Fiscal Imbalances and Borrowing Costs: Evidence from State Investment Losses*

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Abstract

During the last quarter of 2008, state pension funds fell in value by approximately $350 billion. Depending on the state, the losses were equivalent to as little as 12% of the own revenue (taxes, fees, and charges) generated by the state government in the previous fiscal year, or as much as 68%. We quantify a sovereign default channel in the state municipal market by examining how changes in bond spreads vary with state pension fund losses, controlling for credit ratings and various measures of the state's fiscal strength. Municipal bond spreads rose by 7-15 basis points for each 10% of state-generated revenue lost by states in the lower half of the credit quality spectrum.

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Fiscal imbalances in the U.S. have emerged at all levels of government. These imbalances have raised the question of how expensive it will be for governments to finance large deficits, should they persist in the future. At the national level, this debate manifested itself in 2009 in expressions of doubt by Chinese Prime Minister Wen Jiabao regarding the credit quality of U.S. Treasury bonds, and writings about the possible impact of this doubt on bond markets and the economy (Auerbach and Gale (2009)). At the state and local level, analysts have voiced concerns about the credit quality of municipal debt, whose spreads relative to Treasuries rose dramatically when monoline insurers suffered losses during the credit crisis (Roubini (2008)).

A great deal of literature in macroeconomics has focused on understanding the theoretical relation between deficits and interest rates. The literature arguing that deficits matter has focused on models in which deficits affect interest rates because they crowd out private savings, which reduces the capital stock (Modigliani (1961), Feldstein (1974)). In open economies, these effects are weaker. If Ricardian equivalence holds then they are absent (Barro (1989)). Empirical work that connects deficits and interest rates has focused on this traditional channel (see Engen and Hubbard (2004) and Gale and Orszag (2004)).

In contrast, relatively little research has attempted to estimate the effects of fiscal imbalances on borrowing costs through the channel of higher probabilities of default. This "sovereign default" channel (Eaton and Gersovitz (1981), Bulow and Rogoff (1989a, 1989b)) is about the effects of potential repudiation on national or state borrowing costs, and therefore only indirectly about macroeconomic interest rates. Higher borrowing costs are important, however, as they require that more taxpayer money be dedicated to servicing debt, and tie the hands of government if it needs to borrow further in times of crisis (Goolsbee (2007)).

Empirical work on the impact of deficits on the economy has largely focused on time-series analysis. It has faced the challenge of measuring market projections of future federal debt and deficits, as these projections will affect current equilibrium borrowing rates. Furthermore, it is difficult to find cross-sectional variation that is useful for disentangling the simultaneous relationship between government actions and economic variables.

This paper attempts to fill this gap by examining variation across U.S. states in the extent and importance of state-sponsored pension fund investment losses during the last quarter of 2008. When a U.S. state suffers an investment loss in a state-sponsored pension fund, the increased funding gap represents an increase in an unfunded state liability. Given the protections that state constitutions offer to the pensions of public employees, public pension promises are generally at least as senior as state general obligation bonds. Indeed, many states have either constitutional guarantees of pension promises or statutory laws protecting them, and events from past municipal debt crises suggest that pension claims are usually preserved even when the positions of bondholders are impaired (Brown and Wilcox (2009)). As a result, each dollar lost in an underfunded pension fund represents an additional dollar of senior unsecured debt.

We find that for each 10% of annual state-generated revenue lost in pension funds during this period, municipal bond spreads rose by approximately 7 basis points for states rated AA by S&P, and by approximately 15 basis points for states rated AA– and below. Our main results focus on the losses as a percent of the total revenue actually generated by the state through taxes, fees, and charges. That is, the main revenue measure is "total own revenue" which excludes any impact of pension fund earnings and also excludes intergovernmental revenue such as transfers from the federal government.[1] Analogous results hold when the losses are scaled by revenue

[1] In this paper we use the terms stated-generated revenue and own revenue interchangeably to refer to total revenues excluding pension investment trust fund returns and intergovernmental revenue.

including intergovernmental transfers, or by Gross State Product (GSP). Consistent with our hypotheses, we find no effect of the losses in the states that have ratings better than AA.

We choose to investigate this time period because the amount of money lost in state pension funds during this quarter was substantial relative to the amount of state municipal debt outstanding. In the last quarter of 2008, we estimate that assets in pension funds sponsored by U.S. states fell in value by approximately $350 billion, equal to 35% of the $1.00 trillion in total outstanding municipal bond debt at the state level. As a result, during this 3-month period, state municipal bond investors as a group effectively faced the appearance in the state's debt structure of a new, likely senior, off-balance-sheet debt equal to 35% of their existing positions. No other recent time period for which data are available offers this degree of variation.

Importantly, there was substantial cross-sectional variation in the losses across state funds during the last quarter of 2008. For example, West Virginia lost only 12.3% of the revenue it had generated in the fiscal year that ended in June 2008. In contrast, Ohio lost 66.3% of its total own revenue from the fiscal year that ended in June 2008, and Oregon lost 67.8%.[2] Merely observing that municipal bond spreads rose in aggregate during this period would not allow us to conclude that the increase in spreads, and hence state borrowing costs, is due to a sovereign default effect. Many other events were happening simultaneously, including a flight to the quality and liquidity of Treasury bonds and a general deterioration of state and federal public finances. Comparing the change in spreads between the states that were not as affected by the pension fund losses and the states that were more affected eliminates these macroeconomic effects.

The state-level variation comes from three sources: 1.) size of the state employee pension funds relative to the state's economy or revenue base; 2.) the extent to which those promises

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[2] As a percentage of tax revenue alone (that is, excluding fees and charges for state services), Ohio and Oregon lost more than 100% of the entire previous fiscal year of tax collections.

were funded as of September 2008; and 3.) the asset allocation pursued by the state funds. States with larger total pension liabilities relative to their economies or revenue bases, states that have higher funding ratios for a given liability, and states that took greater risk with those assets were therefore more exposed.

We take particular care to address two potential sources of omitted variables bias. First, states with larger unfunded pension liabilities or riskier asset allocations might also have experienced larger economic shocks for reasons unrelated to the pension funding. We find that the results hold within credit rating classes, and they are robust to controlling for the actual drop in state-generated revenue between 2008 and 2009, the historical sensitivity of state revenues to changes in GSP, the size of state pension liabilities, and the amount of state debt. Second, there may have been other bond market factors, such as liquidity premia or the effects of flight to quality, that changed differentially for states hit by the pension shocks. To address these other sources of potential heterogeneity, we use as a control sample pre-refunded bonds, which are bonds that the state has secured to a call date against escrowed Treasury bonds (Chalmers (1998)). If pre-refunded bonds differ from a state's other bonds only in that they do not reflect default risk, then they are a useful control for other omitted factors. Indeed, we find the spreads on pre-refunded bonds are not affected by the pension shocks. To further address cross-sectional variation in changes in the liquidity premium, we also control in all specifications for the size of the issue.

Our analysis is based on pricing data from 15,727 municipal bonds, from which we calculate yields based on bond characteristics. An important technical issue is the treatment of call features in the bonds. To address the fact that many bonds in our sample are callable, we option-adjust the yield spreads we employ in our regression, so that these reflect states' true fixed-rate borrowing costs over horizons equal to the bonds' durations, and not the costs of states maintaining refinancing rights.

Another important issue for the interpretation of the results as increases in state borrowing costs is the fact that the interest on the bonds is tax-exempt for the owner of the bond. The results therefore reflect the increase in the borrowing costs faced by the state alone. That is, they exclude the increase in the cost of the federal government subsidy. To reflect the increase in the marginal cost of new state borrowing inclusive of the cost of the federal government subsidy, the spreads would have to be grossed up by the tax rate of the marginal investor.[3]

The results are also informative about the risk-neutral default probabilities and recovery rates implied in municipal bond prices. As in Duffie and Singleton (1999), changes in bond spreads can be due to: 1.) changes in default probabilities; 2.) changes in the price of a contingent claim in the default state of the world (the "state prices"); or 3.) changes in the market's estimation of recovery rates if the borrower defaults. If recovery rates in default were unchanged, our yield spread results could be interpreted as revealing the increase in risk-neutral (or "subjective") default probabilities, which incorporates both objective probabilities and state prices. For example, consider the 7-15 basis point increase in the yield spread that we find is related to each 10% of state-generated revenues lost during this period. Ignoring the tax treatment of capital losses, the spread increase would be consistent with a 7-15 basis point increase in risk-neutral annual default probabilities assuming no recovery in default, or a 15-30

[3] Poterba and Verdugo (2008) present evidence that the tax rate implied by muni bond prices is approximately 25%. The effect of adjusting the yield spreads upwards by 25% for taxes would therefore be to raise the coefficients by 1/(1-25%) or 4/3rds. Some authors conclude that the marginal investor in municipal bonds has much higher tax rates. In particular, Longstaff (2009) derives a rate of 41.6% based on an affine term-structure model, and Ang, Bansali and Xing (2010) find rates of 75% or even 100% based on the trades of market participants in market-discount bonds.

basis point increase in risk-neutral annual default probabilities assuming the market expected a 50 percent recovery rate in default.

In interpreting the results as changes in implied risk-neutral default probabilities and recovery rates, it must also be recognized that capital gains on municipal debt are taxable, and capital losses are tax deductible to the extent allowable under applicable law. As a result, a given change in yield spreads correlates with a somewhat higher change in risk-neutral default probabilities.

The magnitude of losses during the event period we study is only modestly large. A loss of even 50% of a year's tax revenue is not likely to be catastrophic for a solvent state. However, the magnitude of the effect of these losses on yield spreads indicates that prices in the market for state municipal bonds do at least to some degree reflect default probabilities. This implies that U.S. state borrowing costs will likely increase if unfunded state liabilities continue to grow, making state debt more expensive to finance. We note that if an increased borrowing cost exactly matches the increase in the state's valuable option to default, then states might not care that they face higher borrowing rates. However, to the extent that the state bears costs of financial distress in the event of a default, the default option may well be more of a concern to markets than it is a value to the state.

This paper proceeds as follows. Section I explains relevant institutions and reviews literature. Sections II and III describe the empirical design and data respectively. Section IV explains the calculation of option-adjusted yields from bond prices; the yields reflect states' true fixed-rate borrowing costs and serve as our main dependent variables. Section V discusses the main results. Section VI concludes.

I. Institutional Background and Literature Review

The main objective of this paper is to measure and interpret the change in municipal bond yields that results when state sponsors suffer large investment losses. As such, there are several areas where an explanation of existing literature and institutional details are required.

A. *Municipal Bond Markets*

Municipal bonds are bonds issued by sub-national government entities, including U.S. states. The primary distinction in the modern era between municipal bonds and sovereign bonds is that issuers of municipal finance do not have the ability to control the circulation of the currency in which their debt is denominated. Sovereign entities can effectively repudiate debt denominated in local currency by allowing inflation; and since national governments also typically control statistical offices, there may even be scope for manipulating indices that underlie inflation-indexed debt. States and municipalities do not have the capacity to "inflate away" their debts, although such debts do fall in value if inflation happens on a national scale.

The last state default to occur was Arkansas during the Great Depression in the 1930s. The most significant round of repudiation of state indebtedness happened following the extreme circumstances of the Civil War, in which at least 13 states defaulted (Spiotto (2007)). While institutions such as credit rating agencies and municipal bond insurance have developed since these times for the purposes of protecting investors, occasional county and city-level defaults and the recent financial crisis have exposed the limits of the protections these institutions afford. As a result, some of the default considerations that have arisen in the literature on sovereign defaults may now be relevant for municipal bonds.

The literature on municipal bonds has focused on the impact of their tax treatment on their prices and yields. Interest on U.S. municipal bonds is exempt from federal taxation as long as the bonds meet certain legal requirements. Finance theory going back to Miller (1977) has posited that after-tax yields from comparable taxable and tax-exempt bonds should only differ by the tax rate of the marginal municipal bond investor. A large literature has attempted to measure the tax rate implicit in municipal bonds (Poterba (1986), Green (1993), Poterba and Verdugo (2008), Ang, Bhansali, and Xing (2008), Longstaff (2011), among others) and to understand why the yields on long-term tax-exempt debt were historically quite high relative to the yields on long-term Treasury bonds (Trczinka (1982), Green (1993), Chalmers (1998, 2006)). Municipal bonds may differ from each other and from Treasuries in their liquidity, which is a leading hypothesis to explain the "muni puzzle."

