three-Month	-0.27	0.51	-0.54	-0.15	0.49	-0.31	-0.54	0.44	-1.22

PANEL C: MORTGAGE-BACKED SECURITY - U.S. TREASURY REPOS SPREADS: WEEKLY RETURNS

	12/02/1997-01/30/2012			12/01/2997-12/31/2006			01/02/2007-01/30/2012		
Maturity	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio
Overnight	-0.00	0.13	-0.17	-0.01	0.09	-0.13	-0.00	0.16	-0.03
One-Month	-0.08	0.54	-0.16	-0.07	0.45	-0.16	-0.11	0.66	-0.17

PANEL D: MORTGAGE-BACKED SECURITY - U.S. TREASURY REPOS SPREADS: QUARTERLY RETURNS

	12/02/1997-01/30/2012			12/01/2997-12/31/2006			01/02/2007-01/30/2012		
Maturity	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio	$\mu^{(n)}$	$\sigma^{(n)}$	Sharpe Ratio
Overnight	-0.04	0.16	-0.24	-0.01	0.07	-0.25	-0.08	0.25	-0.31
One-Week	-0.03	0.15	-0.19	-0.00	0.06	-0.07	-0.07	0.24	-0.31
One-Month	-0.02	0.13	-0.14	-0.00	0.06	-0.05	-0.05	0.21	-0.24

Table 6: This table reports the mean, standard deviation, and Sharpe ratios for U.S. Treasury repo and spreads between mortgage-backed security and U.S. Treasury repo rates. The Sharpe ratio is computed as the ratio of the mean of the excess return $\mu^{(n)}$ divided by the standard deviation of the excess return $\sigma^{(n)}$. The first column reports the maturity of the given security, columns 2 through 4 report the statistics for the full sample of data 12/02/1997 - 01/30/2012, columns 5 through 7 report the statistics for the sample period 12/02/1997 - 12/31/2006, and columns 8 through 10 report the statistics for the sample period 01/02/2007 - 01/30/2012. Panel A reports the statistics for quarterly excess returns for U.S. Treasury repos. Panel B reports the statistics for annual excess returns for U.S. Treasury repos. Panel C reports the statistics for weekly excess returns for the spreads between mortgage-backed security and U.S. Treasury repo rates. Panel D reports the statistics for quarterly excess returns for the spreads between mortgage-backed security and U.S. Treasury repo rates. Moments are in units of percentage points.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	R^2
One-Week	-0.38	-0.33	1.11	-0.32	0.00	0.96
	(0.00)	(0.12)	(0.32)	(0.83)	(0.00)	
Two-Week	-0.38	-0.25	1.96	-0.44	0.00	0.89
	(0.00)	(0.16)	(0.48)	(0.98)	(0.00)	
Three-Week	-0.38	-0.30	2.21	-2.40	0.00	0.80
	(0.00)	(0.35)	(0.54)	(1.91)	(0.00)	
One-Month	-0.37	-0.43	2.75	10.41	0.00	0.62
	(0.01)	(0.50)	(0.79)	(5.54)	(0.00)	
Two-Month	-0.37	-0.92	3.74	-5.89	0.00	0.43
	(0.01)	(0.79)	(1.13)	(3.99)	(0.00)	
Three-Month	-0.35	-1.81	2.40	-9.92	0.00	0.25
	(0.01)	(0.99)	(2.13)	(5.88)	(0.00)	

PANEL B: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	R^2
Overnight	0.01	-0.10	-0.19	0.00	0.00	0.18
	(0.00)	(0.07)	(0.16)	(0.09)	(0.00)	
One-Week	0.01	-0.11	-0.06	0.01	0.00	0.19
	(0.00)	(0.06)	(0.15)	(0.09)	(0.00)	
One-Month	0.02	-0.05	0.15	-0.11	0.00	0.23
	(0.00)	(0.05)	(0.13)	(0.09)	(0.00)	

PANEL C: ANNUAL RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	R^2
Overnight	-0.02	-0.67	-1.59	-0.15	0.00	0.18
	(0.01)	(0.15)	(0.24)	(0.25)	(0.00)	
One-Month	0.01	-0.84	-1.81	-0.09	0.00	0.21
	(0.01)	(0.17)	(0.27)	(0.29)	(0.00)	
Three-Month	-0.01	-0.56	-1.19	-0.11	0.00	0.15
	(0.01)	(0.13)	(0.22)	(0.20)	(0.00)	

Table 7: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \sum_{i=1}^{4} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given U.S. Treasury repo, $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure, and PI_t is the Bloom et. al. (2012) policy uncertainty index. The first column is the maturity of the repo, the second through sixth columns display the coefficient estimates, and the seventh column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	*PI*	*VIX*	R^2
One-Week	-0.38	-0.33	1.11	-0.33	0.00	0.00	0.96
	(0.00)	(0.12)	(0.32)	(0.83)	(0.00)	(0.00)	
Two-Week	-0.38	-0.25	1.94	-0.46	0.00	0.00	0.89
	(0.00)	(0.16)	(0.49)	(0.99)	(0.00)	(0.00)	
Three-Week	-0.38	-0.30	2.15	-2.44	0.00	0.00	0.80
	(0.00)	(0.35)	(0.54)	(1.92)	(0.00)	(0.00)	
One-Month	-0.37	-0.43	2.78	10.43	0.00	0.00	0.62
	(0.01)	(0.50)	(0.82)	(5.55)	(0.00)	(0.00)	
Two-Month	-0.37	-0.92	3.56	-6.01	0.00	0.01	0.43
	(0.01)	(0.78)	(1.14)	(4.02)	(0.00)	(0.00)	
Three-Month	-0.35	-1.81	2.08	-10.14	0.00	0.03	0.25
	(0.01)	(0.98)	(2.15)	(5.92)	(0.00)	(0.01)	

PANEL B: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	*PI*	*VIX*	R^2
Overnight	0.01	-0.10	-0.19	-0.01	0.00	0.00	0.18
	(0.00)	(0.07)	(0.16)	(0.09)	(0.00)	(0.00)	
One-Week	0.01	-0.11	-0.07	0.00	0.00	0.00	0.19
	(0.00)	(0.06)	(0.15)	(0.09)	(0.00)	(0.00)	
One-Month	0.02	-0.05	0.11	-0.14	0.00	0.00	0.25
	(0.00)	(0.05)	(0.13)	(0.10)	(0.00)	(0.00)	

PANEL C: ANNUAL RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	*PI*	*VIX*	R^2
Overnight	-0.02	-0.67	-1.47	-0.07	0.00	-0.01	0.19
	(0.01)	(0.15)	(0.23)	(0.23)	(0.00)	(0.00)	
One-Month	0.01	-0.84	-1.68	0.00	0.00	-0.01	0.22
	(0.01)	(0.16)	(0.26)	(0.27)	(0.00)	(0.00)	
Three-Month	-0.01	-0.56	-1.10	-0.04	0.00	-0.01	0.16
	(0.01)	(0.13)	(0.21)	(0.18)	(0.00)	(0.00)	

Table 8: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \sum_{i=1}^{4} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the given U.S. Treasury repo, $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure, PI_t is the Bloom et. al. (2012) policy uncertainty index, and VIX_t is the VIX. The first column is the maturity of the repo, the second through seventh columns display the coefficient estimates, and the eighth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. The sample period is daily from 12/02/1997-01/30/2012.

