Do Municipal Bonds Pose a Systemic Risk? Evidence from the Detroit Bankruptcy*

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December 2014

Abstract

This paper investigates the effect of Detroit's bankruptcy on the market pricing of Detroit's municipal debt and assesses the potential for contagion to the broader municipal bond market. Municipal bonds trade in the OTC market and the investor base is largely made up of high net worth retail investors, through both separate accounts and mutual funds. Studying the market reaction to the bankruptcy has implications both for assessing the pricing efficiency of a predominantly retail market as well as whether financial distress in state and local governments could be a trigger for stress in the larger financial system. The evidence of spillover from Detroit's bankruptcy to abnormal yield changes for other municipalities is relatively limited; only states with heavy pension/financial obligations (Illinois and Puerto Rico) and a few speculative grade securities experienced statistically significant downward repricing. To control for other factors affecting bond yields, we conduct the analysis by modelling structural changes in the municipal bond yield spreads in the period around the Detroit bankruptcy. This is particularly important during the summer of 2013 when longer term US Treasury yields increased significantly. Finally, using data on Puerto Rico sovereign debt, another distressed municipality, we estimate the implicit probability of default and recovery rates of the bonds and assess their dynamics relative to several events during the 2013-2014 period.

Keywords: municipal bonds, Detroit's bankruptcy, yield spreads, monitoring, structural change, recovery rate, default probability.

JEL classification codes: G12, G14, H74

*The views expressed here are the authors' and not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System.

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1 Introduction

The recent Detroit bankruptcy has renewed the debate regarding the potential for municipal bankruptcy(ies) to trigger systemic financial stress. One view is that the highly diverse and decentralized nature of the municipal bond market is well suited to absorb local adverse shocks (bankruptcy) without contagion effects and thus these events do not pose an elevated systemic risk. Indeed, the larger municipal bankruptcy filings prior to 2013 do not seem to have triggered significant stress within the financial system.[1] The common anecdotal explanation among market participants is that these events represented idiosyncratic situations providing little information on the default probabilities of other municipal issuers. This leaves open the alternative view: that the poor financial situation of many high-risk municipalities are correlated and the municipal bond market could experience a series of bankruptcies or defaults which could, in turn, transmit distress to other financial institutions and ultimately threaten the health and the integrity of the U.S. financial system. This alternative view could be supported by a market perception that the underlying cross-sectional correlation of municipal financial distress has increased relative to prior experience and/or that bankruptcy or default has become more likely.

In this paper, we attempt to shed light on this debate by studying the effect of the 2013 Detroit Chapter 9 bankruptcy filing on a large sample of municipal bond yields. While many of Detroit's fiscal problems are much more severe than those facing other municipalities (except perhaps Puerto Rico), Detroit is similar to many other cities with respect to the underfunded status of its public pension funds. Moreover, these unfunded pension liabilities account for 19% of the debt which Detroit's emergency manager is seeking to restructure or gain relief (an estimated \$3.5 billion of a total debt of \$18.5 billion). If Detroit is successful in lessening its pension liabilities through a Chapter 9 federal bankruptcy filing, this may increase the incentives for other municipalities to declare bankruptcy and provide a source of correlated risk in the municipal bond market.[2] Alternatively, the threat of impairment of pension benefits in bankruptcy may provide more incentives for public employee unions to negotiate earlier with municipalities and actually reduce the number of bankruptcies filed. Given this underlying source of correlated stress among municipalities, the underfunded pension liabilities and the risk of impairment, a study of the market response to Detroit's bankruptcy filing and the final outcome provide a uniquely powerful set of events in which to study the potential for market contagion. By assessing the response we can cast some light on the extent to which municipal bond investors rationally impound 'news' on the ability to impair

[1] These include filings by: Jefferson County, AL (2011); Stockton and San Bernardino, CA (2012); Harrisburg, PA (2011); Central Falls, RI (2011) and Orange County, CA (1994).

[2] Currently 21 states allow municipalities to file under Chapter 9, one state specifically prohibits filing (GA) and the other 28 states have no statute in place.

pension liabilities through Chapter 9 in pricing the bonds of other municipal issuers.

In a recent paper, Amromin and Chabot (2013) find that Detroit's bankruptcy had little and short-lived impact on the municipal bond yields outside of Michigan. However, their findings are based on a descriptive analysis of comparing Detroit's yields to that of a few aggregated municipal bond indices. The aggregation across credit quality, maturity, geographical regions etc. may conceal some important differential effects given the highly heterogeneous nature of the U.S. municipal bond market. Furthermore, the timing of the Detroit bankruptcy coincided with non-trivial shifts in the term structure of U.S. treasury market and the proper identification of the movements in both markets requires the use of conditional analysis. To visualize the difficulties surrounding the empirical analysis, Figure 1 plots the yield on the 10-year general obligation (GO) bond index and the yield spread between 10-year GO bond index and the 10-year U.S. Treasury note. While the GO yield dynamics (top graph) appears to suggest that there is a large reaction around the time of the Detroit's bankruptcy, accounting for the shifts in the Treasury curve (due to the 'taper tantrum') in the yield spread tends to eliminate any possible effect of the Detroit's bankruptcy on the rest of the market of GO bonds. However, these aggregated data may conceal important (and possibly large) differential impacts on distressed municipalities/states, low investment grade bonds as well as some revenue bonds.

The virtual extinction of bond insurance, combined with a retail investor base, a large amount of heterogeneity across state and state agency issuers, bond type (GO, revenue, or lease) and sector (health care, utility, housing, etc.), results in an opaque municipal market with a high degree of informational asymmetry between issuers and creditors. Were a default to occur, this opacity and the decision-making of retail investors may increase the likelihood of contagion to other bond issues resulting in lower liquidity and dramatically higher yields. On the other hand, the large retail ownership of municipal bonds may serve as a natural shock absorber and may limit the transmission and amplifications of negative idiosyncratic (such as municipal default) shocks through the financial system.

Despite the low historical default rates and relatively high recovery rates in the municipal market, Detroit's bankruptcy had the potential to trigger a reassessment of default probabilities and the capacity to pay of municipalities and states that are particularly vulnerable to financial distress (i.e. high levels of pension underfunding, high debt to income ratio, depressed economic activity and labor markets, and/or a high percentage of revenue from federal transfers etc. The extent to which this heightened risk could transmit financial distress within and outside of the municipal sector depends on a number of factors such as (i) whether or not holdings of municipal securities are significant part of the portfolios or obligations (i.e., liquidity support agreements, lines of credit) of major financial institutions such that the loss of value could push an institution into financial distress, (ii) whether or not institutions have information on counterparty exposures, (iii) whether retail investors would, as a group, engage in correlated selling behavior (both across investors and across municipal bond issues) and (iv) the extent to which synthetic products have been engineered such that exposure to the municipal sector is larger and more widespread than the 'real money' investor base. This paper takes on the empirical question posed by (iii); will retail investors cause the repricing of the broad market of municipal bonds in response to an event in one issuing municipality.

The rest of the paper is organized as follows. Section 2 describes the municipal bond market broadly. Section 3 describes the data and takes a preliminary look at the factor structure of the municipal bond yields which dictates our choice of model for the event analysis. Section 4 undertakes a statistical monitoring of municipal bond spreads, grouped by credit quality and geographical location, pre- and post-Detroit bankruptcy. This exercise provides useful information on the direction and the magnitude of the Detroit's Chapter 9 filing on different segments of the municipal bond market. Section 4 also identifies and reports the time dynamics of implied recovery rates and default probabilities, extracted from market prices, and provides discussion and policy implications. Section 5 concludes.

2 Characteristics of the Municipal Bond Market

The municipal bond market is large, decentralized and has experienced relatively low default rates. At the end of 2013, the total outstanding debt in the municipal bond market was $3.671 trillion.[3] The average daily trading volume in the municipal bond market is approximately $11.2 billion in 2013 with roughly 40,000 trades a day. The municipal debt market is comprised of a very large number of issuers (54,486 issuers at the end of 2011) selling unique securities (in the range of 1.5–2 million according to Ang and Green, 2011) that trade in over-the-counter (OTC) markets. For comparison, at the most liquid end of the fixed income market spectrum, the US Treasury market had total outstanding value of $11.854trillion in 2011, involves one issuer and averages on the order of $500b trading volume per day. The corporate debt market is more comparable to municipals, with approximately twice the size ($7.45trillion) and average daily volume ($21billion), but involves an order of magnitude less unique issuers (5,656 S&P-rated issuers). By contrast, the number of defaults over the same period of S&P-rated corporate bonds is 2,015 on a base of issuers that is

[3]Data sources: Securities Industry and Financial Markets Association (`www.sifma.org`) and Federal Reserve Board's Financial Accounts, Balance Sheets, and Integrated Macroeconomic Accounts (`www.federalreserve.gov/releases/z1/Current/data.htm`).

about 10 times smaller than that of the municipal bond market. In terms of defaults, the municipal bond market is often perceived as quite 'safe', having experienced only 47 defaults on S&P rated bonds between 1986 and 2011. Over the same time period, S&P rated corporate bonds defaulted 2,015 times, and of course the US Treasury has not experienced a single default.

Compared to other fixed income markets, retail investors play a prominent role in the municipal bond market, likely driven by the perception of safety and the federal and state tax exemptions available to individual taxpayers. As of 2013, approximately 44% of the outstanding municipal bond debt was held directly by household investors according to the Federal Reserve Financial Accounts. This figure is a residual and also includes some hedge fund ownership but until recently those amounts have been quite low.[4] If we include ownership through mutual, money-market, closed-end and exchange-traded funds are included, the estimate of retail ownership is roughly 72%. In the corporate debt market, the analogous figures are 9% and 28%.

The presence of such a high percentage of retail investors makes the study of contagion in this market particularly interesting. Retail investors have long been characterized as less financially sophisticated than institutional investors and there is a large literature on the ways in which retail investor behavior deviates from optimality as presented in theoretical models.[5] In addition, the municipal bond market is highly illiquid and most bonds trade very infrequently (see Ang, Bhansali and Xing, 2010, and Green, Hollifield and Schürhoff, 2007). Furthermore, the over-the-counter municipal bond market is characterized by large markups (1.3–2% according to Green, Hollifield and Schürhoff, 2007), slow price discovery and highly asymmetric price adjustment and dispersion in rising and falling markets (Green, Li and Schürhoff, 2010).

Given the paucity of data on dealer markets in which retail investors dominate, the way in which information is impounded into asset prices in such a market remains an open question. Of particular interest is whether this investor base changed its assessment of other municipal issues in response to some 'headline' events in Detroit, and if so, which issues were impacted.

Municipal bonds are quite heterogeneous; the market includes ample product diversity including general obligation (GO) and revenue bonds, callable and putable bonds, insured and uninsured bonds, bonds with credit ratings (provided by Moody's and S&P) and unrated issues. By source of repayment, 69% of the outstanding municipal bonds in 2013 are revenue bonds and 23% are general obligation bonds. Approximately 87% of the total outstanding municipal debt in 2013 is tax exempt and the details of tax exemption status varies both across states and issues.