Municipal bonds may differ in whether they are secured by specific projects, whether they are callable, whether they are insured (Nanda and Singh (2004), Bergstresser, Cohen and Shenai (2010)), and whether they have been pre-refunded (Chalmers (1998)). When a bond is pre-refunded (or "advance refunded"), new securities are issued and the proceeds are invested in Treasuries and placed in an escrow account to defease the existing obligation until the call date, when issue will be redeemed.[4] Pre-refunded municipal bond spreads are therefore very unlikely to reflect default risk.

This literature informs important choices we make in our analysis. First, we limit the analysis to general obligation (GO) municipal bonds, which are not secured by any special purpose revenue. Second, we consider call features in calculating yield spreads. Third, pre-refunded bonds (16% of our sample) serve as a useful within-state control group, as they should be unaffected by default risk but may capture other sources of changes in yields at the state level

[4] Pre-refunding is thus a mechanism by which states can take advantage of falling borrowing costs or can effectively call bonds before their call dates. Tax law generally allows issuers to invest the proceeds at any yield that is as high as the municipal yield, though not higher (Wood (2008)). Such a transaction was common when Treasury yields were above municipal yields — by using bonds of different maturities states could match the received muni yield with the Treasury bond yield and thus refinance before the call date.

that are unrelated to default risk. For example, they will capture cross-state differences in liquidity premia, if within a given state the liquidity premia tend to move together for bonds that are pre-refunded and bonds that are not pre-refunded.

B. *The Security of State Pension Promises*

In a typical defined benefit (DB) pension plan, an employer pledges an annual pension payment that is a function of the employee's final salary and years of employment. Most states have at least one DB plan for teachers and another for general state employees. Some states have one combined plan for all state employees. Many have a number of smaller plans. While the US corporate sector has moved away from DB plans and towards defined contribution (DC) arrangements such as 401(k) plans, the public sector has seen limited movement in this direction.[5]

Under standards established by the Government Accounting Standards Board (GASB), the reported present value of pension liabilities at the state level currently depends on the expected return on the public pension assets, usually around 8%. Novy-Marx and Rauh (2009, 2011) have found that while unfunded pension liabilities at the state level are approximately $1 trillion using state government accounting, discounting only the already-accrued promised cash flows at zero-coupon Treasury rates with the same terms (i.e., maturities) results in unfunded liabilities of approximately $3 trillion. Many states contain constitutional guarantees that effectively give pension obligations high priority in the state's debt structure, and it seems that accrued pension promises have always been honored in municipal debt crises (Brown and

[5] The Government Accounting Office (GAO) in late 2007 reported that only Alaska and Michigan offered new employees in their "primary pension plan" a DC arrangement but not a DB arrangement, while Indiana and Oregon offered a hybrid plan; all other states offered only DB plans to new employees in their primary plan. Finally, according to data from the Pensions and Investments (P&I) survey of the 1000 largest pension plans, the total magnitude of DC assets was $83 billion, compared to $2.3 trillion in DB assets.

Wilcox (2009)).[6] Given state guarantees, legally accrued pension liabilities are a risk-free claim. Discounting using Treasury rates yields the amount of extra funding needed now to fully fund these liabilities.[7]

Another important question is what counts as a promised benefit. In this paper, we control for pension liabilities using the measure called the Accumulated Benefit Obligation (ABO). The ABO consists only of liabilities already accrued by workers for service to date, promises that most clearly threaten the seniority of state general obligation bonds.

Whether pensions would take strict priority over bonds in a true state debt crisis remains a matter that is yet to be tested. However, given the important position of public-employee pension obligations in the seniority hierarchy, increases in unfunded pension liabilities are a serious concern for municipal bond investors.[8]

C. *The Sovereign Default Channel in Previous Literature*

The large empirical literature examining the macroeconomic channel is summarized Engen and Hubbard (2004) and Gale and Orszag (2004).[9] On the other hand, the empirical literature on the default channel in the US is limited. We are not aware of papers that attempt to measure the effect of sovereign default probabilities on bond yields for US states. There is a small literature on state public finances and how they affect state borrowing costs. Poterba and

[6] Brown and Wilcox (2009) highlight the states with the most and fewest protections. The true stance of many states in the middle may not yet have been tested through court cases, so that variation in these protections does not represent a useful source of identifying variation for our tests. Our results are in any case robust to the exclusion of the states mentioned by Brown and Wilcox (2009) as having particularly weak protections.

[7] There are some caveats. Treasury rates include an inflation-risk premium (Fisher (1975), Barro (1976)), which is generally positive, and likely additionally contain a liquidity discount (Duffie and Singleton (1997), Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2008)).

[8] It should be noted that full funding of pensions may or may not be optimal for a number of reasons (see Novy-Marx and Rauh (2009), Bohn (2011)). In this paper the important issue is that pension and non-pension debt could eventually compete for state government resources.

[9] One of the primary challenges is measuring innovations in government policy that are not foreseen by markets (Plosser (1982, 1987)).

Rueben (2001) find that unexpected state deficits were correlated with higher state bond yields during the 1990s, though this effect was smaller for states with tight balanced-budget rules.

The notion that borrowing rates should be higher when the lender faces a higher probability of default and/or a lower recovery rate is as old as the existence of credit markets. A theoretical literature on the sovereign default channel begins with the observation in Eaton and Gersovitz (1981) that governments might repudiate their external debts even if they are fully able to pay them. Bulow and Rogoff (1989b) argue that the reputation to repay is insufficient to support borrowing by risky sovereign entities and that legal rights of the creditors are most important. Duffie, Pedersen, and Singleton (2003) undertake explicit modeling of borrowing rates and their term structure as a function of the dynamics of the sovereign's option to either repudiate or restructure debt.

II. Hypothesis and Empirical Design

The fundamental question in this paper is to what extent losses in state pension funds during 2008Q4 affected borrowing costs. These losses caused a sudden increase in the net unfunded liabilities of the affected states.

The analysis begins by examining bivariate relations between the behavior of bond *i* during 2008Q4 and the investment losses experienced by the pension fund of the issuing state *s(i)* during the same period. Formally:

$$Y_i = \alpha + \beta * \frac{Loss_{s(i)}}{Own\ Revenue_{s(i)}} + \varepsilon_i$$

where Y_i is either the holding period return or the increase in the spread over comparable duration Treasuries for bond *i* during 2008Q4. The pension investment loss, $Loss_{s(i)}$, is scaled by state revenue for fiscal year 2008, which for all the states in our sample ended before the period over which we measure the losses. When Y_i is bond holding period returns, we expect $\beta<0$, whereas when Y_i is spread increases we expect $\beta>0$.

The pension investment loss $Loss_{s(i)}$ is a function of 1.) the amount of assets that were in state funds ex ante; and 2.) the extent to which these assets were invested in securities that lost money during the quarter. We decompose investment performance into these two pieces and examine the bivariate relation that each of these components has with performance. Specifically, we estimate the above bivariate regression first using just the allocation to riskier assets as the dependent variable and then using only the level of assets in the pension fund as the dependent variable.

While our specifications include controls for pension liabilities at the beginning of the period, we do not exploit variation by state in the value of these liabilities during the time period. Since the duration of the liabilities has been found to be quite similar across states, we expect there to be little cross-sectional variation in this effect.

If investment losses in fact caused lower bond returns (larger spread increases), both risk allocation and size of the assets in the fund should be correlated with the bond returns. Such analysis, however, is only suggestive in the absence controls for factors that might be correlated with risk allocations and pension fund performance. We focus on two major sources of omitted variables bias.

First, states that take more risk in pension funds could in theory be states whose economies are more sensitive to the economic cycle.[10] In that case, both pension investment values and bond prices would decline in a recession, even with no direct effect of pension fund returns on state bond returns. Similarly, states with large pension investment portfolios could be

[10] Standard risk management theory would predict the opposite, namely that the more cyclical states are precisely the ones that should allocate a larger share of assets to less market-sensitive securities.

states whose economies are more sensitive to economic cycles.[11] Thus, it is important to control for the size of economic shocks in the analysis.[12]

Second, changes in liquidity are another potential source of omitted variables bias. Here the concern would be that states with the greatest pension losses also had bonds that experienced the greatest loss of liquidity during the flight to Treasuries that happened in this period. Then in the absence of further controls one might falsely attribute increasing yield spreads to default risk, when in fact these might reflect these states' greater exposure to liquidity risk.[13]

We address these potential omitted variables bias in several ways. First, we estimate difference-in-difference specifications within ratings categories. This means that any confounding factors affecting both pension investment returns and yield changes would have to be operating within credit ratings categories for the identification strategy to be invalid. This address the concern that states with bad investment returns are just “worse states”. It also makes the liquidity hypothesis somewhat less likely. Formally, define Y_i as the change in the bond spread and $X_{s(i)}$ as the scaling variable, which in the results we present is *Own Revenue*$_{s(i)}$. We then estimate:

$$Y_i = \alpha + \beta_1 \left[\frac{Loss_{s(i)}}{X_{s(i)}}\right] + \beta_2 [AA\ or\ Below] + \beta_3 \left[\frac{Loss_{s(i)}}{X_{s(i)}} * AA\ or\ Below\right] + \mathbf{Z}_i + \varepsilon_i.$$

The coefficient of interest is β_3, the effect of the interaction term on changes in bond spreads, and this coefficient is expected to be positive: the larger the pension fund investment losses in states with relatively poor credit quality, the larger the increase in spreads should be. For states of relatively good credit quality, the pension fund investment losses should not affect bond spreads.

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[11] Of course, conditional on liabilities, states with larger pension fund assets entering the quarter should be healthier; by itself this factor would move the bias in β towards zero.

[12] Such economic shocks might also have affected state ability to access new borrowing facilities such as Build America Bonds.

[13] We thank the referee for pointing out this possibility.

Furthermore, we also estimate specifications with finer categories that distinguish between states rated exactly AA and states rated AA– or below. The hypothesis is that the worse the state's rating, the more important the pension fund investment losses should be for yield spreads.

The second method we use to address the potential omitted variables bias is to include variables that might control for either the size of the economic shock to states or the liquidity of the bond issue among the $\mathbf{Z}_i$. As controls for the size of the economic shock, we use the historical sensitivity of the state's own revenues to the economic cycle, as well as the actual drop in own revenues that happened between the 2008 and 2009 fiscal years. This addresses the concern that states with large pension fund declines are just states more exposed to the economic cycle. Additionally, we control for the issuing state's total debt and pension liabilities. To control for liquidity, we include the size of the issue as a control.

Third, we perform triple-difference specifications, the bonds that are pre-refunded as a within-state control group. Pre-refunded bonds (16% of our sample) should be unaffected by default risk, but help capture other sources of changes in yields at the state level that are unrelated to default risk, such as liquidity. Using pre-refunded bonds as a control group consequently captures changes in yield spreads that might be due to the flight to quality and not default risk. It is important to note, however, that because pre-refunded bonds should not be affected by the size of the economic shock to the state, they cannot be used to control for these economic shocks.

Another issue to consider is scaling. We scale by total own revenue in this paper, which is total revenue minus intergovernmental revenue (primarily transfers from the federal government) and minus any revenue recognizes as arising from the pension fund returns themselves.[14] Total Own Revenue has the advantage of reflecting the percent size of the revenue increase needed to make the pension whole, and it also covaries strongly with GSP. As we explain in the footnotes of the results section in some detail, the qualitative results are essentially identical when we use total revenue or GSP.

Every state sponsors DB pension plans, but only 39 have nontrivial amounts of traded general obligation debt.[15] As is the case with most empirical exercises, the estimates must be taken as an effect of the treatment on the treated. However, as shown above we take care to perform estimates within credit ratings categories. The reason that 11 states do not have bond debt primarily reflects their strong financial position. These states would likely be rated AAA and as a result would likely be in the control group of states whose credit ratings are strong and that do not see yield spreads increasing in response to pension fund losses of the magnitude experienced during the sample period.

III. Data and Summary Statistics

This section describes the data and presents summary statistics. We also show raw correlations between municipal bond returns and state investment losses.