PANEL A: DAILY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	VIX	R^2
One-Week	0.00	0.36	-1.26	0.89	0.00	–	0.10
	(0.00)	(0.14)	(0.34)	(0.63)	(0.00)	–	
	0.00	0.36	-1.27	0.87	0.00	0.00	0.10
	(0.00)	(0.14)	(0.35)	(0.63)	(0.00)	(0.00)	
One-Month	0.00	0.79	-2.06	-9.68	0.00	–	0.11
	(0.01)	(0.59)	(0.79)	(6.00)	(0.00)	–	
	0.00	0.79	-2.15	-9.74	0.00	0.01	0.11
	(0.01)	(0.59)	(0.81)	(5.99)	(0.00)	(0.00)	

PANEL B: WEEKLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	VIX	R^2
Overnight	0.00	0.05	0.35	-0.05	0.00	–	0.08
	(0.00)	(0.03)	(0.10)	(0.10)	(0.00)	–	
	0.00	0.05	0.37	-0.04	0.00	0.00	0.09
	(0.00)	(0.03)	(0.10)	(0.10)	(0.00)	(0.00)	
One-Month	0.00	0.02	-0.47	-2.69	0.00	–	0.11
	(0.00)	(0.16)	(0.26)	(0.83)	(0.00)	–	
	-0.01	0.02	-0.46	-2.68	0.00	0.00	0.11
	(0.00)	(0.16)	(0.25)	(0.84)	(0.00)	(0.00)	

PANEL C: QUARTERLY RETURNS

Maturity	PC(1)	PC(2)	PC(3)	PC(4)	PI	VIX	R^2
Overnight	0.00	0.10	-0.14	0.01	0.00	–	0.11
	(0.00)	(0.08)	(0.09)	(0.11)	(0.00)	–	
	0.00	0.10	-0.06	0.07	0.00	-0.01	0.21
	(0.00)	(0.07)	(0.09)	(0.10)	(0.00)	(0.00)	
One-Week	0.00	0.04	-0.21	0.01	0.00	–	0.11
	(0.00)	(0.07)	(0.09)	(0.10)	(0.00)	–	
	0.00	0.05	-0.13	0.07	0.00	-0.01	0.21
	(0.00)	(0.06)	(0.09)	(0.10)	(0.00)	(0.00)	
One-Month	0.00	-0.01	-0.16	0.11	0.00	–	0.09
	(0.00)	(0.05)	(0.07)	(0.12)	(0.00)	–	
	0.00	-0.01	-0.09	0.16	0.00	-0.01	0.18
	(0.00)	(0.05)	(0.08)	(0.13)	(0.00)	(0.00)	

Table 9: This table displays the results from the regressions $aprx_{t+1}^{(n)} = \alpha^{(n)} + \sum_{i=1}^{4} \beta_i^{(n)} PC_t(i) + \beta_5 PI_t + \beta_6 VIX_t + \varepsilon_{t+1}^{(n)}$, where $aprx_{t+1}^{(n)}$ is the approximate excess holding period return over holding period n at time $t+1$ for the spread between mortgage-backed security and U.S. Treasury repos, $PC_t(i)$ is the i^{th} principal component of the U.S. Treasury repo term structure, PI_t is the Bloom et. al. (2012) policy uncertainty index, and VIX_t is the VIX. The first column is the maturity of the repo, the second through seventh columns display the coefficient estimates, and the eighth column is the R^2 of the regression. Below each coefficient estimate is a standard error with a Newey-West correction with 18 lags. Panel A reports daily excess returns regressions, Panel B reports quarterly excess returns regressions, and Panel C reports annual excess returns regressions. In each panel, for each maturity, the first set of results corresponds to the regressions without VIX, while the second set of results corresponds to the full regression. The sample period is daily from 12/02/1997-01/30/2012.