[4] http://www.bondbuyer.com/issues/122_219/muni-watchers-view-hedge-fund-presence-liquidity-favorably-1057349-1.html

[5] For example, see Del Guercio and Tkac (2002) and Bhattacharya et al. (2012), including citations therein.

Another source of heterogeneity in the municipal bond market is the lack of uniformity regarding creditors' rights in an event of bankruptcy. Currently only 21 states permit Chapter 9 filings by their municipalities, 28 have no statute, and 1 (Georgia) explicitly prohibits municipal bankruptcy. In the event of severe financial distress, when additional access to debt markets is no longer possible, municipalities typically first resort to raising taxes and cutting expenditures and seeking support from their state government rather than defaulting on their obligations. As a result, the creditors face a great deal of uncertainty regarding recovery rates should a default occur.

Finally, the municipal bond market has experienced a noticeable drop in municipal bond insurance since its peak in 2010. While in 2005 close to 60% of the new debt issued by municipalities was insured, the proportion of insured new issue debt dropped to below 5% in 2012 and the first half of 2013. Several of the monoline insurers experienced significant financial distress, and failure, during the financial crisis due to insurance they wrote on secruritized products involving subprime MBS. The reduction in the percentage and strength of bond insurance has quite arguably complicated the analysis of individual municipal credits post crisis.

3 A Preliminary Look at the Data

3.1 Data Description

The data used in the empirical analysis is based on CUSIPs administered by the Municipal Securities Rulemaking Board (MSRB). MSRB provides trade execution data with the municipal bond's CUSIP, trade type, order size, price, and yield. The construction of a comprehensive balanced panel of municipal bond yields poses a number of challenges following from the market characteristics described above. First, given that the market is dominated by buy-and-hold retail investors, the majority of the CUSIPs are traded infrequently and there is a lack of continuous trading data. As a result, the recorded price movements are discontinuous and the market liquidity of a large number of CUSIPs is low. In addition, the heterogeneity in product types mentioned earlier (e.g., general obligation vs. revenue) is further exacerbated by CUSIP-specific factors including maturity, coupon payments, miscellaneous provisions and tax exemption.

Given that the main events related to the Detroit bankruptcy are May 14 2013 (notice of creditor mediation), June 14, 2013 (notice of default on GO debt) and July 18, 2013 (Chapter 9 bankruptcy filing), we've chosen February 1, 2012 to March 31, 2014 as our sample period for an event-study style analysis. We have split this into an estimation sample window set to February 1, 2012 to April 30, 2013 and an event window of May 1, 2013 to March 31, 2014. In constructing the data, we employ the following sampling criteria. We include only CUSIPs that have (i) at least 180 days of trading data, and (ii) at least one trading day pre- and post-event date for the three Detroit event windows. Origination trades, zero-coupon and variable coupon debt as well as bonds with maturities earlier than 2015 are excluded from the sample. Daily yields to maturity are computed based on current price and maturity date assuming that the municipal bond (CUSIP) will be held to maturity (ignoring call provisions). Individual trades are aggregated to the daily level using par-weighted prices. After applying these sampling criteria to the original sample of 19.5 million trades from 718,824 CUSIPs, our sample consists of 5.2 million trades from 17,528 CUSIPs, which are used to build 8.4 million daily observations.

To deal with shifts in the U.S. term structure over the sample period, we construct the yield-to-maturity spread over a US Treasury-based synthetic risk-free equivalent. This transformation allows us to isolate the events surrounding the Detroit bankruptcy from the movements in the term structure of interest rates that accompanied Federal Reserve communications related to tapering of its asset purchase program during the summer of 2013. Given the high persistence of the resulting municipal bond spreads, we work with the changes of the spreads which induces stationarity and ensures the validity of the standard statistical inference.

In constructing the municipal bond yield spreads, we follow Gilchrist and Zakrajšek (2012) and Gürkaynak, Sack and Wright (2007). In particular, let the price of a municipal bond i at time t with maturity m and a sequence of coupon payments or cash flows $C(j)$ (for $j = 1, 2, ..., m$) be

$$Y_{it} = \sum_{j=1}^{m} D(t_j)C(j),$$

where $D(t) = e^{-r_t t}$ is the discount factor in period t. The price R_{it} of the synthetic risk-free equivalent is obtained by discounting $C(j)$ using the smoothed zero-coupon Treasury yields estimated as in Gürkaynak, Sack and Wright (2007). The resulting synthetic risk-free price matches the exact coupon and maturity structure of the municipal bond. Y_{it} and R_{it} are then used to obtain the corresponding yields y_{it} and r_{it}, respectively.

3.2 Factor Analysis

In this section, we characterize the factor structure of the municipal bond yields and isolate the common components that drive their dynamic behavior. Given the possible nonstationarity of the municipal bond yields over the sample period, we follow the panel analysis of nonstationarity in the idiosyncratic and common components (PANIC) approach of Bai and Ng (2004). Let X_{it} $(i = 1, ..., N,\ t = 1, ..., T + 1)$ denote the i-th observed municipal bond spread at time t, where N is the total number of CUSIPs and $T + 1$ is the number of time series observations. Suppose that

X_{it} admits an approximate factor structure of the form

$$X_{it} = c_i + \lambda_i' F_t + e_{it},$$

$$A(L)(1-L)F_t = u_t,$$

$$(1-\rho_i L)e_{it} = C_i(L)\varepsilon_{it},$$

where F_t is an $r \times 1$ vector of latent common factors, λ_i is a $r \times 1$ vector of latent factor loadings, e_{it} is a vector of idiosyncratic errors, $A(L)$ and $C_i(L)$ are possibly infinite dimensional lag polynomials, and u_t is a vector of *iid* errors with mean zero and a constant variance-covariance matrix. The idiosyncratic shocks are assumed to be uncorrelated with the factors at all leads and lags although heteroskedasticity and a limited amount of cross-correlation is permitted (Stock and Watson, 2002). Finally, ε_{it}, u_t and λ_i are assumed to be mutually independent.

As Bai and Ng (2004) show, valid estimates of the latent factors F_t can be obtained from the first-differenced form of the model given by

$$x_{it} = \lambda_i' f_t + z_{it},$$

where $x_{it} = X_{it} - X_{it-1}$, $f_t = F_t - F_{t-1}$ and $z_{it} = e_{it} - e_{it-1}$. Let $\triangle X$ denote the stacked $T \times N$ data matrix with its t-th row given by $x_t' = [x_{1t}, x_{2t}, ..., x_{Nt}]$ and $\triangle F = [f_1 \; ... \; f_r]$ be the $T \times r$ matrix of common factor changes. Provided that $N, T \to \infty$, the latent factors and factor loadings can be estimated by the method of principal components by minimizing the objective function $(NT)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \lambda_i' f_t)^2$ subject to the identifying restriction $\triangle F' \triangle F/T = I_r$. Concentrating out $[\lambda_1', ..., \lambda_N']'$, the estimate of the factor matrix $\triangle F$, $\triangle \hat{F}$, is obtained by maximizing $\mathrm{tr}(\triangle F'(\triangle X \triangle X') \triangle F)$ and $\triangle \hat{F}$ is a matrix of $\sqrt{T}$ times the r eigenvectors corresponding to the r largest eigenvalues of the matrix $\triangle X \triangle X'$. The estimated matrix $\triangle \hat{F}$ can then be used to obtain an estimate of $\Lambda = [\lambda_1, ..., \lambda_N]'$ as $\hat{\Lambda} = \triangle X' \triangle \hat{F}/T$. Then, the $r \times 1$ vector of partial sums $\hat{F}_t = \sum_{s=2}^{t} \hat{f}_s$ provides a consistent estimate of the latent common factors of interest F_t (see Bai and Ng, 2004).

Let $X_{it} = y_{it} - r_{it}$ denote the municipal bond spread, where y_{it} is the yield to maturity on the i-th municipal bond and r_{it} is its synthetic risk-free equivalent. The point-wise 5th, 50th and 95th percentiles of the cross-sectional distribution of the municipal bond yields are presented in Figure 2. Interestingly, the dynamics of the municipal bond spreads does not exhibit drastic differences around the timing of the Detroit bankruptcy. This could be due to the confluent effects of the shifting U.S. term structure of interest rates (reflected in the synthetic risk-free rates) and the aggregated nature of the summary statistics (percentiles) reported in the figure. Our subsequent analysis will try to disentangle these confounding factors and characterize the effects of Detroit's bankruptcy at a disaggregated level.

Using the approach described above, we compute the first two principal components of $x_{it} = \triangle X_{it}$ which explain approximately 30% of the variation of x_{it}. The accumulated estimated factors $\hat{F}_t$ are plotted in Figures 3 and 4. The first factor (Figure 3) closely follows the dynamics of the 10-year Treasury note yield. The second factor (Figure 4) appears to capture some common variation in the municipal bond market. In particular, it exhibits similar dynamics with the 5-year GO municipal yield index. In our event study analysis below, we will use the 10-year Treasury note and 5-year GO bond index yields as observed proxies of the factor structure of the municipal bond spreads.

4 Monitoring of the Effect of Detroit's Bankruptcy

4.1 Methodology

In this section, we briefly describe the setup and the methodology used for our analysis. Our interest lies in identifying the causal effects of three events – (i) Detroit's notice of creditor mediation (May 17), (ii) Detroit's notice of default on GO debt (June 14) and (iii) Detroit's Chapter 9 bankruptcy filing (July 18) – and see if these events produce differences in the magnitude and the dynamic behavior of individual and aggregated municipal bond yields. Another source of variation that could enhance our identification strategy is the observation that these events have an impact on the municipal market but not on the market for government securities. Furthermore, the Treasury bond yields serve as a natural benchmark for gauging the riskiness of the municipal bonds. However, exploiting the Treasuries as a "control" group is partly hampered by the movements at the long end of the U.S. Treasury yield curve that occurred as a result of hints about possible tapering of the monthly asset purchases of the Fed. For this reason, we need to control for factors that capture the common shifts and variations in the Treasury and municipal yield curves over the estimation and event windows. Our preliminary analysis in Section 3 suggests a model with the 10-year Treasury yield and a GO bond index yield. In order to span better the municipal bond yield curve, we employ the following four-factor model:

$$\begin{aligned} \triangle \tilde{x}_{jt} &= \alpha_j + \beta_{1j} \triangle i_t^{10US} + \beta_{2j} \triangle (i_t^{1GO} - i_t^{1US}) \\ &\quad + \beta_{3j} \triangle (i_t^{10GO} - i_t^{10US}) + \beta_{4j} \triangle (i_t^{30GO} - i_t^{30US}) + \epsilon_{jt}, \end{aligned} \quad (1)$$

where $\tilde{x}_{jt} = \tilde{y}_{jt} - \tilde{r}_{jt}$ denote municipal bond yield spreads aggregated by state, rating, issue type, industry or some other criterion, i_t^{kUS} and i_t^{kGO} $(k = 1, 10, 30)$ denote the yields on the k-year Treasury note and the GO municipal bond index, respectively, and $E(\epsilon_{jt} | \triangle i_t^{10US}, \triangle(i_t^{1GO} - i_t^{1US}), \triangle(i_t^{10GO} - i_t^{10US}), \triangle(i_t^{30GO} - i_t^{30US})) = 0$.