A. *Data*

For municipal bond data, we use two main sources. The first source is the S&P Municipal Bond CUSIP Master File.[16] This file contains CUSIP identifiers, and the attributes file allows us to determine which bonds are issued by states as opposed to municipalities, as well as which are

[14] Unfunded pension liabilities are off of the states' balance sheets and have only an indirect effect on the state's budgetary income statement, through imputed revenues from and expenditures on employee retirement funds. The imputed revenues primarily consist of investment gains plus contributions from employers other than the state entity, and the imputed expenditures are essentially benefit payments to beneficiaries. See http://www.census.gov/govs/www/06classificationmanual/chapter04.html for further details.

[15] The states that are excluded from the sample due to a lack of debt are Arizona, Colorado, Idaho, Indiana, Iowa, Kansas, Kentucky, Nebraska, North Dakota, South Dakota, and Wyoming.

[16] CUSIP is an acronym for the Committee on Uniform Security Identification Procedures.

general obligation bonds and which are revenue bonds. We retain only state-issued general obligation bonds that are unsecured and mature in 2008 or later. These bonds represent the great majority of total value in the muni portion of the CUSIP master file.

State ratings data were also collected from S&P for this time period. Of the 39 states in the study, 17 were rated AA+ or AAA, 17 were rated AA, and 5 were rated AA- or below. S&P did not change the ratings on any these states' general obligation debt during the sample period.

The remaining bond attributes are obtained from Bloomberg: whether the bond is insured and if so by which monoline insurer, the size of the issue, whether the bond is callable, call price, first call date, whether the bond is pre-refunded and if so at what price and to what date. From Bloomberg, we also took the price of each bond as of September 30, 2008 and as of December 31, 2008. The final sample is 15,727 bonds that were outstanding during this entire time period. These bonds represent a total of $707 billion in value.[17]

Figure 1 gives a general overview of the entire municipal bond market during this period. These graphs are based on Bloomberg aggregates and, unlike our sample, are not limited to state general obligation bonds.[18] The top graph shows yield spreads on September 30th for municipal bonds issued by states rated A-, A+, AA+, and AAA. Spreads at the short end of the curve ran from around 0.5 percentage points for AAA bonds to around 1 percentage point for A- bonds. Spreads were somewhat smaller at less than a 10-year horizon. At a 15-year horizon they are similar to the short-horizon spreads. At a 30-year horizon, spreads were around 0.9 percentage points for AAA bonds and 1.6 percentage points for A- bonds.

The middle graph shows the December 31st spreads, which requires a much broader scale on the vertical axis. While very short-horizon spreads remained about where they were on

[17] This total is consistent with disclosures by the U.S. Census Bureau suggesting that states have around $300 billion in public debt for specific private purposes for a total of approximately $1 trillion in debt outstanding.
[18] In fact, the lowest state level credit rating at the time was A.

September 30th, the yield curves steepened dramatically for all credit rating categories. The bottom graph shows this change in yield spreads. An important point illustrated by the bottom graph is that spreads on municipal bonds of all credit ratings increased substantially. Spreads in the 5-10 year range increased by about 1 percentage point, while spreads in the 10-30 year range increased by about 1.5 percentage points. To a large extent this reflects what was happening in the Treasury market, as investors fled to the safety and liquidity of U.S. Treasury bonds.

For data on state public finances, we use data from two main sources. First, the U.S. Census Bureau database of state and local government finances provides current and historical information on state revenues. State revenue can broadly be decomposed into: i.) tax revenues, ii.) inter-governmental revenues (such as transfers from the federal government), iii.) charges levied for the use of state services (e.g. tuition at state universities, airport fees, etc), and iv.) revenues the state imputes as arising from the investment returns of trust funds such as its pension funds. In this paper, we obviously exclude (iv) from this total, as including it would generate a mechanical correlation between state revenues and our identifying source of variation. Our primary scaling variable is total own revenue, which consists of (i) and (iii) above, although the results are completely robust to scaling by GSP, tax revenue, or total revenue. Second, we use data from the Bureau of Economic Analysis for current and historical information on state economic activity and gross state product.

Pensions and Investments (P&I) survey of the 1000 largest pension plans provides state pension assets and asset allocation as of September 30, 2008. The P&I asset allocation data decomposes assets into 9 categories: Domestic Stock, International Stock, Domestic Fixed Income, International Fixed Income, Cash and Equivalents, Private Equity, Real Estate Equity, Mortgages, and Other. Using the database of state pension fund reports compiled by Novy-Marx and Rauh (2009, 2011), we check the quality of these reported asset allocations and find them consistent. The state reports themselves have the disadvantage of not all being harmonized to the same date, which is why we use the P&I data, but calculations based on the reports yield similar results

To estimate returns during this period, we use return indices for the pension fund asset classes from September 2008 through December 2008. These were collected from the Kenneth R. French Data Library (the Fama-French factors), Barra MSCI, and Lehman Brothers / Barclays. States do not typically report quarterly asset levels, making this estimation necessary. This method also has the advantage that if states do engage in home bias in their public pension fund investing, it is preferable to use estimated returns based on asset classes than realized returns, as the realized returns in a home-oriented portfolio could generate a mechanical correlation between pension returns and muni yield changes.[19] Appendix Table 1 shows these returns for all state investment funds included in the *Pensions and Investments* survey. There were 71 such funds, covering 116 plans across 50 states.

A major constraint on the ability to do this exercise on other time periods is that asset allocation data are only available on a consistent basis from *Pensions and Investments* as of September 30th of each year. It is unusual to have a quarter where the initial asset allocation is well measured over which very substantial changes occurred to asset values with significant cross-sectional variation. In Section V, we include discussion of some suggestive evidence that the spread increases we measure reversed during the 2009Q2-2009Q3 recovery.

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[19] For example, Massachusetts has mandated since 1983 that the pension fund should make investments "as much as reasonably possible to benefit and expand the economic climate within the Commonwealth." These incentives were strengthened by a 2003 policy on Economically Targeted Investment or ETI (Hagerman, Clark, and Hebb (2006)). The Washington State Investment Board adopted an ETI policy in 2003. Recent working papers by Brown, Pollett and Weisbenner (2011) and Hochberg and Rauh (2011) have documented the extent of this home-state overweighting in public equity and private equity investments respectively.

For pension liabilities and discount rates, we use the database constructed from Comprehensive Annual Financial Reports (CAFRs) described in Novy-Marx and Rauh (2009, 2011). Those data were collected from the most recent Comprehensive Annual Financial Report (CAFR) for each pension plan. Data items include stated actuarial liabilities for each plan, as well as the present value calculations in Novy-Marx and Rauh (2011) of already-promised state pension liabilities using Treasury yields as discount rates.

B. *Summary Statistics*

Tables 1 and 2 present summary statistics on the bonds and the state-level variables respectively. The median bond matures in 2017 and has a coupon of 5%. 32% of the bonds are insured, 16% were pre-refunded by the end of the sample period, and 61% were callable. The mean holding-period return on these bonds was 0.9%. The mean duration of the payments (ignoring call features) was 5.8 years.[20]

Section IV explains in detail how we calculate yields and yield spreads from bond prices, accounting for the bonds' call features. The mean yield spread for a bond in our sample was 0.638 percentage points on September 30, 2008, and rose to 1.651 percentage points on December 31, 2008, for a mean increase of just over 100 basis points. This was largely due to the bonds that were not pre-refunded (84% of our sample). The pre-refunded bonds on average showed small positive increases in their spreads to Treasuries, of approximately 26.8 basis points, a likely indication of the flight to quality happening at the time and consistent with press reports.

Table 2 shows state-level fiscal and pension summary statistics. The 39 states that both sponsor pension plans and have nontrivial amounts of bond debt had average fiscal 2008 tax

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[20] If we calculate the duration of the tradable bond, accounting for the option feature, we find that the returns on duration-matched Treasury bonds were 7.9%, for a mean excess muni bond return of -7.0%.

revenue of $18.1 billion, average fiscal 2008 total own revenue (which includes fees and charges) of $25.2 billion, and average fiscal 2008 total revenue (which includes intergovernmental revenue) of $37.3 billion. The average debt outstanding at the end of fiscal 2008 was $35.7 billion. Not that the fiscal year 2008 ended before 2008Q4 for all of the states in our sample. The average gross state product (GSP) for calendar year 2007 was $315 billion, so that a typical year of revenue is about 10% of GSP.[21]

States lost substantial amounts in their investment funds during the last quarter of 2008. In dollar terms, the average loss was $8.4 billion during these three months. This is an average of 21.1% of total revenue and 28.5% of total own revenue. One cross-sectional standard deviation of the loss amounted to $12 billion, or 9.0% of total own revenue.

IV. Calculations of Bond Yields and Other Characteristics

To determine the effects on borrowing costs, we must calculate yields that take the option features (callability) of the bonds into account. This section explains these calculations.

A. *Option-Adjusted Bond Yields*

Most municipal bonds (more than 61 percent of our sample) are callable. Owning a callable bond is like owning a non-callable bond and being short a call on the bond, so callable bonds are cheaper than non-callable bonds, *ceteris paribus,* and consequently pay higher yields. These higher yields do not reflect higher fixed-rate borrowing costs, but are the cost of the states' refinancing option. States' true fixed-rate borrowing costs are consequently more accurately reflected by option-adjusted bond yields, *i.e.,* yields on "synthetic" non-callable bonds, constructed by adding the calls back to the callable bonds.

[21] GSP is only relevant for this paper as a scaling variable alternative to total own revenue. We refer to 2007 GSP data because GSP is on a calendar year basis from the BEA and we want any scaling variable to be lagged relative to the event we are studying.

Roughly 30 percent of the callable bonds in our sample have been pre-refunded (roughly 17 percent of our total sample). These bonds are typically secured by an escrow account holding a replicating portfolio of U.S. Treasury securities, which will pay off the bond on the first call date. Consequently, while technically callable these bonds are effectively non-callable, maturing on their pre-refund dates with face values equal to their call prices (which for roughly 30 percent of the pre-refunded bonds exceeds their face values).

For the non-prerefunded callable bonds (roughly 44 percent of our total sample), calculating an option-adjusted yield requires that we calculate an option-free bond price. That is, the price of the "synthetic" non-callable bond is constructed by adding the call back to the callable bond. The call embedded in a callable bond can be valued as a receiver swaption. A swaption is an option to take a position in an interest-rate swap agreement at some date in the future, where the swap's fixed rate is specified in the swaption contract. The state can force bond holders to deliver their fixed coupon bonds in exchange for a lump-sum payment, usually par. Because a bond newly issued at the swap rate trades at par, this is equivalent to forcing the bond holders to exchange a stream of fixed payments (the bond's coupons) for a different, currently unknown, stream of fixed payments (the future swap rate). Options of this sort are typically valued using Black's model for options on futures (see Technical Appendix 1 for details). The implicit assumption is that the future swap rate is log-normally distributed around its current level. Bloomberg provides swaption prices, quoted in Black volatilities (*i.e.,* the implied volatility of the future swap rate), for expiration dates out to ten years written on swaps with up to ten years maturity at option expiration. The implied volatility surface interpolated from this matrix can be used, with Black's model, to calculate the value of a swaption with any time to expiration and tenor.[22]

For each callable bond, we calculate its option-free price by summing 1) the bond's price obtained from Bloomberg, and 2) the price of the receiver swaption struck at the bond's coupon rate, expiring on the bond's first call date, with a tenor equal to the call's remaining maturity at expiry. We then add back accrued interest, which is not included in the quoted prices. Under market conventions, quoted prices do not include any interest that has accrued since the last coupon date, which the bond purchaser is required to buy at the time of purchase.

A bond's option-free yield is then calculated as the single discount rate that when used to discount all the bond's payments yields the bond's price (option-adjusted and including accrued interest). The yield spread is the difference between the bond's yield and the yield on a treasury security with the same duration.

B. *Duration and Convexity*

The price of an option-free bond (*i.e.,* a non-callable bond, or an option-adjusted callable bond) is given by

$$P = \sum_i \frac{c/2}{(1+y/2)^{2t_i}} + \frac{F}{(1+y/2)^{2T}} ,$$

where t_i are the times until coupons are paid, T is the time until principle is repaid, y is the bond's yield (annualized with semi-annual compounding), c is the coupon rate, and F is the face value (or for pre-refunded bonds, price at which issue is pre-refunded). The duration of an option-free bond is the value-weighted average time at which the bond coupons and principle are paid,

$$D = \frac{1}{P}\left(\sum_i \frac{t_i c/2}{(1+y/2)^{2t_i}} + \frac{TF}{(1+y/2)^{2T}}\right).$$

[22] Our prices are for swaptions written on US dollar LIBOR, and we consequently have the volatility surface for LIBOR swap rates. We employ it here as the best available proxy for the volatility surface for muni swap rates.