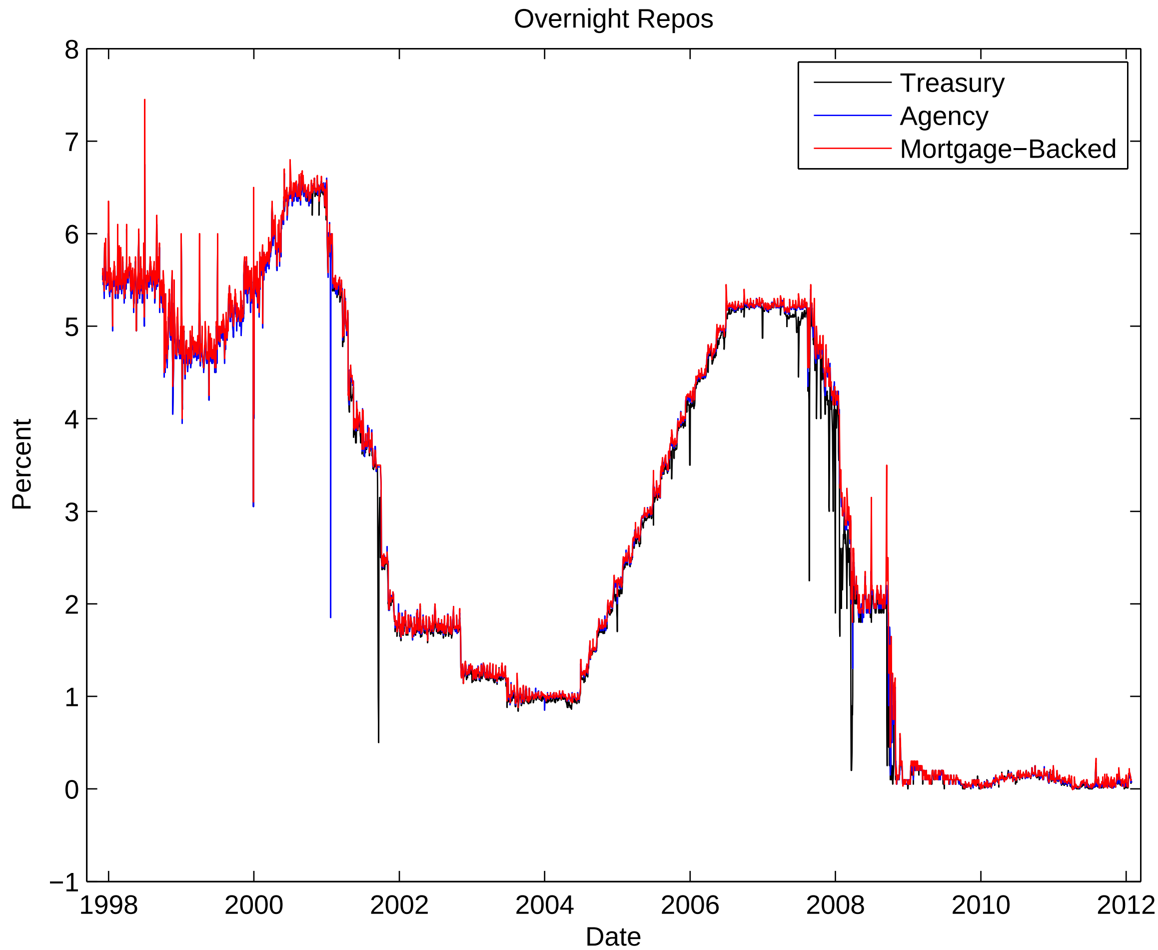

Figure 1: This figure plots the overnight repo rates for U.S. Treasury (black), agency (blue), and mortgage-backed security (red) repos. The time period is September 1997 through January 2012 using daily data. Data is collected from Bloomberg.

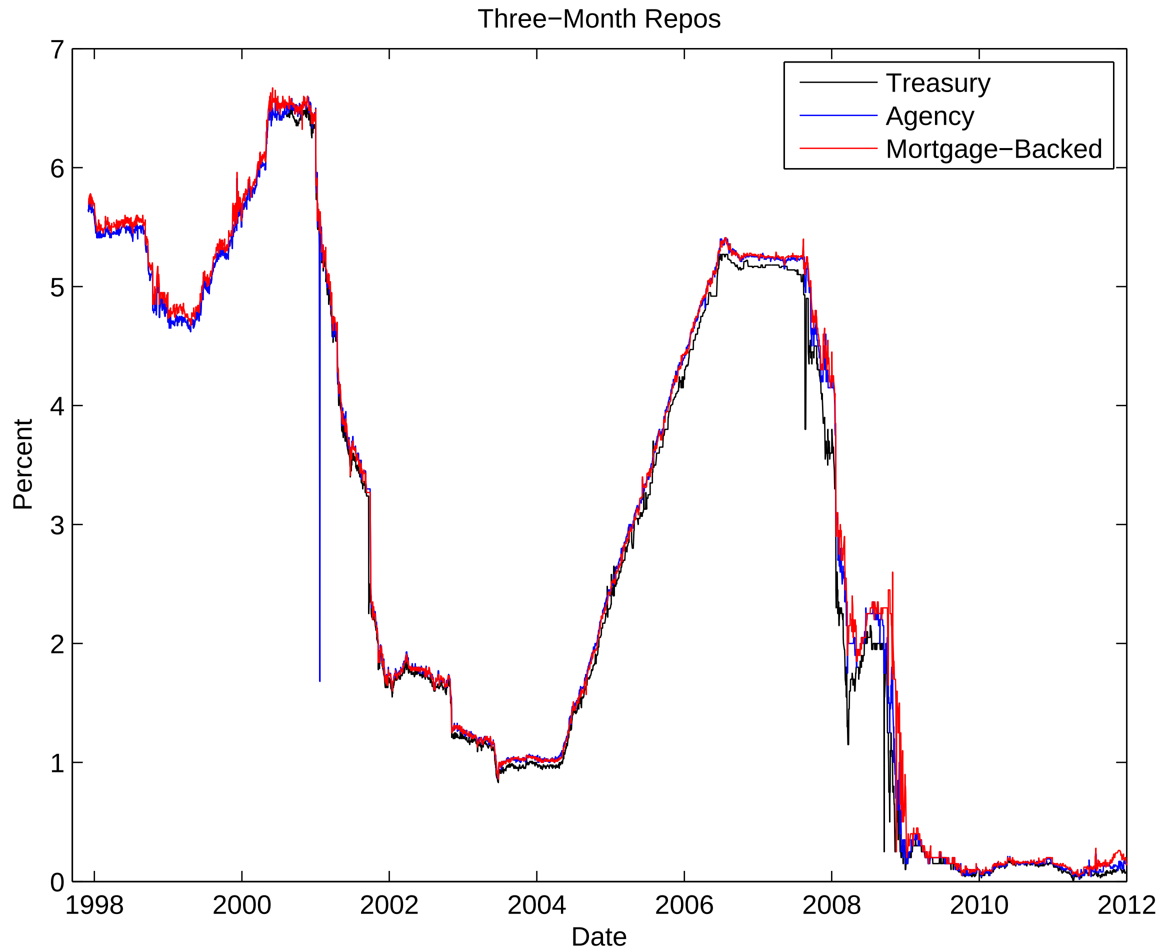

Figure 2: This figure plots the three-month repo rates for U.S. Treasury (black), agency (blue), and mortgage-backed security (red) repos. The time period is September 1997 through January 2012 using daily data. Data is collected from Bloomberg.