Given the relatively well-defined nature of the events of interest, one possibility is to employ event study analysis. While the methodology that we use below is similar in spirit to the event study analysis, we depart from the event study framework for the following reasons. First, given the highly illiquid and opaque structure of the municipal bond market, there is substantial uncertainty about the timing of these events on the municipal bond prices. This also requires a longer time period to monitor and evaluate the effects of these events across the different securities. Finally, testing for potential changes in the dynamics of the underlying series for a sequence of candidate event dates gives rise to a multiple testing problem where a large number of consecutive test would indicate structural change with probability approaching one even when the underlying process is stable (Chu, Stinchcombe and White, 1996).

In what follows, we adopt an approach, proposed by Chu, Stinchcombe and White (1996), of monitoring the dynamics of the process implied by model (1), estimated over a particular sample, as the new, real-time data arrive. It replaces the conventional individual tests of a null hypothesis with a sequence of tests whose value path is compared to a boundary which ensures the asymptotic size of the test procedure is controlled. This approach has gained some popularity in monitoring the predictability of economic and financial data (Anatolyev, 2008; Inoue and Rossi, 2005) and disruptions in financial markets (Andreou and Ghysels, 2006). A related method for controlling the false discovery rate in multiple testing has been used recently by Barras, Scaillet and Wermers (2010) for mutual fund performance evaluation and by Gospodinov, Kan and Robotti (2014) for selection of risk factors in asset pricing models.

The sequential testing procedure can be described briefly as follows. Let T denote the number of observation in the estimation sample (February 1, 2012 to April 30, 2013), n be the number of observations in the whole sample (February 3, 2012 to March 31, 2014) and $n-T$ be the observations in the monitoring window. Also, rewrite model (1) as

$$\triangle \tilde{x}_{jt} = z_t' \gamma_j + \epsilon_{jt},$$

where $\gamma_j = (\alpha_j, \beta_{1j}, \beta_{2j})'$ and $z_t = (1, \triangle(i_t^{1GO} - i_t^{1US}), \triangle(i_t^{10GO} - i_t^{10US}), \triangle(i_t^{30GO} - i_t^{30US}))'$. Furthermore, let $\hat{\gamma}_j = (\sum_{t=1}^{T} z_t z_t')^{-1} (\sum_{t=1}^{T} z_t \triangle \tilde{x}_{jt})$ be the OLS estimator obtained using the T observations in the estimation sample under the maintained assumption of constant parameters. Our main interest lies in determining if the regression parameters γ_j remain constant in the post-estimation (monitoring) period so that $H_0 : \gamma_{j\tau} = \gamma_j$ in $\triangle \tilde{x}_{j\tau} = z_\tau' \gamma_j + \epsilon_{j\tau}$ for $\tau = T+1, T+2, ..., n$. To stay as close as possible to the event study framework, we define the residuals (also called "abnormal returns" in the event analysis literature)

$$\hat{\epsilon}_{j\tau} = \triangle\tilde{x}_{j\tau} - z'_\tau\hat{\gamma}_j.$$

The monitoring sequential test is based on the CUSUM statistic of Ploberger and Krämer (1992)

$$Q_\tau = \frac{1}{\hat{\sigma}\sqrt{T}}\left(\sum_{s=T+1}^{\tau}\hat{\epsilon}_{js}\right)$$

where $\hat{\sigma}$ is the standard deviation of the estimation sample residuals $\triangle\tilde{x}_{jt} - z'_t\hat{\gamma}_j$ for $t = 1, ..., T$. Let α denote the nominal size of the test. To complete the sequential testing procedure, we need a boundary b_τ that controls the asymptotic size of the two-sided test such that

$$\Pr\{|Q_\tau| < b_\tau \text{ for } \forall\tau \in |H_0\} = 1 - \alpha.$$

While several boundary choices are available in the literature (Brown, Durbin and Evans, 1975; Chu, Stinchcombe and White, 1996; Zeileis, Leisch, Kleiber and Hornik, 2005), we use the "uniform" boundaries of Anatolyev and Kosenok (2001) which ensure that the size is uniformly distributed over the monitoring horizon. For details on the computation of these boundaries, see Anatolyev and Kosenok (2001).

4.2 Main Results

4.2.1 Monitoring

The results for monitoring structural changes in the municipal bond yield spreads due to Detroit's bankruptcy are presented in Figures 5 to 9. For all graphs, we use a boundary (a sequence of critical values) b_τ at 1% nominal level. The decision rule is to reject the constancy of the model parameters (including the intercept) over the monitoring period if the test statistic Q_τ crosses the boundary b_τ from below. Figure 5 plots the statistic Q_τ and the boundary b_τ for selected municipal bond yield spreads aggregated by state. It appears to be strong statistical evidence for an effect of Detroit's bankruptcy on the bond yields in Illinois, Michigan and Puerto Rico. Illinois and Michigan follow a similar dynamic pattern - they increase almost immediately after the notice of default (June 14) and Detroit's Chapter 9 bankruptcy filing (July 18) but do not exhibit much reaction to the notice of creditor mediation in May. In contrast, the test statistic for Puerto Rico crosses the boundary significantly later with a much larger magnitude of the response. As we discuss later, this is likely the result of Puerto Rico specific events in the later summer. The bond yields for the other states in the graph also exhibited some instability (mainly as a result of the notice of default on June 14) but these effects dissipated by the end of the monitoring period as the test statistic returned below the boundary. The remaining states and territories that are not presented in Figure 5 tend to exhibit either minor or no effect from the Detroit's bankruptcy announcement.

As expected, Figure 6 indicates that the speculative-grade municipal bonds have been affected much more strongly that the investment-grade bonds. However, there are bonds in the investment-grade group that have reacted to the Detroit's bankruptcy and made the test statistic for the investment-grade bonds borderline significant at the end of the monitoring period.

Figures 7 and 8 plot the abnormal yields by issue type (GO with unlimited liability (GOU), GO with limited liability (GOL) and revenue) and by a decomposition of the revenue bonds by industry. These graphs suggest that Detroit's bankruptcy has had a statistically significant effect on revenue bonds (and initially on GO bonds with unlimited liability) with tobacco exhibiting the largest impact. Finally, Figure 9 presents evidence for individual distressed municipalities. Only Detroit's bonds have reacted statistically significantly to the notice of default on June 14 with Chicago following suit after the Chapter 9 bankruptcy filing on July 18. As mentioned before, Puerto Rico's test statistic crossed the boundary only in early August and continued its upward trajectory from then on. Interestingly, other distressed markets such as Minneapolis MN, Portland OR, San Bernardino CA and Stockton CA do not seem to be affected at all.

4.2.2 Another View of Contagion

In this section, we examine the possibility of contagion within the municipal bond market as well as from the municipal bond market to other financial markets from a different perspective. One way to define contagion is as an increase in the correlation between two securities or markets. To measure the potential increase in cross-market linkages as a result of the Detroit's bankruptcy, we use the rolling correlation estimator

$$\rho_{jD,t} = \frac{\sum_{s=1}^{m} \triangle \tilde{x}_{j,t-s} \triangle \tilde{x}_{D,t-s}}{\sqrt{\left(\sum_{s=1}^{m} \triangle \tilde{x}_{j,t-s}^2\right)\left(\sum_{s=1}^{m} \triangle \tilde{x}_{D,t-s}^2\right)}},$$

where $\tilde{x}_{j,t}$ is the yield spread for bond j and $\tilde{x}_{D,t}$ is Detroit's bond yield spread. The rolling window m is set to 22.

Figure 10 plots the rolling correlation coefficients of investment-grade, speculative-grade, Puerto Rico and Chicago bond yields against Detroit. During 2012, these correlations were large and stable. The correlation coefficients dropped at the end of 2012 and beginning of 2013 but increased again to 0.7 and above quickly after that. Around the Detroit's notice of default in June 2013, the correlations fell sharply. They reversed somewhat by September 2013 but decreased again much below their historical levels with only the correlation between speculative-grade bonds and

Detroit's bonds remaining high. This evidence suggests that the cross-market linkages weakened rather than strengthened after Detroit's shock and does not support the view of possible contagion in the municipal bond market.

To assess the possibility of spillover from the municipal bond market to other financial markets, we resort to historical monthly data from February 1953 to December 2013. The variables under consideration are returns on long-term corporate bonds (with an approximate maturity of 20 years), long-term US government bonds (with an approximate maturity of 20 years), medium-term bonds (with an average maturity of 5 years), S&P500 index and Bond Buyer GO 20-bond municipal bond index. The corporate and government bond returns are from Ibbotson Associates while the S&P500 returns are from CRSP. The 20-bond municipal bond index consists of 20 general obligation bonds of mixed quality (with an average rating roughly equivalent to Moody's Aa2 rating and Standard & Poor's AA rating) and a 20-year maturity (source: Board of Governors of the Federal Reserve System).

Table 1 presents the results from estimating a VAR(1) model of the five asset returns over the whole sample as well as over the subsamples February 1953 – December 1989 and January 1990 – December 2013.[6] Several interesting observations emerge from the VAR(1) results. First, variations in municipal bond returns do not seem to cause future movements in any of the other asset returns. So, based on historical data, a spill-over from a potential turmoil in the municipal bond market to the other major asset markets seems unlikely. Interestingly, however, there exists a strong predictability of the municipal bond returns by medium-term government bond, stock, and especially corporate bond returns. While the predictive power of government bond and stock returns can be explained by term-structure factors and the 'great rotation' hypothesis between stocks and bonds (which is also evident for the other bond returns), the consistent predictive power of corporate bond returns over all sample periods may be related to the opaqueness of the municipal bond market that we alluded to earlier. In summary, these historical patterns suggest that the municipal bond market is more likely to react to shocks elsewhere in the financial system than being a precursor of instability that spreads to the other asset markets.

4.2.3 Market-Implied Recovery Rates and Default Probabilities

Having documented a significant repricing of some municipal securities following Detroit's bankruptcy, especially speculative grade bonds, we now investigate how to decompose such a response into effects related to default probabilities v. estimated recovery rates. A municipal bankruptcy

[6] The results for returns in excess of the risk-free (30-day) rate as well as for inflation-adjusted returns are very similar to those reported in Table 1.

such as Detroit's could quite plausibly affect market assessments of both measures. The success, or failure, of bankruptcy resolution could incent other municipalities to file strategically (increasing probability of default) or provide an incentive for public pensions to negotiate reforms less aggressively and lower potential defaults. In addition, Chapter 9 is a much less standard form of bankruptcy than the Chapter 7 or 11 options available for corporations. For example, creditors cannot force bankruptcy or seize assets; there are no clear priorities when it comes to pension obligations versus explicit debt, etc. If it were a state, rather than a municipality, that suffered severe financial distress, the uncertainty would be even greater as there is no bankruptcy option for US states and territories.

It would be valuable to identify if the widening yield spreads for the speculative-grade municipal bonds are attributed to elevated default probability, lower expected recovery or both when assessing the potential for a larger systemic impact. Consider, for example, 4 possible alternatives: (1) little/no change in default probabilities or recovery rates; (2) little/no change in default probabilities but decreases in recovery rates; (3) increases default probabilities but no change in perceived recovery rates; and (4) significant increases in default probabilities and decreases in perceived recovery rates. These alternatives represent increasing levels for the potential impact on the broader municipal bond market. Moreover, decomposing price effects into these two components will provide insight into the details of the market's information processing of complex events.