The convexity is the value-weighted squared average time of the bond's payments:

$$C = \frac{1}{P}\left(\sum_i \frac{t_i^2 c/2}{(1+y/2)^{2t_i}} + \frac{T^2 F}{(1+y/2)^{2T}}\right).$$

Note that these are simply the duration and convexity of a non-callable bond and are appropriate for use with the option-adjusted yield spreads, which are calculated using the synthetic option-free bonds.[23]

C. *Excess Returns*

The municipal bond returns we employ are simply the change in the quoted prices of the tradable bonds. These prices are not adjusted for call features, and are "clean," in that they do not include interest accrued from the previous coupon date. Municipal bonds' excess returns are calculated by subtracting from each bond's return the return to a duration-matched Treasury security (i.e., a Treasury with the same duration as the traded municipal bond).

D. *The Term Structure of Defaultable Bonds*

Duffie and Singleton (1999) show that, under the appropriate technical conditions, the market value of a defaultable claim to a dollar that will be paid T in the future, is given by

$$E^Q\left[\exp\left(-\int_0^T (r_t + h_t L_t + l_t)dt\right)\right]$$

where E^Q denotes the risk-neutral expectation, r_t is the short term interest rate process, and h_t, L_t and l_t are the t ahead hazard rate for default, expected fractional loss given default and liquidity carrying cost, respectively. That is, a defaultable claim should be discounted using a cumulative adjusted short-rate, where this adjusted short-rate accounts for both the time-value of money, r_t,

[23] The duration of a *callable* bond is the value-weighted average duration of the underlying option-free bond and the embedded call,

$$D_{callable\ bond} = D_{noncallable\ bond} + w(D_{noncallable\ bond} - D_{call}),$$

where $w = P_{call} / P_{callable\ bond}$. A completely analogous relation holds for convexity. For each callable bond the duration and convexity of the call can be calculated numerically, using Black's formula, assuming a parallel shift of the yield curve. As shown in Table 1, the mean duration of the bonds in our sample, treating them as option-free, was 5.8 years. The mean duration of the tradable bonds, some of which are callable, is shorter at 5.2 years, as the investors receive their cash earlier whenever a state exercises its call option.

and the "short-spread," $s_t = h_t L_t + l_t$, which reflects the total risk and liquidity adjusted mean-loss rate.

Changes in yield spreads therefore reflect changes in the average expected short-spread over a bond's life, and thus reflect changes in the expected default rate, the expected recovery rates given default, and the expected carrying cost of illiquidity. For example, assuming a fixed recovery rate given default of 50 percent and a fixed one percent annual cost of illiquidity, an increase in a bond's yield spread over treasuries of one percent implies an increase in the risk-neutral hazard rate of default of two percent per year.

V. Discussion of Results

A. *Bivariate Correlations*

Figure 2 shows bivariate correlations between average state muni bond returns and the estimated losses suffered by the state's pension funds during the period 9/30/2008-12/31/2008. Figure 3 shows bivariate correlations between average changes in state muni bond *spreads* and the estimated losses suffered by the state's pension funds during the same period. The bond returns and spread changes are value-weighted within states.[24]

Within each figure, the four graphs differ in the horizontal axis, showing: i.) the share of pension fund assets in equity and real estate; ii.) the estimated pension fund percentage loss in 2008Q4; iii.) the level of state pension assets as a share of state government total own revenue; and iv.) the estimated value lost in the pension fund as a percentage of state government total own revenue. The solid line represents a fitted linear relation in which all states are weighted equally. The dashed line weights the states by the amount of debt outstanding. The dotted line

[24] Only the 7,947 bonds that are not pre-refunded and that mature in 5 years or greater are included in calculating the average returns. In the regression analysis, we control explicitly for bond duration.

shows the unweighted linear relation excluding California, in order to address the concern that California may be an influential outlier.[25]

Equity and real estate are the categories that ex post lost substantially more in value than the fixed income categories. Across states, the mean of this variable is 67% and the standard deviation 7.5%. Taken literally, the top left graph of Figure 2 implies that for each additional percentage point of state assets allocated to equity and real estate as of September 30, 2008, municipal bond investors realized an additional loss of 10.1 basis points. Weighting by debt outstanding this effect was 20.1 basis points. Unweighted and excluding California, this effect was 6.7 basis points. In all cases the effect is statistically significant. The analogous graph in Figure 3 implies that for a one standard-deviation (7.5 percentage point) increase in state assets allocated to equity and real estate as of September 30, 2008, municipal bond investors saw spreads increase by 7.5 (=1.00*7.5), 14.6 (=1.95*7.5), or 5.1 (=0.68*7.5) basis points respectively, depending on the weights used and the treatment of California. The upper left graphs of Figures 2 and 3 therefore illustrate one of the reduced form relationships present in the data: states that were taking more risk in pension funds at the beginning of this period saw their muni spreads increase by more during this period than states that were taking less risk.

The upper right graphs of Figures 2 and 3 move from considering risk allocation to considering the estimated return. Since the estimated return is a linear function of the allocation to risky assets, the conclusions from this graph are very similar. In unweighted regressions, for each additional percentage point of pension asset value lost, muni returns were 36 basis points lower and spreads increased by 5 basis points more.

[25] We also address this by highlighting the fact that the unweighted regression results are significant within both the A to AA– ratings category (which includes California) and the AA category (which does not include California but which includes almost half of the states in the sample). Consistent with our hypotheses, the magnitude of the effect in the regressions is largest in the A to AA– category (15 basis points), strong in the AA category (7 basis points), and absent in the remaining category (AA+ and above).

The lower left graphs of Figures 2 and 3 shows another reduced form relationship, namely the one between the level of pension fund assets (as a share of own revenue) and the performance of the muni bonds. Other things equal, we should have seen states with more investable assets to lose perform worse during this period. We find that this is roughly the case. Although the relationship is weak, it is clearly upward sloping. This is the opposite of what one would expect if our result were simply picking up variation in rich states versus poor states, and is consistent with the idea that states that lost more in their investment funds were punished more by municipal bond markets.

The graphs in the lower right put the effects together and show the relation between the value lost in the pension fund as a share of state government revenue and the change in the yield spreads on the state municipal bonds. Taken literally, these graphs imply (in unweighted regressions) that for each additional 10% of total state own revenue lost in pension funds, muni returns were 62 (=6.18*10) basis points lower and spreads increased by 6.3 (=0.63*10) basis points more.

These graphs are suggestive that borrowing costs did rise for states that experience poor investment returns in their pension funds. However, the graphs analyze only average returns and spread changes, without controls for other characteristics of the bonds and states that sponsor them. In particular, they do not control for the maturity or duration of the bonds, which may differ across states, and longer duration bonds are more sensitive to changes in interest rates. The figures also do not account for whether the bonds are callable. They analyze investor returns, which are the most easily measured, and not the actual borrowing costs implicit in the prices. The graphs in Figures 2 and 3 also do not control for state level differences such as credit quality, level of debt, level of pension liabilities, and sensitivity of revenues to changes in U.S. GSP. These will be important controls in our regression analysis.

B. *Multivariate Regression Results*

Table 3 presents the first set of regression results. There are three columns of regressions. The first column present results for the entire sample without any weights or exclusions, so that a $5,000 tranche of a muni series (the smallest) gets the same weight as a $1 billion tranche (the largest). The second column present results only for bonds with issue size greater than $10M, also unweighted. The third column present results for the full sample but weighted by their issue size. Standard errors are clustered by state in all regressions.

Treating the smallest and largest bonds equally has the disadvantage that these bonds may be less liquid and some of the pricing information less accurate. Bloomberg’s data providers estimate the prices of bonds that may not have traded on a given day based on the last traded price and on recent trades in other similar municipal bonds. However, some of the better rated states have smaller bond issues, which is why we present results under these three different treatments of the data. Later in this section, we also investigate the sensitivity of the result to limiting the sample to bonds that were traded around the start and end dates of the sample, using trade data from the Municipal Securities Rulemaking Board (MSRB).

Using non pre-refunded bonds only (13,160 out of 15,727), Table 3 shows the effect of the value losses on tax-adjusted yield spreads. The interaction effect between ratings of AA or below and the loss as a fraction of own revenue is statistically significant at the 5% or 1% level in all specifications. A loss of 10 percentage points of state revenue is correlated with a spread increase of around 7.4-9.5 basis points. Note that all regressions contain the full set of controls for bond characteristics: the insured indicator, duration, convexity, and size of issue. The regressions also all contain controls for state characteristics: state debt as a share of own revenue, pension liabilities as a share of own revenue, the sensitivity of own revenue to changes in U.S. GSP, and the own revenue drop between 2008 and 2009.[26]

The *Insured* control variable shows that yield spreads on insured bonds increase on average by around 20-25 basis points more than non-insured bonds over this time period, likely reflecting the problems faced by monoline municipal insurers, and the decreasing value of the insurance they provided. The use of municipal bond insurance during this period still something of a mystery, given the possible extent of counterparty risk that was in fact revealed during the financial crisis and in light of the evidence of Bergstresser, Cohen, and Shenai (2010).

As discussed in Section II, the pre-refunded bonds excluded from Table 3 (approximately 16% of the sample) provide useful within-state control samples to identify the effect of the investment losses. Given the security offered by pre-refunded bonds, these should not be affected by default considerations (Chalmers (1998)), and the pre-refunded bonds should be similar to the non pre-refunded bonds on dimensions other than default risk. As a check, Appendix Table 2 repeats Table 3 but for the pre-refunded bonds only, and finds no effect (or if anything, slightly negative correlations) between losses and spread changes.

In Table 4 we therefore use the full sample of 15,727 bonds to estimate an effect on non-prerefunded bonds in states rated AA or below. Of the 39 states in the sample, 22 are AA or below, accounting for 63% of the bonds, and we would not expect an effect of investment losses on yields in the more highly rated states. In all specifications, the triple interaction shows a

[26] If instead the explanatory variables are scaled by GSP, the effects are 7-11 basis points per percentage point of GSP lost across the three specifications, with the unweighted regression displaying statistical significance at the 5% level and the weighted regression at the 10% level. If the explanatory variables are scaled by total revenue including intergovernmental revenue, the effects are 9 to 10 basis points per 10 percentage points of revenue last, statistically significant at the 10% level in the first two columns and at the 5% level in the weighted regression. The robustness of Table 3 is more dependent on scaling than Tables 4 and 6.

strong and highly statistically significant effect of investment losses on this group of bonds. For each 10 percentage points of revenue lost, spreads increased on non-prerefunded bonds in AA-or-below states by 12.5-19.3 basis points. The result is statistically significant at the 1% level in all specifications in Table 4.[27]

One consequence of having small issues in the sample is that they may not trade often. Table 5 examines the robustness of the basic yield spread results in Tables 3 and 4 to the time of trades relative to the measurement dates, to address the concern that the results could be partly driven by deviations between Bloomberg's quoted prices and actual trade prices.

Data from the Municipal Securities Rulemaking Board (MSRB) details every trade in state bonds during this time period. The first column of Table 5 repeats the statistics from the first columns of Tables 3 and 4. The second column restricts the sample only to bonds that traded within one month of the beginning or end of the 3-month sample period (first row of each panel) or within one month of the beginning *and* end of the 3-month sample period (second row of each panel). The either-or one month restriction reduces the sample size by around 50%, whereas the more restrictive "beginning and end" restriction reduces it to a much smaller fraction of the original size. In both cases the results are completely robust. The other columns of Table 5 show that the results from both Table 3 and Table 4 are robust to considering much narrower trading day bands, such as 10 trading days, 5 trading days, and (in the either-or specification) on the last trading day of the quarter itself.[28] While it is true therefore that a large portion of the bonds do not trade around the beginning and end of the quarter, limiting the sample to those bonds that do

[27] If instead the explanatory variables are scaled by GSP, there is an effect of 15-20 basis points per percentage point of GSP lost, statistically significant at the 1% level in all three regressions. If the explanatory variables are scaled by total revenue including intergovernmental revenue, the effect is 16-25 basis points per percentage point of total revenue lost, also fully robust at the 1% level in all three regressions. Since intergovernmental revenue increases own revenue by around 40%, the fact that the magnitudes are larger using total revenues is not surprising.