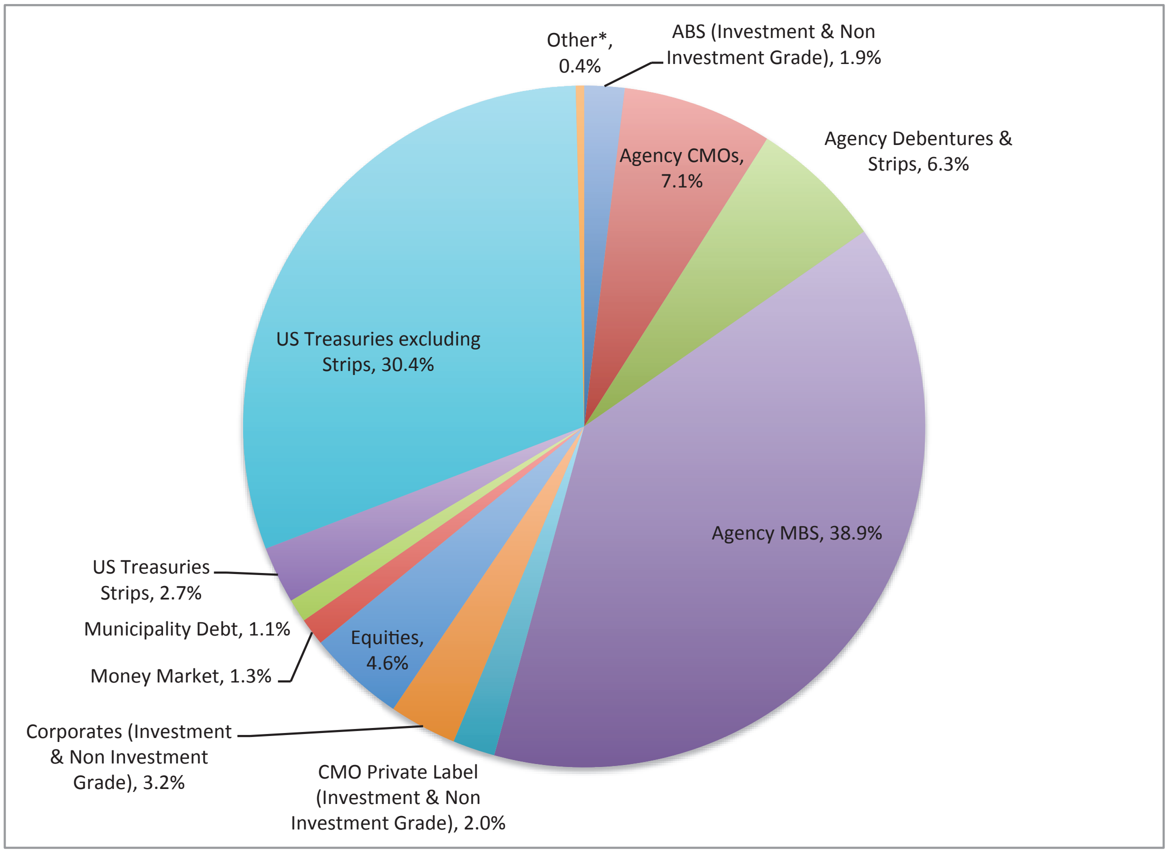

Figure 3: This chart breaks down the total tri-party repo market into the type of collateral underlying each repurchase agreement. Data is from the Federal Reserve Bank of New York.

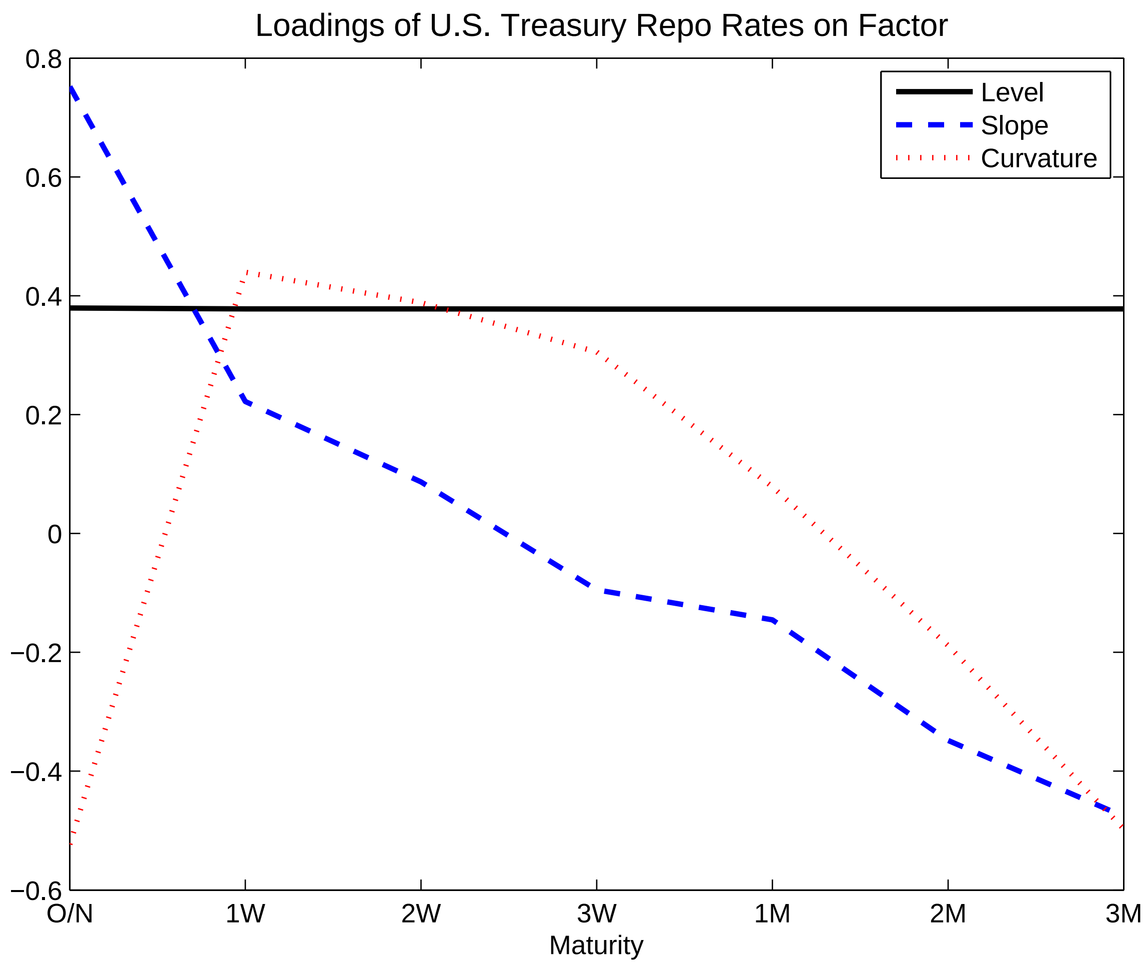

Figure 4: This figure plots how each of the first three principal components of the U.S. Treasury repo market load onto each individual U.S. Treasury repo. The *x*-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the level factor), the dashed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