Our methodology of identifying and estimating recovery rates and default probabilities is based on the literature of modeling the term structure of defaultable corporate and sovereign bonds (Bakshi, Madan and Zhang, 2006; Duffie and Singleton, 1999; Jarrow and Turnbull, 1995; Longstaff, Mithal and Neis, 2005; among others). Consider a defaultable coupon bond with face value F, maturity m, a random default time $\mathcal{T}$ and a recovery of face value $w(\mathcal{T})F$, where $0 \leq w(\mathcal{T}) \leq 1$. For $0 \leq t \leq m$, let $\mathcal{D}(t) = 1$ if $t \geq \mathcal{T}$ and 0 otherwise, $S(t)$ denote the cumulative probability of default during the time interval $[0, t]$ and $h(t)$ denote a positive risk-neutral hazard rate process defined as

$$E^Q[1 - \mathcal{D}(s)] = \exp\left(-\int_0^s h(t)dt\right),$$

where E^Q is the expectation operator under the risk-neutral probability measure Q. Then, with continuous-coupon payments $C(t)$ and spot interest rate $r(t)$, the price of a defaultable coupon bond with random recovery is given by (Bakshi, Madan and Zhang, 2006; Duffie and Singleton, 1999; Jarrow and Turnbull, 1995; Longstaff, Mithal and Neis, 2005)

$$
\begin{aligned}
B(t,T) \quad = \quad & E^Q\left[\int_t^m \exp\left(-\int_0^s (r(u)+h(u))du\right) C(s)ds\right] \\
& +E^Q\left[\int_t^m \exp\left(-\int_0^s (r(u)+h(u))du\right)\right] F \\
& +E^Q\left[\int_t^m \exp\left(-\int_0^s (r(u)+h(u))du\right) w(s)h(s)ds\right] F. \qquad (2)
\end{aligned}
$$

Note that the second term (the discounted face value) allows, for given dynamics of the spot interest rate, the identification of the hazard rate (or default probability) while the third term (the discounted recovery payout on default) helps to identify the recovery rate.

To make the problem operational, we set the recovery rate as $w(t) = w_0$ and use a version of the Nelson-Siegel parameterization for the hazard rate (Andritzky, 2006)

$$h(t) = \beta_0 + \beta_1 \exp(-t/2), \qquad (3)$$

where $\beta_0 > 0$. The conditional default probability between time 0 and t is then given by

$$S(t) = 1 - \exp\left[-\beta_0 t - \beta_1 t \frac{1-\exp(-t/2)}{t/2}\right].$$

Given the parameterizations of $w(t)$ and $h(t)$, the unknown parameter vector $\theta^{(j)} = (\beta_0^{(j)}, \beta_1^{(j)}, w_0^{(j)})'$ can be estimated at each point t from a cross-section of N bonds for municipality j by minimizing the weighted nonlinear least squares objective function

$$Q_N(\theta^{(j)}) = \sum_{n=1}^{N} \omega_n^{(j)} \left(B_n(\theta^{(j)}) - \tilde{B}_n^{(j)}\right)^2,$$

where $B_n(\theta^{(j)})$ is the discretized model price from equation (2) for the n-th bond of municipality j (with $w(t) = w_0$ and (3) substituted in for $h(t)$), $\tilde{B}_n^{(j)}$ is the corresponding market bond price and $\omega_n^{(j)}$ are weights that satisfy $\sum_{n=1}^{N} \omega_n^{(j)} = 1$. In our empirical analysis, we set the weights to be inversely proportional to the duration of the municipal bonds.

Similarly to yield curve estimation (see Gürkaynak, Sack and Wright, 2007, for instance), minimizing $Q_N(\theta^{(j)})$ is characterized by multiple local optima that gives rise to instability of the estimated parameters from one tome period (day) to another. To address this problem, we resort to the quasi-Bayesian approach of Chernozhukov and Hong (2003). It is based on the quasi-posterior of $\theta^{(j)}$ given by

$$p_N(\theta^{(j)}) = \frac{e^{-Q_N(\theta^{(j)})}\pi(\theta^{(j)})}{\int_\Theta e^{-Q_N(\theta^{(j)})}\pi(\theta^{(j)})d\theta^{(j)}},$$

where $\pi(\theta^{(j)})$ is a prior (strictly positive and continuous over Θ) probability density. An MCMC (Monte Carlo Markov Chain) method is then employed to produce point and interval estimates of a given continuously differentiable function g of $\theta^{(j)}$, $g(\theta^{(j)})$, by evaluating integrals of the form

$$\int_{\Theta} g(\theta^{(j)}) p_N(\theta^{(j)}) d\theta^{(j)}.$$

This allows us to report various statistics (mean, median, standard deviation, quantiles) of the quasi-posterior distribution for the hazard rate (default probability) and recovery rate which can be used to conduct inference. In the MCMC computation, we use Metropolis-Hastings algorithm with a Gaussian transition kernel and a flat prior with 1,000,000 draws, 800,000 of which is a burn-in sample.

4.2.4 A Case Study: Puerto Rico

Puerto Rico's municipal debt provides the perfect laboratory for estimating and tracing the dynamics of the probability of default and recovery rate over our sample period. In addition to assessing the impact of Detroit events on this debt, Puerto Rico experienced some significant events of its own over the past year that could affect default probabilities and recovery rates. Puerto Rico is a distressed market with precarious finances (persistent budget deficits with approximately 20% of the budget for servicing debt), high unemployment (15.4% at the end of 2013), low labor force participation rate (42.4% at the end of 2012), and declining economic activity (-5.35% change in Puerto Rico's Government Development Bank economic activity index between December 2012 and December 2013). Despite this underlying economic risk, Puerto Rico's debt (total of $71.3 bln. as of December 2013 (Federal Reserve Bank of New York, 2014)) is widely held by U.S. institutional and retail investors due to its triple tax-exempt status. Though this distress had been building for a long period of time, shortly after Detroit's bankruptcy filing a Barron's article highlighted Puerto Rico's long-standing financial distress (August 2013) and six months later its debt was finally downgraded by the major rating agencies (S&P, Moody's and Fitch) to junk status (February 2014). Recall that we found some evidence of a price reaction in Puerto Rico debt following the Detroit announcement but the significant repricing came following the Barron's article.

With concerns about the broader impact of Detroit's bankruptcy receding by late 2013 and early 2014, market attention turned to Puerto Rico as a potential source of municipal bond market instability. In retrospect we see that the large cumulative abnormal yields in Puerto Rico debt during the fall of 2013 do not seem to have caused broader municipal repricing but this was not clear at the time. In particular, there was some concern from market participants prior to the downgrade that mutual funds with significant exposures would be forced to sell holdings of Puerto

Rico debt due to investment restrictions or might sell off more liquid municipal bond holdings to meet any large redemptions that might materialize. Oppenheimer Funds, the largest mutual fund holder of Puerto Rico debt, responded with a public statement clarifying its restrictions and assuring investors that no forced selling would be necessary. Franklin Templeton, another large holder, however, did not issue similar public statements. Moreover, there were reports of increased hedge fund interest and ownership of Puerto Rico debt and again market uncertainty over whether this development was stabilizing or destabilizing. Perhaps surprisingly, on March 4, 2014, only a month after the downgrade, Puerto Rico successfully placed a $3.5 bln. of GO debt in a single bond issue maturing in 2035 at a yield-to-maturity of 8.73 percent. This was the largest municipal junk bond issue in U.S. history and it was reportedly 3-5 times oversubscribed with strong interest and participation by hedge funds. The bonds were issued with provisions intended to reduce investor risk. In particular, the bonds included a prioritization of any government surplus toward repayment and were issued under the jurisdiction of New York State which includes a waiver of sovereign immunity. All else equal and if credible, these provisions should have reduced the probability of default and/or increase projected recovery rates on the newly issued bonds relative to outstanding Puerto Rico debt. An open question is whether or not this issuance changed market perceptions regarding the probability of default and/or recover rates on the previously issued bonds. Some market reports at the time suggested that issuing under New York jurisdiction could make it easier for Puerto Rico to default on previously issued debt while still maintaining market access.

Finally in June 2014 Puerto Rico passed new legislation (Puerto Rico Public Corporations Debt Enforcement and Recovery Act) that allows public corporations (such as the heavily indebted Electric Power Authority, Aqueduct and Sewer Authority, and Highway and Transportation Authority) to defer or reduce payments on outstanding debt obligations that had been implicitly backed by the Commonwealth's full faith and credit. This legislation, in part, motivated the credit rating agencies to further downgrade Puerto Rico's debt in July. The concern stated by Moody's was that the new law represented an effort by the government to reduce its willingness to support public debt with revenue enhancements and austerity measures, and to begin attempting to shift the burden to creditors.

To quantify the effect of these events on the pricing of Puerto Rico (PR) municipal bonds, we extended the sample period until the end of September 2014 and decompose the PR yield spreads into probability of default and recovery rate components. For each day in our sample, we use a cross-section of PR bond prices to estimate the probability of default and recovery rate as described in the previous section. To illustrate the composition of the sample used for estimation, we briefly discuss the available data for October 1, 2013. In addition to applying the sampling criteria described in Section 2.1, we further restrict our sample to non-callable and uninsured bonds. As a result, the daily sample for October 1, 2013 consists of 134 GO and revenue PR bonds – all of which rated Ba2 by Moody's – with maturities ranging between 0.75 years (July 1, 2014) to 12.75 years (July 1, 2026) and coupons 2.5-6.5% paid semi-annually. The coupon payments and bond maturities are then used to construct synthetic riskless equivalents and, with the adopted parameterizations of the probability of default and recovery rate, model bond prices. The model parameters are estimated by MCMC and the reported estimates (confidence intervals) are the mean (quantiles) of the quasi-posterior density of the probability of default and recovery rate. It should be noted that obtaining stable and reliable estimates of the default probability and recovery rate requires sufficient cross-sectional variation in the PR bond prices across different maturities. The informational content of the bond prices and the precision of the resulting estimates are reflected in our reported 90% confidence intervals.

The dynamics of the estimated 1-, 2- and 5-year probability of default, plotted in Figure 11, warrants some remarks. First, the term structure of the PR probability of default appears to be fairly steep. While the 1-year probability is contained below 10% until the middle of 2014, the 5-year probability is in the 33%–50% range even before the Detroit's bankruptcy and stays elevated during the whole sample period. Second, the three probabilities of default appear to exhibit similar reaction over time. Interestingly, the PR probabilities of default have increased persistently between April-May 2012 and the middle of 2013 and, in line with our earlier results using cumulative abnormal yields, were largely unaffected and even declined in the immediate aftermath of the Detroit's bankruptcy. The probabilities of default started to increase again following the Barron's article in August 2013, reached a local peak after the downgrade in February 2014, and declined around the successful bond issue. The final adjustment in the PR default probability came about in the summer of 2014 when the one- (two-) year probability jumped from around 5% (10%) to almost 20% (30%). Thus, the market seemed to share Moody's concerns that default on Puerto Rico sovereign debt is indeed now more likely.