[28] There were not enough observations that traded both on September 30th, 2008 and on December 31st, 2008 to estimate a specification using the "beginning and end" restriction.

trade around these times does not reduce the statistical or economic significance of the results at all.

Table 6 further expands the analysis by examining interactions with finer ratings categories. Again, a natural hypothesis is that states with worse credit ratings ex ante should display larger responses, and this is indeed what the results in unweighted regressions show. Among the states that are rated between A and AA-, the effect in unweighted regressions is 15 basis points per 10% of annual total own revenue lost. Among states that are rated AA, the effect in the unweighted regression is only 7 basis points. Among states rated AA+ or AAA (the omitted interaction), the effect is not present. This evidence is consistent with the idea that markets punished states with greater investment losses through higher yields due to concerns about possible defaults. However, it is worth nothing that the effect we detect on the states rated AA only depends on our inclusion of the smaller bond issues in the sample, and disappears if we weight by issue size. This is due to the fact that bonds with better ratings tend to have less debt overall and smaller issue sizes.[29]

The fact that the results are robust to credit rating interactions shows that even within these categories, states that had greater losses experienced relatively larger yield spread increases on their traded, non-refunded bonds. The effect is therefore not simply due to a correlation of large investment losses with poor credit ratings, or due to one or two outlying states in the worst rating category.

Figure 4 illustrates the results of Table 6 in graphical form. The figure shows the effects of state investment losses on yield spreads during the period September-December 2008 for non pre-refunded bonds of differing credit quality. The numbers shown are from the triple-difference

[29] The statistical significance of the results is unchanged when explanatory variables in Table 6 are scaled by GSP and by total revenue including intergovernmental revenue. The relationships among the magnitudes for the different scaling is very similar to the findings from the Table 4 specification (see footnote 27).

regression shown in column (1) of Table 6, in which the omitted indicator is the indicator for the highest rating category (AA+ to AAA). The losses in Figure 4 are scaled by total own revenue and the effects presented are for 10 percentage point changes.

The first group of bars in Figure 4 shows that the effect on the yield spread for non pre-refunded bonds increases as credit quality decreases. It does not show the full effect found in Table 6, because the triple interaction of [Not Pre-Refunded]*[Loss / Own Revenue]*[AA Rated] also exploits the differences in spread changes between pre-refunded versus not pre-refunded bonds in the same state. The second group of bars shows the calculation analogous to the first group of bars but for the pre-refunded bonds only, and the third group of bars shows the differences between not pre-refunded and pre-refunded bonds. Note that the pre-refunded bond control reduces the magnitude of the effect in the A to AA- states from 18.4 to 13.8, and increases the effect in the AA group from 4.0 to 5.6. The triple difference estimates in Table 6 can be derived from the figure as 15.3 = 13.8 – (–1.5) and 7.1 = 5.6 – (–1.5), i.e. by subtracting the difference-in-difference effect of the AA+ to AAA control states from the difference-in-difference effects of the other two groups respectively.

Regarding the other controls in Table 6, pension liabilities are measured under Treasury discount rates as calculated in Novy-Marx and Rauh (2011), which reflects the assumption that market participants were sophisticated enough to view the state disclosures as substantially understated. However, the results are not affected if we use stated liabilities as a control.[30]

In untabulated results, we limit the sample to only those 8,089 bonds that are not pre-refunded and rated AA or below, in order to examine whether bonds covered by a monoline insurer were less affected by the investment losses. We might have expected the insurance to

[30] The measure is also an accumulated benefit obligation (ABO). It consists only of liabilties already legally accrued by workers for service to date, as these are the ones that more clearly threaten the seniority of state general obligation bonds. See Novy-Marx and Rauh (2009, 2010) for further discussion.

provide some protection, but at the same time, the value of the insurance during this period declined substantially. In most of the specifications, the existence of insurance does not have a statistically significant protective effect on the increase in yield spreads — though it should be noted that the insured bonds of course had lower yield spreads to begin with. In the regressions on the sample of issues greater than $10 million, the effect of the investment losses on the change in the yield spread is about half as large for insured bonds as it is for uninsured bonds. Furthermore, there is only weak evidence that the yield spread effect is higher at the long end of the yield curve.

As discussed in Section II, there are a number of limitations on our ability to examine whether the reverse of the effect we measure happens in 2009Q2-2009Q3. We obtained some suggestive evidence by examining data from the state yield curves from Bloomberg for the 20 states for which it is available: CA, CT, FL, GA, IL, MD, MA, MI, MN, NJ, NY, NC, OH, PA, SC, TN, TX, VA, WA, and WI. For each point on the yield curve we regressed the 20 observations of the change in yield spread over comparable maturity Treasury bonds on the 2008Q4 pension fund loss scaled by total own revenue. We performed this exercise on both the 9/30/2008-12/31/2008 change in the yield spread as well as on the 3/31/2009-9/30/2009 change in the yield spread. For all maturities, the correlation between the 2008Q4 pension fund loss and the yield spread change is positive during 9/30/2008-12/31/2008 and negative during 3/31/2009-9/30/2009. That is, states that had large losses in 2008Q4 indeed had larger spread increases during 2008Q4 and larger spread decreases during 2009Q2 and 2009Q3.

C. *Discussion of Tax Effects*

The results presented in the previous section reflect spread changes without any adjustment for tax effects. In this section, we consider how the tax treatment of municipal bonds might affect the interpretation of our results. Specifically, the interest on municipal bonds is tax deductible for investors, but the capital losses and capital gains on these bonds are taxable.

The relevance of these tax effects depends on the desired interpretation of the results. One interpretation of the results is that they reflect the increases in the marginal costs of new borrowing faced by the state itself. By definition, there is no tax adjustment needed for that interpretation. However, that ignores the fact that the federal government bears a portion of the state's borrowing costs, and that the overall borrowing cost inclusive of the federal subsidy is not reflected entirely in the observed yield but rather in a tax-adjusted yield. If one wanted to interpret the results as the change in the total cost of state borrowing inclusive of the federal subsidy, the spreads would have to be grossed up by the ordinary marginal tax rate of municipal bond investors.

Poterba and Verdugo (2008) present evidence that the tax rate implied by muni bond prices is approximately 25%, based on the historical spreads of Treasury bonds over municipal bonds. The effect of adjusting the yield spreads upwards by 25% for taxes would therefore be to raise the coefficients by 1/(1-25%) or 4/3rds. There is, however, great disagreement in the literature about the appropriate way to measure the tax rate of the marginal investor in the municipal market, with authors such as Longstaff (2011) and Ang et al (2010) calculating considerably higher rates using different measurement techniques. The higher the tax rate of the marginal investor, the greater the overall borrowing cost increase, inclusive of the federal subsidy, that is implied by our results.

To interpret the results as increases in risk-neutral default probabilities, the investor's marginal tax rate on interest income is not relevant. However, one would want to consider here the fact that capital gains and losses on municipal bonds are treated in the same way as capital gains and losses on other securities, and accordingly the change in spread should be grossed up by one minus the capital gains tax rate. The tax rate on capital gains reflects the fact that after tax losses are smaller than before tax losses. For example, if actual expected loss is the event of default are 50%, after writing the losses off they are only 42.5%, assuming the long-run rate capital gains rate of 15%). If effective losses in the event of default are smaller, then a given change in yield spreads corresponds to a greater change in the risk-neutral hazard rate of default. In the case of a 15% rate, the change in the risk-neutral hazard rate of default would in fact be 1/0.85 – 1 = 17.6% higher.

VI. Conclusions

This paper uses variation across states in investment losses during the last quarter of 2008 to measure the effects of increases in unfunded liabilities on municipal bond yields at the state level. Our results imply that U.S. state municipal bond yields will likely increase if unfunded state liabilities continue to grow, making new state debt more expensive to finance.

Given that state revenues are pro-cyclical, our analysis also highlights the fact that by investing pension funds in equities, states experience increased borrowing costs under exactly those conditions when their tax base is decreasing, i.e., in recessions and at times when the stock market performs poorly. Analysis of optimal state pension fund investment policy starts from the premise that if citizens can (and do) undo the investment decisions made by states, then pension fund investment policy is not relevant for social welfare (see for example Lucas and Zeldes (2009)). However, the correlation we find between poor asset performance and higher borrowing costs represents an additional reason why state public pension fund investment policy might have welfare implications.

In interpreting our results as increases in risk-neutral default probabilities, it is important to note that during the recession there was clearly an increase in yield spread per unit of default risk, either because default risk became more closely linked to market risk during the crisis, or because investors are more liquidity constrained. Thus the link between spreads and default risk may have been magnified during this period.

It is instructive to compare the states' fiscal position to that of the U.S. federal government. Across all 50 states, state government debt amounts to approximately $1.00 trillion, while unfunded pension liabilities are $3.2 trillion when measured at Treasury rates. Given total state own revenue of around $1.1 trillion, the ratio of unfunded liabilities to revenue for the 50 states combined is about 3.8, excluding public medical programs. This fiscal position appears stronger than that of the U.S. government, which collects about $2.5 trillion in annual revenue, compared to $9 trillion in debt, and an approximately $10.5 trillion gap in Social Security (Geanakoplos and Zeldes (2009)). In total, the U.S. government's unfunded liabilities excluding public medical programs are therefore around 8 times its annual revenue.

The behavior of municipal yield spreads therefore highlights the fact that fundamental differences between state governments and the U.S. federal government — or differences between the markets for their debt — generate important differences in borrowing rates. The U.S. dollar plays a unique role as a reserve currency at the world's central banks, and U.S. Treasury debt enjoys superior trading liquidity as well as a perception by market participants that it is risk-free (Krishnamurthy and Vissing-Jorgensen (2008)). The nature of the default events and likely extent of recovery are also very different, with the federal government retaining the capacity to erode the value of its debt through inflation. Understanding the effects of state and federal fiscal decisions on bond markets is an important avenue for future research.

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Figure 1: General Obligation Municipal Bond Yield Spreads, 9/30/2008 - 12/31/2008

The figures show yield spreads of par yield curves over Treasuries on 9/30/2008, 12/31/2008, and the change over that time period. Data are from the Bloomberg yield curve function (F82 for the Treasuries, and M49, M45, M163, and M159 for the AAA, AA+, A+, and A- general obligation municipals respectively).