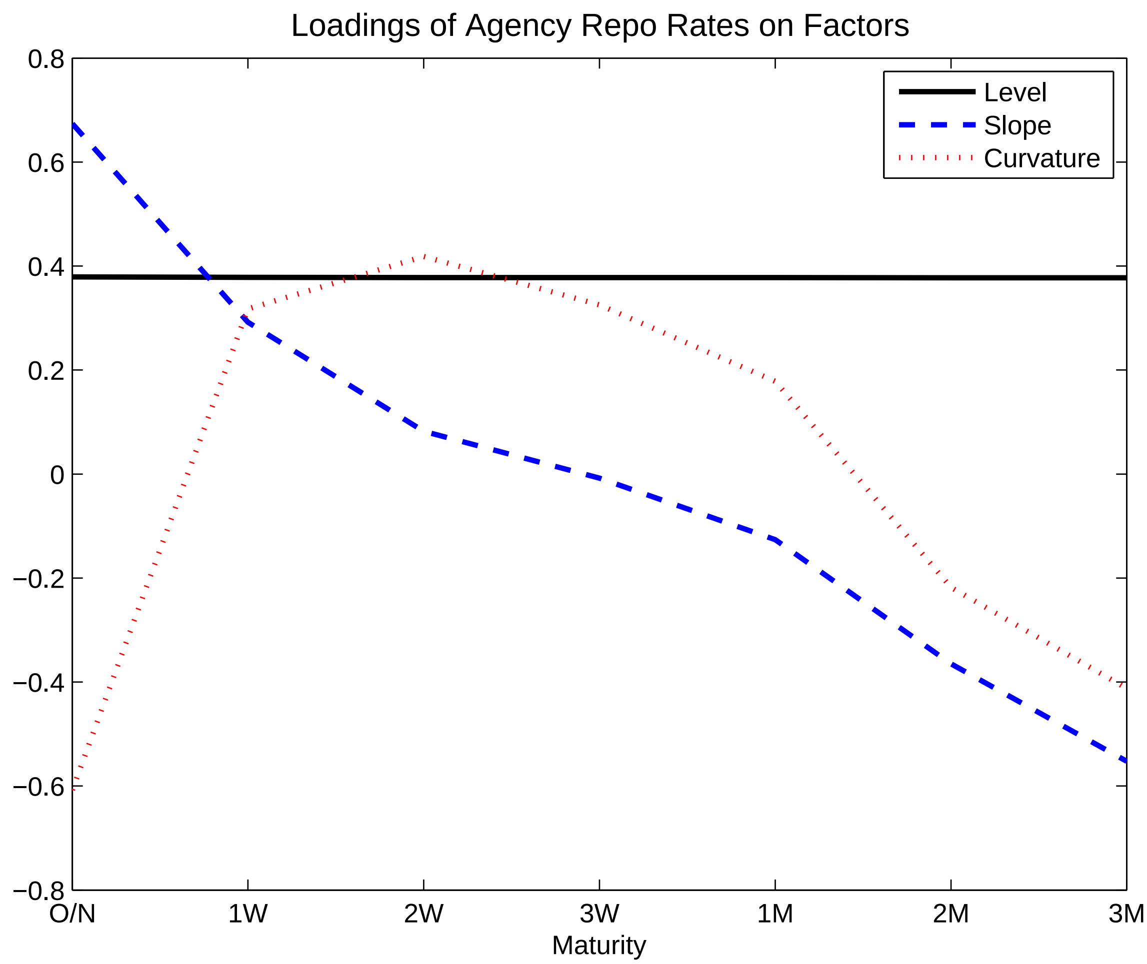

Figure 5: This figure plots how each of the first three principal components of the agency repo market load onto each individual agency repo. The *x*-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the level factor), the dashed blue line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

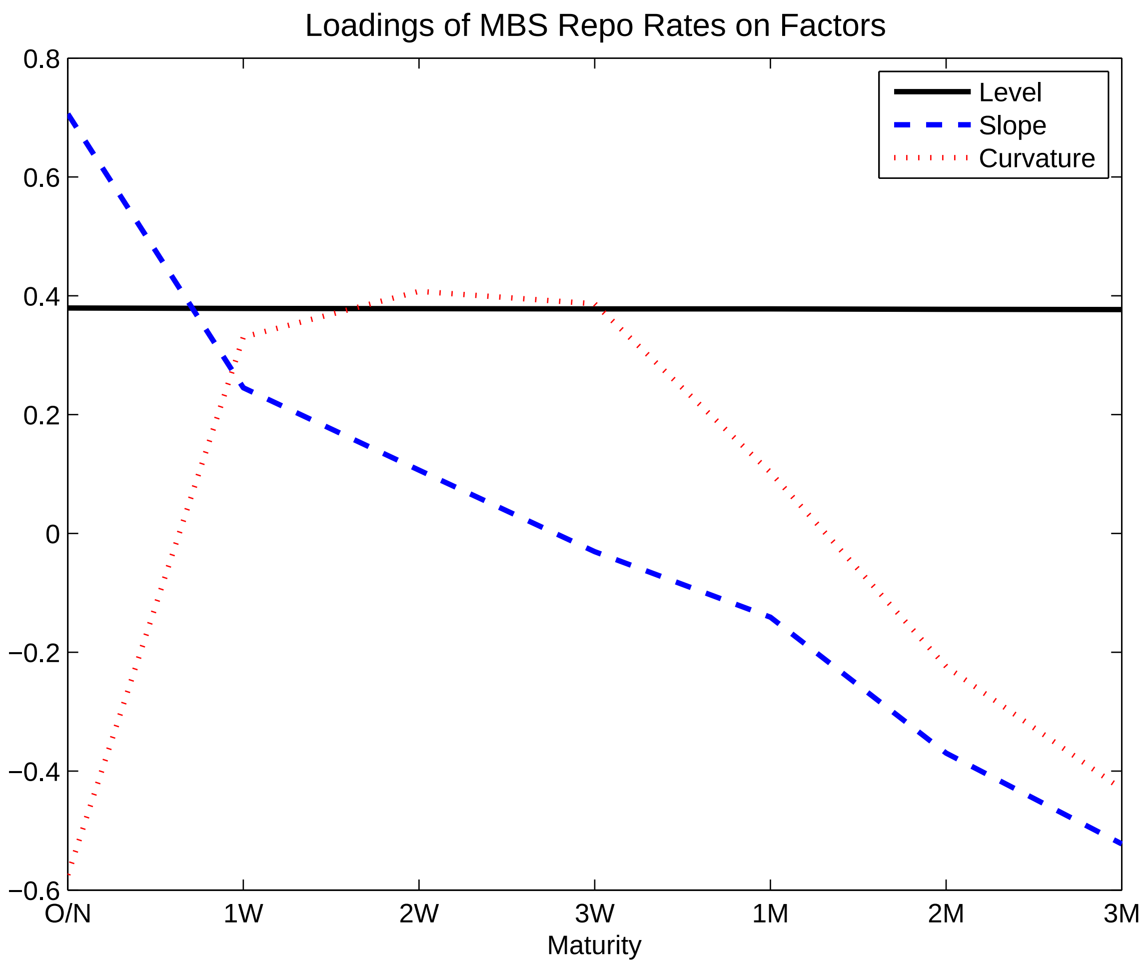

Figure 6: This figure plots how each of the first three principal components of the mortgage-backed security repo market load onto each individual mortgage-backed security repo. The *x*-axis is maturity of the underlying repo. The solid black line is the loadings on the first principal component (the 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).