Figures 12 and 13 present the spline-smoothed mean, 5th and 95th percentile of the quasi-posterior density of the 5-year probability of default and recovery rate, respectively. Until September 2013, the confidence bands for the probability of default are fairly wide suggesting that the daily samples of bonds used for estimation were not very informative. However, Detroit's bankruptcy and Barron's article seem to have prompted some re-pricing of the different maturity bonds which benefited the estimation of the model parameters and tightened the confidence bands. Finally, Figure 13 reveals that the recovery rate is characterized with different dynamics than the time evolution of the default probabilities in Figure 11. While the recovery rate remained largely stable (at around 85%) in the first part of the sample, it started to decline noticeably after Detroit's bankruptcy until the summer of 2014 when it stabilized at a level of 30%–40%. The differences in the dynamics of the probability of default and recovery rate are interesting and tend to suggest that they might be driven by different (short-term vs. long-term or informational vs. fundamental) factors.

The figures together also suggest a characterization of the stress in Puerto Rico debt according to the combination of changes in the default probability and recovery rate. For example, during fall 2013, estimated default probabilities were rising as recovery rates were falling, suggesting the most potential for an effect on the broader municipal market. In contrast, the increases in default probabilities in the summer of 2014 coincided with improving recovery rates; and the most recent decrease in recovery rates has been accompanied by decreasing default rates. Both of these dynamics mitigate the potential effect on Puerto Rico debt and to the extent that the market is prompted to reassess other bonds, on the broader municipal market.

5 Conclusions

This paper studies the effect of Detroit's bankruptcy on the market pricing of its municipal debt and assesses whether or not there was contagion to the rest of the opaque, retail investor dominated U.S. municipal bond market. . Our findings suggest that contagion to the broader municipal market has been limited as a whole. Our empirical strategy is based on monitoring structural changes in the municipal bond yield spreads prior, during and after the Detroit's bankruptcy. Interestingly, while Detroit's, Chicago's yields have recorded a statistically significant increase in the summer of 2013, other distressed markets such as Minneapolis, Portland, San Bernardino and Stockton did not appear to be affected at all. All four of these cities have highly underfunded pensions, similar to Detroit, and are in states that allow Chapter 9 bankruptcy filings. The lack of significant repricing may reflect the fact that, at the time, there was still much uncertainty around the resolution of Detroit's pensions, a market assessment that Detroit would receive relief and this might prompt renegotiation with unions in other cities, or a perception that Minneapolis and Portland are 'farther from default' while the two California cities are far enough in the restructuring process (following bankruptcy filings in 2012) to be consider 'done deals'. Importantly, our results also indicate that, after accounting for changes in the underlying Treasury term structure, there is no evidence of contagion via 'headline risk' related to Detroit's bankruptcy filing or Puerto Rico's substantial repricing. This retail investor market seems to have, in broad terms, repriced some securities (i.e. Chicago) that had reasonable similarities to Detroit while not significantly changing its assessment of dissimilar securities. Thus the presence of a largely retail investor base does not appear to necessarily create the conditions for 'irrational' broad market repricing events. Likely this is due in part to the important role that financial advisors play in the investment decisions of their clients. In terms of the broader financial market, our evidence suggests that the distress in Detroit and Puerto Rico debt during 2013-2014 did not affect other asset markets including equities, corporate bonds and U.S.

One interesting avenue for future research is the effect of (lack of) liquidity in the municipal bond market on financial stability. While the diversity of the investors' base disperses the risk among a larger pool of investors, the diversity of municipal bonds could hamper liquidity due to difficulties in matching products with non-standardized characteristics between buyers and sellers. This lack of liquidity is manifested in the data by a large proportion of stale prices and a very low number of trades. As a result, in the event of an adverse shock, the lack of liquidity could prompt earlier sell-offs (i.e., before significant events manifest), especially as institutional investors are becoming more prevalent in the municipal bond market. Quantifying this effect will shed further light on the need for standardization of the municipal bond products and synchronization of the bond issuance.

References

[1] Amromin, G. and B. Chabot (2013), "Detroit's Bankruptcy: The Uncharted Waters of Chapter 9," *Chicago Fed Letter*, 316, Federal Reserve Bank of Chicago.

[2] Anatolyev, S. (2008), "Nonparametric Retrospection and Monitoring of Predictability of Financial Returns," *Journal of Business and Economic Statistics*, 27, 149–160.

[3] Anatolyev, S., and G. Kosenok (2011), "Sequential Testing with Uniformly Distributed Size," CEFIR/ES Working Paper No. 123.

[4] Andreou, E., and E. Ghysels (2006), "Monitoring Disruptions in Financial Markets," *Journal of Econometrics*, 135, 77–124.

[5] Andritzky, J. (2006), *Sovereign Default Risk Valuation: Implications of Debt Crises and Bond Restructurings*, Springer.

[6] Ang, A., V. Bhansali, and Y. Xing (2010), "Taxes on Tax-Exempt Bonds," *Journal of Finance*, 65, 565–601.

[7] Ang, A., and R. C. Green (2011), "Lowering Borrowing Costs for States and Municipalities Through CommonMuni," Hamilton Project Discussion Paper 2011–01, Brookings Institute.

[8] Bai, J. and S. Ng (2004), "A PANIC Attack on Unit Roots and Cointegration," *Econometrica*, 72, 1127–1177.

[9] Bakshi, G., D. Madan, and F. Zhang (2006), "Understanding the Role of Recovery in Default Risk Models: Empirical Comparisons and Implied Recovery Rates," Working Paper, University of Maryland.

[10] Barras, L., O. Scaillet, and R. Wermers (2010), "False Discoveries in Mutual Fund Performance: Measuring Luck in Estimated Alphas," *Journal of Finance*, 65, 179–216.

[11] Bhattacharya, U., A. Hackethal, S. Kaesler, B. Loos, and S. Meyer (2012), "Is Unbiased Financial Advice to Retail Investors Sufficient? Answers from a Large Field Study," *The Review of Financial Studies*, 25, 975–1032.

[12] Brown, R. L., J. Durbin, and J. M. Evans (1975), "Techniques for Testing the Constancy of Regression Relationships over Time," *Journal of Royal Statistical Society B*, 37, 149–163.

[13] Chernozhukov, V., and H. Hong (2003), "An MCMC Approach to Classical Estimation," *Journal of Econometrics*, 115, 293–346.

[14] Chu, C. S. J., M. Stinchcombe, and H. White (1996), "Monitoring Structural Change," *Econometrica*, 64, 1045–1065.

[15] Del Guercio, D., and P. Tkac (2002), "The Determinants of the Flow of Funds of Managed Portfolios: Mutual Funds vs. Pension Funds," *Journal of Financial and Quantitative Analysis*, 37, 523–557.

[16] Duffie, D., and K. Singleton (1999), "Modeling Term Structures of Default Risky Bonds," *Review of Financial Studies*, 12, 687–720.

[17] Federal Reserve Bank of New York (2014), *An Update on the Competitiveness of Puerto Rico's Economy*, July 31, 2014.

[18] Gilchrist, S., and E. Zakrajšek (2012), "Credit Spreads and Business Cycle Fluctuations," *American Economic Review*, 102, 1692–1720.

[19] Gospodinov, N., R. Kan, and C. Robotti (2014), "Misspecification-Robust Inference in Linear Asset Pricing Models with Irrelevant Risk Factors," *Review of Financial Studies*, 27, 2139–2170.

[20] Green, R. C., B. Hollifield, and N. Schürhoff (2007), "Financial Intermediation and the Costs of Trading in an Opaque Market," *Review of Financial Studies*, 20, 275–314.

[21] Green, R. C., D. Li, and N. Schürhoff (2010), "Price Discovery in Illiquid Markets: Do Financial Asset Prices Rise Faster Than They Fall?" *Journal of Finance*, 65, 1669–1702.

[22] Gürkaynak, R. S., B. Sack, and J. H. Wright, (2007), "The U.S. Treasury Yield Curve: 1961 to the Present," *Journal of Monetary Economics*, 54, 2291–2304.

[23] Inoue, A., and B. Rossi (2005), "Recursive Predictability Tests for Real Time Data," *Journal of Business and Economic Statistics*, 23, 336–345.

[24] Jarrow, R., and S. Turnbull (1995), "Pricing Derivatives on Financial Securities Subject to Credit Risk," *Journal of Finance*, 50, 53–85.

[25] Longstaff, F., S. Mithal, and E. Neis (2005), "Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit-Default Swap Market," *Journal of Finance*, 60, 2213–2400.

[26] Ploberger, W., and W. Krämer (1992), "The CUSUM Test with OLS Residuals," *Econometrica*, 60, 271–285.

[27] Schultz, P. (2012), "The Market for New Issues of Municipal Bonds: The Roles of Transparency and Limited Access to Retail Investors," *Journal of Financial Economics*, 106, 492–512.

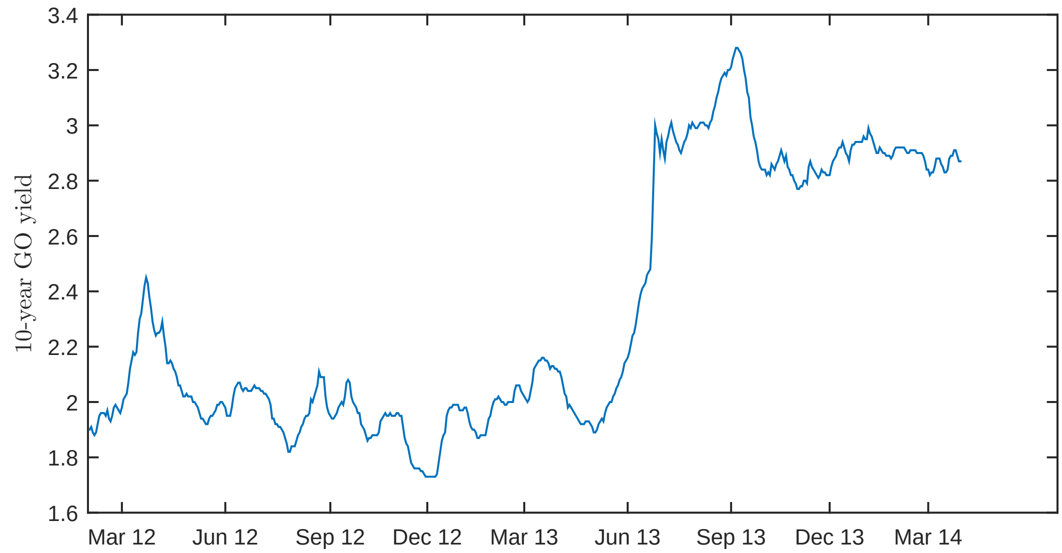
[28] Stock, J. H., and M. W. Watson (2002), "Forecasting Using Principal Components from a Large Number of Predictors," *Journal of the American Statistical Association*, 97, 1167–1179.

[29] Zeileis A., F. Leisch, C. Kleiber, and K. Hornik (2005), "Monitoring Structural Change in Dynamic Econometric Models," *Journal of Applied Econometrics*, 20, 99–121.