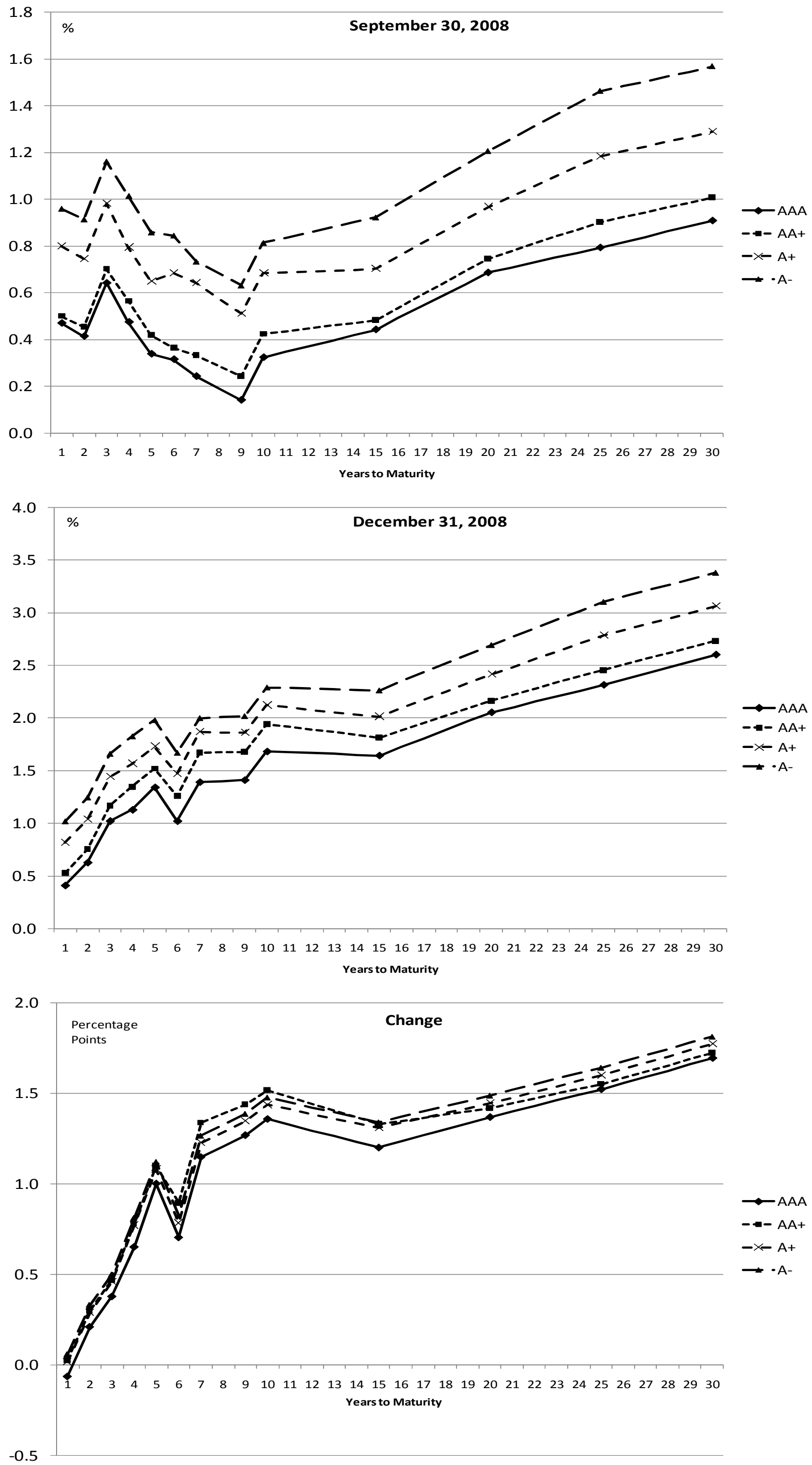

Figure 2: Average General Obligation Municipal Bond Returns and State Pension Funds, September-December 2008

These figures show relations between value-weighted average returns on state bonds between September 30, 2008 and December 31, 2008 (the vertical axis in all four graphs) and state pension fund variables. Of the 15,727 bonds in the universe, only the 7,947 bonds with duration greater than 5 years that have not been pre-refunded are included. The graphs differ in the horizontal axis, showing: i.) the share of pension fund assets in equity and real estate; ii.) the estimated pension fund percentage loss in 2008Q4,; iii.) the level of state pension assets as a share of state government own revenue (taxes plus fees, and charges); and iv.) the estimated value lost in the pension fund as a percentage of state government revenue own revenue.

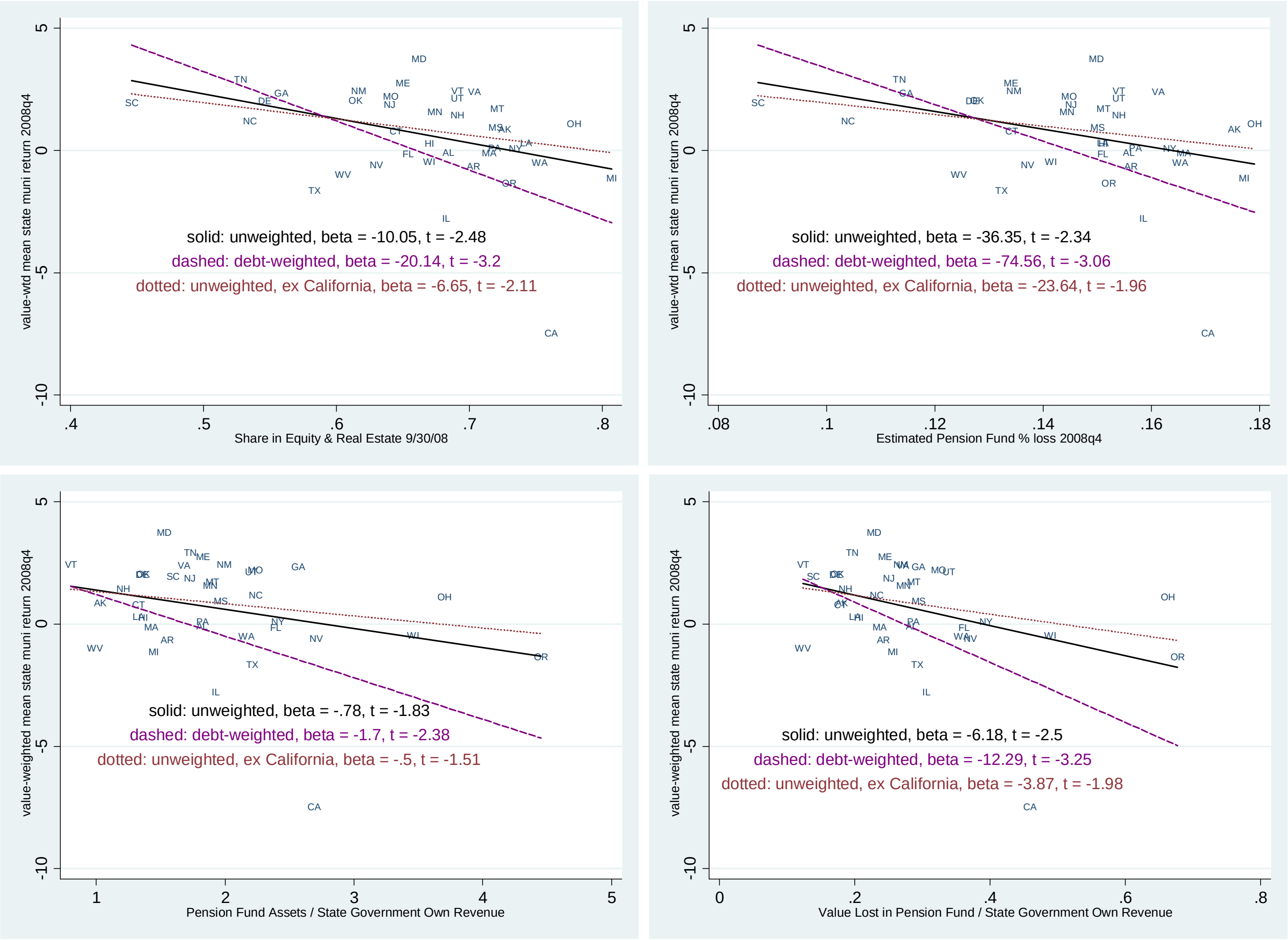

Figure 3: Spread Changes and State Pension Funds, September-December 2008

These figures show relations between changes in spreads on state bonds between September 30, 2008 and December 31, 2008 (the vertical axis in all four graphs) and state pension fund variables. Of the 15,727 bonds in the universe, the 7,947 bonds with duration greater than 5 years that have not been pre-refunded are included. The graphs differ in the horizontal axis, showing: i.) the share of pension fund assets in equity and real estate; ii.) the estimated pension fund percentage loss in 2008Q4,; iii.) the level of state pension assets as a share of state government own revenue (taxes plus fees and charges); and iv.) the estimated value lost in the pension fund as a percentage of state government revenue (taxes plus fees and charges).

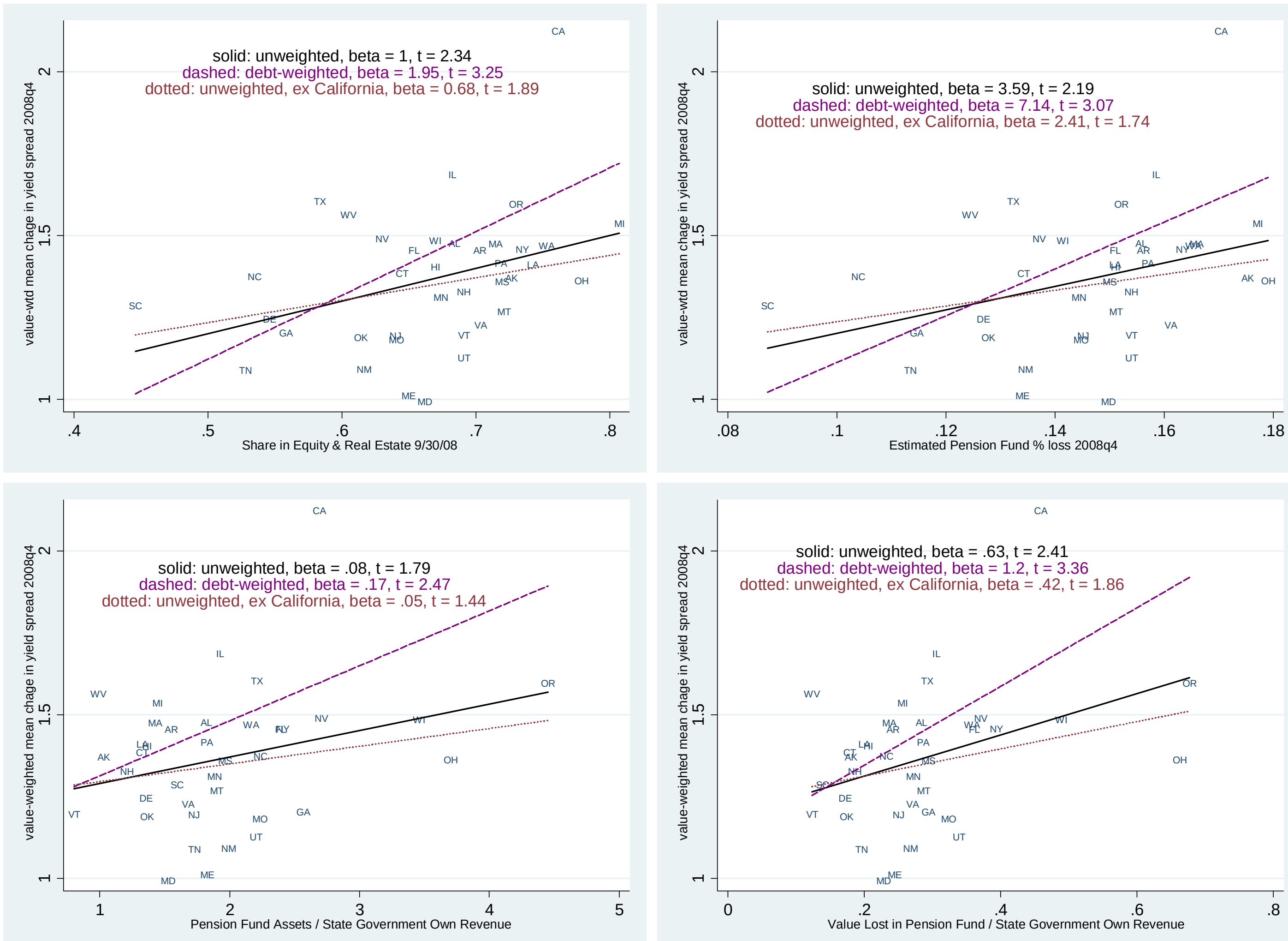

Figure 4: Effects of Investment Losses on Yield Spreads, September-December 2008

The figure shows the effects of state investment losses on yield spreads during the period September-December 2008 for non pre-refunded bonds of differing credit quality. The numbers shown are calculated from the triple-difference regression shown in column (1) Table 6, in which the omitted indicator is the indicator for the highest rating category (AA+ to AAA). The effects shown are in basis points per 10 percent of own revenue lost. For states in the highest rating category (AA+ to AAA), the Not Pre-Refunded bar represents the sum of coefficients on [Loss / Own Revenue] and [Not Pre-Refunded]*[Loss / Own Revenue]. For states in the AA category, the Not Pre-Refunded bar is the sum of 4 coefficients: i.) [Loss / Own Revenue], ii.) [Not Pre-Refunded]*[Loss / Own Revenue], iii.) [Loss / Own Revenue]*[AA Rated] and iv.) [Not Pre-Refunded]*[Loss / Own Revenue]*[AA Rated]. For states in the A to AA- category, the Not Pre-Refunded bar is the sum of 4 coefficients: i.) [Loss / Own Revenue], ii.) [Not Pre-Refunded]*[Loss / Own Revenue], iii.) [Loss / Own Revenue]*[A to AA-] and iv.) [Not Pre-Refunded]*[Loss / Own Revenue]*[A to AA-]. The Pre-Refunded bars are calculated analogously to the Not Pre-Refunded Bars. The Difference bars represent the difference between the Not Pre-Refunded bars and the Pre-Refunded bars.