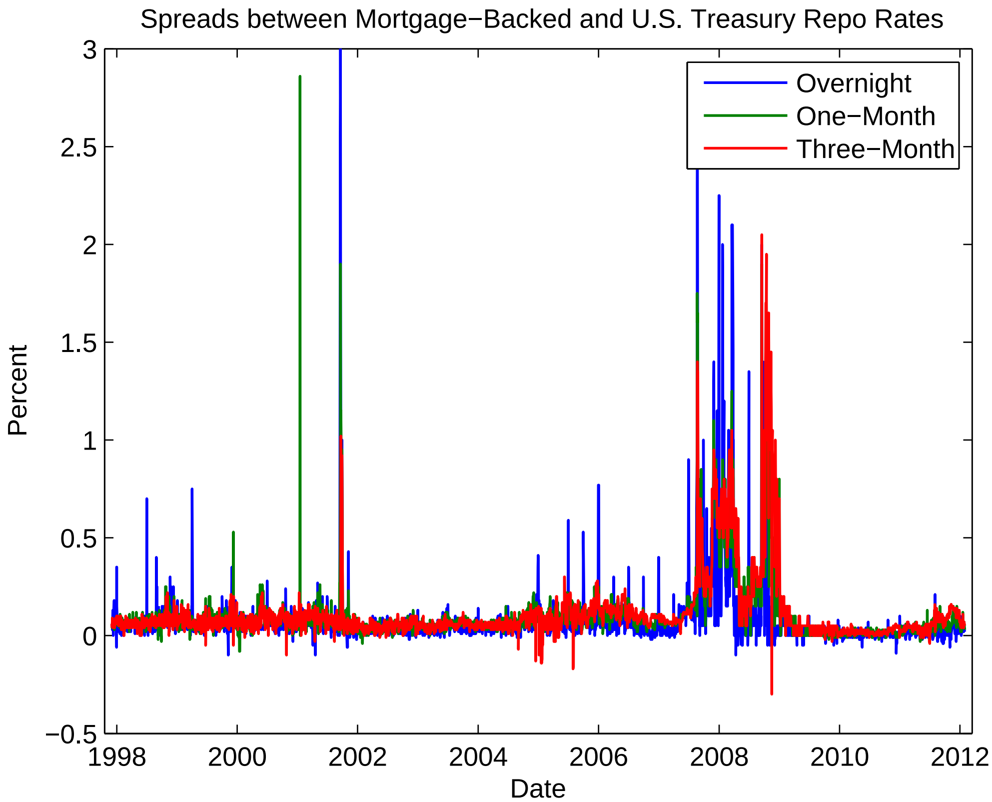

Figure 7: This figure plots the spreads between mortgage-backed security and U.S. Treasury repo rates at the overnight (blue), one-month (green), and three-month (red) maturities. The time period is September 1997 through January 2012 using daily data. Data is collected from Bloomberg.

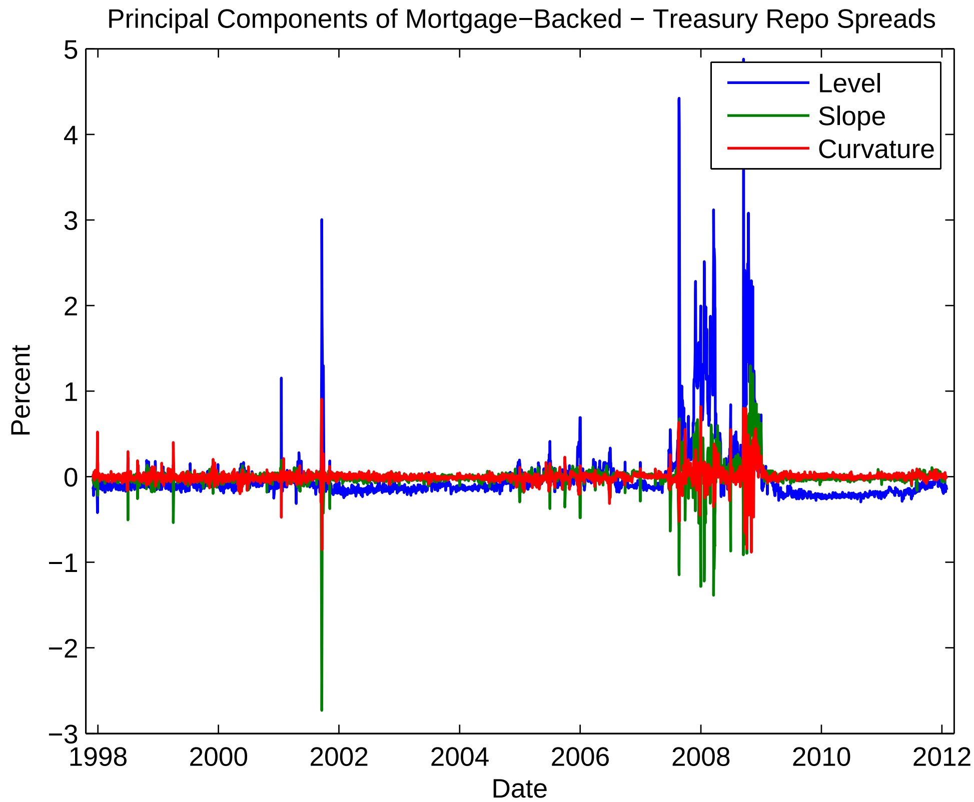

Figure 8: This figure plots the first three principal components of the term structure of the spreads between mortgage-backed security and U.S. Treasury repo rates. The blue line represents the first principal component (the level factor), the green line represents the second principal component (the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