Table 1. Estimation results from a VAR(1) model of returns on long-term corporate bonds (r^{corp}), long-term government bonds (r^{lgov}), medium-term government bonds (r^{mgov}), municipal bonds (r^{muni}) and S&P500 index ($r^{s\&p}$).

	r_t^{corp}		r_t^{lgov}		r_t^{mgov}		r_t^{muni}		$r_t^{s\&p}$	
	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat
(1)					1953:2-2013:12					
r_{t-1}^{corp}	0.057	0.739	0.064	0.733	0.089	1.970	0.579	4.731	0.281	2.110
r_{t-1}^{lgov}	-0.062	-0.795	-0.214	-2.460	-0.041	-0.908	-0.092	-0.753	-0.192	-1.446
r_{t-1}^{mgov}	0.404	3.623	0.539	4.256	0.144	2.208	0.916	5.156	0.131	0.676
r_{t-1}^{muni}	-0.017	-0.659	-0.005	-0.186	-0.019	-1.337	-0.078	-1.973	0.068	1.586
$r_{t-1}^{s\&p}$	-0.078	-3.450	-0.101	-3.929	-0.068	-5.112	-0.079	-2.192	-0.002	-0.049
R^2	0.058		0.050		0.062		0.244		0.023	
(2)					1953:2-1989:12					
r_{t-1}^{corp}	0.041	0.360	0.149	1.174	0.204	2.827	0.549	2.734	0.158	0.800
r_{t-1}^{lgov}	-0.078	-0.748	-0.331	-2.837	-0.077	-1.165	0.108	0.587	-0.229	-1.267
r_{t-1}^{mgov}	0.525	3.643	0.640	3.958	0.123	1.335	1.019	3.988	0.415	1.651
r_{t-1}^{muni}	-0.020	-0.647	-0.020	-0.594	-0.049	-2.528	-0.117	-2.176	0.108	2.038
$r_{t-1}^{s\&p}$	-0.087	-2.975	-0.076	-2.333	-0.060	-3.237	-0.185	-3.595	-0.024	-0.475
R^2	0.087		0.062		0.073		0.295		0.044	
(3)					1990:1-2013:12					
r_{t-1}^{corp}	0.032	0.283	-0.011	-0.087	0.011	0.203	0.488	3.602	0.261	1.372
r_{t-1}^{lgov}	0.011	0.085	-0.101	-0.715	-0.003	-0.047	-0.038	-0.253	0.008	0.038
r_{t-1}^{mgov}	0.176	0.887	0.370	1.659	0.084	0.868	0.359	1.522	-0.406	-1.225
r_{t-1}^{muni}	-0.020	-0.421	-0.002	-0.028	0.016	0.674	-0.018	-0.308	-0.023	-0.286
$r_{t-1}^{s\&p}$	-0.067	-1.764	-0.125	-2.927	-0.077	-4.181	0.046	1.026	0.029	0.453
R^2	0.027		0.046		0.079		0.199		0.018	

Figure 1: 10-year GO bond index yield (top graph) and yield spread between 10-year GO bond index and 10-year U.S. Tresury note (bottom graphs). Both series are in percentage points.



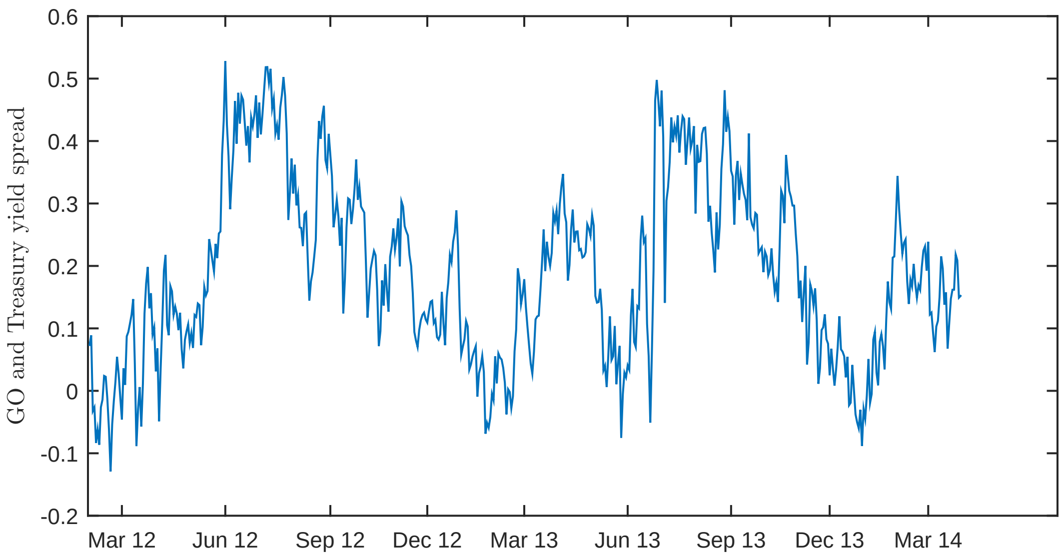


Figure 2: Percentiles (5th, 50th and 95th) of the distribution of municipal bond spreads (over their synthetic risk-free equivalents). The dates of Detroit's notice of default on GO debt (June 14, 2013) and Detroit's Chapter 9 bankruptcy filing (July 18, 2013) are denoted by vertical (magenta and black) lines.

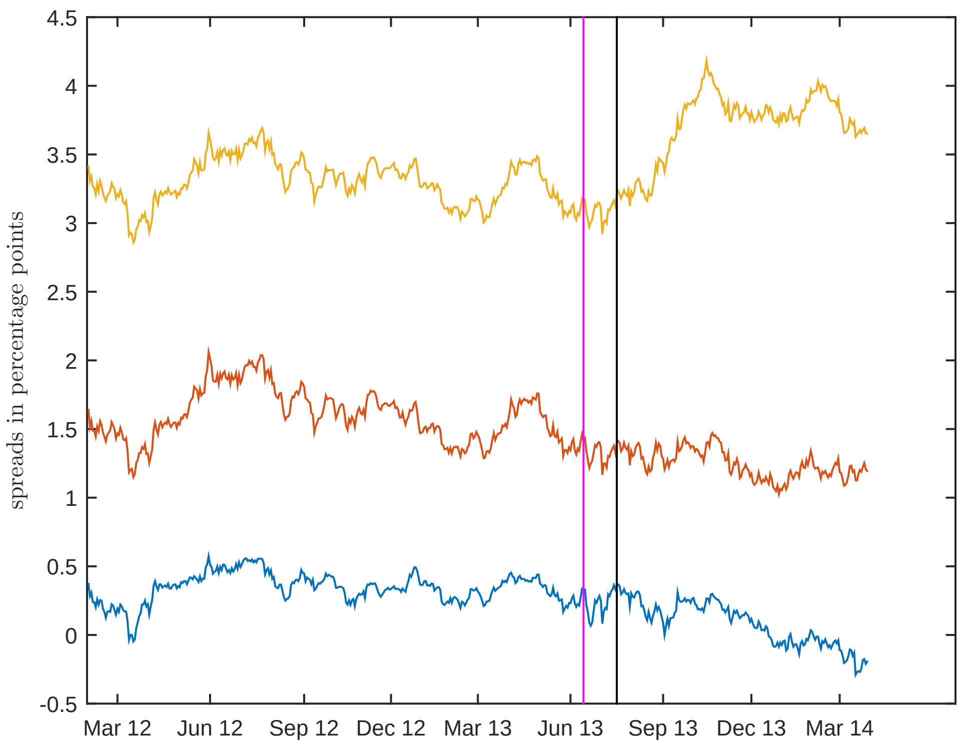


Figure 3: Standardized first municipal bond spread factor and yield on 10-year Treasury note.

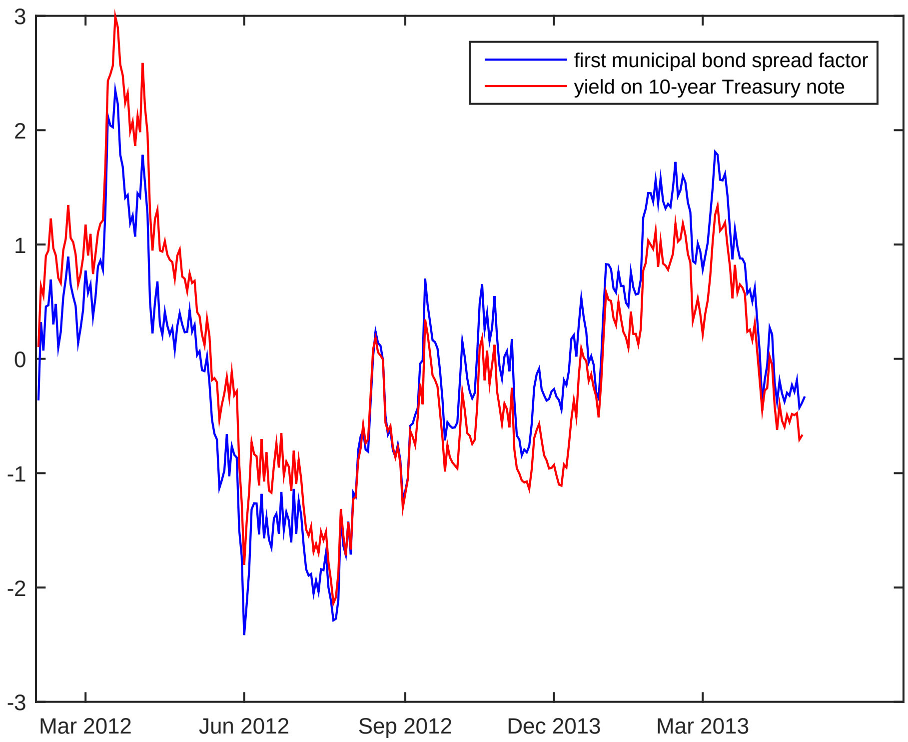


Figure 4: Standardized second municipal bond spread factor and yield on 5-year GO municipal bond index.

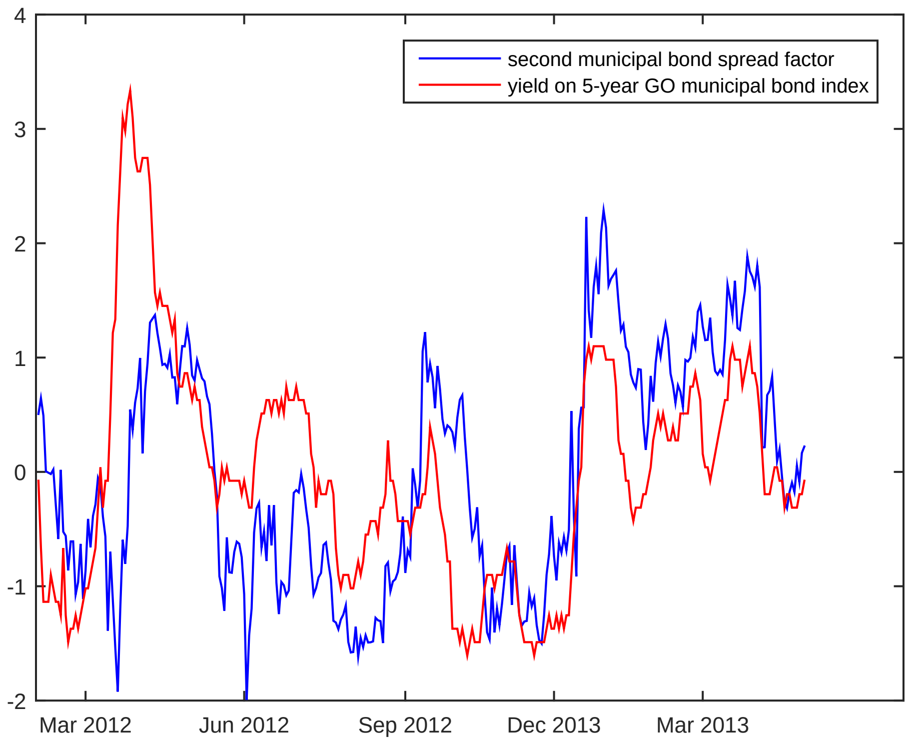


Figure 5: Monitoring of municipal bond yield spreads by state using the CUSUM test. The figure plots cumulative abnormal yield spreads and the 1% boundary (blue line). Crossing the boundary from below indicates structural change in the post-estimation path of the series.