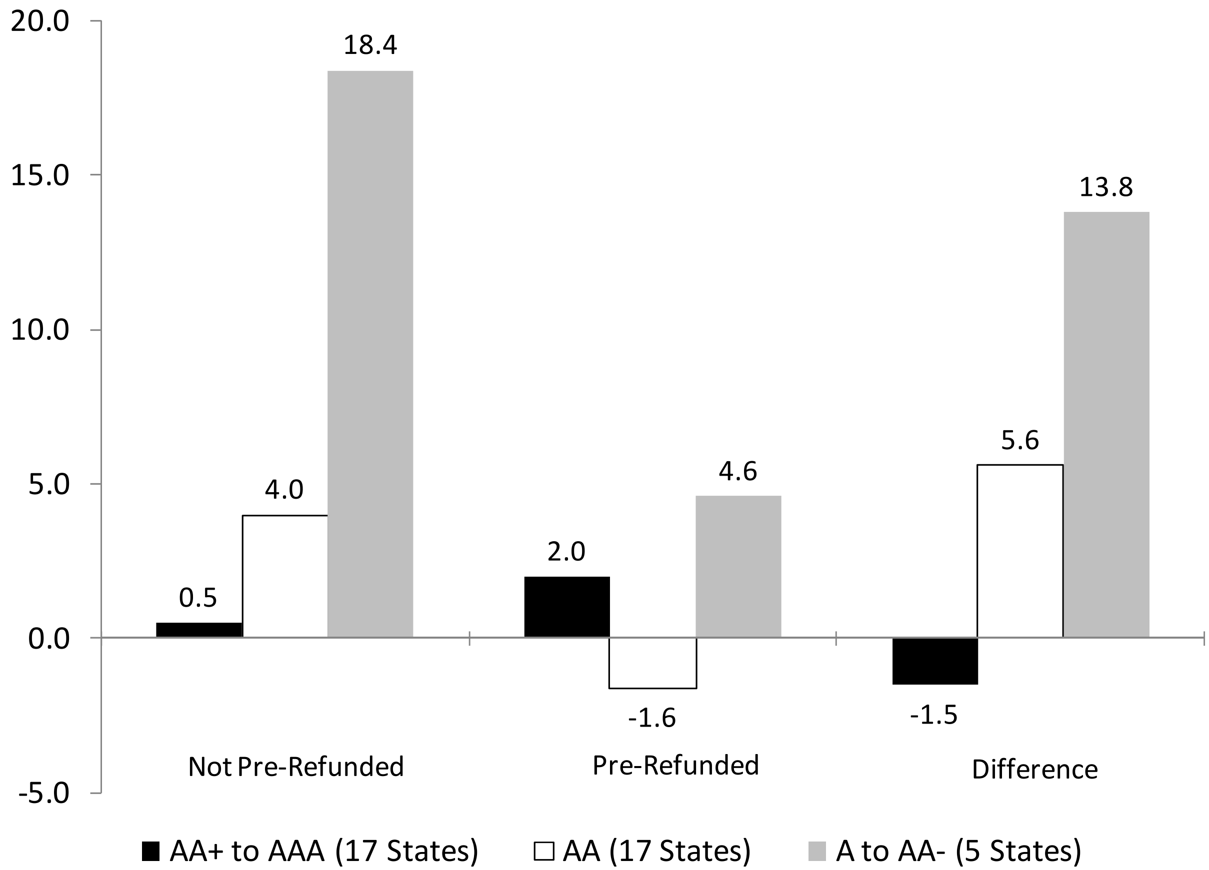

Table 1: Municipal Bond Summary Statistics (N = 15,727)

This table shows summary statistics on the 15,727 municipal bonds used in the study. The sample consists of the universe of state sponsored, general obligation municipal bonds in the S&P CUSIP Master File that were outstanding during the sample period of September 30, 2008 through December 31, 2008.

Characteristics

	Mean	median	stdev	p25	p75
Issue Size ($ millions)	44.9	6.7	226.0	1.4	16.8
Issue Year	2003	2003	4	2001	2006
Maturity Year	2017	2015	5	2012	2020
Coupon	4.631	5.000	1.126	4.250	5.125
Insured Indicator	0.322	0.000	0.467	0.000	1.000
Pre-Refunded	0.163	0.000	0.370	0.000	0.000
Callable	0.607	1.000	0.488	0.000	1.000

Yields, Spreads, and Returns

	Mean	median	stdev	p25	p75
Simple Return (%)	0.942	1.345	2.792	0.209	2.538
Duration	5.789	5.142	3.581	2.695	8.458
Convexity (÷100)	0.552	0.286	0.652	0.075	0.830
Yield 9/30/2008 (%)	3.719	3.685	0.877	2.982	4.449
Yield 12/31/2008 (%)	3.258	3.219	1.327	2.255	4.306
Yield Spread 9/30/2008	0.638	0.550	0.415	0.426	0.724
Yield Spread 12/31/2008	1.651	1.453	0.722	1.193	2.100
Change in Yield Spread	1.014	1.035	0.556	0.604	1.393
- Not Pre-Refunded Only (N=13,160)	1.159	1.162	0.467	0.808	1.449
- Pre-Refunded Only (N=2,567)	0.268	0.163	0.328	0.077	0.420

Table 2: State-Level Fiscal and Pension Summary Statistics (N=39)

Summary statistics are presented for the 39 states that sponsored pension plans for employees and had traded general obligation municipal bonds in 2008. State fiscal measures are from the Bureau of Economic Analysis (for Gross State Product) and the U.S. Census Bureau (for all revenue measures). Fiscal Year 2008 ended on June 30, 2008 for all states except Alabama and Michigan (September 30, 2008), New York (March 31, 2008) and Texas (August 31, 2008). Pension fund assets and asset allocation as of September 2008 are from *Pensions and Investments*. Pension fund liabilities are from states' Comprehensive Annual Financial Reports and Novy-Marx and Rauh (2009). Loss is calculated by using return indices for the pension fund asset classes from September 2008 through December 2008, which were collected from the Kenneth R. French Data Library (the Fama-French factors), Barra MSCI, and Lehman Brothers / Barclays. Total Revenue is the sum of taxes, intergovernmental revenue, fees, and charges; it excludes revenue the states impute as arising from their pension funds. Total Own Revenue is Total Revenue minus intergovernmental revenue (transfers from the federal government). Own Revenue Drop is the proportional change in Total Own Revenue from 2008 to 2009.

State Fiscal Measures	mean	median	stdev	p25	p75
Gross State Product (GSP), $ billion [Calendar 2007]	315.2	216.3	361.0	82.4	389.7
Tax Revenue, $ billion, FY 2008	18.1	11.0	21.1	6.1	22.8
Total Own Revenue, $ billion, FY 2008	25.2	15.7	27.5	9.1	31.8
Total Revenue, $ billion, FY 2008	37.3	25.2	40.5	12.9	51.4
State Debt, $ billion, FY 2008	35.7	21.1	37.6	11.3	51.3
- as share of Total Own Revenue	0.667	0.632	0.323	0.479	0.801
S&P Rating AAA	0.231	0.000	0.427	0.000	0.000
S&P Rating AA+	0.205	0.000	0.409	0.000	0.000
S&P Rating AA	0.436	0.000	0.502	0.000	1.000
S&P Rating A to AA–	0.128	0.000	0.339	0.000	0.000

Pension Fund Assets and Liabilities	mean	median	stdev	p25	p75
Number of Pension Plans	2.4	2.0	1.4	1.0	3.0
Pension Fund Assets, September 2008, $ billion	54.6	29.2	72.9	16.5	63.3
Liabilities: Stated Rates and Methods, $ billion	69.7	42.8	86.8	20.6	72.5
Liabilities: Treasury Rates, ABO ($ billion)	107.9	71.8	130.8	34.0	121.0
- as share of Total Own Revenue	4.667	4.361	1.415	3.706	5.122

Pension Fund Asset Allocation (9/30/2008)	mean	median	stdev	p25	p75
Domestic Stock	0.349	0.351	0.072	0.309	0.410
Domestic Fixed Income	0.243	0.243	0.079	0.202	0.276
International Stock	0.184	0.180	0.039	0.164	0.208
International Fixed Income	0.034	0.007	0.068	0.000	0.035
Cash and Equivalents	0.015	0.010	0.016	0.003	0.021
Private Equity	0.071	0.060	0.057	0.031	0.093
Real Estate Equity	0.059	0.062	0.040	0.033	0.090
Mortgages	0.005	0.000	0.008	0.000	0.009
Other	0.039	0.020	0.043	0.003	0.068
Estimated Return (9/30/2008 - 12/31/2008)	-0.146	-0.151	0.020	-0.157	-0.134

Pension Fund Value Loss (9/30 to 12/31)	mean	median	stdev	p25	p75
Loss ($ billions)	8.4	4.1	12.3	2.3	9.1
- as share of Total Revenue	0.211	0.194	0.090	0.158	0.238
- as share of Total Own Revenue	0.285	0.268	0.123	0.200	0.324

Economic Shock Controls	mean	median	stdev	p25	p75
Sensitivity of Own Revenue to U.S. GDP Growth	0.013	0.014	0.009	0.008	0.018
Own Revenue Drop (2009 over 2008)	-0.056	-0.056	0.043	-0.087	-0.026

Table 3: Change in Yield Spread and Value Lost in Pension Funds, Non Pre-Refunded Bonds

This table shows regressions of municipal bond yield spreads on changes in the value of state pension fund assets for non pre-refunded bonds only. The change in the yield spread is the change in the spread of the bond between September 30, 2008 and December 31, 2008 over comparable duration Treasury bonds.

	Dependent Variable: Change in Yield Spread		
	(1)	(2)	(3)
[Rated AA or Below]*[Loss / Own Revenue]	0.95	0.85	0.74
	(0.37)**	(0.33)**	(0.27)***
[Loss /Own Revenue]	0.17	0.51	0.47
	(0.23)	(0.26)*	(0.22)**
[Rated AA or Below]	-0.15	-0.13	-0.13
	(0.12)	(0.12)	(0.11)
Insured	0.21	0.25	0.25
	(0.03)***	(0.04)***	(0.03)***
Duration	0.13	0.13	0.13
	(0.01)***	(0.01)***	(0.00)***
Convexity ÷ 100	-0.20	-0.15	-0.03
	(0.06)***	(0.06)**	(0.03)
Size of Issue (B)	0.04	0.00	-0.02
	(0.02)	(0.02)	(0.01)**
State Debt / Own Revenue	-0.06	-0.03	-0.03
	(0.06)	(0.05)	(0.04)
Pension Liabilities / Own Revenue	-0.03	-0.05	-0.04
	(0.02)*	(0.02)**	(0.02)**
Sensitivity of Own Revenue to U.S. GDP Growth	-2.93	5.48	3.15
	(4.26)	(3.93)	(2.88)
Own Revenue Drop (2009 over 2008)	-1.45	-1.90	-1.92
	(0.82)*	(0.71)**	(0.54)***
Constant	0.35	0.06	0.04
	(0.13)**	(0.09)	(0.10)
R^2	0.75	0.84	0.84
Sample	Not Pre-Refunded	Not Pre-Refunded, Issue>$10M	Not Pre-Refunded
Weights	None	None	Issue Size
Observations	13160	4972	13160

Robust standard errors in parentheses, clustered by state

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Yield Spread Changes by State Investment Loss, Credit Rating and Pre-Refunded Status

This table shows regressions of municipal bond yield spreads on changes in the value of state pension fund assets, interacted with credit rating categories and indicators for whether the bond is pre-refunded. 22 of the 39 states in the sample, accounting for 63% of the bonds, are rated AA or below. Credit ratings are from S&P.