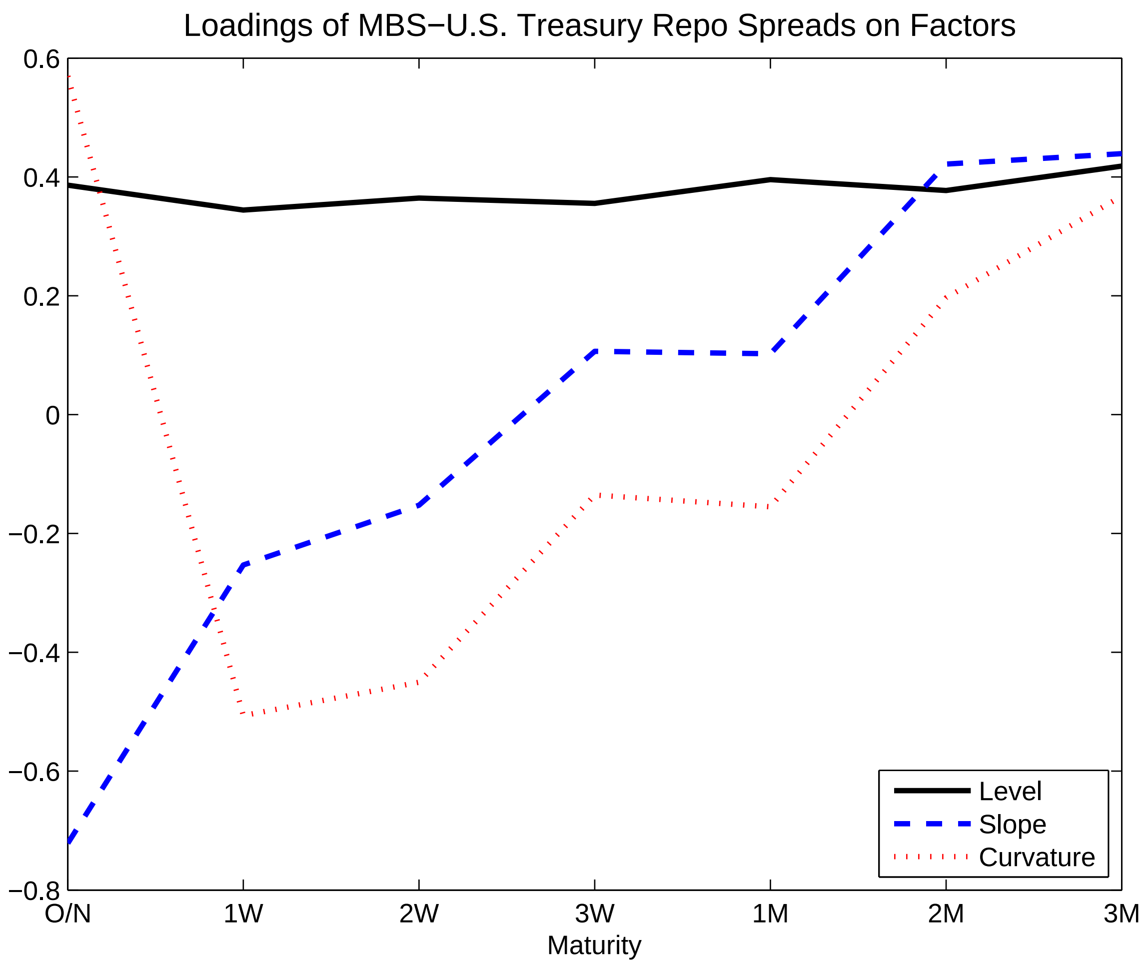

Figure 9: This figure plots how each of the first three principal components of the U.S. Treasury repo market load onto each spread between mortgage-backed security and U.S. Treasury repo rates. The *x*-axis is maturity of the underlying repo spread. The solid black line is the loadings on the first 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).

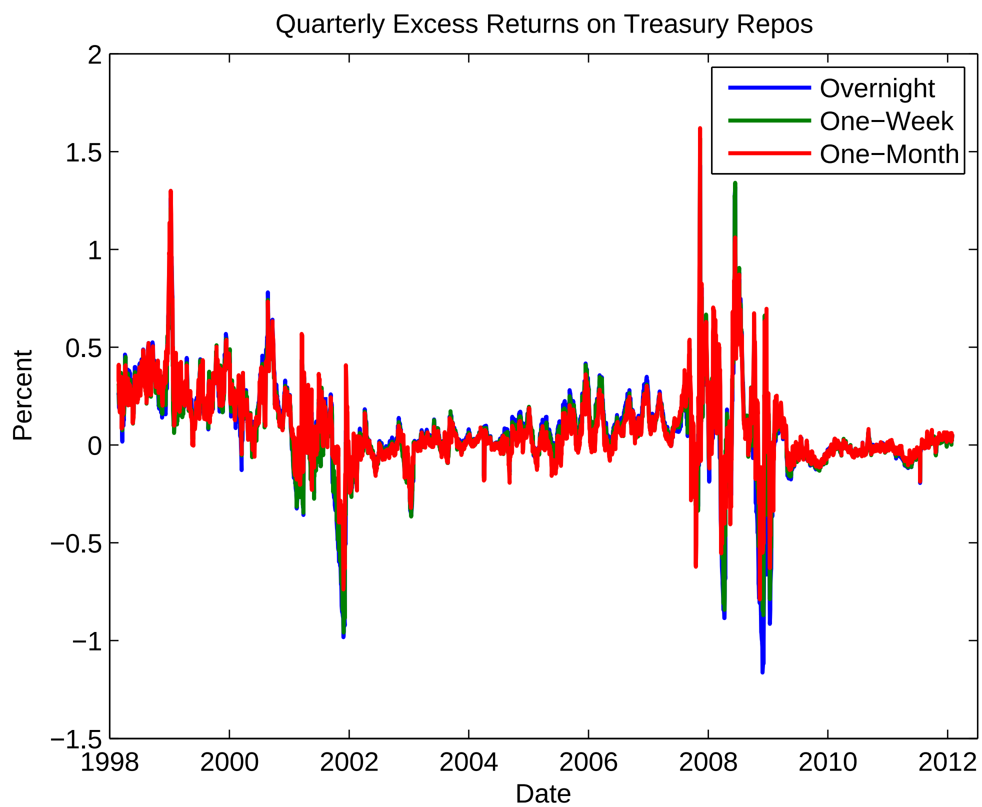

Figure 10: This figure plots quarerly excess returns on U.S. Treasury repos at the overnight (blue), one-week (green), and one-month (red) maturities.

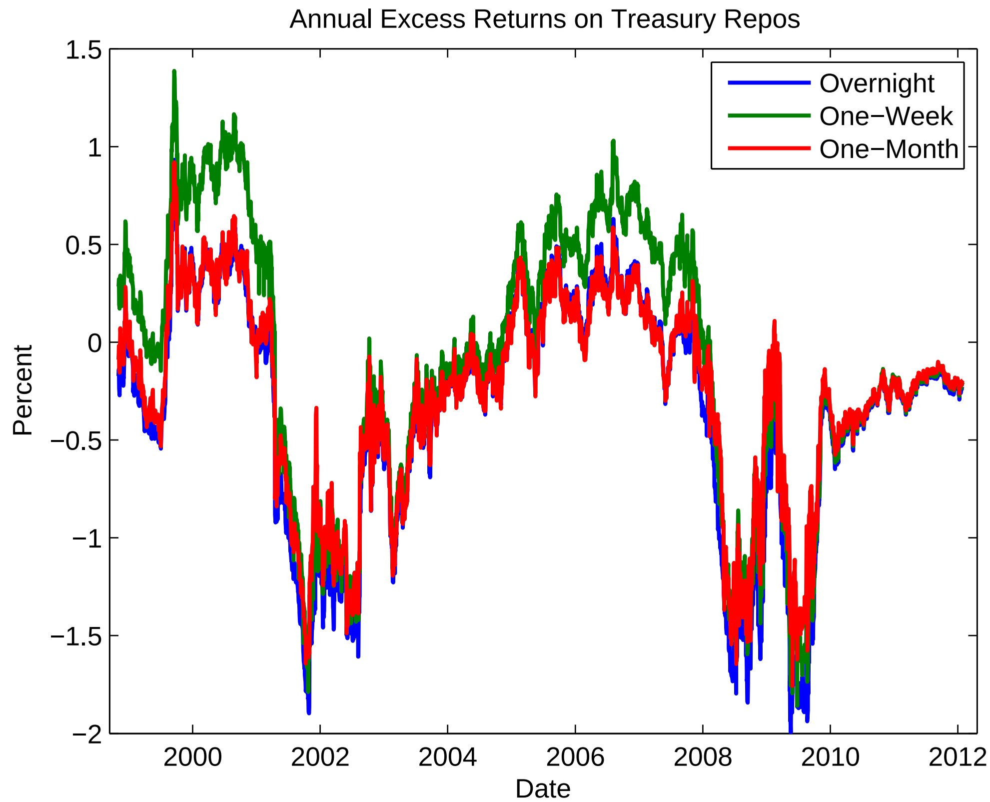

Figure 11: This figure plots annual excess returns on U.S. Treasury repos at the overnight (blue), one-week (green), and one-month (red) maturities.