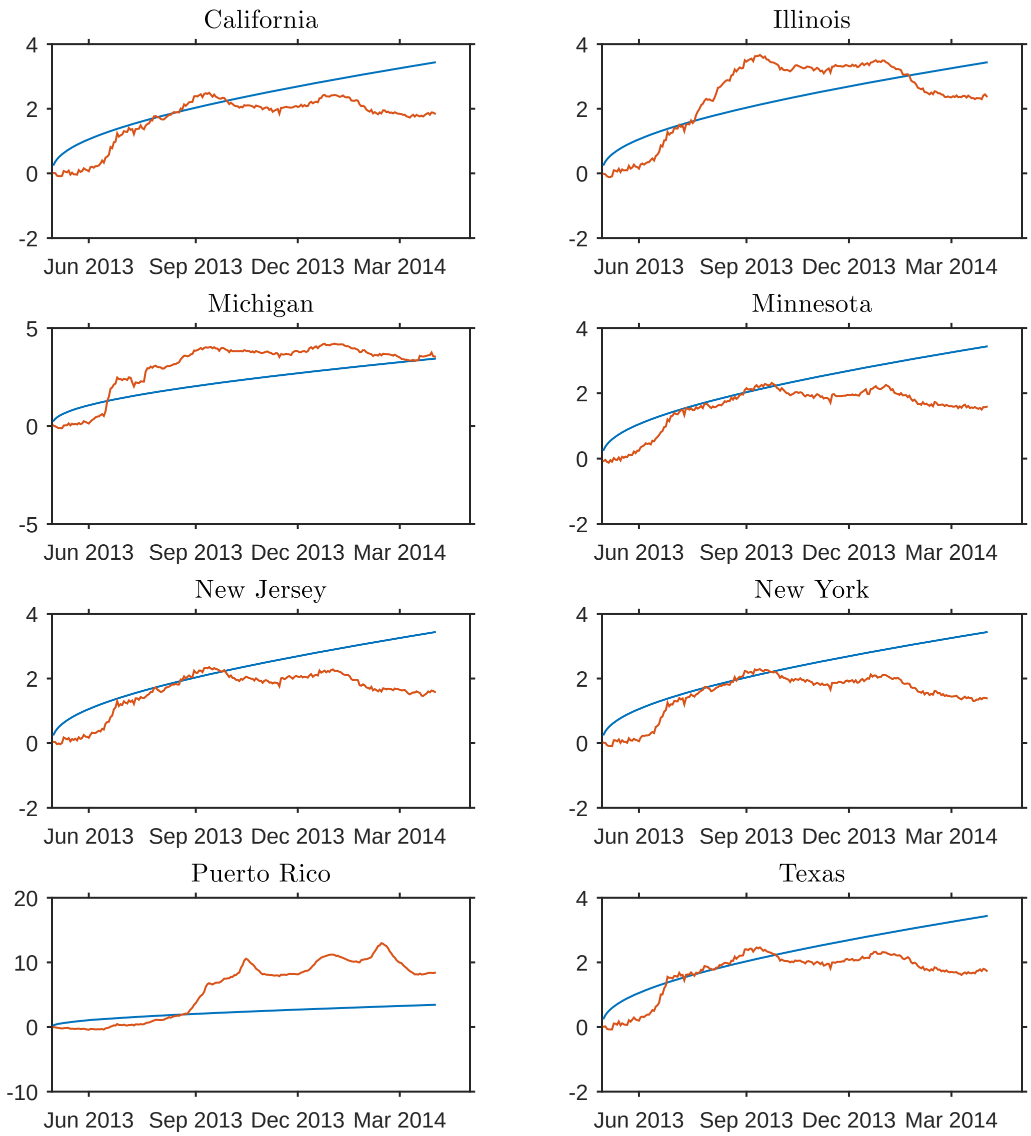


Figure 6: Monitoring of municipal bond yield spreads by rating using the CUSUM test. The figure plots cumulative abnormal yield spreads and the 1% boundary (blue line). Crossing the boundary from below indicates structural change in the post-estimation path of the series.

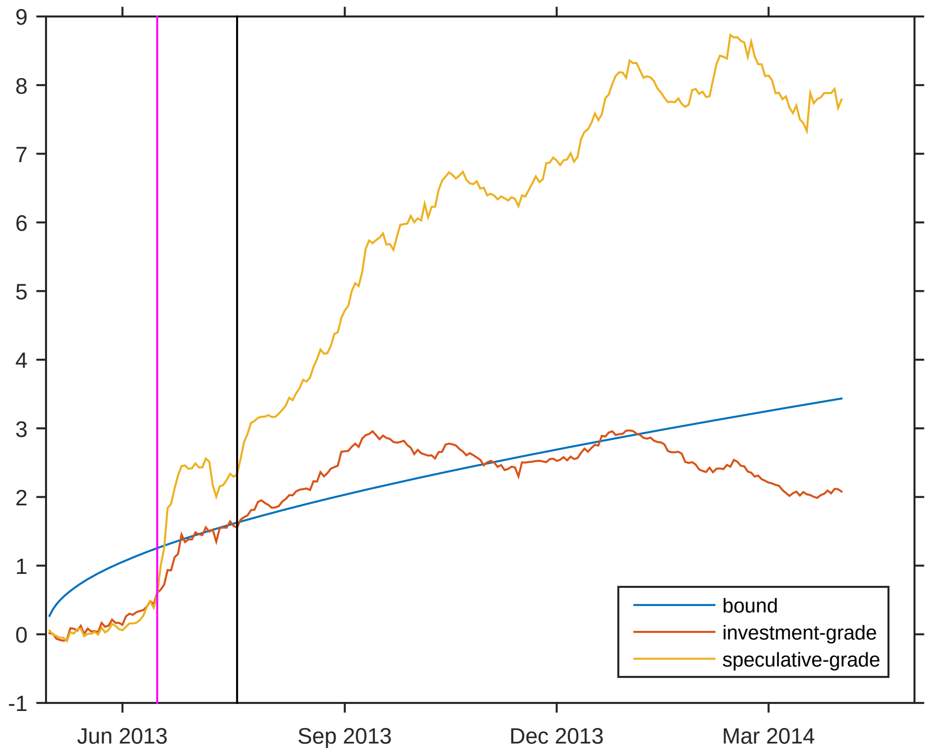


Figure 7: Monitoring of municipal bond yield spreads by issue type using the CUSUM test. The figure plots cumulative abnormal yield spreads and the 1% boundary (blue line). Crossing the boundary from below indicates structural change in the post-estimation path of the series.

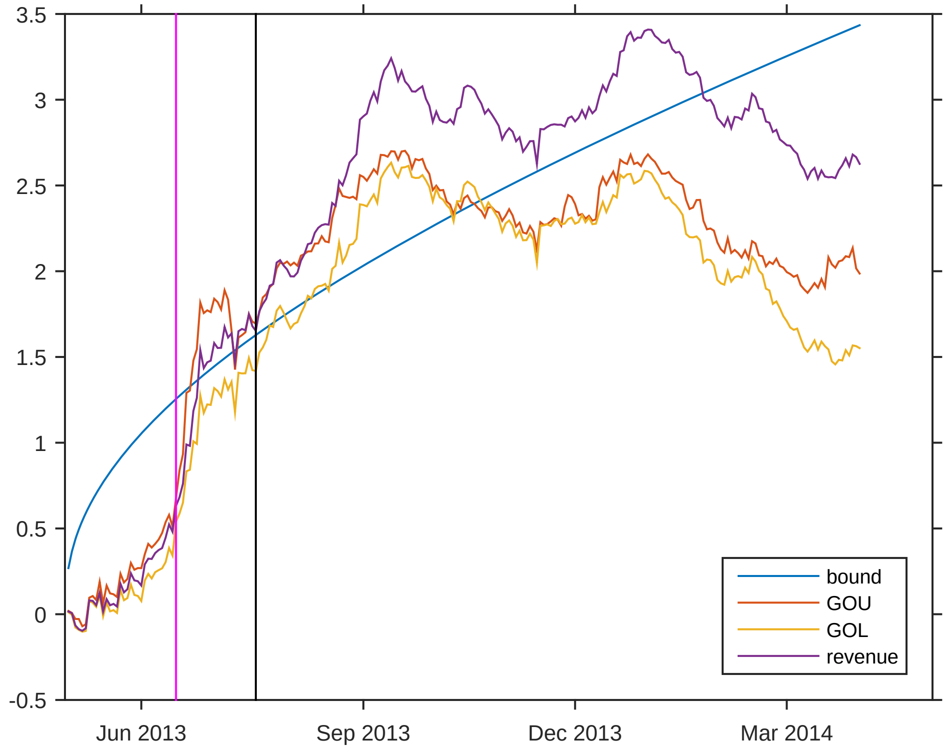


Figure 8: Monitoring of municipal bond yield spreads by industry using the CUSUM test. The figure plots cumulative abnormal yield spreads and the 1% boundary (blue line). Crossing the boundary from below indicates structural change in the post-estimation path of the series.