	Dependent Variable: Change in Yield Spread		
	(1)	(2)	(3)
Triple Interaction			
[Not Pre-Refunded]*[Loss/Own Rev]*[AA or Below]	1.25	1.93	1.38
	(0.45)***	(0.43)***	(0.23)***
Double Interactions			
[Not Pre-Refunded]*[Loss/Own Revenue]	-0.29	-0.34	-0.04
	(0.11)**	(0.15)**	(0.21)
[Rated AA or Below]*[Loss/Own Revenue]	-0.36	-1.04	-0.58
	(0.33)	(0.28)***	(0.26)**
[Not Pre-Refunded]*[AA or Below]	-0.16	-0.36	-0.20
	(0.13)	(0.14)**	(0.11)*
Controls			
[Rated AA or Below]	0.04	0.23	0.08
	(0.11)	(0.11)**	(0.11)
[Loss/GSP]	0.45	0.80	0.45
	(0.20)**	(0.20)***	(0.27)
Pre-Refunded (= 1-Not-Prerefunded)	-0.37	-0.33	-0.22
	(0.06)***	(0.08)***	(0.10)**
Insured	0.18	0.21	0.23
	(0.03)***	(0.04)***	(0.02)***
Duration	0.14	0.15	0.15
	(0.01)***	(0.01)***	(0.01)***
Convexity ÷ 100	-0.24	-0.20	-0.09
	(0.05)***	(0.05)***	(0.02)***
Size of Issue (B)	0.04	0.01	-0.02
	(0.02)**	(0.02)	(0.01)***
State Debt / Own Revenue	-0.06	-0.05	-0.03
	(0.04)	(0.04)	(0.03)
Pension Liabilities / Own Revenue	-0.03	-0.05	-0.04
	(0.02)*	(0.02)**	(0.02)**
Sensitivity of Own Revenue to U.S. GDP Growth	-2.67	4.50	2.93
	(3.52)	(3.13)	(2.81)
Own Revenue Drop (2009 over 2008)	-1.26	-1.54	-1.67
	(0.68)*	(0.54)***	(0.49)***
Constant	0.32	0.06	-0.03
	(0.11)***	(0.08)	(0.09)
R^2	0.83	0.88	0.88
Sample	All	Issue>$10M	All
Weights	None	None	Issue Size
Observations	15727	6249	15727

Robust standard errors in parentheses, clustered by state

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Robustness of Basic Yield Spread Change Results to Time of Trades

This table revisits the key coefficients in Tables 3 and 4 using subsamples based on the time window in which the bond was last traded. The first column of the top panel repeats the results from Table 3, Column 1. The first column of the bottom panel repeats the results from Table 4, Column 1. The successive columns then narrow the band of trading days. For example, the first row second column excludes bonds that did not trade within one month of the beginning or end of the sample period, and the second row of the second column excludes bonds that did not trade both within one month of the beginning *and* one month of the end of the sample period.

	All	+/- 1 mth	+/- 10 trading days	+/- 5 trading days	on last trading day
Table 3, Column 1					
Beginning or End					
[Rated AA or Below * dFunds / Own Revenue]	0.95	0.91	1.01	1.02	1.13
	(0.37)**	(0.28)***	(1.28)***	(0.30)***	(0.29)***
	13160	6149	4308	2977	664
Beginning and End					
[Rated AA or Below * dFunds / Own Revenue]	0.95	1.16	1.26	1.39	–
	(0.37)**	(0.23)***	(0.20)***	(0.20)***	–
	13160	539	431	313	–
Table 4, Column 1					
Beginning or End					
[Not PreRef]*[Loss / Own Revenue]*[AA or Below]	1.25	1.38	1.57	1.67	1.65
	(0.45)***	(0.56)**	(0.55)***	(0.57)**	(0.51)***
	15727	7707	5458	3751	813
Beginning and End					
[Rated AA or Below * dFunds / Own Revenue]	1.25	1.98	1.84	1.92	–
	(0.45)**	(0.39)***	(0.37)***	(0.36)***	–
	15727	670	529	385	–

Robust standard errors in parentheses, clustered by state. * significant at 10%; ** significant at 5%; *** significant at 1%. Observation counts shown below standard errors.

Table 6: Triple Difference Specification, Finer Ratings Categories

This table shows regressions of municipal bond yield spreads on changes in the value of state pension fund assets, interacted with credit rating categories and indicators for whether the bond is pre-refunded.

	Dependent Variable: Change in Yield Spread		
	(1)	(2)	(3)
Triple Interaction			
[Not Pre-Refunded]*[Loss/Own Revenue]*[A to AA-]	1.53	1.75	1.24
	(0.47)***	(0.32)***	(0.45)***
[Not Pre-Refunded]*[Loss/Own Revenue]*[AA Rated]	0.71	0.45	-0.03
	(0.18)***	(0.23)*	(0.29)
Double Interaction			
[Not Pre-Refunded]*[Loss/Own Revenue]	-0.15	-0.27	0.07
	(0.16)	(0.17)	(0.23)
[Loss/Own Revenue]*[A to AA-]	0.26	0.20	0.51
	(0.32)	(0.33)	(0.40)
[Loss/Own Revenue]*[AA Rated]	-0.36	-0.40	-0.02
	(0.19)*	(0.18)**	(0.28)
[Not Pre-Refunded]*[A to AA-]	-0.09	-0.17	-0.11
	(0.21)	(0.15)	(0.20)
[Not Pre-Refunded]*[AA Rated]	-0.06	-0.02	0.14
	(0.08)	(0.11)	(0.11)
Controls			
[Loss/Own Revenue]	0.20	0.35	0.02
	(0.17)	(0.15)**	(0.24)
A to AA-	-0.18	-0.19	-0.23
	(0.12)	(0.14)	(0.18)
AA Rated	0.03	0.02	-0.12
	(0.08)	(0.08)	(0.11)
Pre-Refunded (= 1-Not-Prerefunded)	-0.31	-0.29	-0.16
	(0.07)***	(0.09)***	(0.11)
Insured	0.18	0.21	0.22
	(0.03)***	(0.04)***	(0.01)***
Duration	0.15	0.14	0.15
	(0.01)***	(0.00)***	(0.01)***
Convexity ÷ 100	-0.25	-0.18	-0.09
	(0.05)***	(0.04)***	(0.02)***
Size of Issue (B)	0.01	-0.00	-0.02
	(0.01)	(0.01)	(0.01)***
State Debt / Own Revenue	-0.05	0.00	0.03
	(0.02)**	(0.02)	(0.02)
Pension Liabilities / Own Revenue	-0.01	-0.01	-0.01
	(0.01)	(0.01)	(0.01)
Sensitivity of Own Revenue to U.S. GDP Growth	-3.27	-2.03	-2.04
	(2.79)	(1.64)	(1.36)
Own Revenue Drop	0.69	0.57	0.92
	(0.39)*	(0.38)	(0.36)**
Constant	0.37	0.25	0.15
	(0.09)***	(0.08)***	(0.06)**
R^2	0.85	0.90	0.89
Sample	All	Issue>$10M	All
Weights	None	None	Issue Size
N	15727	6249	15727

Robust standard errors in parentheses, clustered by state

* significant at 10%; ** significant at 5%; *** significant at 1%

APPENDIX MATERIAL FOR

Fiscal Imbalances and Borrowing Costs:
Evidence from State Investment Losses

FOR WEB PUBLICATION ONLY, NOT FOR PRINT

Technical Appendix 1: The Black Value of a Swaption

This appendix shows the computation of the Black value of a swaption, expiring in *t* and written on a swap with tenor *T* making semi-annual payments at the rate *c*. Define F as the future swap rate, adjusted for the call's strike:

$$F = \frac{2\left((strike/face)\times B_t - B_{t+T}\right)}{\sum_{i=1}^{2T} B_{t+i/2}},$$

where B_τ in the price of a zero-coupon bond of the same quality as the bond underlying the swap maturing at τ. The Black value of the swaption is then

$$A \times \left(\frac{c}{2}\, N(-d_2) - \frac{F}{2}\, N(-d_1)\right),$$

where *A* is the sum of the state prices for all the swap's payment dates, *N* is the cumulative normal distribution σ is the implied volatility of a swap maturing it *t* with tenor *T*, $d_1 = \frac{log(F/c)+\sigma^2 t/2}{\sigma\sqrt{t}}$, and $d_2 = d_1 - \sigma\sqrt{t}$.

Technical Appendix 2: Capital Gains Taxes and the Risk-Neutral Hazard Rate of Default

This appendix shows how the capital gains tax rate affects the relationship between the measured increase in spreads and the increase in the risk-neutral hazard rate of default. The after tax expected instantaneous risk-neutral yield on the bond should equal that on a risk-free (taxable) asset. That is

$$\left(y - \left(1 - \tau_{c.g.}\right)\alpha\lambda^*\right)dt = (1 - \tau_{e.i.})r_f dt$$

where y is the yield on the muni bond, α is the loss in the event of default, $\tau_{c.g.}$ and $\tau_{e.i.}$ are the tax rates on capital gains and earned interest, respectively, and λ^* is the risk-neutral hazard rate of default. The change in the risk-neutral hazard rate of default is related to the change in yield by

$$\Delta\lambda^* = \frac{\Delta y}{\left(1 - \tau_{c.g.}\right)\alpha}.$$

Appendix Table 1: Asset Allocation and Asset Class Returns

The top panel shows asset allocation for 71 investment funds across 116 pension plans for 50 states as reported by *Pensions and Investments*, as of September 2008. As a proxy for the returns to domestic stock, international stock and real estate we use the returns to Barra/MSCI Investible Indices (USA, World ex-USA and US REIT, respectively). For domestic fixed income, international fixed income, mortgages and the "other" category we use Barclays Capital Indices (US Government/Credit, Global Aggregate Ex USA, US MBS and Asset-Weighted Hedge Fund, respectively). The returns to cash and equivalents are from Ken French's website (one month risk-free rate). For the return to private equity we use the mid-point of the range estimated by Steven N. Kaplan (private conversation).

	Asset-Weighted Average Asset Allocation								
	Domestic Stock	International Stock	Domestic Fixed Income	International Fixed Income	Cash and Equivalents	Private Equity	Real Estate Equity	Mortgages	Other
Pensions & Investments, September 2008	35.1%	17.8%	23.7%	2.2%	1.5%	8.0%	7.3%	0.9%	3.4%

	Returns								
	Domestic Stock	International Stock	Domestic Fixed Income	International Fixed Income	Cash and Equivalents	Private Equity	Real Estate Equity	Mortgages	Other
Returns Used to Calculate Totals									
September 2008 to December 2008	-22.8%	-21.5%	2.7%	5.7%	0.2%	-12.5%	-39.1%	-15.0%	-7.4%

Appendix Table 2: Falsification Exercise Using Pre-Refunded Bonds

This table is a version of Table 3 that uses the pre-refunded bonds only, as opposed to the not pre-refunded bonds, as a falsification exercise.

	Dependent Variable: Change in Yield Spread		
[Rated AA or Below]*[Loss/Revenue]	-0.18	-0.26	0.19
	(0.14)	(0.12)**	(0.30)
[Loss/Revenue]	0.01	-0.02	-0.30
	(0.12)	(0.12)	(0.38)
[Rated AA or Below]	0.03	0.10	-0.08
	(0.07)	(0.06)	(0.13)
Insured	0.04	0.03	0.13
	(0.02)**	(0.02)**	(0.03)***
Duration	0.17	0.15	0.21
	(0.02)***	(0.02)***	(0.02)***
Convexity ÷ 100	0.07	0.23	-0.04
	(0.18)	(0.08)***	(0.06)
Size of Issue (B)	0.03	0.03	-0.14
	(0.02)	(0.02)	(0.06)**
State Debt / Revenues	-0.07	-0.10	-0.03
	(0.02)***	(0.02)***	(0.03)
Pension Liabilities / Revenues	-0.00	0.00	0.02
	(0.01)	(0.01)	(0.03)
Sensitivity of Own Revenue to U.S. GDP Growth	-0.29	1.81	2.19
	(1.24)	(1.78)	(2.73)
Own Revenue Drop	-0.30	-0.02	-0.15
	(0.17)*	(0.22)	(0.37)
Constant	-0.07	-0.08	-0.25
	(0.05)	(0.05)	(0.09)***
R^2	0.76	0.80	0.80
Sample	Pre-Refunded	Pre-Refunded, Issue>$10M	Pre-Refunded
Weights	None	None	Issue Size
N	2567	1277	2567

Robust standard errors in parentheses, clustered by state
* significant at 10%; ** significant at 5%; *** significant at 1%