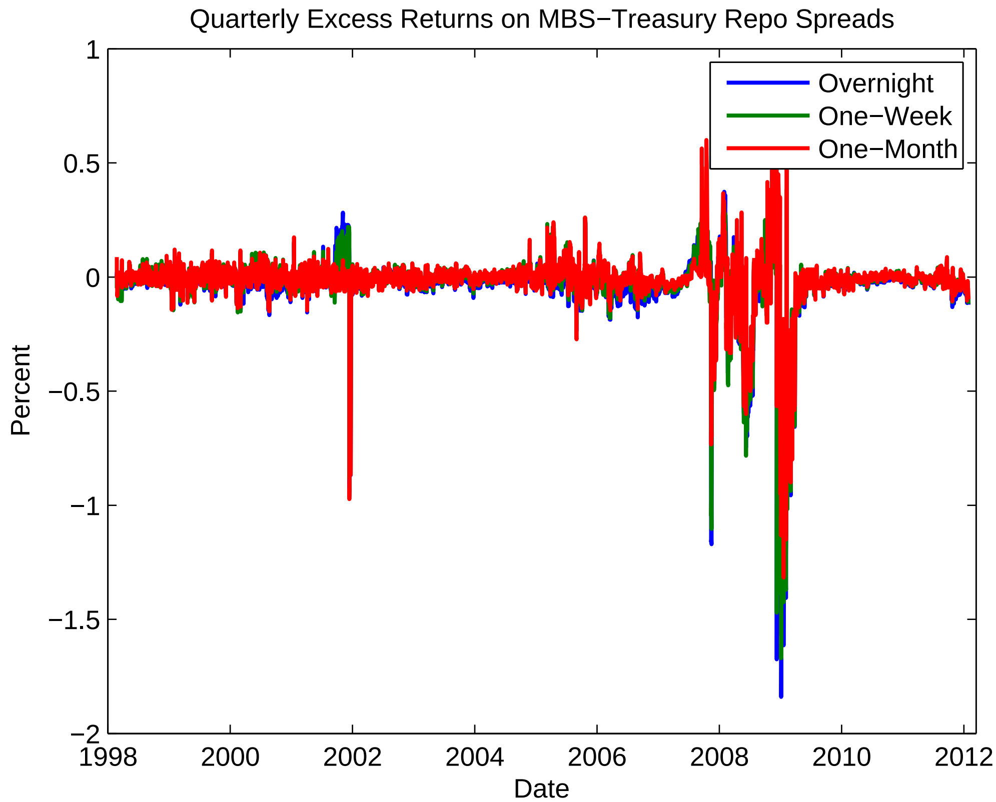

Figure 12: This figure plots quarterly excess returns on the spreads between mortgage-backed security and U.S. Treasury repo rates at the overnight (blue), one-week (green), and one-month (red) maturities.

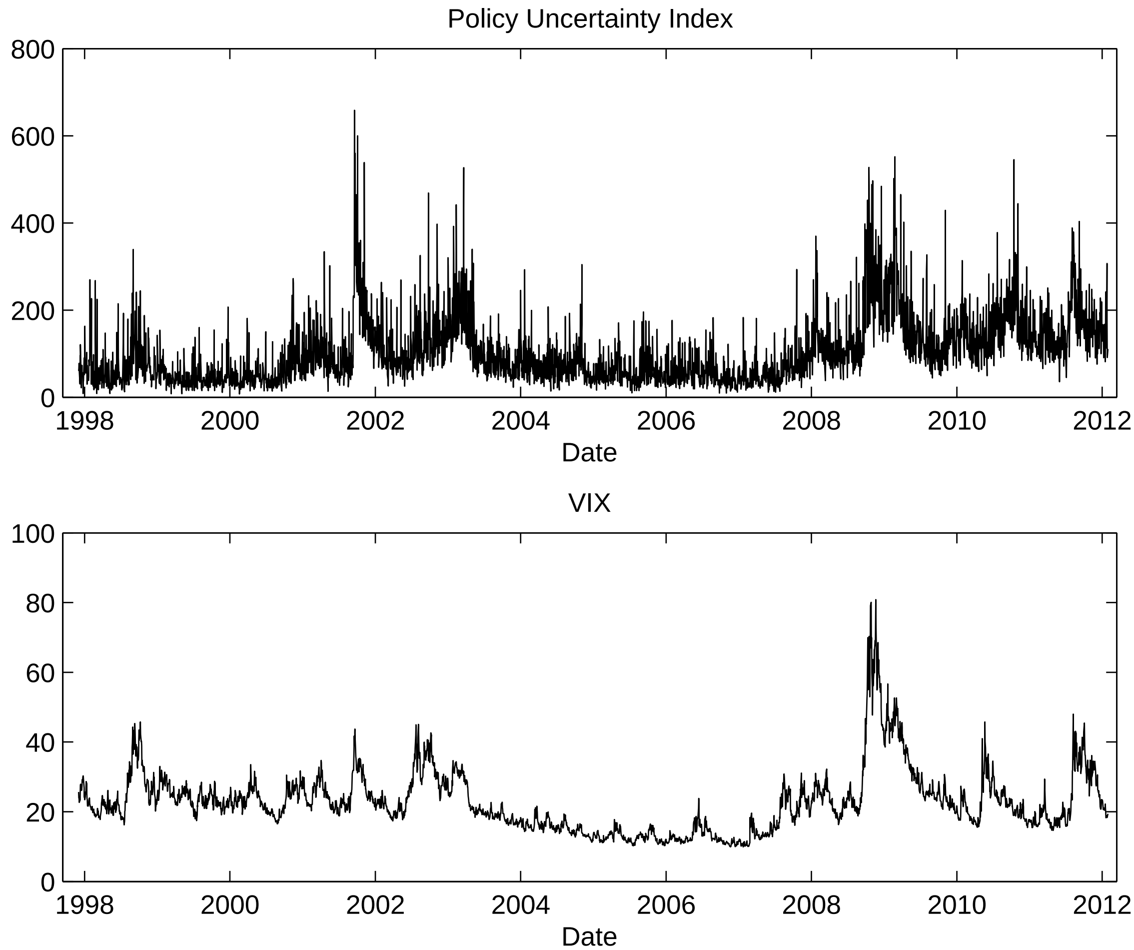

Figure 13: This first panel of this figure plots the Bloom et. al. (2012) policy uncertainty index from September 1997 to January 2012 at the daily frequency. The second panel of this figure plots the SP VIX index from September 1997 to January 2012 at the daily frequency.