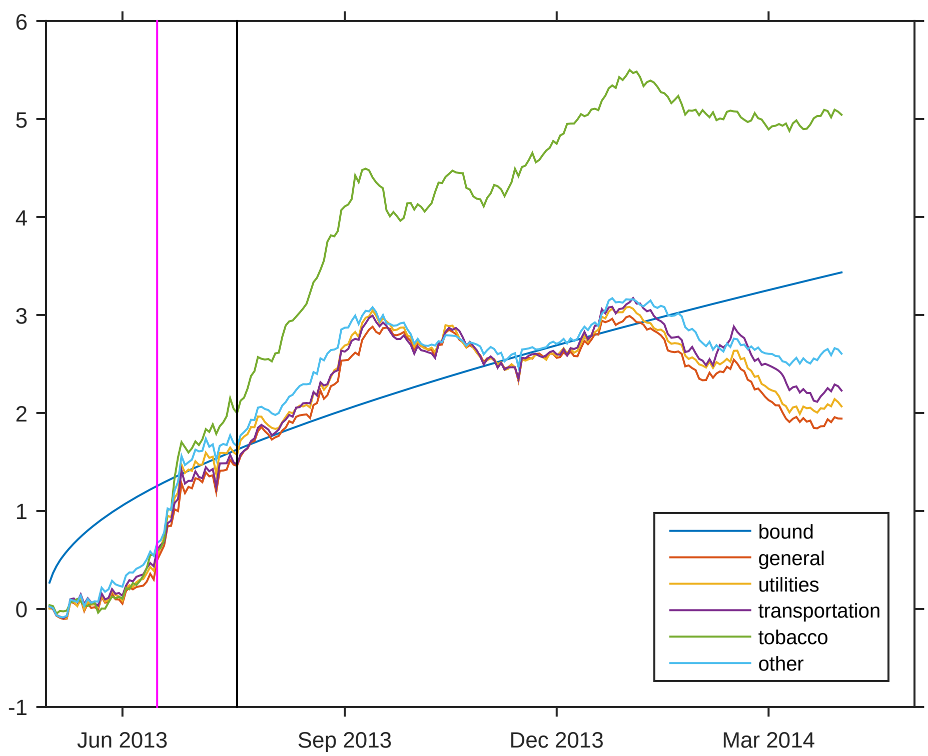


Figure 9: Monitoring of distressed market yield spreads using the CUSUM test. The figure plots cumulative abnormal yield spreads and the 1% boundary (blue line). Crossing the boundary from below indicates structural change in the post-estimation path of the series.

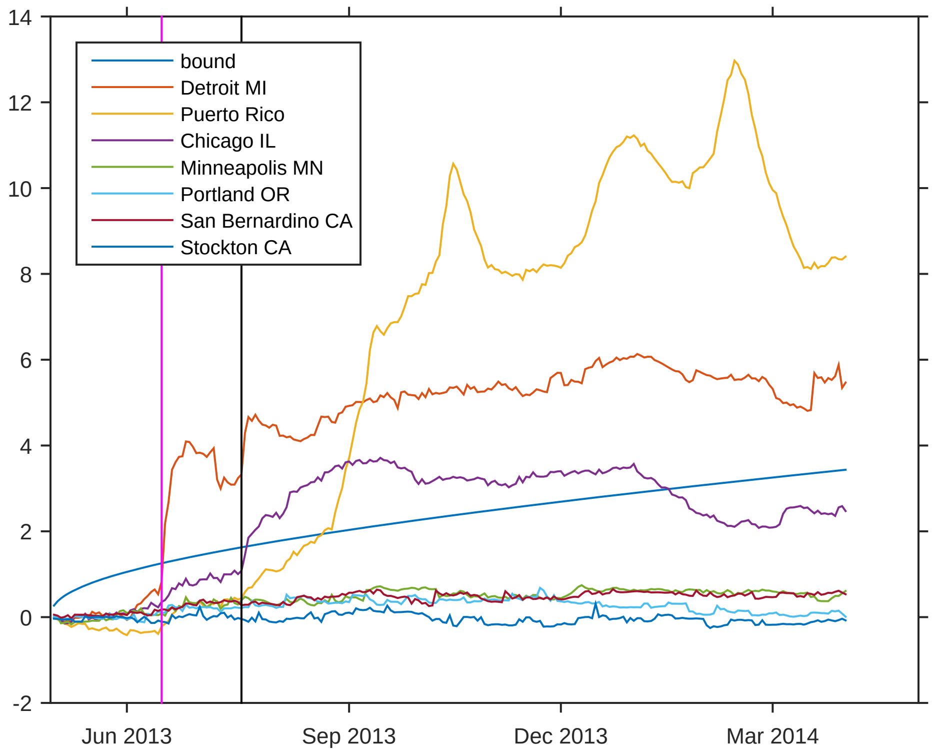


Figure 10: Rolling correlation coefficients of various municipal bond yield spreads with Detroit's municipal bond yield spread.

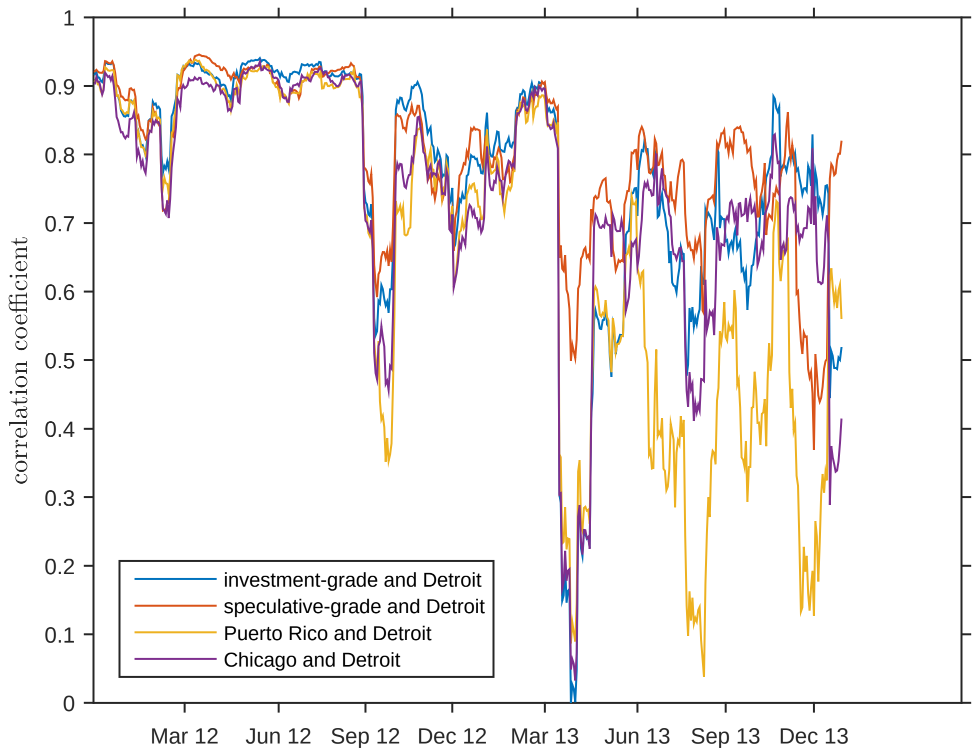


Figure 11: Spline-smoothed estimates of one-, two- and five-year cumulative default probabilities for Puerto Rico bonds.

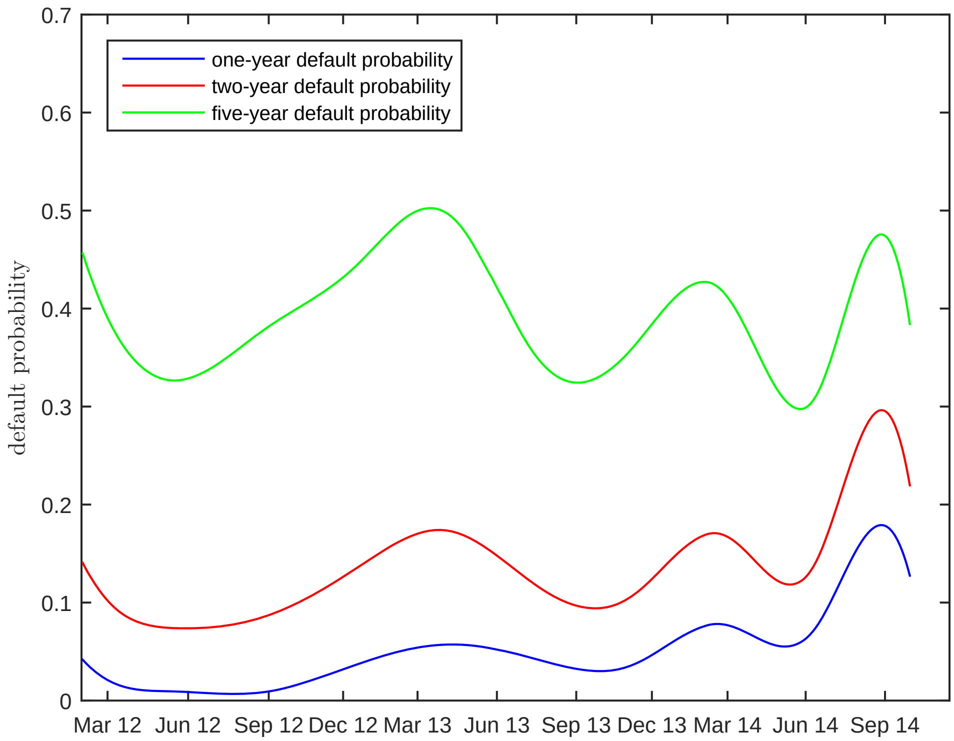


Figure 12: Spline-smoothed estimates and 90% confidence bands of the five-year default probability for Puerto Rico bonds.

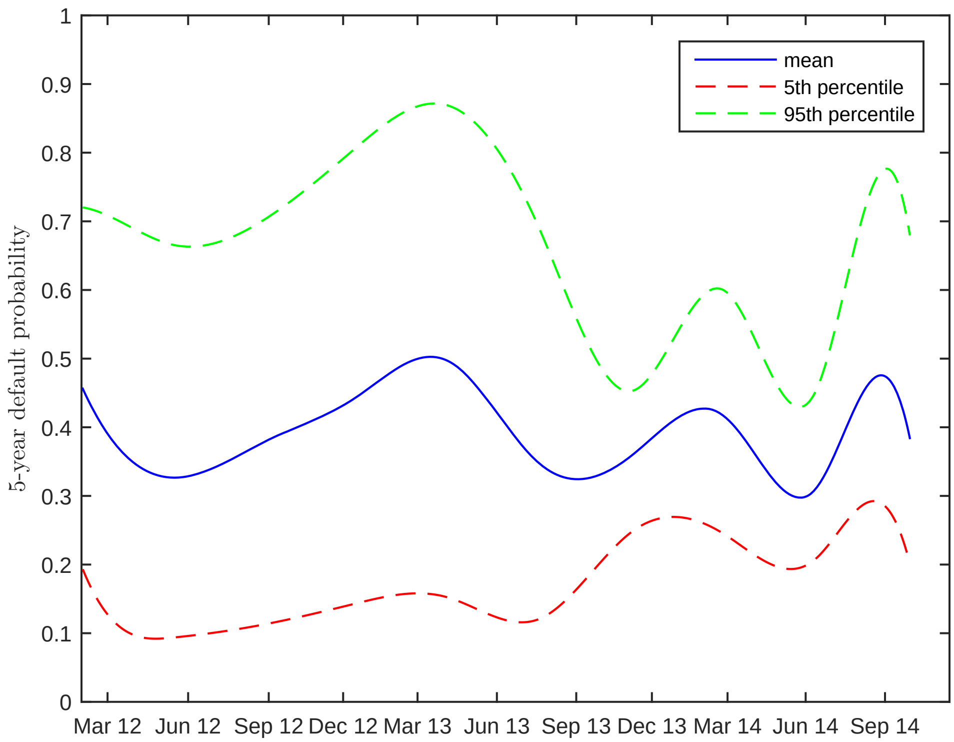


Figure 13: Spline-smoothed estimates and 90% confidence bands of the recovery rate for Puerto Rico bonds.